Newtown Creek Storm Surge Barriers Study

Final Report

Prepared for

New York City Economic Development Corporation and the Mayor's Office of Recovery and Resiliency

January 2016

CH2MHILL®

22 Cortlandt Street 31st Floor
New York, NY 10007

WXY | TETRA TECH | HR&A Analyze. Advise. Act. | AKRF | eDesign Dynamics

Version No.	Status	Date of Issue	Approver Details
1.0	Final	January 15, 2016	JLG

This page was intentionally left blank.

Executive Summary

Located at the heart of one of New York City's (City) largest industrial zones and within blocks of some of its most rapidly growing residential neighborhoods, Newtown Creek (the Creek) forms the border between Queens and Brooklyn, and, flowing into the East River, provides diverse waterfront opportunities, but also poses significant resiliency challenges. The low-lying lands on either side of Newtown Creek are subject to flood hazard, as waters from the East River are brought inland by the Creek. On October 29, 2012, Hurricane Sandy demonstrated the area's vulnerability, with more than 350 acres of land along the Creek inundated by the storm. Newtown Creek is also a United States Environmental Protection Agency (USEPA) Superfund Site. Remediation plans are expected to be developed and pursued over the next decade.

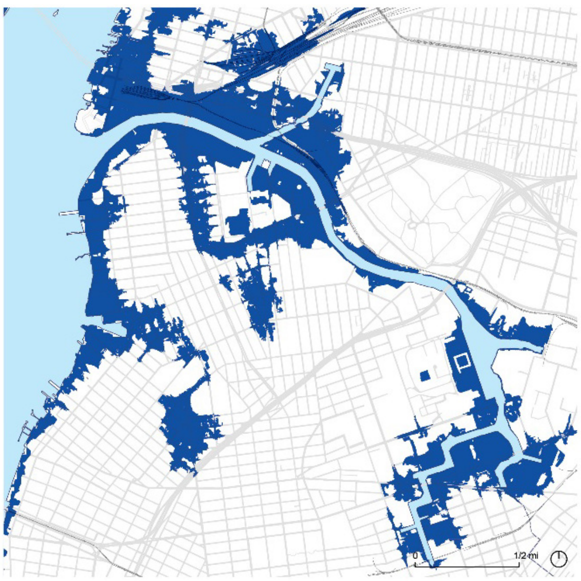


FIGURE ES-1
Hurricane Sandy Inundation in the Newtown Creek Area

The Gowanus Canal and Newtown Creek Storm Surge Barrier Studies project is a conceptual feasibility study that may be used in assessing the need to advance to more a detailed and complete feasibility study and could inform such a study or the project implementation that may follow. This report focuses on the Newtown Creek Storm Surge Barrier Study. The primary study goals are as follows:

- Identify a flood protection strategy that benefits communities in the Newtown Creek study area.
- Produce a study that complements and informs City and United States Army Corps of Engineers (USACE) planning activities.

To achieve these goals, the study adopted a conservative design flood elevation (DFE) of +17-foot North American Vertical Datum of 1988 (NAVD88). This DFE established the natural elevation contour to which a Newtown Creek Storm Surge Barrier system would extend and terminate. The study then compared multiple concept options for both in-water barriers as well as upland defense systems, identifying fatal flaws for each option and evaluating each on relative cost, benefit, reliability, and ease of implementation. This comparison led to a preferred concept option of an in-water barrier at either 2nd Street or Manhattan Avenue, between Greenpoint, Brooklyn and Hunters Point South, Queens, and upland defenses along the shoreline. Both neighborhoods are rapidly changing, with numerous new mixed-use residential projects in various stages of construction, planning and approvals. These are expected to be completed within the next few years. The shoreline alignment would run primarily at the edge of existing and planned parkland, including the Greenpoint waterfront esplanade, a public-private partnership initiative that will be handed over to the New York City Department of Parks and Recreation (NYCDPR) upon completion. An alternative concept option, in which the upland defenses were integrated into public and private sites, was also considered.

The study then analyzed the impacts of these concept options, including high-level hydrodynamic modeling and a preliminary benefit-cost analysis, and provided a road map for implementation, including potential funding strategies and permitting considerations. The study did not include detailed design solutions.

The results of this study are intended to advance discussions with USACE, which could potentially proceed with this project on one of two pathways. On the first pathway, the project would be incorporated into and recommended by the NY NJ Harbor and Tributaries Feasibility Study, which is already authorized and is estimated to commence in the first quarter of 2016. On the second pathway, the project would not be recommended by the NY NJ Harbor and Tributaries Feasibility Study, leaving the study area vulnerable; USACE would therefore obtain authorization for an independent study of the project with an estimated commencement date post-2019. The start of construction and project implementation is assumed to be contingent upon the completion of Superfund remediation, implying a time horizon of 15 or more years.

The study includes numerous recommendations for next steps for the City to take, including:

- Refine cost-estimating methodologies with USACE to obtain more accurate cost/benefit ratios.
- Establish flood protection funding and financing mechanisms such as assessment districts;
- Revisit the City's zoning text and flood-resistant construction requirements to develop a long-term strategy that is responsive to sea level rise;
- Implement zoning changes and coordinate planning to integrate parcels and infrastructure into a flood protection system, including further investigation into potential public-private partnerships to capture private funding through parcel development integration;
- Establish administrative processes and operational protocols for flood defenses;
- Acquire strategic parcels and easements to support flood defense projects; and
- Define an approach to surface water flood mitigation to be integrated with storm surge defenses.

The remainder of this Executive Summary poses and answers the key questions investigated by the study in order to help the City advance discussions among a variety of stakeholders, including City Hall, City Agencies, USACE, political leaders, and community members.

What is a storm surge barrier system, as envisioned at Newtown Creek?

- A storm surge barrier system for Newtown Creek would comprise three connected parts A. in-water barrier, B. upland defenses and C. natural elevation.
- The in-water barrier location and gate type are typically selected first.
  - Location is based on a variety of siting considerations and physical constraints.
  - Gate type selection considered the required gate width and depth, space available for recesses or access, ease of operations, navigation height restrictions, vulnerability to damage from navigation impact, time for barrier closure, and landscape impact.

– This study's preliminary investigation suggests that a radial sector gate at 2nd Street or a vertical lift gate at Manhattan Avenue could be likely barrier types (**Figure ES-2 and ES-3)**. The 2nd Street in-water barrier location is preferable from a navigation perspective while the Manhattan Avenue location is preferable from an urban design and integration perspective

Lake Borgne Barrier, New Orleans. Overall aerial view of radial sector (horizontal rotating) barrier. Source: USACE,

Hull Barrier, UK – Lifting gate in normal open position rotated 90 degrees to maximize navigation clearance

FIGURE ES-2
Precedent Gate Types: Radial Sector Gate (left) and Vertical Lift Gate (right)

FIGURE ES-3
Potential Newtown Creek In-water Barrier Locations: 2nd Street (left circle) or Manhattan Avenue (right circle)

- Following selection of the in-water barrier, upland defenses are then designed to tie the in-water barrier to natural elevation at the desired DFE.
  - Design of the alignment can be influenced by a number of factors important to the City and local stakeholders, including urban design considerations, physical constraints, environmental impacts, as well as cost.
  - Similar to in-water barrier gate selection, the type of upland defenses erected is influenced by available space, opening width and height requirements, ease of maintenance and operations, storage requirements, visual impact, cost and the trade-offs each defense type offers. While permanent components such as embankments, levees, rock revetments, and flood walls offer greater reliability, and lower operations and maintenance demands than do deployable components such as operable gates and post and panel segments, permanent features can require more physical space and can impose barriers to access and connection.
  - Given the dynamic urban context and the myriad types of activities that need to be accommodated, any storm surge barrier system at the Creek is expected to combine a variety of permanent and deployable components (**Figure ES-4**).
- The in-water barrier and any deployable components remain in the open/non-deployed position during normal day-to-day operating conditions and are closed only in lead-up to a storm event or during annual test exercises.

FIGURE ES-4
Precedent Upland Defense Types

What could a Newtown Barrier Storm Surge barrier system protect?

- A storm surge barrier system could successfully limit risk at the Creek up through a 500-year storm event, based on a +17-foot NAVD88 DFE, and enable the City to achieve three essential goals:
  - Protecting Jobs and Businesses.
    - Around 19,000 people work in flood-prone areas surrounding the Creek. Nearly half of these jobs are in industrial sectors, performing critical functions within the local economy

as well as providing employment opportunities for persons with low educational attainment, limited English language proficiency, and minority and immigrant populations.

    - Across all sectors, the 1,630 businesses and 19,000 employees in the Protected Area (all properties that would be inundated during a 500-year flood event without the project, but would not be inundated with the project) generate more than $4 billion in direct annual economic output and earn nearly $1.3 billion in compensation. Applying economic multipliers, this direct economic activity generates nearly 30,000 jobs, $2.1 billion in earnings, and $6.3 billion in total output.

  - Protecting Residents.
    - The neighborhoods surrounding Newtown Creek are home to more than 15,000 residents, with most individuals living in older buildings, which were not built to flood-resistant standards. As new buildings are constructed in the coming decades, the area's population is poised to quadruple, with most of this growth happening in the 100-year flood zone.

  - Protecting Critical Infrastructure.

The Protected Area includes the G train subway line, the rail yards bound by 2nd Street to the west and Bordon Avenue to the north, the Midtown Tunnel exit to the Long Island Expressway, and the New York City Department of Environmental Protection (NYCDEP) wastewater treatment plant.

What other benefits could a Newtown Creek storm surge barrier system convey?

- *Protection beyond current standards*. While Appendix G of the New York City Building Code requires flood-resistant construction for new or substantially improved buildings in the 100-year flood zone, the storm surge barrier system would offer extra flood protection since it incorporates additional freeboard (a safety factor that compensates for factors, such as wave action, that could contribute to higher flood heights exceeding those calculated for a select flood condition) and an allowance for sea level rise. The 2015 New York City Panel on Climate Change report projects that, due to climate change, the 100-year flood in the 2050s may reach an elevation up to 2.5 feet higher than today's 100-year flood. A building built to code today would flood under these circumstances, but a storm surge barrier system built to the 17-foot design elevation would still offer protection. Similarly, today's standards do not protect against the less frequent but more severe 500-year flood event, with a 15-foot elevation, while the flood barrier would.
- *Reduced flood insurance and avoided mandatory floodproofing costs*. A storm surge barrier project at Newtown Creek could help community members realize substantial savings through both reduced flood insurance premiums and avoided mandatory floodproofing costs.
- *New public amenities*. There are potential opportunities for new public amenities. A bicycle/pedestrian connection could form a part of an in-water barrier at Manhattan Avenue or new recreational space might be possible atop infill at a 2nd Street barrier location.
- *Habitat enhancement*. Native plant communities could be added adjacent to a barrier or crevices and habitats could be designed into a barrier structure. Vegetated berms with salt marsh plantings or coastal shrub might also be possible.
- Additional benefits that may be conveyed to the City and its residents that should be studied in detail as part of a complete feasibility study include:
  - Avoided loss of life and injuries.
  - Avoided evacuation costs.

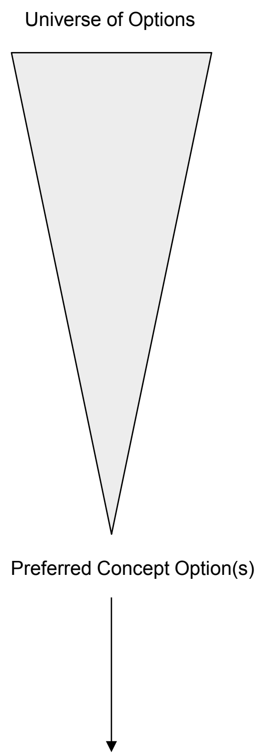
- Avoided relocation costs.
- Avoided business interruptions.
- Preserved services and protected infrastructure.
- Green infrastructure secondary benefits.

How real is a Newtown Creek storm surge barrier project?

The Newtown Creek Storm Surge Barrier Study follows from other New York City resiliency studies that are ongoing or nearing completion, which have worked to open and advance discussions with USACE. Unlike some other similar studies, there is currently no funding identified in the City's 10-year capital program for a Newtown Creek storm surge barrier system. However, given the importance of the two industrial waterways and the dynamic changes taking place around them, the City has elected to study potential storm surge barriers and to envision how resiliency efforts in these locations might look. Any potential project would be very expensive and very complex, as it would tie into the pre-existing urban fabric. However, by starting to advance thinking now, and engaging with USACE from the onset, the intent is to set up and position the study so that the City can transition the work to USACE to carry forward as UCASE undertakes and completes its NY NJ Harbor and Tributaries Feasibility Study.

What did the Newtown Creek Storm Surge Barrier Study explore?

At this conceptual stage, the objective was to identify fatal flaws and determine whether a storm surge barrier system, consisting of both an in-water storm surge barrier and upland defenses, could be a possible solution for the City or USACE to further investigate and consider. High-level preliminary analysis was completed to answer, or in some cases, identify for future investigation, critical questions around how a potential flood defense system could tie into the existing, dynamic urban fabric, and how a system would intersect with the City's operational partners. Detailed design solutions were not a part of the study's scope, but rather, a roadmap has been developed for next steps should the study outputs be transitioned and advanced. This roadmap includes suggestions for further site and engineering investigations, stakeholder engagement, permitting and regulatory considerations, funding and financing approaches, and policy implications. The study process is summarized in **Figure ES-5**.

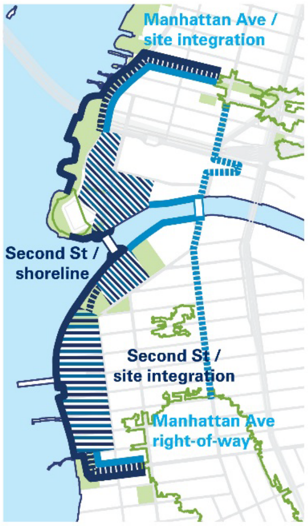


- **Two-stage Comparative Evaluation Process**
  - **Part I: In-water barrier screening**
    - Coarsely evaluate and compare potential barrier locations
    - Funnel study towards more feasible barrier locations around which to develop the upland defense schemes
    - Address key siting considerations
  - **Part II: Comparative alignment screening**
    - Evaluate potential concept options (in-water + upland connections) relative to each other to identify preferred concept option
    - Consider costs, benefits, reliability and implementation
    - High-level assessment. Quantify or evaluate metrics and convert to relative comparative scores where applicable
- **Project Analysis**
  - High-level hydrodynamic modeling: storm surge, flushing and rainfall assessment
  - Preliminary benefit-cost analysis
  - Local funding strategies
  - Implementation and permitting

FIGURE ES-5
Study Process

This study used a filtering approach to develop and consider a number of alternative concept options. Initially, the analysis identified three potential in-water barrier locations. One concept option was dropped from consideration based on a number of major weaknesses. The two remaining concept options advanced to the development stage where the potential for upland defense tie-ins to natural elevations were assessed.

Five alternative concept options were developed around the two in-water barrier sites that explored different issues with which the City or USACE might contend should a project be pursued beyond this conceptual study. These options included shoreline alignments, site integration alignments, and right-of-way (ROW) alignments. Each alignment offered different strengths, and weaknesses and highlighted tradeoffs and challenges that add to the overall understanding of the opportunities and complexities entailed in adopting a storm surge barrier system as part of the City's overall approach to flood defenses and resiliency. The screening outcomes are summarized in **Figure ES-6**.



	Criterion	Second St shoreline	Second St site integration	Manhattan Ave site integration	Manhattan Ave right-of-way
Cost	Total cost	Red	Yellow	Yellow	Green
Cost	Ability to leverage other investments	Yellow	Green	Green	Yellow
Cost	O&M costs	Green	Red	Red	Red
Benefit	Protects jobs	Green	Yellow	Yellow	Red
Benefit	Protects homes	Green	Yellow	Yellow	Red
Benefit	Utilizes green infrastructure	Green	Yellow	Yellow	Red
Benefit	Minimizes impact on public safety	Green	Yellow	Yellow	Red
Reliability	Extent of in-place vs deployable barriers	Green	Red	Red	Red
Reliability	Number of responsible parties	Green	Red	Red	Green
Implementation	Complexity of legal/planning approvals	Red	Red	Red	Yellow
Implementation	Disrupts access for residents & businesses	Green	Yellow	Yellow	Red
Implementation	Maintains view corridors	Red	Green	Green	Green
Implementation	Maintains waterfront access	Red	Green	Green	Green
Implementation	Reliance on third-party commitments	Yellow	Red	Red	Green
Implementation	Improves neighborhood connections	Yellow	Yellow	Green	Green

**Site integration = incorporation of defense line segments into private parcels, funded by developers*
- *Current development approvals and site status precludes realization of full site integration concept option.*
- *Benefits criteria ratings could be green or yellow, depending on defense line placement between East River and West Street*

Preferred Concept Option (*Manhattan Ave barrier possible*) — Alternate Concept Options* (*for comparative, policy exploration purposes*)

FIGURE ES-6
Concept Option Comparative Screening Results

What is the preferred Newtown Creek storm surge barrier system concept option?

Based on the evaluation screening, discussions with the New York City Economic Development Corporation (NYCEDC) and the Mayor's Office of Recovery and Resiliency (ORR), and feedback from City agencies, the shoreline concept options with an in-water barrier at either 2nd Street or Manhattan Avenue were selected for additional analysis as the preferred concept options (**Figure ES-7**).

FIGURE ES-7
Preferred Concept Options: Shoreline Alignment with 2nd Street or Manhattan Ave In-water Barrier

Some of the benefits and implications of the preferred concept options include the following:

- It maximizes the potential zone of protection.
- It minimizes disruption to residential and commercial activities and potential adverse impacts to public safety by staying out of the public right of way (ROW) to the extent possible.
- It maximizes reliability, incorporating floodwalls and permanent structures with long design lives, tying into natural or landscaped topography wherever possible, and minimizing the use of deployable components.
- It is anticipated that it would provide a positive return on investment for the City and its partners. The preliminary Benefit-Cost Ratio (BCR) at this conceptual stage was found to range between 1.5 and 3.1. The range reflects the sensitivity of the project benefits to the replacement structure values used in quantifying avoided damages and the variation in construction estimation data sets such as Marshall & Swift (M&S) as compared to local construction market intelligence.
  - Capital costs are estimated to range between $229 million to $242 million.
  - Operations and Maintenance (O&M) costs are estimated to be $807,000 to $854,000 on an annualized basis or $19.4 million to $20.4 million on a 50-year present value basis.
  - The present value of expected annual damages (EAD) for the 50-year period of analysis, the benefits, are $391.5 million or $16.3 million annualized.
  - Net benefits were estimated to range between $121 million and $136 million based on one data set. However, the value of avoided damages relies significantly on the real estate construction values used and could be substantially greater.
  - Construction estimation data sets, such as M&S, understate the value of avoided damages. A future detailed feasibility study should include research and verification of market construction values for New York City.
  - Greatest uncertainty and cost risks are likely to come from barrier gate sizing; stormwater pumping or storage requirements (an allowance accounting for 25% of the in-water barrier conceptual cost estimate including contingencies, or approximately 13% of total storm surge barrier system costs, was made at this study stage); utility and service diversions; environmental remediation separate from Superfund works; land acquisition; and legal challenges. These are areas that should be further investigated at a complete feasibility study stage beyond this initial study.
  - The benefits reflected in the BCR are limited to avoided damages. The future feasibility study stage should consider expanding the criteria to capture and monetize the broader set of benefits.
- The major weakness of the shoreline alignment is the anticipated complexity of the legal and planning process, reflecting not only New York State Department of Environmental Conservation (NYSDEC) in-water permitting requirements for a barrier and fill, but also the interface with planned residential water development projects and new park features. Planned residential and park developments at both Hunters Point South and Greenpoint, including the Greenpoint waterfront esplanade, Box Street Park and Newtown Barge Park, are designed at elevations below the study DFE. In addition, a shoreline alignment would be expected to have some adverse impact on waterfront access and view corridors. These challenges and exploration of potential design

solutions will necessitate further investigation and stakeholder engagement as part of a future complete feasibility study.

What alternative concept option might be considered for a Newtown Creek Storm Surge Barrier?

The site integration concept options with either in-water barrier location, in which portions of the defense line are integrated into private development parcels and funded by the parcel owner, were retained as alternative concept options (**Figure ES-8**). This was done primarily as a tool to explore site elevation and other funding and financing approaches to reducing capital costs that might be employed in other locations throughout the City as part of broader resiliency efforts.

FIGURE ES-8
Alternative Concept Option: Site Integration Alignment with 2nd Street or Manhattan Ave In-water Barrier

- The alternate concept option is the Site Integration Alignment with an in-water barrier at either 2nd Street or Manhattan Avenue.
  - Like the preferred concept option, it also anticipated that it would provide a positive return on investment for the City and its partners. The preliminary BCR at this conceptual stage was found to range between 1.8 and 3.8, reflecting a cost reduction by transferring parts of the alignment to private developers.
    - Capital costs are estimated to range between $183 million to $196 million.
    - Operations and Maintenance (O&M) costs are estimated to be $821,000 to $868,000 on an annualized basis or $19.7 million to $20.8 million on a 50-year present value basis.
    - The present value of EAD for the 50-year period of analysis, the benefits, are $391.5 million or $16.3 million annualized.
    - Net benefits were estimated to range between $169 million and $183 million, based on one data set. However, the value of avoided damages relies significantly on the real estate construction values used and could be substantially greater.
    - Cost and benefit uncertainty and actions to refine assumptions are the same as those for the preferred concept option.
  - Given the likely timing of a potential Newtown Creek storm surge barrier project, the status of parcel development and approvals, and the additional anticipated approval complexities due to easement requirements for Federal Emergency Management Agency (FEMA) certification, the

site integration alignment in its entirety is not viewed to be a realistic option. This alternative concept option was explored more with a view toward understanding trade-offs and identifying value capture mechanisms that the City could consider as part of its resiliency efforts. That said, there are specific opportunities on a site-by-site basis that merit further consideration, and a final design and barrier alignment may incorporate aspects from both the Shoreline and Site Integration concept options.

What level of storm surge risk reduction will a Newtown Creek storm surge barrier system provide?

- As part of coordination and initial planning between the City and USACE for a full feasibility study, a policy decision will be required to set the DFE and the level of risk reduction for the project to achieve.
  - This study assumed a conservative +17-foot NAVD88 DFE for the upland defenses and a +21-foot NAVD88 DFE for the in-water barrier. This includes allowances for freeboard and sea level rise. (**Figure ES-9**). Sea level rise allowances reflect the New York City Panel on Climate Change's 2015 findings that forecast mid-range (25th – 75th percentile) changes in sea level rise of 11-24 inches by the 2050s and 18-39 inches by the 2080s.
  - Federal policy may dictate that funding would only be provided for projects be built to a DFE lower than that assumed in this study. This could impact minimum design elevations and funding limits.
  - City preference for greater risk reduction may require a Locally Preferred Plan, in which the City is financially responsible for capital costs above and beyond the USACE plan. Alternatively, the City might consider a gradual approach, expanding the barrier and increasing the height over time.
  - The study's DFE and analysis is based on the FEMA 2013 FIRM (Flood Insurance Rate Map) data. During the course of this study, after much of the project analysis had been completed, the City filed an appeal challenging that FEMA's updated FIRMs overstate Base Flood Elevations. In general, in the case that the City's appeal is successful, and less conservative FIRMs are issued, it is anticipated that the estimated benefits, as well as capital costs could decrease as a lower DFE requirement would be anticipated. This caveat is not study specific, but rather, is applicable to all City resiliency studies whose assumptions have been based off the FEMA 2013 p-FIRM data.

FIGURE ES-9
Study Design Flood Elevations

How vulnerable would the Newtown Creek storm surge barrier system be to sea level rise?

- The preliminary storm surge modeling included scenarios of the barrier system performance up through today's 500-year storm event and today's 100-year storm event plus 3 feet of SLR (assumes the 2015 New York City Panel on Climate Change's 50th percentile SLR value for 2100).
- Sea level rise adaptation of a flood defense system might be pursued as part of a longer-term strategy.
  - Low-lying areas north of the study area are vulnerable to flooding from the East River as water moves south into Long Island City and could introduce a future backdoor entry point for water flow into Newtown Creek if the flood stages are high (**Figure ES-10**). Further definition of ground elevations in this area could result in a reduction or elimination of the estimated flooding. Future feasibility studies would conduct elevation spot-checks.
  - A Queens waterfront strategy to contain the East River flood source north of the Newtown Creek Study area could include the extension of the Newtown Creek defense line (but leaves Queens vulnerable), possible Metropolitan Transportation Authority (MTA) rail yard protection measures that contain water from Newtown Creek, a comprehensive Queens waterfront flood protection strategy tie-in to a Newtown Creek system, or incorporation of protection measures into Long Island City redevelopment plans.

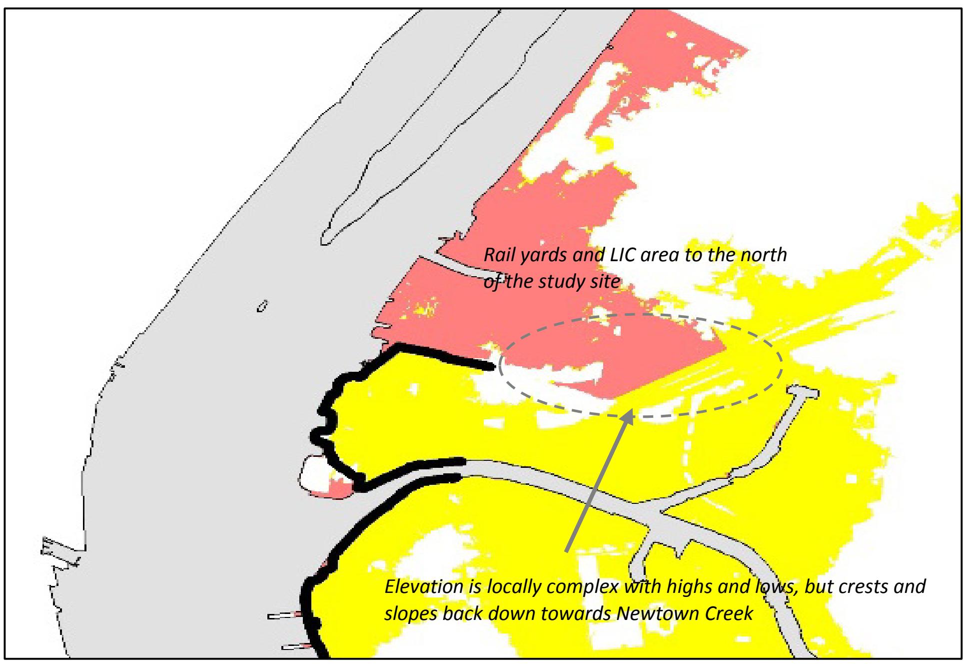


FIGURE ES-10
Future Flood Risk from Queens Waterfront to the North

Would a Newtown Creek storm surge barrier system worsen flooding or water quality?

- The preliminary storm surge modeling performed as part of this study found that the potential storm surge barrier system did not increase the risk of flooding to properties outside of or adjacent to the barrier.
- This study did not perform detailed drainage modeling or analysis of stormwater pumping stations or storage options. Instead, a preliminary, high-level analysis of rainfall and storage capacity was

performed in order to point to the need for future investigations and to anticipate required stormwater infrastructure. This preliminary capacity analysis found that longer duration storms likely cannot be contained within the Creek when the gate is in the closed position beginning at low tide (maximum storage capacity scenario). In the open/non-deployed position, the storm surge barrier system would not impact existing stormwater drainage.

  - In this simplified analysis, storms larger than the 1-hour, 1-year event rainfall volume were not contained within the canal/creek system.
  - Stormwater pump stations will almost certainly be required as part of a storm surge barrier system to pump rainwater out of the Creek over the barrier. Conceptual cost estimates built up for this study have made an allowance for an additional stormwater pump station for all concept options, but the requirements could be significantly larger.
  - A detailed surface water and drainage study will need to be performed as part of a complete feasibility study and a policy/design determination made as to the appropriate barrier design condition—expressed as the joint probability of a particular rainfall event occurring at the same time as a particular storm surge event.

- A high-level flushing analysis found that in-water barriers at Newtown Creek would appear to reduce the tidal exchange by about 5 percent.
  - Future detailed analysis could dictate that a wider barrier gate be included as part of a storm surge barrier flood defense system in order to further reduce impact to flushing performance.

How will operations and maintenance responsibilities be handled for a Newtown Creek storm surge barrier?

- A Newtown Creek storm surge barrier project is just one of many city-wide resiliency efforts and a Newtown project will be preceded by many other storm surge protection projects. O&M protocols and roles and responsibilities will be in place long before project implementation.

How have City, stakeholder, and community concerns been addressed by the study?

- For this stage of preliminary fatal flaw analysis, stakeholder engagement was limited to City and state agencies, including NYCDEP, NYCDPR, New York City Department of Transportation (NYCDOT), New York City Department of City Planning (NYCDCP), New York City Department of Housing, Preservation and Development (NYCHPD), New York State Department of Transportation (NYSDOT) and USACE. Community engagement would be conducted should a Newtown project proceed beyond this conceptual study stage. That said, in order to highlight trade-offs and build on community feedback the City had gathered previously, a broad array of evaluation criteria, reflecting City and community interests, were considered when identifying potential in-water barrier locations and in developing the upland defenses. These criteria included navigation, interface with developments, impacts to waterfront access and view corridors, disruptions to the business and residential communities, the ability to attract or leverage private investment or other publicly financed projects, the ability to achieve FEMA certification, protected jobs and affordable housing, share of green infrastructure, protection of critical infrastructure and impact on public safety.
- Any project at Newtown Creek will present challenges, face a complex regulatory and permitting phase comprising federal, state, and City reviews and approvals arena, require major investment, and demand close coordination with agencies, regulatory bodies, and the community to foster a better understanding of the risks and the tradeoffs at stake in adopting a solution. Stakeholder and

community engagement will play an important role in any USACE-led feasibility study. Specific topics expected to be explored as part of outreach and engagement at such a future stage include the following:

- Where a 2nd Street horizontal rotating in-water storm surge barrier is selected, it would require infill, which will trigger NYSDEC involvement. Depending upon how the gate is sized and the volume of infill required, environmental permitting could be very difficult or require extensive mitigation activities.
- Where a Manhattan Avenue vertical lift gate barrier is selected, it would require consultation with the navigation community to confirm acceptable vertical clearance requirements, coordination with the MTA in the vicinity of the G-train subway line around which abutments would need to be constructed, and engagement with utility owners to identify potential service diversions.
- NYCDPR will be a critical implementation partner. The integration of upland defenses with existing and planned parks may adversely impact view corridors and waterfront access, and could reduce active space—an issue heavily contested by the communities. NYCDPR will need to be engaged early to consider design alternatives and opportunities to retrofit and integrate the flood defense scheme with the waterfront. Parkland alienation issues could also be triggered. Interface with the planned Greenpoint waterfront esplanade, a public-private public amenity initiative, and other planned waterfront projects will require consideration of design solutions.
- Plans for Superfund remediation within the Creek are not yet determined. Coordination with USEPA, NYCDEP, and other parties involved with the Newtown Creek Superfund remediation work should take place. Bulkhead improvements could be designed to accommodate the in-water storm surge barrier as well as any floodwalls that run along the Creek edge.
- Engagement with the Newtown Creek communities to explain the challenges and trade-offs associated with erecting a storm surge barrier system in such a vibrant and dynamic community will be a vital component of building allies and public acceptability for a project to be successful. Community members and developers will want to know about design impacts on development projects, park areas, waterfront access, planned view corridors, or any changes to parking. The incorporation of upland defenses within existing parks could reduce active space—an amenity heavily valued by the communities. Parkland alienation issues could also be triggered. Design solutions can seek to minimize adverse interface impacts, but some worsening to the public experience as currently envisioned in planned waterfront amenities is likely.
- FEMA certification, essential to realizing flood insurance savings, requires that a flood protection system be owned and maintained by a community participating in the National Flood Insurance Program or an agency created by such a community. Where any site elevation components are pursued as part of a flood defense scheme or components of a flood defense system are incorporated across privately owned parcels, easements will need to be obtained in order to ensure 24-hour access to berms, barriers or operable gates, and for maintenance activities. Engagement with FEMA officials earlier on can help ensure the City meets its objectives for certification and savings for property owners.

How could a Newtown Creek storm surge barrier system be funded?

- The estimated capital costs for the storm surge barrier system are $230 million, and under USACE funding guidelines, the City would be responsible for 35 percent of capital costs, or $81 million. The City would also be responsible for O&M costs, with an annualized estimate of $864,000; the present value of this annualized cost is $21 million. The total cost to the City of protecting this area is just more than $100 million.
- An assessment district is one potential funding path. Many of the benefits of a storm surge barrier accrue to private property owners, and the City would therefore be justified in trying to capture some of this value to meet its obligations for 35 percent of capital funding and all O&M costs.

  A conceptual model of an assessment district suggests that this tool may be a promising source of funds for both capital and O&M costs, as districtwide net benefits would far exceed the required assessment and average assessment rates would be less than 1 percent of assessed value.
- Capital cost reductions through new urban design requirements and leveraging private investment are a second potential funding pathway. The strong development environment along the Brooklyn-Queens waterfront, as well as the public investments that will accompany new development, create opportunities for the City to plan now for an eventual barrier. Potential actions include:
  - Publicly Owned Sites:
    - Establish design standards for new parks and streets.
    - Invest in elevating existing parks and streets.
    - Require development of city-owned parcels to integrate into a flood defense system.
  - Privately Owned Sites:
    - Require private redevelopment that is still in need of City action or approvals to integrate into a flood defense system.
    - Approach as-of-right redevelopment site developers about the potential for site integration into a flood defense system.

What future investigations are anticipated to be included in a detailed feasibility study?

- Future studies, investigations, and analyses that are anticipated to be scoped into a detailed feasibility study in order to refine cost and benefit estimates include, but are not be limited to:
  - Elevation spot checks of LIDAR (aerial laser topography) data as part of storm surge modeling.
  - Comprehensive drainage and water quality modeling, including combined probability analysis of storm surge and rainfall events.
  - Sampling and detailed environmental site investigations on parcels along the storm surge barrier alignment.
  - Utility investigations and as-needed service diversion or relocation studies.
  - Real estate studies and plan.
  - Benefit valuation methodologies to reduce uncertainty around local replacement construction values as well as interruption impacts.

   - Expanded benefits quantification and monetization, such as avoided relocation costs, avoided business interruptions, preserved services and protected infrastructure, and green infrastructure secondary benefits.

What is the potential implementation timeline for a Newtown Creek storm surge barrier system?

- Two potential pathways are currently envisioned:
   - A. The project is incorporated into the NY NJ Harbor and Tributaries Feasibility Study, which is estimated to commence in the first quarter of 2016; or
   - B. The project is not recommended by NY NJ Harbor and Tributaries Feasibility Study, the study area is left vulnerable by the recommended regional project, and, therefore, a separate study authorization is pursued with an estimated commencement date post-2019.
- The start of construction and project implementation is assumed to be contingent upon the completion of Superfund remediation, implying a time horizon of 15 or more years. However, should the boundary of Superfund work not extend beyond the Pulaski Bridge to where the in-water barrier placements are envisioned, the timeline could move earlier.
- Other uncertainties likely to affect timing are the potential need for a stable environmental baseline period post-remediation, the complexity of multi-agency coordination, and the timing of Congressional Authorizations for funding.

What can the City do in lead-up to a project and to strengthen its overall citywide resiliency efforts?

- There is much that the City can do to prepare for a storm surge barrier system, including:
   - Establish flood protection funding and financing mechanisms, such as assessment districts, or implement zoning changes and coordinated planning to integrate parcels into a flood protection system.
      - Further study into a potential assessment district should examine the legal process, the distribution of benefits and financial burden and the relationship to other public policy goals.
      - Interagency discussions should continue to investigate the potential for private parcel site integration and new urban design standards as a means for reducing public capital contributions.
   - Develop a long-term strategy that considers how sea level rise and adaptation tie into the City's zoning text and flood-resistant construction requirements.
   - Refine cost-estimating methodologies with USACE.
   - Build support with both local stakeholders and congressional representatives.
   - Establish administrative processes to improve the efficiency of approvals, permits, and implementation for flood defense projects.
   - Establish protocols, roles, and responsibilities for O&M of a storm surge barrier system that will comply with FEMA certification requirements.
   - Acquire strategic parcels and easements as part of a real estate plan developed to support flood defense projects.

– Define an approach to surface water flood mitigation that can be integrated with flood defense projects.

Conclusion

Newtown Creek is a unique waterway in New York City, surrounded by an active industrial sector and thriving residential neighborhoods. Infrastructure improvements accompanying the upcoming Superfund remediation have the potential to spark new investment in important industrial businesses along the Creek, and recent rezonings and market activity will expand the area's population tremendously.

Although a storm surge barrier system may still be decades from construction, the City can act now to increase the project's likelihood of success. The first step is for the City to recognize the broad array of benefits that could accrue beyond those recognized by USACE. Next, by refining valuation methodologies and aligning public investments and regulatory tools to reduce project costs, the City can increase the project's USACE BCR and increase the likelihood of federal funding. Finally, by employing a value capture tool and site-barrier integrations, the City can limit the amount of public funding that will be necessary to realize this flood protection.

This page was intentionally left blank.

Contents

Part IV: Supporting Analysis and Background Documents

Appendixes

Tables

Figures

Acronyms and Abbreviations

2D	two-dimensional
AIS	Automatic Identification System
AOC	Administrative Order of Consent
ASA/CW	Assistant Secretary of the Army for Civil Works
BCR	benefit-cost ratio
BFE	Base Flood Elevations
BID	Business Improvement District
Canal	Gowanus Canal
CFR	Code of Federal Regulations
City	New York City
COC	constituent of concern
Creek	Newtown Creek
CSO	combined sewer overflow
DDF	depth-to-percent damage function
DEM	Digital Elevation Model
DFE	design flood elevations
DO	dissolved oxygen
DRV	depreciated replacement value
DSNY	City of New York Department of Sanitation
EAD	expected annual damage
EIS	environmental impact statement
FEMA	Federal Emergency Management Agency
FIA	Flood Insurance Administration
FIRM	Flood Insurance Rate Map
ft^2	square feet
GIS	geographic information system
HAZUS	FEMA Hazards United States model
HEC-FDA	Hydrologic Engineering Center’s Flood Damage Assessment model
HUD	Department of Housing and Urban Development
IBO	Independent Budget Office
IBZ	Industrial Business Zone
IDC	interest during construction
IFPS	Integrated Flood Protection System

kV	kilovolt
LCC	Locally Preferred Plan
LTCP	Long-Term Control Plan
M&S	Marshall & Swift Valuation Service
MG	million gallon
mg/L	milligram per liter
MOTF	Modeling Task Force
MTS	marine transfer station
NACCS	USACE's North Atlantic Coast Comprehensive Study
NAVD88	North American Vertical Datum of 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NPCC2	New York City Panel on Climate Change
NPV	net present value
NYC	New York City
NYCDCP	New York City Department of City Planning
NYCDEP	New York City Department of Environmental Protection
NYCDOT	New York City Department of Transportation
NYCDPR	New York City Department of Parks and Recreation
NYCEDC	New York City Economic Development Corporation
NYCHA	New York City Housing Authority
NYSDEC	New York State Department of Environmental Conservation
O&M	operations and maintenance
OER	Office of Environmental Remediation
OLTPS	Office of Long-Term Planning and Sustainability
OMB	Office of Management and Budget
OMRRR	Operation, Maintenance, Repair, Replacement, and Rehabilitation
ORR	Office of Recovery and Resiliency
OSE	Other Social Effects
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
p-FIRM	preliminary Flood Insurance Rate Map

PMP	Project Management Plan
PPA	Project Partnership Agreement
PV	present value
RED	Regional Economic Development
RI/FS	Remedial Investigation/Feasibility Study
ROD	record of decision
ROW	right-of-way
SFHA	Special Flood Hazard Area
SLR	sea level rise
SPDES	State Pollutant Discharge Elimination
TBC	Tug & Barge Committee
TCE	trichloroethene
ULURP	Uniform Land Use Review Procedure
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	volatile organic compounds
WOPC	without project condition
WPCP	Water Pollution Control Plants
WWTP	wastewater treatment plant

This page was intentionally left blank.

Part I:
Project Overview and Baseline Information

This page was intentionally left blank.

1 Project Overview

1.1 Study Goals and Objectives

The Gowanus Canal and Newtown Creek Storm Surge Barrier Study project is a conceptual feasibility study that may be used in assessing the need to advance to more a detailed and complete feasibility study and could inform such a study or the project implementation that may follow. This report focuses on the Newtown Creek Storm Surge Barrier Study. The primary study goals are as follows:

- Identify a flood protection strategy that benefits communities in the Newtown Creek (Creek) study area.
- Produce a study that complements and informs New York City (City) and United States Army Corps of Engineers (USACE) planning activities.

The Newtown Creek Storm Surge Barrier Study follows from other New York City resiliency studies that are ongoing or nearing completion and that have worked to open and advance discussions with USACE. Unlike some other similar studies, there is currently no funding identified in the City's 10-year capital program for a Newtown Creek surge barrier. However, given the importance of the industrial waterway and the dynamic changes taking place around it, the City has elected to study potential storm surge barriers and to envision how resiliency efforts in these locations might look. Any potential project would be very expensive and very complex, as it would tie into the pre-existing urban fabric. However, by starting to advance thinking now, and engaging with the USACE from the onset, the intent is to set up and position the study so that the City can transition the work to the USACE to carry forward as the Corps undertakes and completes its NY/NJ Harbor and Tributaries Feasibility Study.

At this conceptual stage, the objective is to identify fatal flaws and determine whether a surge barrier flood defense system, consisting of both an in-water storm surge barrier and upland defenses, may be a possible solution for the City or USACE to further investigate and consider. High-level preliminary analysis was completed to answer, or in some cases, identify for future investigation, critical questions around how a potential flood defense system could tie into the existing, dynamic urban fabric, and how a system would intersect with the City's operational partners. Detailed design solutions are not a part of the study's scope, but rather, a roadmap has been developed for next steps should the study outputs be transitioned and advanced. This roadmap includes suggestions for further site and engineering investigations, stakeholder engagement, permitting and regulatory considerations, funding and financing approaches, and policy implications.

1.2 Engineering Goals

The overarching engineering goal for this study is to design a system, at a conceptual level, to reduce the risk of flooding during extreme events. This study developed and assessed a number of alternative concept options for the study site. As conceived, such a system, and thus each concept option, would comprise three connected parts:

A. In-water barrier
B. Upland defenses
C. Natural elevation

For the purpose of the preliminary study phase, a conservative approach has been employed to establish design flood elevations (DFE). As potential projects advance to subsequent stages, such as feasibility analysis and potential implementation—especially by the USACE—the DFE typically undergoes an engineering review and economic assessment. This process maximizes the level of protection for a given level of investment and provides a policy review to determine the level of protection the City ultimately wants. However, for this conceptual evaluation stage, where the objective is to identify and understand the broad array of anticipated challenges and complexities that might be encountered, the conservative approach has been adopted.

In accordance with the guidance outlined in Sections 2.4 and 2.5 of this report which describe the Federal Emergency Management Agency (FEMA) and USACE design requirements, the DFE for the in-water storm surge barrier is based on the FEMA 2013 Preliminary-Flood Insurance Rate Map (p-FIRM) 500-year flood elevation of +15-foot North American Vertical Datum of 1988 (NAVD88). Allowance is provided for 3 feet of freeboard and 3 feet of sea level rise for a total elevation of +21-foot NAVD88 DFE. The DFE for the upland defenses is based on the FEMA 2013 p-FIRM 100-year flood elevation and allows for 3 feet of freeboard and 2 feet of sea level rise for a DFE of +17-foot NAVD88 DFE. The sea level rise allowances reflect the New York City Panel on Climate Change's 2015 findings that forecast mid-range (25th – 75th percentile) changes in sea level rise of 11-24 inches by the 2050s and 18-39 inches by the 2080s. This difference between the in-water barrier and upland defense DFE reflects the difficulty and expense of retrofitting an in-water barrier as compared to future-proofing the upland defenses. For the storm surge barrier, this includes not just raising the gate height, but expanding the foundations, operational equipment, and support infrastructure—which is much more challenging than expanding upland defense systems. This conservative approach, with differences between the in-water and upland DFE, is commonly employed in Europe as well.

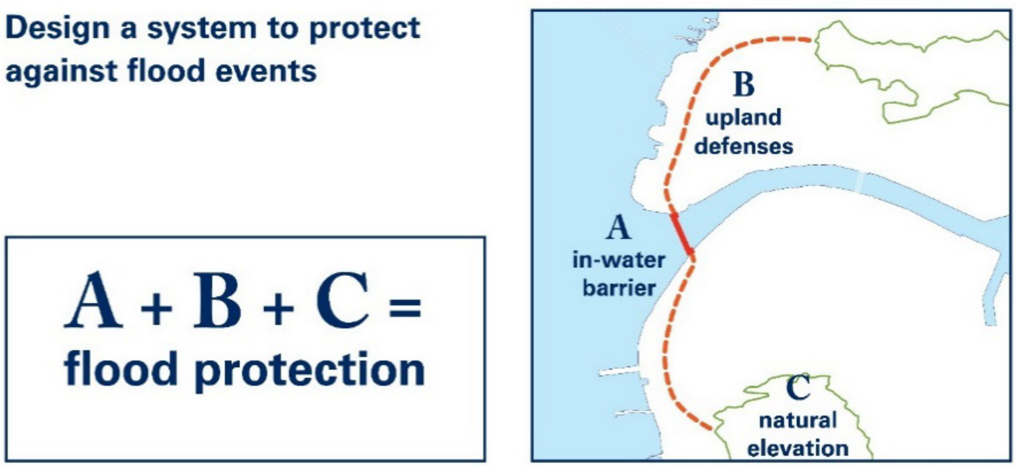


FIGURE 1-1
Storm Surge Barrier System Components

FIGURE 1-2
Study Design Flood Elevations

Figure 1-3 shows the +17-foot NAVD88 DFE around the Brooklyn and Queens waterfront. The study site boundaries for a Newtown Creek storm surge barrier system were roughly defined as the East River to the west, 48th Avenue to the north, and Transmitter Park/Greenpoint Avenue to the south.

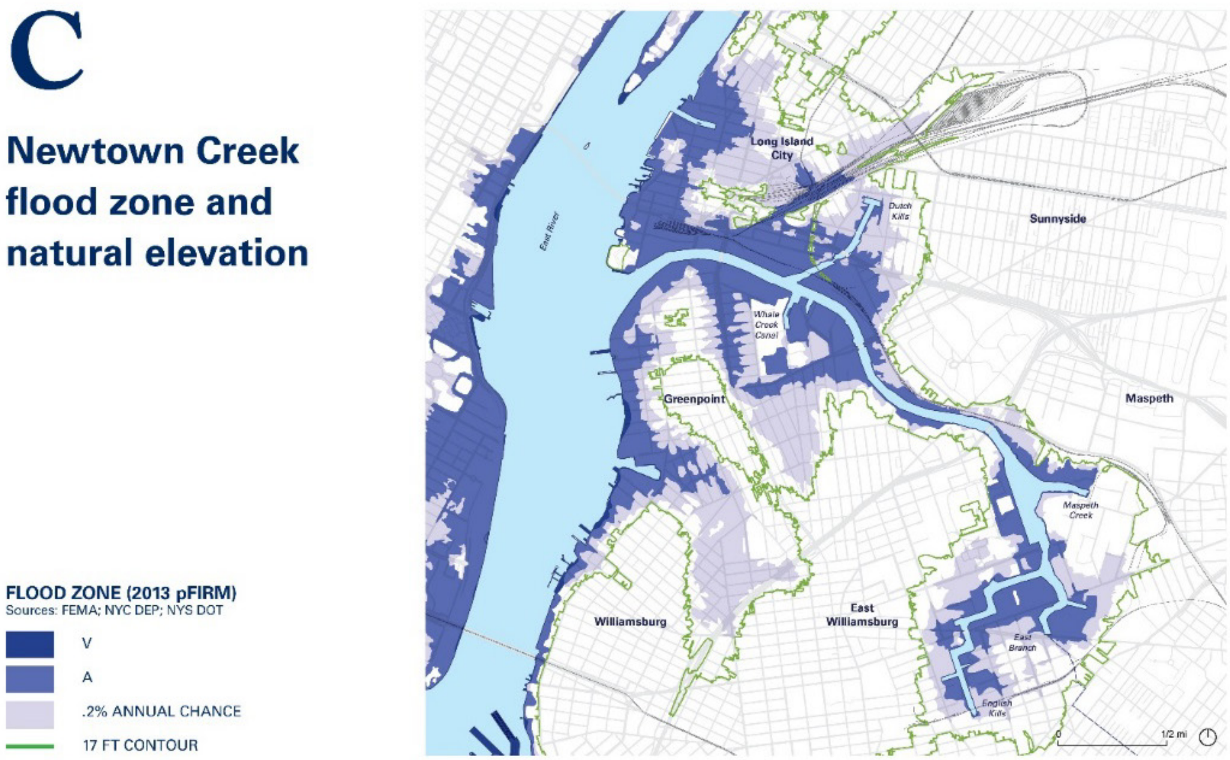


FIGURE 1-3
Newtown Creek Flood Zone and Natural Elevation

It should be noted that during the course of this study, on June 26, 2015, after much of this study's analysis had been completed, the City of New York filed an appeal of FEMA's preliminary flood insurance rate maps following an independent review that identified scientific and technical errors in FEMA's modeling approach.

The City's appeal found that FEMA's 2015 p-FIRMs overstate Base Flood Elevations (BFEs) by more than 2 feet in many areas of New York City and have unnecessarily placed 26,000 buildings and 170,000 residents in the Special Flood Hazard Area.

The Newtown Creek Storm Surge Barrier Study methodology uses the FEMA 2013 FIRM data as the basis of the analysis. Throughout this report and subsequent deliverables, caveats and discussions are provided around potential implications of a reissuance of FEMA's 2015 preliminary Flood Insurance Rate Map (p-FIRMs) at a future date on this study's findings and analyses.

In general, in the case that the City's appeal is successful, and less conservative (Flood Insurance Rate Map) FIRMs are issued, it is anticipated that the estimated benefits, especially around avoided damages, would be lower than those calculated in this study. At the same time, estimated capital costs would also be expected to decrease as a lower DFE requirement would be anticipated. This caveat is not study specific, but rather, is applicable to all City resiliency studies whose assumptions have been based off the FEMA 2013 p-FIRM data.

1.3 Influences on Alignment Development

The study looked at existing conditions as well lessons learned and best practices from other storm surge barrier projects. These conditions and themes generally fell into four priority areas, which include:

- Protect lives and livelihoods.
- Support an active and healthy waterfront.
- Integrate flood protection into neighborhoods.
- Facilitate funding for a flood protection system.

Combined, these considerations influenced the siting analysis and the principles guiding concept option development. Many of the considerations are reflected in the evaluation framework developed for the study and described in more detail in Section 5 of this report. Within the study's evaluation framework, they have been translated into evaluation categories consistent with the USACE planning regulations framework for purposes of consistency and potential transition. Discussion around the siting considerations and evaluation criteria is presented in Section 6 and Section 8 where the in-water storm surge barrier and the concept option assessments are described.

Some factors, such as Superfund remediation work, environmental conditions, habitat creation or impact, and future development potential, influence timing and implementation.

1.3.1 Protect Lives and Livelihoods

Protection of lives and livelihoods considers residential, commercial, and industrial land use to assess where the people and jobs are located within the study sites. The category also considers the location of critical infrastructure for which a potential storm surge barrier system could eliminate or reduce the risk of damage by flooding.

Newtown Creek's residential and commercial population is clustered by the mouth of the Creek while the industrial activities are further upstream along the Creek. The specific zone of protection corresponding to the alternative concept options is presented and compared in subsequent sections of this report for both the 100 and 500-year flood zone. A zone of protection is defined as the area that is inundated without the project, but is not inundated with the project, according to hydrodynamic modeling (see Section 9). Appendix N contains the complete tables of socioeconomic benefits, as well as sources and methodology.

Within the 100- and 500-year flood zones surrounding Newtown Creek, there is a sizeable community that could be protected, depending upon the ultimate alignment of a storm surge barrier system. Relative to New York City overall, this population has a smaller proportion of both children (11 percent are under age 18, compared to 21 percent across the city) and seniors (7 percent older than 65 compared to 12 percent). The population also has a smaller percentage of racial and ethnic minorities, as 69 percent are white non-Hispanic, compared to just 33 percent of the City. There are relatively fewer low- and moderate-income residents in the area compared to the city overall, with 20 percent and 28 percent of families earning below $40,000 and $60,000 a year respectively, compared to 36 percent and 51 percent for the city as a whole.

The Newtown Creek vicinity contains parts of the Long Island City, Maspeth, and North Brooklyn Industrial Business Zones (IBZs), which together are home to 33 percent of all jobs in IBZs citywide. As such, the protected area has a high concentration of businesses and jobs, particularly in the industrial sectors. The area has a job density of almost 31 jobs per acre. This is triple the typical job density along the New York City waterfront, considering the jobs per acre in the 2007 FIRM 100-year flood zone. The area has almost 21 industrial sector jobs per acre, over seven times the industrial job density of the city overall.

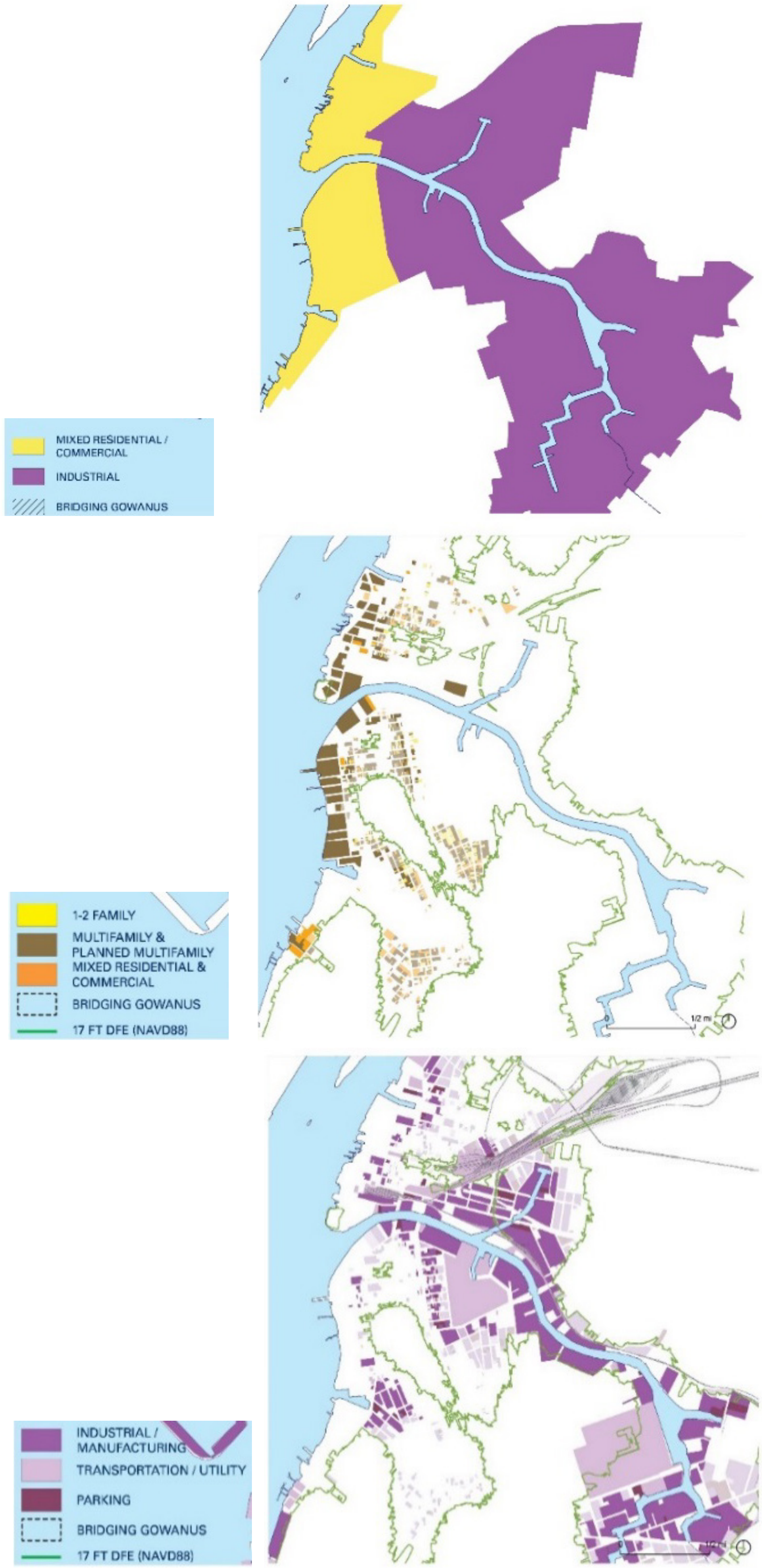


FIGURE 1-4
Newtown Creek Existing Conditions

Critical infrastructure at Newtown Creek that could be affected by flooding includes:

- The G train, the subway line that runs underground along Manhattan Avenue in Greenpoint, Brooklyn, before crossing under Newtown Creek to 21st Street in Long Island City, Queens.
- The rail yards bound by 2nd Street to the west and Bordon Avenue to the north.
- The Midtown Tunnel exit to the Long Island Expressway by Vernon Boulevard and Bordon Avenue.
- The New York City Department of Environmental Protection (NYCDEP) operated wastewater treatment plant on Newtown Creek for which creek-based vessel access is vital.

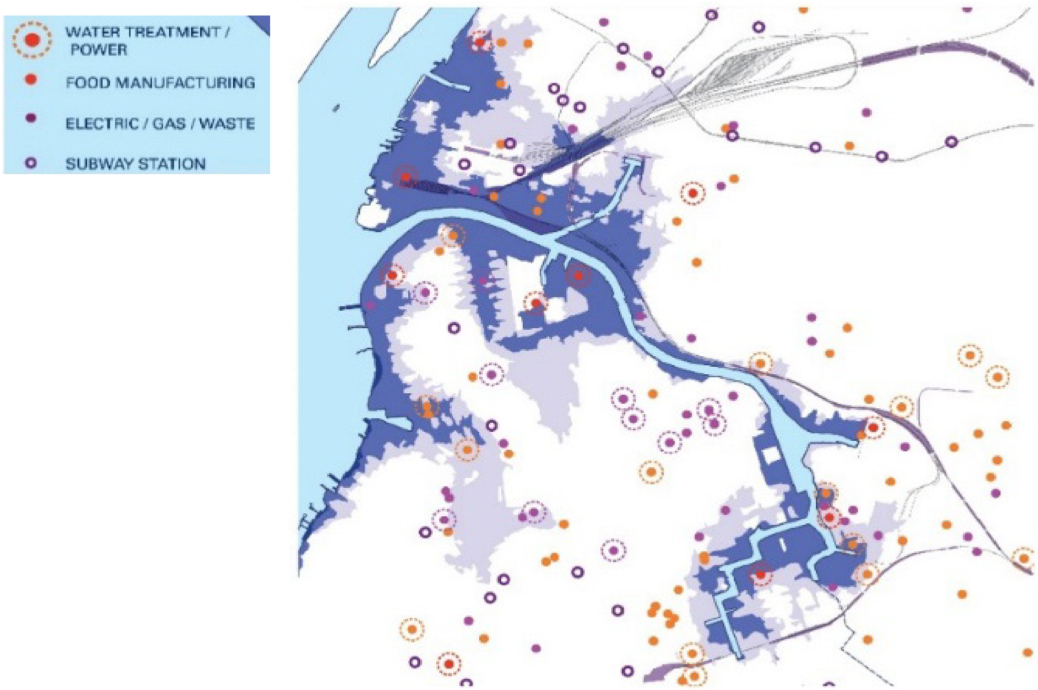


FIGURE 1-5
Newtown Creek Critical Infrastructure Sites

1.3.2 Support an Active and Healthy Waterfront

Ensuring that any potential storm surge barrier system supports an active and healthy waterfront requires consideration of current and future waterway usage. This includes understanding current vessels operating in the waterways both in terms of size and maneuvering. The study team conducted preliminary discussions with NYCDEP and the Tug & Barge Committee (TBC) of the Maritime Association of the Port of New York and New Jersey to get initial feedback on navigation constraints and possible in-water storm surge barrier locations. The study team also reviewed a one month sample dataset of vessel tracking at Newtown Creek. Moffat & Nichol collected the Automatic Identification System (AIS) dataset for an ongoing bulkhead raising study they are conducting for NYCEDC.

Support for an active and healthy waterfront must also consider potential impacts to existing water quality and marine habitat. The study team performed flushing analyses for the with-project situation to assess potential impacts to water exchange by an in-water storm surge barrier. Marine habitat surveys were also undertaken to assess existing conditions and potential impacts. It is recognized that existing conditions will change post-Superfund remediation work and that a future detailed feasibility study would be anticipated to consider such changed conditions.

A guiding principle applied to the development of all of the concept options is to minimize any potential adverse water quality impacts by trying to maintain the current cross-sectional constraints and navigation limits imposed by the Pulaski Bridge to the degree possible to avoid adverse navigation impacts or water quality impacts within reason. More detailed discussion of these considerations and analyses is provided in Sections 6.2 Storm Surge Barrier Assessment and 9 Hydrodynamic Modeling, and in the Appendices.

1.3.3 Integrate Flood Protection into Neighborhoods

Given the active and dynamic nature of the neighborhoods adjacent to Newtown Creek, and in particular, the level and types of street activity, integrating a potential upland flood defense system at any location poses challenges and complexities. The requirement of tying into high ground at the +17-foot NAVD88 DFE requires that any concept option will require at least some segment that connects with or runs along public right-of-way (ROW).

Erecting a flood-defense system in or adjacent to a street leads to design questions about how an upland flood-defense system would interfere with or could work around a variety of street elements, including on-street parking, sidewalks, bicycle lanes, street light distribution, street trees, curb cuts, drainage and utility systems, building entrances and exits, and loading docks. From a day-to-day City operations perspective, there are challenges associated with fire and life safety emergency access, roadway maintenance, snow removal, street cleaning, and waste collection.

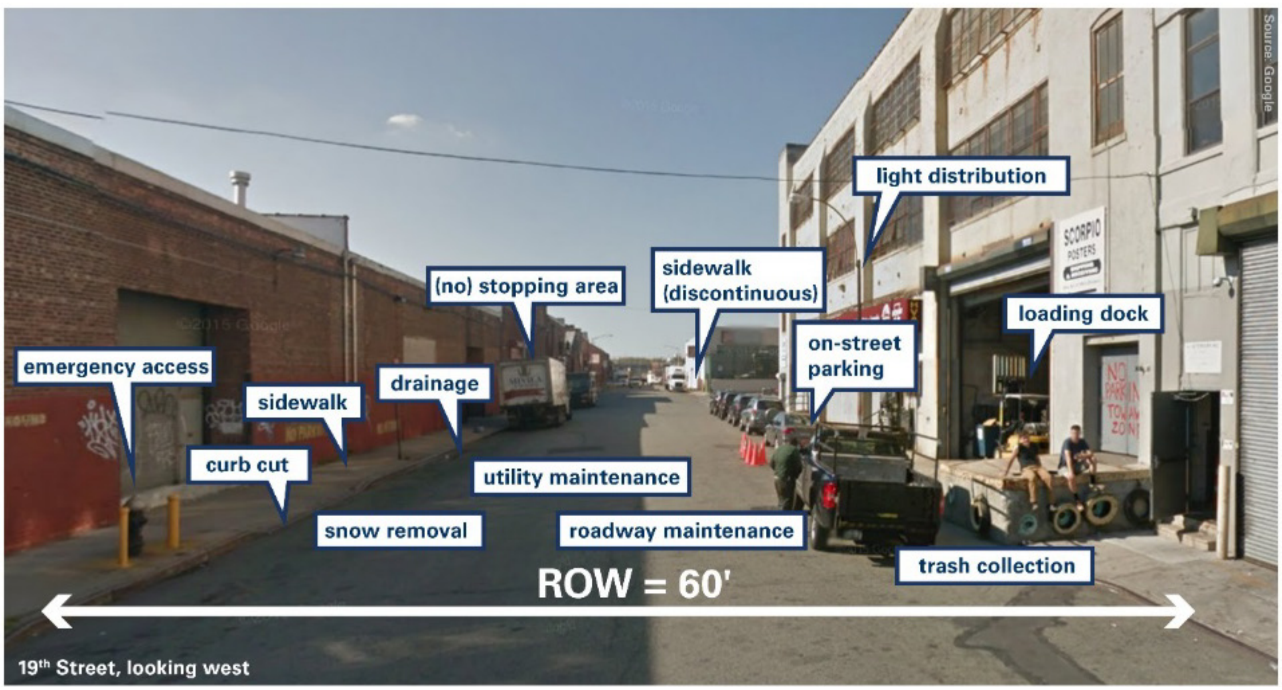


FIGURE 1-6
Profile of Commercial Street Activity

FIGURE 1-7
Profile of Residential Street Activity

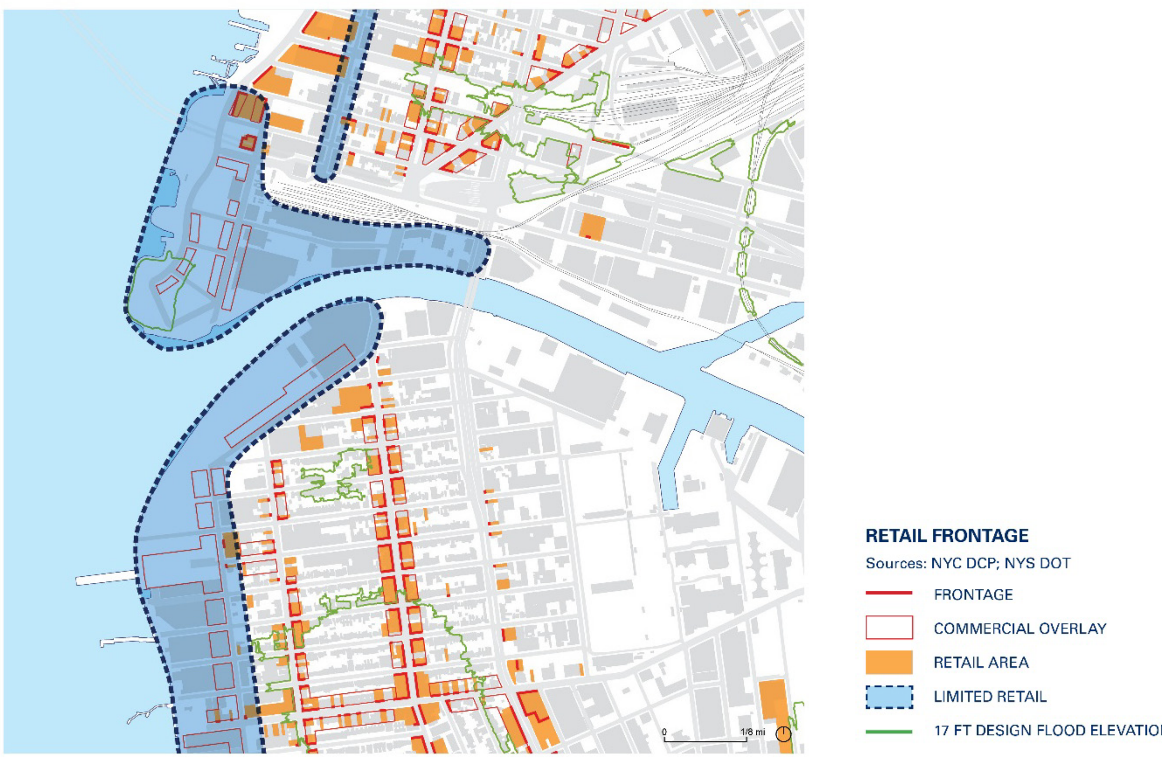


FIGURE 1-8
Newtown Creek Retail Frontage Assessment

The development of alternative concept options considered future development plans, waterfront access, and view corridors. To the degree possible, the concept options aim to minimize neighborhood disruptions. This included understanding the location of retail corridors, street widths, competing street uses and curb cuts. For example, at Newtown Creek, shifting the upland defense alignment closer to the shoreline avoids the major retail corridors where pedestrian and vehicular activity is heaviest.

At the same time, physical space requirements need to be balanced. A wider ROW, such as Manhattan Avenue on the Brooklyn side of the Creek, could have better capacity to absorb an upland defense component than a narrower one such as Franklin or West Streets, depending upon the streetscape activity and other competing factors.

Curb cuts are another street element that add to design complexity. Access to driveways, especially for industrial and commercial businesses, is critical, and requires the inclusion of operable gates to preserve access. To the degree possible, the concept options developed work to minimize access disruptions. For example, operable gates at pier entrances would be required to maintain access to the India Street Pier and the Hunters Point South/Long Island City ferry stops.

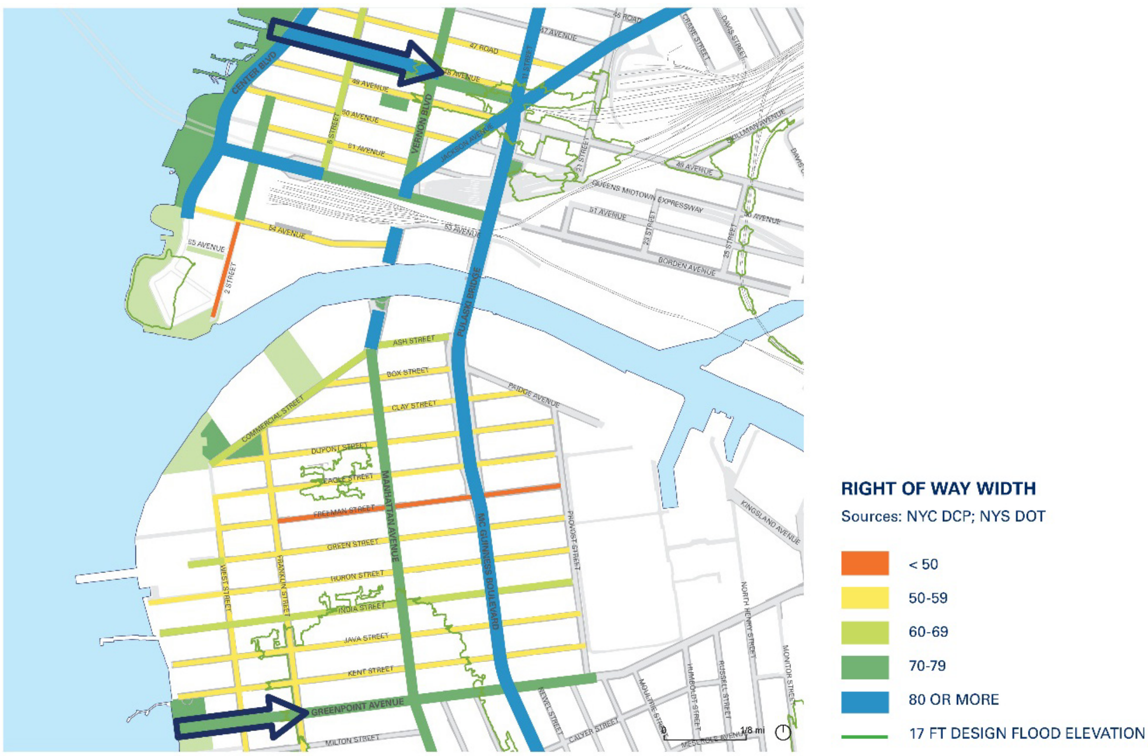


FIGURE 1-9
Newtown Creek ROW Dimension Assessment

What becomes clear from the siting considerations and complexity around upland defense alignments, as elaborated on in detail in Section 8, is that any selection and ultimate implementation of a storm surge barrier system necessitates trade-offs in priorities, impacts and benefits.

1.3.4 Facilitate Funding for a Flood Protection System

A final area of focus in thinking about concept option development and the potential implementation of a storm surge barrier system addressed funding considerations, and anticipated changes to the built environment. If the USACE were to ultimately advance a project for this study site, the federal contribution would be expected to be 65 percent of total capital costs while non-federal sources would need to fund 35 percent.

A number of funding-related criteria were considered during the concept option development and screening stages. These included opportunities to reduce capital costs, the potential for incorporating and leveraging the investments from future private and public projects, and the influence of ownership on potential funding and implementation strategies. Consideration of public or private ownership implies trade-offs between cost, control, reliability and flood insurance benefits.

FIGURE 1-10
Capital Cost Reduction Strategies

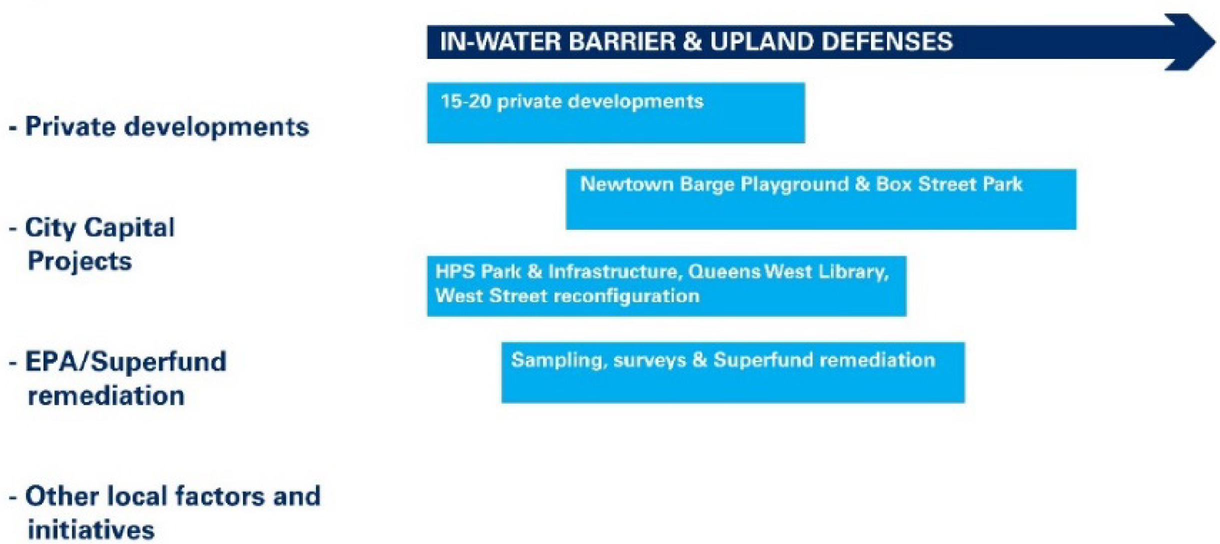


FIGURE 1-11
Planning in a Dynamic Environment

Understanding anticipated timing of changes to the study site communities over the foreseeable future is important. There are many planned or anticipated projects that are taking place over the next decade, and given the long time horizon before any project is likely to be realized at Newtown Creek, the concept options developed have worked to account for these to the degree possible.

At Newtown Creek, these projects include private residential or mixed-use developments at Greenpoint and Hunters Point South, new parks and public amenities, as well as other location initiatives. At some point in the future, U.S. Environmental Protection Agency/Superfund remediation of the Creek will take place, though plans and timing are undetermined at the time of this study.

Raised site elevation is one of the factors being considered in looking at ways to leverage developer contributions in order to reduce total capital costs. Where a development site could be elevated, and an engineered landscape element could form a component of the upland defense system, the total amount of floodwall or upland defense to be funded by the public sector could be reduced. A potential site integration concept option is presented for Newtown Creek in Section 8 as one of the alternative alignments. Discussions were held with City agencies to explore the potential for site elevation requirements as an additional tool in the city’s approach to flood defenses. ORR and NYCEDC should continue to advance these discussions beyond this project.

FIGURE 1-12
Newtown Creek Parcel Development Status

1.4 FEMA Certification Requirements

One goal of this project is to develop concepts for a flood protection system that will ultimately be accredited by FEMA, which allows a reduction in flood insurance requirements on the protected side of the system. To be accredited by FEMA, technical and operation data must be provided as part of a certification submittal. The following briefly discusses these requirements as identified in 44 Code of Federal Regulations (44 CFR) Part 65. More detail on federal requirements, including 44 CFR 65.10 as well as other guidance memos, is provided in Appendix P.

1. Freeboard: A system must provide a minimum base freeboard of 3 feet. Additional height above the base freeboard is required in certain locations (e.g., at constrictions and upstream limit of the system). The base freeboard can be reduced by up to 1 foot (for a minimum base freeboard of 2 feet) if supported by a risk and uncertainty analysis.
2. Evidence that all closures (e.g., storm drains) have closure devices.

3. Engineering analyses to show that the embankment protection is adequate.
4. Engineering analyses to show that the embankment and foundation is stable. Specific load cases as identified in USACE guidance document "Design and Construction of Levees" (EM 1110-2-1913) must be provided.
5. An evaluation of settlement. This evaluation must comply with the USACE guidance document "Soil Mechanics Design - Settlement Analysis" (EM 1100-2-1904).
6. An analysis of the interior drainage: This analysis should be based on the joint probability of flooding between the interior (protected) and exterior (flood) side of the system.
7. Operation and Maintenance (O&M) Plans: These plans must be officially adopted by a community or agency of a community that participates in the National Flood Insurance Program (NFIP). Where human intervention is required for operation, the flood warning system to allow for adequate implementation time must be documented. All maintenance activities (inspection, testing, and training) to be performed, the frequency (typically annually), and the party responsible must be detailed. In some cases, an O&M plan, separate from the floodwall system O&M plan, may be developed for the pump station (where pump stations are required).

These considerations of the FEMA requirements have been incorporated into the alternatives in Section 8 in order to provide for ultimate FEMA accreditation of the system. Should a project advance beyond this conceptual study, early discussions between the City and FEMA may help to establish a clear pathway for coordination from planning and design through to system accreditation.

1.5 USACE Design Considerations

The concept designs have been developed to assess the potential feasibility of storm surge barriers in terms of expected costs and benefits (damages reduced), including consideration of environmental impacts. Barrier system concept designs with a likely positive benefit to cost ratio may be candidates for further study, design, and implementation through cost-shared storm and flood risk management programs of the USACE.

If barrier systems are to be advanced through a USACE cost-shared program, design would need to be performed in a manner compliant with applicable USACE design guidance. Applicable USACE design guidance includes but is not limited to:

- Design and Construction of Levees. Engineer Manual 1110-2-1913. U.S. Army Corps of Engineers. April 30, 2000.
- Design of Coastal Revetments, Seawalls, and Bulkheads. Engineer Manual 110-2-1614. U.S. Army Corps of Engineers. June 30, 1995.
- Coastal Engineering Manual. Engineer Manual 110-2-1009. U.S. Army Corps of Engineers. April 30, 2002.
- Geotechnical Investigations. Engineer Manual 1110-1-1804. U.S. Army Corps of Engineers. January 1, 2001.
- Retaining and Flood Walls. Engineer Manual 1110-2-2502. U.S. Army Corps of Engineers. September 29, 1989.
- Real Estate Handbook. Engineer Regulation 405-1-12. U.S. Army Corps of Engineers. November 20, 1985.
- Planning Guidance Notebook. Engineer Regulation 1005-2-100. U.S. Army Corps of Engineers. April 22, 2000.
- Engineering and Design for Civil Works Projects. Engineer Regulation 1110-2-1150. U.S. Army Corps of Engineers. August 31, 1999.

- Civil Works Cost Engineering. Engineer Regulation 1110-2-1302. U.S. Army Corps of Engineers. September 15, 2008.
- Hydraulic Design for Coastal Shore Protection Projects. Engineer Regulation 1110-2-1407. U.S. Army Corps of Engineers. November 30, 1997.
- Hazardous, Toxic and Radioactive Waste Guidance for Civil Works Projects. Engineer Regulation 1165-2-132. U.S. Army Corps of Engineers. June 26, 1992.
- Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures. U.S. Army Corps of Engineers. April 30, 2014.

The USACE guidance provides engineering considerations and requirements for the further design of the barrier system through USACE programs. USACE does not prescribe a level of protection for storm damage reduction projects. Typically a USACE feasibility study would include optimization analysis to identify the levee height and configuration that results in maximum net benefits (benefits minus cost) as the National Economic Development (NED) plan.

As previously noted in Section 2.1, for this preliminary study, the proposed top elevation for the barrier system was set at +21-foot NAVD88 (in-water storm surge barrier) and +17-foot NAVD88 (upland defense components) based upon current FEMA regulatory floodplain mapping conducted as part of the NFIP. USACE guidance on the agency's procedures for NFIP levee system evaluation can be found in:

- USACE Process for the NFIP Levee System Evaluation. Engineer Circular 1110-2-6067. U.S. Army Corps of Engineers. August 31, 2010.

USACE Civil Works planning guidance does not necessarily support federal funding of construction of storm damage reduction projects to the same elevation required for NFIP levee certification. USACE program regulations specify that the federal interest is to fund a specified percentage (typically up to 65 percent) of the NED plan. The elevation that provides this maximum net benefit may not equal the elevations used in this analysis as required to obtain levee certification through the NFIP.

For example, a barrier system designed to a lower elevation than that required for NFIP certification could be identified as the NED plan if it provided greater net benefits. In such a case, USACE could only fund up to the federal share of the construction costs of the NED Plan and any additional height required for NFIP certification would be at 100 percent local cost. If future cost shared studies of the barrier options are conducted with USACE, these studies would likely include more detailed design consistent with the above engineering guidance, more detailed evaluation of expected costs and benefits, identification of the NED plan, and determination of cost sharing percentages consistent with USACE policy.

2 History

2.1 Site History and Background

2.1.1 Site History

Excerpted and expanded from the NYCDEP Newtown Creek: Waterbody / Watershed Facility Plan, June 2011 (2.1-2) unless noted.

Newtown Creek (Creek) is a tidally-influenced estuary comprised of five branches that join together and flow into the East River (**Figure 2-1**). Dutch explorers completed the first survey of Newtown Creek in 1613-14, and it was acquired from the local Mespatches tribe shortly thereafter. The Creek area, first used for trading and agriculture, also housed early industrial commerce and became an important industrial zone following the Revolutionary War. Farmland was replaced by glue and tin factories, rope works, tanneries and the Sampson Oil Cloth Factory.

Commerce along the Creek eventually shifted to shipbuilding, with hundreds of boats built in the Pre-Civil War era. In the Post-Civil War era, the Industrial Revolution began and textile manufacturing and oil refining replaced shipbuilding in the area. The first kerosene refinery (1854) and the first modern oil refinery (1867) in the United States transformed the Creek into an industrial waterway. In 1865 the city surveyor, J.S. Stoddard, recommended against plans to run sewer lines to the Creek. His advice went unheeded and the city began dumping raw sewage directly into the Creek. The influx of industry was accompanied by infrastructure development, including the Long Island Railroad Hub (1861), and later by the Queensboro Bridge (1909) and the IRT subway line (1917).

FIGURE 2-1
Newtown Creek, 1891 (Source: Brooklyn, New York Bay, Jersey City, Hoboken, Bayonne and Newark Bay Map, Julius Bien & Co., 1891).

By 1880, there were at least 50 petroleum refineries on the Queens side of the Creek alone, and by the end of the 19th century, Standard Oil was operating more than 100 refineries on both sides of the Creek.[1] Long Island City had the highest concentration of industry found anywhere in the United States.

The channelization and dredging of Newtown Creek was largely completed to its current configuration by the 1930s.[2] The aim was to accommodate heavier shipping traffic, and thus Newtown Creek succeeded in becoming a major shipping hub for the Northeast United States. Raw materials were imported from all over the world while manufactured products were exported domestically. The Creek became home to such businesses as sugar refineries, canneries, copper wiring plants and petroleum and oil refineries. The Creek soon became one of the dirtiest bodies of water in America as industries had free rein to dispose of unwanted byproducts.

Water quality degradation was accelerated by the cumulative effects of waterbody and watershed alterations and the lack of wastewater treatment (the Newtown Creek wastewater treatment plant [WWTP] was not completed until 1967). Water quality problems were so pronounced by the early 1900s that the New York State Legislature directed the City of New York to create the Metropolitan Sewerage Commission to study water quality in the New York Harbor. The Sewerage Commission began sampling the harbor in 1909, and characterized several tributaries of the harbor (including Newtown Creek) as “little more than open sewers” based on their investigation. They recommended against swimming in the harbor, and suggested that the oyster industry be abandoned.

2.1.2 Physical Transformation

Excerpted and expanded from the Newtown Creek BOA Step 2 Nomination Report, April 2012 (19-23) unless noted.

As early as the 1850s, filling, bulkheading and subdividing activities began along the East River shoreline up to the mouth of the Creek. The US Army Corps of Engineers first surveyed the Creek in 1878 and began channelization improvements two years later. By 1884, the East Branch of Newtown Creek and Whale Creek were regularized to accommodate increased shipping and distribution of building materials.

The tributary of Dutch Kills was developed largely due to the efforts of a private interest, Degnon Terminal & Realty Company. Between 1905 and 1912, the Degnon Company regularized and bulkheaded remaining portions of Dutch Kills, as well as filled marshes and promoted industrial development of the newly created land. Between federally-funded dredging and channelization activities and the similar activities of private interests in Newtown Creek, by 1919, all tributaries of the Creek had been modified, widened or deepened in some capacity and were slated for similar future projects vis-à-vis the Congressional Rivers and Harbors Act of 1919. The Act authorized seven projects to channelize and deepen portions of the Creek and its tributaries, including Maspeth Creek and English Kills. These projects were largely completed by the 1930s.

2.1.3 Site Characteristics

Excerpted and expanded from the NYCDEP Newtown Creek: Waterbody / Watershed Facility Plan, June 2011 (2.1-2).

Today the Creek is 3.8 miles from the East River to its farthest reach inland, and has a total surface area of approximately 165 acres. Dredging has provided depths of 15 to 16 feet at mean low water (MLW) and widths between 200 and 300 feet. The tributaries and branches are also relatively deep, between 10 and 17 feet MLW, although they are shallower toward their head ends. English Kills, upstream of Metropolitan Avenue, becomes very shallow for a significant distance toward it head end. The downstream reach of Newtown Creek is significantly wider, averaging about 550 feet, and expanding to approximately 820 feet as it enters the East River. These widths and depths accommodate small ship and barge navigation through most of the waterbody, and although waterfront industrial activities have significantly declined over the years, Newtown Creek still remains an active area for manufacturing, wholesale distribution, solid waste

[1] Greenpoint Manufacturing and Design Center, Newtown Creek Alliance, and Riverkeeper, Newtown Creek BOA Step 2 Nomination Report. April 2012.

[2] U.S. Environmental Protection Agency (USEPA). 2011. Newtown Creek: Cultural Resources Survey Stage 1A Work Plan; Remedial Investigation / Feasibility Study, prepared by Anchor QEA. November.

handling, oil storage and distribution, and municipal uses, including the WWTP. From 1985 through 1987, waterborne commerce averaged approximately 2,000 round trips per year by tankers and barges transporting mostly petroleum products, sand and gravel, scrap metal and solid waste materials.[3]

2.1.4 Superfund Designation

Excerpted and expanded from the Newtown Creek BOA Step 2 Nomination Report (April 2012): 8-9; 77.

2.1.4.1 Soil and Groundwater Contamination

In 1976, an oil slick was discovered on Newtown Creek originating from the bulkhead near Meeker Avenue. Subsequent studies have revealed this to be among the largest oil spills ever recorded in the United States, with an estimated 17 million to 30 million gallons of petroleum products having leached into the soil over many decades. The discharges formed an underground plume several acres in size (**Figure 2-2**) below residential and business areas of Greenpoint. According to the Riverkeeper website: "The spill has been oozing under Greenpoint for five decades, destroying the local aquifer, rendering more than 50 acres of land undevelopable, settling under more than 100 homes on three residential blocks, severely contaminating Newtown Creek, and threatening aquatic life harbor-wide."[4]

Recovery efforts begun in 1979 did not gain momentum until the 1990s when the state ordered ExxonMobil to undertake more active cleanup measures. Since 2004, three lawsuits have been brought against ExxonMobil and other companies. For case management purposes all three lawsuits were consolidated by the federal court in Brooklyn. A settlement reached in fall 2010 required ExxonMobil to pay a $25 million penalty; commit to a rigorous cleanup operation at the company's expense; and provide quarterly and annual reports on the status of the remediation efforts. $19.5 million of the settlement money, the largest single payment of this kind in state history, was earmarked for environmental projects benefitting Greenpoint.

Investigation of the Greenpoint oil spill extent also revealed plumes of tetrachloroethene (PCE) and trichloroethene (TCE)—hazardous chlorinated solvents resulting from decades of dumping by former and current dry-cleaning and metalworking businesses sited around and south of Meeker Avenue. New York State Department of Environmental Conservation (NYSDEC) is currently pursuing the owners of these properties for cleanup and remediation costs under the state Superfund program. The findings of this report could also be coordinated with the USEPA for use under its federal Superfund activities.

[3] URS Consultants, Inc. (URS), *Newtown Creek Water Quality Facility Planning Project, Draft Facilities Plan Report*, prepared for the City of New York Department of Environmental Protection, January 1993.

[4] "Greenpoint Oil Spill on Newtown Creek." Accessed online at http://www.riverkeeper.org/campaigns/stop-polluters/newtown/.

Source: NYSDEC, "Greenpoint Petroleum Remediation Project," 2008. Accessed online at http://nysdecgreenpoint.com/ProjectHistory.aspx.

FIGURE 2-2
Newtown Creek Plumes

2.1.4.2 National Priorities List Designation (Superfund)

Newtown Creek was designated for inclusion on the National Priorities List by U.S. Environmental Protection Agency (USEPA) on September 29, 2010. On September 7, 2011, an Administrative Order of Consent (AOC) was reached between USEPA and Phelps Dodge Refining Corporation, Texaco Inc., BP products North America, Brooklyn Union Gas Company doing business as National Grid NY, ExxonMobil Oil Corporation, and the City of New York as respondent parties to begin work at the Newtown Creek Superfund Site.

In 2008, Congress requested that the USEPA evaluate the Newtown Creek water body for Superfund status. USEPA's initial mandate was to investigate four facilities for contributions to contamination in the Creek: Phelps Dodge, BCF Oil, Quanta Resources and National Grid. USEPA expanded this list and identified an extensive list of potential contamination sources, both historic and existing. These include oil refineries and depots, former manufactured gas plants (MGPs), chemical plants, manufacturing facilities, rail yards, auto repair shops, tank cleaning companies, recycling and waste management facilities, and other potentially contributing enterprises and operations, including various State and City agencies. During the designation process, the City of New York voiced concern about the impact of designation to planned economic development projects such as the mixed-use redevelopment of Hunters Point in Queens. The City also voiced concern that the listing could impact plans by the New York City Department of Environmental Protection (NYCDEP) for approximately $500 million of water quality improvements, including work on combined sewer overflows (CSOs).

Several major landowners and operators along the Creek requested that the listing be withdrawn or delayed, including Texaco and ExxonMobil. Their opposition was based primarily on the assertion that the ongoing sedimentation and bacterial loading of the Creek as a result of CSOs would endanger the efficacy and success of any remediation of Creek sediments. The intent of the Superfund designation is to develop a remediation plan which will mitigate negative impacts to human health and the environment. The USEPA recognizes the City's and business and property owners' desire to see that the formal Superfund process not delay the revitalization of the area. USEPA has indicated willingness to work with business and property owners and larger area residents to have the Superfund process work to achieve its remedial goals as well as community redevelopment goals in a coordinated and expedient way.

2.1.5 Site Characteristics

Excerpted and expanded from the USEPA Newtown Creek: Remedial Investigation / Feasibility Study Work Plan, prepared by AECOM Environment, June 2011 (2.2-5) unless noted.

2.1.5.1 Geology

Newtown Creek's basic landforms were crafted during the most recent ice age, from around 12,000 years ago when the glacier that shaped New England began to melt, giving shape to Long Island.[5] The unconsolidated deposits in and around the Creek consist of fill (e.g., construction debris and domestic refuse) that overlay salt-marsh deposits and alluvium dating from that era. Beneath these lie a sequence of Pleistocene-age till and ground moraine from the Upper Glacial Aquifer. Based on well and test boring indications, the Upper Glacial Aquifer overlies the Precambrian-age crystalline bedrock from the mouth of Newtown Creek to just south of Greenpoint Avenue. Bedrock is approximately 30 feet below ground surface near the mouth of Newtown Creek and slopes southeastward to a depth of over 190 feet below ground surface at the southeastern extent of Newtown Creek. In the area east of Greenpoint Avenue through the end of Newtown Creek, the Raritan Clay (mainly deltaic clay and silty clay beds with some interbedded sand) underlies the Upper Glacial Aquifer over the bedrock. A marine clay (Gardiner's clay) separates the Upper Glacial Aquifer from the Raritan Clay at the southeastern extent of Newtown Creek beginning at the intersection of the East Branch and English Kills.

2.1.5.2 Surface Water Hydrology

Surface water circulation in Newtown Creek reflects the influence of two different mechanisms: tidal fluctuations and freshwater inputs. Generally, freshwater (including stormwater, municipal and industrial outfalls, and groundwater) flows downstream as a surface layer over denser estuarine water. The average estuarine water flow is typically in the upstream direction creating an underlying salt water wedge.

Aside from tidal cycles, the flows in Newtown Creek and its tributaries are comprised of wastewater discharges from CSOs, wastewater discharges from the surrounding industrialized areas, stormwater runoff from adjacent properties, and groundwater discharges. The CSO and storm sewer outfall point source discharges make up over 90 percent (annual baseline discharge volume of 2040 million gallons) of the wet weather flow in Newtown Creek and its tributaries. Base flow in Newtown Creek and its tributaries from groundwater discharge is estimated by the United States Geological Survey (USGS) as approximately 71 million gallons per year. This groundwater base flow, when compared to other discharges, makes up less than three percent of the total annual freshwater flow in Newtown Creek and its tributaries.

The drainage area for the Newtown Creek watershed is fully urbanized with no remaining natural marshlands or freshwater streams. The Newtown Creek watershed drains an area of approximately 7,440 acres, of which up to 50 percent is impervious because of extensive paving, construction, and urban development throughout the Newtown Creek watershed.

Approximately 17 percent of the Newtown Creek watershed surface area drains directly to the Creek through storm sewers, highway drains, and other direct discharges while the remaining 83 percent of the

[5] Greenpoint Manufacturing and Design Center, Newtown Creek Alliance, and Riverkeeper, Newtown Creek BOA Step 2 Nomination Report. April 2012.

Newtown Creek watershed surface area drains into a sewer system that collects stormwater, sanitary sewage, and industrial discharges. The results of NYCDEP modeling of flow indicate that in a typical precipitation year, such overflows occur, on average, approximately 70 times per year with a total annual discharge volume of approximately 1.4 billion gallons of untreated wastewater.

2.1.5.3 Site Hydrogeology

Groundwater flow in the Newtown Creek area has changed over time. Prior to the inception of public water supply pumping in the area (1903), groundwater in the water table aquifer followed its natural flow path, flowing toward and discharging to the nearest surface waterbody. In the early decades of the twentieth century, public water supply withdrawals in Kings County, southwest of Newtown Creek, created a cone of depression in the water table that possibly extended into Queens County to the northeast. At the center of this cone of depression, water levels in the water table aquifer were approximately 45 feet lower than during the pre-pumping period. This cone of depression possibly extended under Newtown Creek and, based on water level mapping in the area, the groundwater was depressed such that it may have flowed from the north under Newtown Creek toward the pumping center. Pumping for the public water supply was discontinued in Kings County in 1947, and groundwater levels recovered from this pumping by 1974.

The USGS developed a groundwater flow model for Kings and Queens Counties in New York. The report on this modeling describes the groundwater baseflow to Newtown Creek as 0.3 cubic feet per second which equates to approximately 135 gallons per minute.

Groundwater is expected to flow from upland areas toward Newtown Creek; however, groundwater flow is affected by bulkheads, remediation systems, discharge pipes, and tidal influences. The presence of bulkheads in various states of repair has the potential to locally divert shallow groundwater flow. Remediation systems at upland sites also have the potential to capture and prevent direct groundwater flow. The presence of numerous discharge pipes has the potential to create preferential flow paths toward the Creek. Additionally, tidal fluctuations in surface water levels influence the discharge of groundwater to Newtown Creek and its tributaries and result in periods during the day when the surface water elevation may be higher than the adjacent groundwater elevation (up to half of each day during high tides). During periods of the day when the surface water elevation is above the groundwater elevation, a reverse groundwater gradient may occur. With the return of the low tide cycle, the gradient reverses and groundwater discharges to the Creek.

2.1.5.4 Sediment Characteristics

Excerpted from the EPA Newtown Creek: Public Health Assessment, February 2014 (11).

The USEPA collected 58 sediment samples from Newtown Creek and six from the nearby Atlantic Basin for comparison. USEPA collected sediment samples at 0 to 2 feet (shallow) and 2 to 6 feet (deeper) depth intervals under water that was 7 to 23 feet deep. None of the samples were taken from locations where sediments are available for contact by the public. The Atlantic Basin is further south down the East River, near where the River meets the New York Upper Bay and across from Governor's Island. USEPA had the sediment samples analyzed for metals, volatile organic compounds, semi-volatile organic chemicals and polychlorinated biphenyls (PCBs).

USEPA compared Newtown Creek sediment results to the samples collected from the Atlantic Basin and reported contaminants in the Newtown Creek samples that exceeded levels detected in the Atlantic Basin samples.[6]

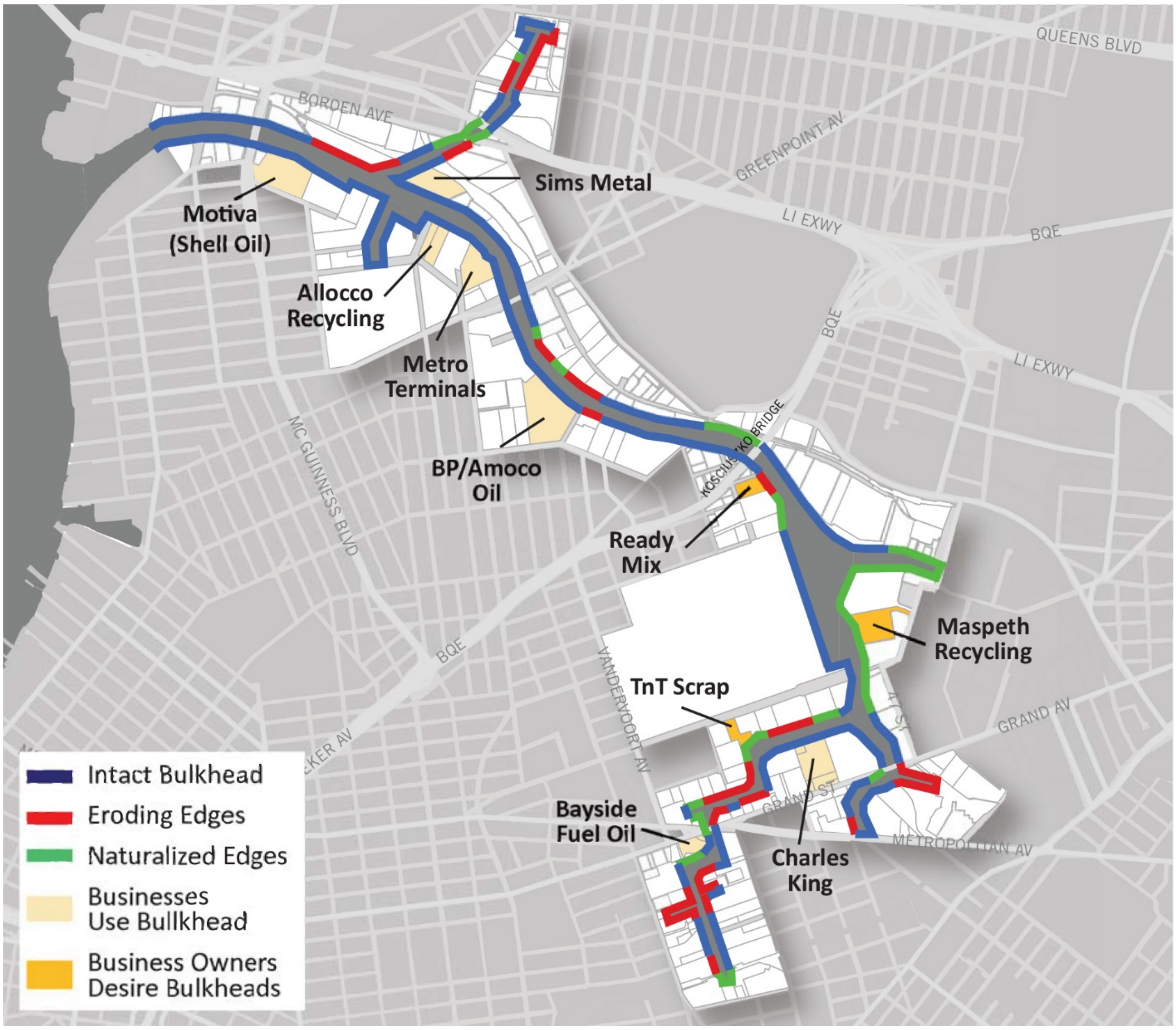
USEPA reported that several metals, volatile organic chemicals, semivolatile organic chemicals and PCBs in some Newtown Creek shallow sediment samples exceeded levels found in Atlantic Basin samples. The specific organic contaminants having higher levels in shallow sediment from the Newtown Creek included chlorobenzene, isopropylbenzene, polycylclic aromatic hydrocarbons, bis(2-ethylhexyl)phthalate), and two

[6] Weston Solutions, Inc. 2009. Expanded Site Inspection Report Newtown Creek Brooklyn/Queens, New York. July.

commercial mixtures of PCBs (Aroclor 1242 and Aroclor 1254). Several of the deeper sediment samples contained petroleum related compounds at levels above Atlantic Basin samples.

2.1.5.5 Shoreline and Bulkhead Characteristics

Originally a natural stream with fringe marshes and side channels, Newtown Creek and its tributaries are currently channelized. The banks and channel were reworked from a natural drainage condition to one that is largely governed by engineered and institutional controls (**Figure 2-3**). These institutional controls include discharge and other permits, zoning restrictions, security, and public health advisories. Most of the current shoreline is characterized by bulkheads with some riprap. Bulkheads are generally wood, steel, cement, or stone and are in various states of repair. Vegetation exists along eroded bulkheads, on sediment mounds, and similar locations.



Source: Kate Zidar and Damion Lawyer / Newtown Creek BOA Step 2 Nomination Report, April 2012, 62.

FIGURE 2-3
Newtown Creek Bulkhead Conditions

The majority of the shoreline area is zoned M3-1 for heavy manufacturing and industrial use. Small portions of each of the north and south shorelines near the mouth of Newtown Creek have been rezoned for residential use. Current operations along the Creek include a cement plant, scrapyard, beverage distributor, construction supply company, recycling plant for used concrete, plumbing fixture show room, dry ice manufacturer, petroleum bulk storage facilities, liquefied natural gas storage site, and the Newtown Creek WWTP.

Two public access areas have been constructed on the Greenpoint side of Newtown Creek; these are the only official locations where the public can approach and come in contact with the shore. A street end access area was constructed at the end of Manhattan Avenue, and a shoreline promenade was constructed at Whale Creek as part of the upgrades to the Newtown Creek WWTP. The shoreline promenade at Whale Creek was temporarily closed, and while now reopened, it bears cautionary signs to alert promenade users that Newtown Creek is a heavily trafficked maritime area and, further, has been designated by USEPA as a Federal Superfund Site.

2.2 SIRR Report and Lessons Learned

2.2.1 Sandy and Its Impacts

Excerpted from PlaNYC, A Stronger, More Resilient New York, June 2013 (11-12).

[Hurricane] Sandy hit New York with punishing force. Its surge and waves battered the City's coastline along the Atlantic Ocean and Lower New York Bay, striking with particular ferocity in neighborhoods across South Queens, Southern Brooklyn, and the East and South Shores of Staten Island, destroying homes and other buildings and damaging critical infrastructure. Meanwhile, the natural topography of the city's coastline channeled the storm surge that was arriving from the ocean northward into New York Harbor, elevating water levels in Jamaica, Sheepshead, Gravesend, and Gowanus Bays, as well as in Upper New York Harbor and the East and Hudson Rivers. At the same time, the storm surge also was pushing water into Long Island Sound, and from there south.

In short, the ocean fed bays; the bays fed rivers; the rivers fed inlets and creeks. Water rose up over beaches, boardwalks, and bulkheads. It was an onslaught of water.

2.2.2 What Happened During Sandy

Excerpted from PlaNYC, A Stronger, More Resilient New York, June 2013 (43).

[One of three ways] Sandy's surge impacted the City was via less direct routes. In these cases, the City's many bays, inlets, and creeks functioned as “backdoor” channels, funneling ocean waters inland. For example, much of the flooding in Southern Brooklyn came not only over the area's beaches, but also via Coney Island Creek and Sheepshead Bay. Likewise, floodwaters from Jamaica Bay contributed to the inundation of the Rockaway Peninsula, where, as area residents explained, "the ocean met the bay." Newtown Creek, meanwhile, overflowed its banks, flooding Maspeth, Greenpoint, East Williamsburg, and Bushwick.

2.2.3 Brooklyn-Queens Waterfront

Excerpted and expanded from PlaNYC, A Stronger, More Resilient New York, June 2013 (237-268).

Sandy highlighted the area's vulnerabilities. Although the waterfront's sheltered location largely protected the area from destructive waves, the storm surge did cause extensive flooding throughout the area—in many places more than six feet deep. Not surprisingly, flooding occurred along the Harbor and River-facing western edge of the waterfront, inundating neighborhoods, industrial properties, and retail corridors. The surge also made its way up Newtown Creek, flooding areas much farther inland. The result of this deluge was damage to building systems and contents, loss of power, displacement of residents, and weeks to months of lost revenue for businesses and nonprofits.

2.2.3.1 Area Characteristics

Because of the significant amount of area occupied by industry, the waterfront area has a relatively low population density (20 people per acre) as compared to the citywide average (42 people per acre). Greenpoint/Williamsburg is one of the only exceptions (50 people per acre), which has more concentrated residential areas.

Bordering Greenpoint, and separating Brooklyn from Queens, is Newtown Creek, which remains an active industrial waterway, spanned by six movable NYCDOT bridges and bordered by bulkheads suited to maritime use. There are over 2,700 buildings along the Creek, housing 12,400 people and 1,800 businesses. Though more than half of the surrounding buildings are occupied by maritime and other industrial uses, nearly 40 percent are residential walkups and 1- to 2-family homes.

The northernmost area of the waterfront is Long Island City, located at the intersection of the East River and Newtown Creek. It is a transportation hub, with easy access to Manhattan. Long Island City is also a flourishing arts center and an important business center, with large commercial buildings, housing, and, among other things, back offices for Citigroup and the headquarters for JetBlue. A 2001 rezoning led to the development of new waterfront residential buildings that are complemented by other large projects such as Queens West and Hunter's Point South, the largest middle-income housing development in the city since Starrett City. Large new buildings are under construction at both sites.

2.2.3.2 What Happened During Sandy

In Greenpoint, water from the East River and Newtown Creek caused flooding of streets and properties all along the neighborhood's perimeters. Floodwaters, for example, came significantly inland in the neighborhood's northeast, entering largely along Greenpoint Avenue and McGuinness Boulevard. The Newtown Creek wastewater treatment plan lost approximately half of its flow after the Manhattan Pumping Station shut down due to significant flooding. Still, the plant managed to continue treating sewage throughout the storm. The area also experienced flooding in its southwest section, close to the border it shares with Williamsburg.

As Sandy's surge pushed into Newtown Creek from the East River, the Creek, carried those waters inland, including to parts of Maspeth, Bushwick, and East Williamsburg. As with floodwaters off of the Gowanus Canal, floodwaters off of Newtown Creek also raised health concerns in surrounding communities. However, USEPA testing here also showed that bacteria levels did not appear to pose a danger to area residents. The USEPA also found that, post-Sandy, the various chemicals for which it tested were all below levels that should cause concern for area residents.

In Long Island City, inundation came from Newtown Creek as well as the East River, primarily via Anable Basin. While much of the neighborhood was unaffected, many buildings—such as those along 2nd Street, 5th Street, 51st Avenue, and Borden Avenue—experienced up to 6 feet of flooding, with important public infrastructure, such as Gantry Plaza State Park, also affected.

Overall, along the Brooklyn-Queens waterfront, more than 8,000 residential buildings were within the inundation area. These buildings contained nearly 49,000 residential units and housed almost 100,000 people. In many cases, Sandy's inundation forced people out of their homes for days, weeks, and even months. In some cases, this was because they lived in flooded ground-floor or basement apartments that were destroyed by flooding. In others, such as along Pioneer Street in Red Hook, it was because vital building mechanical systems supporting their living spaces were knocked out of service.

Also impacted by Sandy were waterfront businesses, which were impacted significantly by the storm, particularly as floodwaters filled ground floors and basements, damaging building systems and contents. In total, approximately 3,100 businesses employing some 34,600 people were impacted by Sandy.

2.2.3.3 What Could Happen in the Future

Given the waterfront's coastal exposure, the most significant climate change-related risks for its neighborhoods are storm surge and flooding from coastal storms, which is likely to be exacerbated by projected sea level rise. This risk is significant even today along the waterfront, as illustrated by flood maps released in June 2013 by the Federal Emergency Management Authority. According to these Preliminary Work Maps, the 100-year floodplain, the area with a 1 percent or greater chance of flooding in any given year, has expanded beyond that shown on the 1983 maps that were in effect when Sandy hit. In the new maps, the growth in the floodplain is most pronounced in Red Hook, Greenpoint, and Long Island City. The new maps show an expanded V Zone, the area where waves could exceed 3 feet in height, along the length of the waterfront's coastline, including along piers containing buildings and equipment.

As the 100-year floodplain has expanded in size, there has been also an increase in the number of buildings in the floodplain—a 6 percent rise in residential buildings (from approximately 850 to 900 buildings) and a 15 percent increase in commercial buildings (from almost 1,350 to nearly 1,550 buildings). In addition, approximately 100 buildings—all commercial—are now located in a V Zone. Base Flood Elevations—the height to which floodwaters could rise during a storm—have increased 1 to 3 feet throughout the area.

2.2.3.4 SIRR Initiatives

The SIRR Initiatives for the Brooklyn and Queens waterfront are mapped in **Figure 2-4.** The proposal for a Newtown Creek storm surge barrier was a specific action identified in the SIRR. The SIRR actions relevant to this study include:

Coastal Protection Initiative 26: Call on and work with the United States Army Corps of Engineers (USACE) to study and install local storm surge barriers at Newtown Creek

Newtown Creek was the source of extensive flooding during Sandy, carrying its surge miles inland. The risk of such flooding in the future is expected to grow as the climate changes. The City, through Office of Long-Term Planning and Sustainability (OLTPS), therefore, will call on the USACE to develop an implementation plan for, and construct, a storm surge barrier and associated levees at the mouth of Newtown Creek. Such a barrier would be navigable during non-storm periods and would close in advance of storm activity to protect the areas inland of the barrier. As Newtown Creek is a Superfund site, proper coordination with the USEPA and others will be required to implement the project successfully. Water quality impacts also will be considered in the study of this project. OLTPS will seek to have the USACE complete this project, subject to available funding, within six years following the completion of the development by USACE of its study.

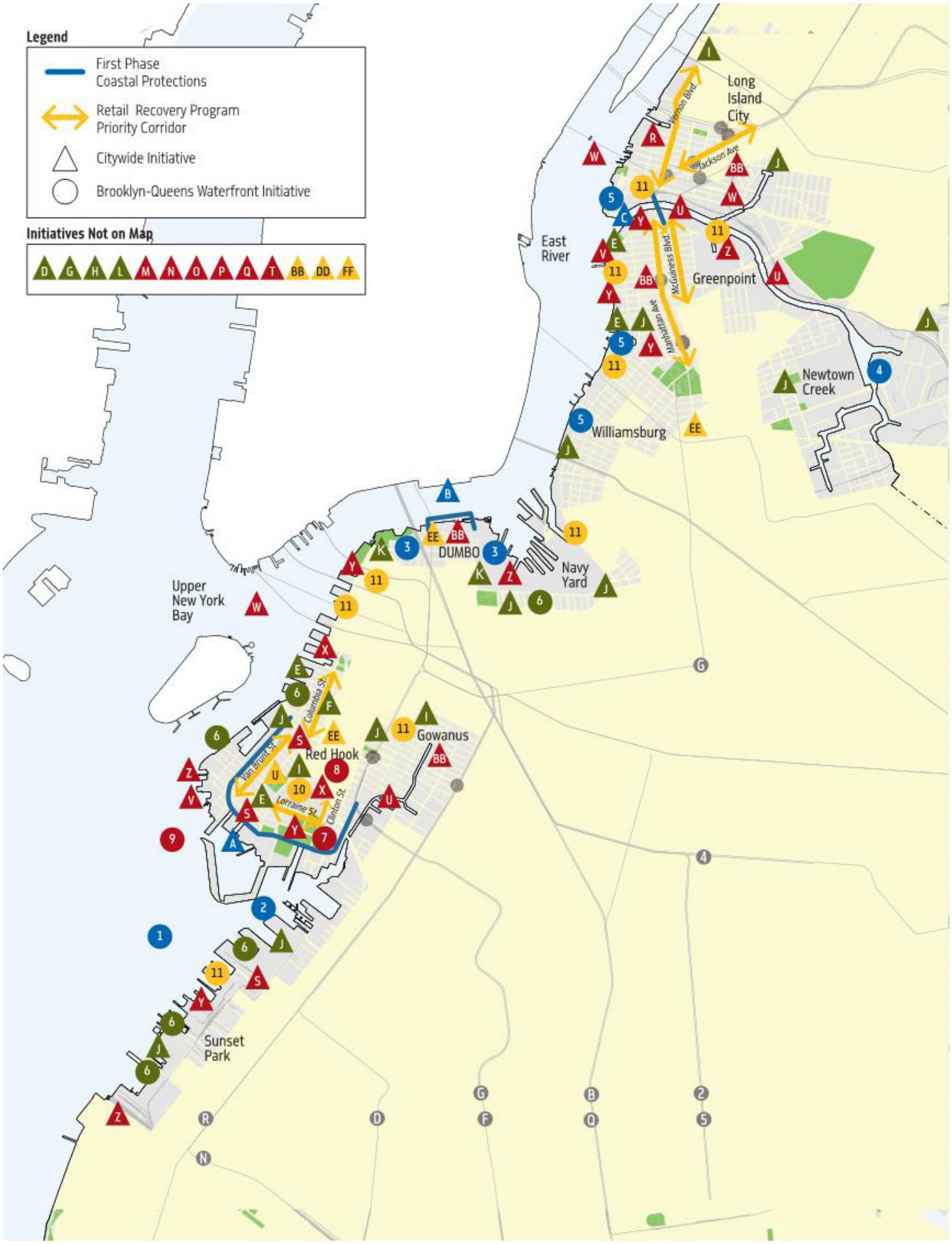


FIGURE 2-4

Brooklyn-Queens Waterfront Initiative Summary (Source: Special Initiative for Rebuilding and Resiliency, A Stronger, More Resilient New York, June 2012, 253-254)

Brooklyn-Queens Waterfront Initiative 4: Support private investments that reduce flood risk along Newtown Creek

Although the storm surge barrier at Newtown Creek described above would provide comprehensive protection for nearby properties, it could take time to build, leaving industrial and residential properties at risk in the near-term. A barrier also would not protect against the impacts of sea level rise outside of extreme weather events. The City, therefore, will offer technical assistance to businesses interested in obtaining relevant permits and investing private capital in restoring and upgrading bulkheads and making additional improvements that provide protection against flooding and sea level rise. NYCEDC will work with individual businesses, as well as local business improvement districts (BIDs) and local development corporations, to identify and advance these private investments, focusing, in particular, on the complicated permitting process that often accompanies them.

Transportation Initiative 5: Install watertight barriers to protect movable bridge machinery

The mechanical equipment that moves 25 of the city's bridges—including five over the Gowanus Canal and six over Newtown Creek and its tributaries—is vulnerable to flooding. Damage to this equipment could, if it were to lock bridges in either an open or closed position, disrupt marine and roadway traffic. Therefore, over the next three years and subject to available funding, NYCDOT will install watertight barriers to protect the bridges' mechanical equipment.

Water and Wastewater Initiative 8: Reduce combined sewer overflows (CSOs) with Green Infrastructure

As climate change brings increasing rainfall volume to the New York area, the city may also experience shifts in the frequency and volume of CSOs. The City will continue to implement its Green Infrastructure Plan and CSO Long-Term Control Plans (LTCPs) to reduce such CSOs. For this purpose, DEP, working with the DPR and NYCDOT, will continue to pursue its plan to capture the first inch of runoff in 10 percent of impervious surfaces citywide by 2030. At the same time, DEP also will continue to develop LTCPs to evaluate long-term solutions to reduce CSOs and improve water quality in New York City's waterways. DEP will issue an LTCP for Alley Creek in Queens in 2013, with nine additional water body-specific LTCPs and one citywide LTCP to follow through 2017—including for Coney Island Creek, the Gowanus Canal, Newtown Creek, and Jamaica Bay. DEP will continue to implement this program in 2013, with the Gowanus Canal LTCP targeted for issuance in 2015 and Newtown Creek LTCP in 2017.

Water and Wastewater Initiative 9: Reduce combined sewer overflows with high-level storm sewers

While the construction of new, green infrastructure is an effective solution for managing rainfall and reducing CSOs in some locations, in other areas, it will be more cost-effective to enhance the city's existing sewer system. The City, through DEP, will augment existing combined sewers with so-called "high-level storm sewers" in certain areas, including along the Waterfront. These high-level storm sewers sit on top of a combined sewer and accept stormwater from the street before diverting it to a nearby waterway, capturing up to 50 percent of rainfall before it enters combined sewers. DEP, therefore, will continue to pursue high-level storm sewer projects along the waterfront, including at 3rd Avenue in Gowanus; West Street in Greenpoint; and at multiple locations in DUMBO. These projects are to be completed by 2023. DEP will continue to seek additional opportunities for similar projects near the water's edge along the waterfront, including a project in the Hunter's Point section of Long Island City that, as of the writing of this report, is in the design phase. Finally, the City also is making sewer investments in connection with new developments along the waterfront, including at Hunter's Point South in Long Island City.

3 Existing Conditions

Existing site conditions at Newtown Creek (Creek), which provide baseline data and influenced the siting assessment and development of the in-water storm surge barrier and upland flood defense options, are summarized here. Photos from a January 2015 site visit are provided in **Appendix A**. Additional detail and baseline maps of the study area are provided in **Appendix B-E**. Key findings and information relevant to the concept option siting and development are summarized in the following sub-sections. While this preliminary investigation provides a general characterization of conditions at the site and is sufficient for information assumptions at this conceptual stage of study, should a Newtown Creek storm surge barrier project advance beyond this conceptual study, detailed site investigations will be needed to fully characterize soil properties, bulkhead and other structural conditions, potential environmental site contamination, in addition to other due diligence investigation in order to inform detailed design of a barrier and flood protection system.

3.1 Physical Characteristics

3.1.1 Bathymetry

Bathymetry data within the Creek is shown in the maps below. This is based on the following datasets:

- New York City Department of Environmental Protection (NYCDEP) 2012 bathymetric survey (2012): This survey was post Superstorm Sandy of 2012. The coverage of this data is shown in **Figure 3-1**.
- MIKE CMAP database (MIKE by DHI, 2012), which is based on bathymetric data in nautical charts. Coverage is shown in Figure 3-2. This was used to supplement the NYCDEP survey data, after correction for the different vertical datum.

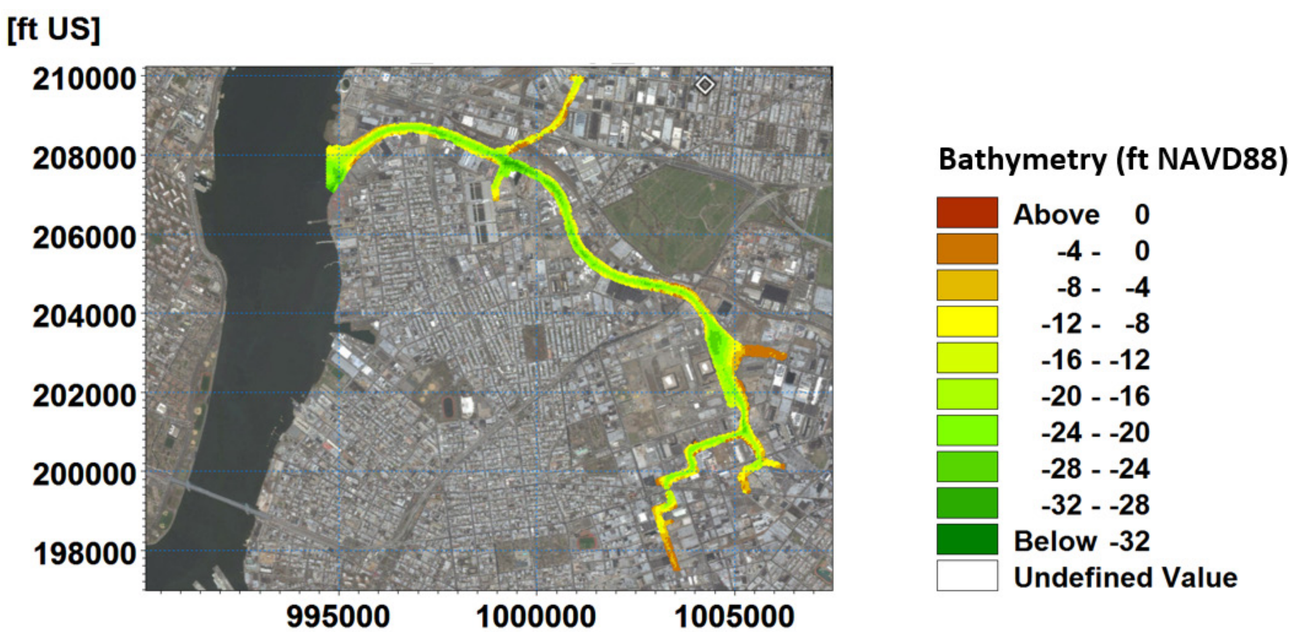


FIGURE 3-1
NYCDEP 2012 Bathymetric Survey Data, Newtown Creek; Horizontal Datum North American Datum (NAD) 1983 NY—Long Island (feet)

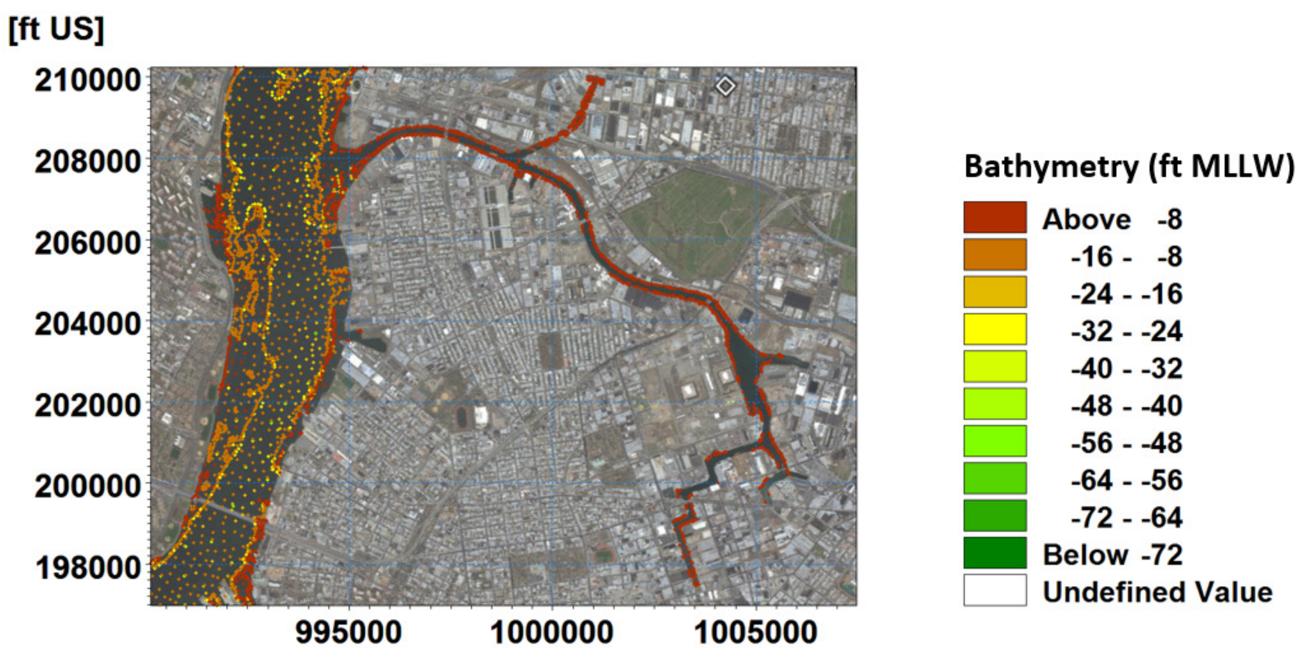


FIGURE 3-2
CMAP Scatter Data near Newtown Creek; Horizontal Datum NAD 1983 NY—Long Island (feet)

3.1.2 Geology and Geotechnical Conditions

The following characterization is based on available historical subsurface information in the vicinity of Newtown Creek. Beneath the surficial materials present on-land along the shoreline, fill materials are initially expected. These materials are expected to consist of sand and gravel, with varying amounts of silt and clay. The fill material is also expected to contain minor amounts of cobbles and boulder size rock, and miscellaneous materials, such as brick fragments, cinders, wood, and other debris.

On-land beneath the fill materials, a layer of organic silts is expected. On the water side, organic silt is expected to be the initial stratum encountered at the mudline. These materials are expected to consist of soft organic silts and clays. A natural sand deposit is expected beneath the organic silts. This natural sand deposit is expected to consist of fine to coarse sand with varying amounts of gravel and silt. A varved (layered) clay and silt deposit is expected to be the next stratum beneath the natural sand. This stratum is also expected to include minor amounts of sands. A glacial till deposit is expected beneath the varved clay. This material is expected to consist of sand and gravel, with varying amounts of silt and clay. Occasionally, boulders, cobbles, and decomposed rock can be encountered within the stratum. Bedrock, consisting of gneiss is expected to be encountered beneath the glacial till.

A detailed site investigation program would be required to inform the detailed design and construction of a barrier flood protection system.

3.2 Natural Features and Habitat

3.2.1 Biological Resources Survey

The following section is a summary of a desk study of existing ecological conditions across Newtown Creek for the purpose of assessing the potential risks to existing habitat from interventions proposed for flood protection and also for the potential to improve ecological value as part of a proposed intervention. The review references several reports published between 1998 and 2013, with greatest emphasis given to the Draft Phase 1 Remedial Investigation Field Program Data Summary Report (USEPA, 2013), Preassessment Screen for Newtown Creek, Brooklyn and Queens, New York (DOI, 2012), and the Waterbody/Watershed Facility Plan Report Newtown Creek (NYCDEP, 2011).

Newtown Creek and its tributaries, Dutch Kills, Maspeth Creek, Whale Creek, East Branch, and English Kills, encompass a 3.8-mile reach of tidal estuary that has been highly altered by more than 150 years of development activities and waste disposal. Bulkheads or other forms of vertical or near vertical embankments were constructed beginning in the mid-19th century in order to accommodate the filling and development of adjacent wetlands and dredging of the waterway for industrial transport. The highly altered environment and the history of industrial and sanitary discharges have severely degraded intact ecosystems associated with Newtown Creek and its former tidal wetlands, resulting in designation of the waterway by the U.S. Environmental Protection Agency (USEPA) on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List in 2010, commonly known as Superfund.

No delineated terrestrial wetlands within the creek zone exist today, and polluted sediments lie accumulated on the creek bed. Additionally, wet weather contributions to the creek system today consist almost entirely of combined sewer overflows (CSO), providing limited flushing within the Creek and sustaining hypoxic and eutrophic conditions throughout. In response, the New York City Department of Environmental Protection (NYCDEP) began operating an aeration facility in the Upper English Kills in 2008 and the Lower English Kills in 2014 to improve dissolved oxygen (DO) and other environmental conditions in the creek. However, continual CSO discharges to the Creek limit the rate at which conditions can improve. A number of aquatic and avian species are expected to spend limited time foraging in the Creek waters, but given the high levels of industrial contamination, are at risk of bioaccumulating toxins.

The wealth of biological and water quality surveys performed in the past 15 years show that conditions supporting marine life are more improved near the western mouth of the creek than at its upper reaches. However, little to no highly-valued habitat that warrants protection exists within the area of Newtown Creek. Some signs of limited habitat recovery can be observed along degraded bulkheads and riprap walls where vegetation has taken hold, this representing approximately 67 percent of the shoreline. Plant communities have emerged at some of the uppermost reaches of the canal where sediment deposition and cessation of dredging have reduced peak water depths. These vegetated areas consist mostly of non-native grasses, weeds, and shrubs along with native and non-native invasive tree species. Benthic community richness (number of species per sample location) decreases toward the upper reaches but mean abundance is somewhat consistent throughout. Annelid worms represent the vast majority of benthic individuals. A few other species have been collected in the middle and head of the creek, although the total numbers of individuals were low.

Despite these conditions, a small number of fish species have been found to utilize the lower areas of the Creek for spawning. Species found in the creek are similar to what are found in the East River, though in lower density. Crabs, mussels, shrimp, sea squirts, barnacles, and hydroids have also been collected, showing greater abundance and diversity at the middle and mouth of the creek. However, almost all of the organisms collected in Newtown Creek are pollution tolerant. Furthermore, a number of shorebirds, mostly herons, gulls, and cormorants, commonly visit the site to forage. A 1998 survey identified 39 avian species, including the peregrine falcon (New York State listed endangered species) and American bittern, which are both listed as New York State species of special status. However, none of the bird species observed has federally protected status, and most are not considered rare or uncommon in New York City.

3.2.2 Wetland Mapping

To ensure that any short or long term strategies related to the Newtown Creek storm surge barrier system are both in compliance with local, state, and federal regulations and cause no disturbance to any existing critical habitats, a wetland mapping review was conducted through the evaluation of the National Wetland Inventory (NWI) published by the United States Fish and Wildlife Service (USFWS) and the New York State Department of Environmental Conservation (NYSDEC) Tidal Wetland maps. In addition to assessing wetland extent, a desktop review of tidal elevations was performed by reviewing National Oceanic and Atmospheric Administration tidal stations (harmonic and subordinate) data as well as a tidal investigation completed as part of the United States Environmental Protection Agency's Remedial Investigation Report. The wetland mapping and tidal investigation will inform habitat preservation and restoration efforts, noting the estuarine conditions of the water body such as typical tidal patterns, channel geometry, and boundary conditions.

Newtown Creek is a tributary of the East River, which is part of the New York – New Jersey Harbor Estuary. The NWI classifies the main stretch of Newtown Creek as Estuarine, Subtidal, Unconsolidated Bottom, Subtidal (E1UBL) with its Dutch Kills, Whale Creek, English Kills and East Branch tributaries as Estuarine, Subtidal, Unconsolidated Bottom, Subtidal, Excavated (E1UBLx). The NWI defines Estuarine systems as "deepwater tidal habitats and adjacent tidal wetlands that are influenced by water runoff from and often semi-enclosed by land." Being classified by the NWI as Subtidal, Newtown Creek has no instances of tidal wetlands along its shores, which are dominated by bulkheads constructed of wood, metal, concrete, and riprap. Its Unconsolidated Bottom is permanently flooded and consists of cobbles, gravel, at least 25 percent cover of particles smaller than stones (6-7cm), and vegetative cover less than 30 percent, and the Creek's overall channel geometry has been modified by humans through various means. NYSDEC classifies the entirety of Newtown Creek as 2020 LZ Littoral Zone, which includes all lands under tidal waters not included in other NYSDEC categories and not deeper than six feet at mean low water (http://www.dec.ny.gov/lands/5120.html). Map 7: Wetland Mapping demonstrates both the NWI and NYSDEC extents.

Despite the lack of existing wetlands in Newtown Creek, habitat improvements can be realized through "softening" of channel walls or riprap edge conditions. Opportunities within the intertidal zone include native low salt marsh restoration of *Spartina alterniflora* (planted in the upper third of the mean tidal range) and high salt marsh restoration of *Spartina patens* (planted between mean high water and mean higher high water). Salt marsh plays an essential role in the marine ecosystem, providing nutrients and organic matter for lower trophic organisms, which subsequently support the establishment of insects, decapods and ultimately wading bird populations.

Further investigation of tidal elevations (as reported in Section 2.4.1) through reference sites or through extended tidal monitoring is recommended for any potential planting elevation determination.

3.2.3 Field Investigation

On June 12, 2015, study team member eDesign Dynamics performed a field visit of Newtown Creek by kayak to confirm the biological resources characterization and wetland mapping. These field visits took place in June to maximize the visibility of existing habitat conditions. While no sampling was performed, visual inspection of edge and habitat conditions confirmed that the Creek is a highly altered environment with limited high-value habitat.

FIGURE 3-3
Degraded Shoreline: Tree of Heaven with Poison Ivy

FIGURE 3-4
Degraded Shoreline: Invasive Mulberry

The observed edge conditions of the Creek generally confirmed those in published documents. The waterway is largely bulkheaded with a few stretches of riprap, and vegetative cover consisting mostly of non-native and/or invasive trees. *Acer platanoides*, *Acer negundo, Ailanthus altissima*, *Morus alba*, and *Robinia pseudoacacia* were commonly found at Newtown Creek. *Phragmites australis* was also found in the intertidal zone and upland areas and *Fallopia japonica* was found in the upland areas. All of this vegetation suggests that the edge conditions consist of high pH disturbed soils and urban fill.

Given the bulkheaded condition, there are limited opportunities for native salt marsh to establish. No *Spartina alterniflora* was observed at the Creek.

Given that this field visit was performed by kayak, visibility was limited to fauna immediately visible by the water. No mussel colonies were observed at the Creek. Observed wading birds included a great egret and an ibis, and observed waterbirds included cormorants and terns.

3.3 Shoreline Investigation

A high level visual inspection of the waterfront was undertaken by boat on March 17, 2015. The scope of the inspection was limited to what could be seen above water at the time of inspection while traveling on a boat alongside the waterfront. A topside inspection of the upland areas and the retained fill was not performed and the scope of the investigation is considered to be more cursory than a Rapid Level inspection, as defined in the EDC's Waterfront Facilities Maintenance Management System (WFMMS). As a result, the structure types are based on engineering judgment from what was observed above water during the time of inspection. In addition, it should be noted that condition assessment ratings were not assigned to structures that were inaccessible to the boat or where the inspector was not able to get close enough to the structure for a meaningful visual inspection.

The survey focused on the area where a potential barrier and associated upland flood defenses might be constructed. It started on the Queens (north) side of the Creek and extended south from Anable Basin on the East River, into the Creek to Pulaski Bridge, then back to the mouth and south along the Brooklyn shoreline to Bushwick Inlet. An inventory of structure type and condition is given in the Table 3-2. The general condition of the above water and visible portion of the structure was characterized by the scoring system given in Table 3-1, which is based on the condition assessment ratings in the EDC's WFMMS. It is noted that the primary objective of the inspection was to categorize the type of structures along the waterfront and that the condition assessment ratings being assigned to each structure will need to be verified with a more in-depth inspection of the structure should this study advance to a detailed feasibility study. In particular, the pile-supported relieving platform type structures should be re-inspected below water to confirm its condition.

Typically structures fell into the following categories:

- Vertical bulkheads in a range of conditions, in some cases acting as operating berths (e.g., NYCDEP berth at the mouth of the Creek). This is more typical within the Creek, up to Pulaski Bridge.
- Piled relieving platforms and piers, such as along the East River waterfront at Queens West and Hunters Point South.
- Armored slopes, either riprap or stone armor that has been designed as slope protection, with a fairly uniform stone grading, slope and stone profile, or more ad hoc protection, often from construction waste materials such as broken concrete blocks, etc. This is more typical along parts of the Hunters Point South frontage and along the Greenpoint frontage to the south of the Creek.

TABLE 3-1
Structure Condition Rating

Code	Condition Rating	Description
1	GOOD	No problems or only minor problems noted. Structural elements may show some very minor deterioration, but no overstressing observed.
2	SATISFACTORY	Minor to moderate defects and deterioration observed, but no overstressing observed.
3	FAIR	All primary structural elements are sound; but minor to moderate defects and deterioration observed. Localized areas of moderate to advanced deterioration may be present but do not significantly reduce the load bearing capacity of the structure.
4	POOR	Advanced deterioration or overstressing observed on widespread portions of the structure, but does not significantly reduce the load carrying capacity of the structure.
5	SERIOUS	Advanced deterioration, overstressing, or breakage may have significantly affected the load bearing capacity of primary structural elements. Local failures are possible and loading restrictions may be necessary.
6	CRITICAL	Very advanced deterioration, overstressing, or breakage has resulted in localized failure(s) of primary structural elements. More widespread failures are possible or likely to occur and load restrictions should be implemented as necessary.

TABLE 3-2
Newtown Creek waterfront structure inventory (see photos in Appendix B)

Location	Defense length reference	Structure type	Condition (see Table 3-1)
North of Anable Basin	A	Riprap slope protection	Satisfactory
Anable Basin	B	Pile-supported platform	Fair
	C	Steel sheet pile bulkhead	Satisfactory
	D	Retaining wall (timber crib)	Fair
	E	Riprap slope protection	Fair

TABLE 3-2
Newtown Creek waterfront structure inventory (see photos in Appendix B)

Location	Defense length reference	Structure type	Condition (see Table 3-1)
	F	Retaining wall (timber crib)	Fair
	G	Steel sheet pile bulkhead	Satisfactory
Queens West	H	Riprap beneath pile-supported platform	Satisfactory
	I	Riprap slope protection	Satisfactory
	J	Pile-supported pier	Satisfactory
	K	Retaining wall	**No Rating***
	L	Pile-supported pier	Satisfactory
	M	Riprap slope protection	Satisfactory
	N	Pile-supported pier	Satisfactory
	O	Riprap slope protection	Fair
Hunters Point South	P	Pile-supported pier	Satisfactory
	Q	Riprap slope/retaining wall	Satisfactory
Long Island City Ferry terminal	R	Pile-supported platform	Satisfactory
Hunters Point South	S	Riprap slope protection	Satisfactory
	T	Rubble/debris slope	Poor
	U	Retaining wall	Poor
	V	Rubble/construction debris	Poor
Newtown Creek North side	W	Riprap slope protection	Satisfactory
Vernon Boulevard to Pulaski Bridge	X	Rubble/debris slope	Poor
	Y	Retaining wall (stacked stones)	Fair
	Z	Retaining wall (timber crib)	Poor
Pulaski Bridge to Manhattan Avenue	AA	Retaining wall (timber crib)	Poor
		Pile-supported relieving platform	Fair
	AB	Pile-supported platform w/ fender panels	Satisfactory
Manhattan Avenue	AC	Retaining wall (concrete wall)	Satisfactory
Greenpoint Manufacturing and Design Center	AD	Pile-supported platform w/ timber crib	Poor
Future Box Street Park site	AE	Steel sheet pile bulkhead	Satisfactory
Greenpoint Landing site	AF	Rubble/construction debris	Poor
DEP berth/Future Newtown Barge Park Site	AG	Pile-supported relieving platform	Fair
Development site (Eagle to Green Street)	AH	Rubble/debris slope	Fair
Degraded pier at Green Street	AI	Pile-supported pier	Serious
Development site at India Street	AJ	Riprap slope protection Steel sheet pile bulkhead (under construction)	Fair Satisfactory
India Street Ferry Terminal	AK	Pile-supported pier	Satisfactory
East River shoreline Greenpoint Ave to Oak Street	AL	Riprap slope protection	Satisfactory

TABLE 3-2
Newtown Creek waterfront structure inventory (see photos in Appendix B)

Location	Defense length reference	Structure type	Condition (see Table 3-1)
Bushwick Inlet	AM	Rubble/debris slope	Poor
	AN	Riprap slope protection	Satisfactory

* Structure was inspected from afar so condition cannot be confirmed.

3.4 Utilities and Water Quality

Key infrastructure and utilities that are of relevance to the barrier feasibility study are discussed below.

3.4.1 Subsea Pipeline and Cables

There are a number of subsea pipelines and cables located in the Creek.

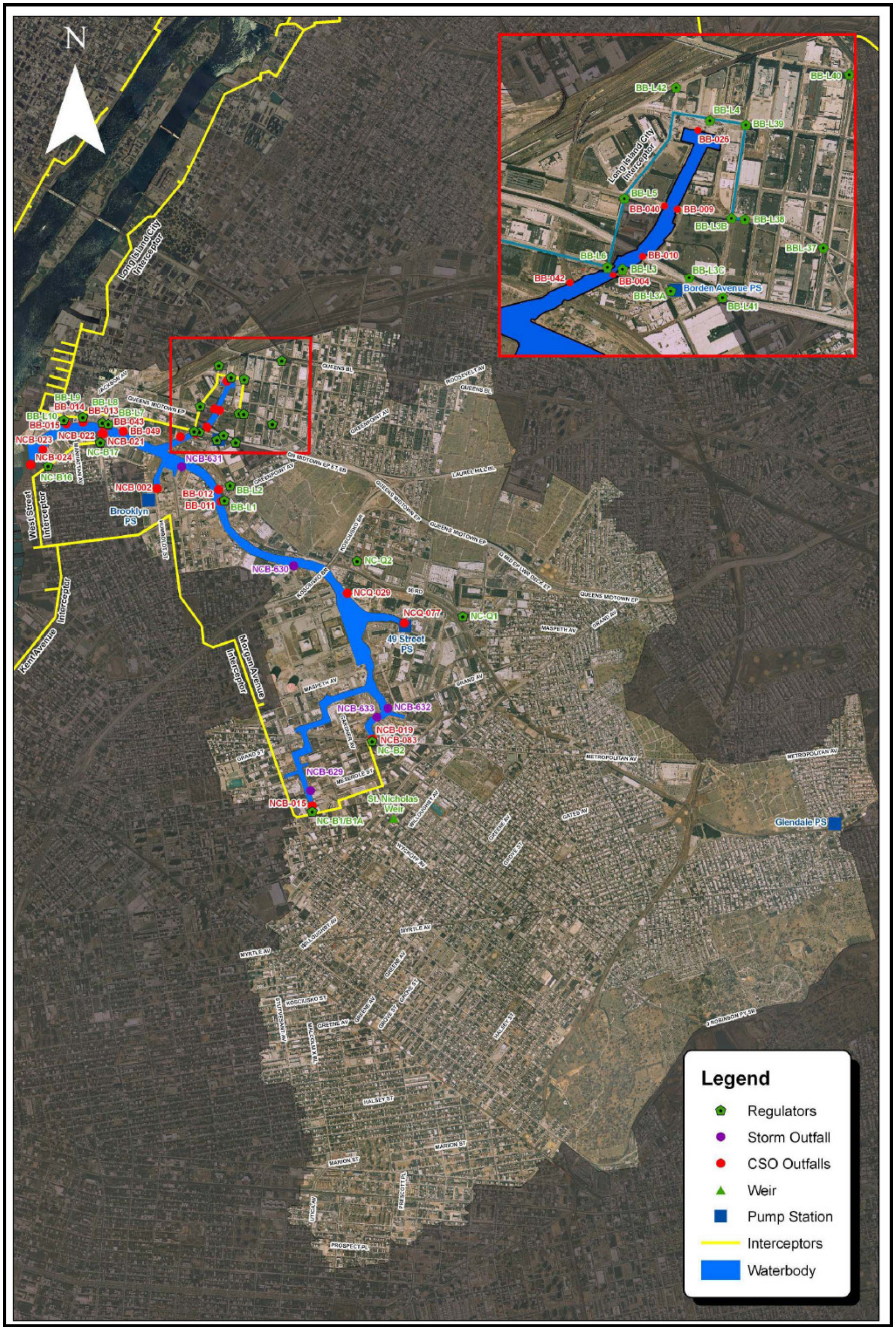
A transportation analysis for the Kosciusko Bridge (New York State Department of Transportation [NYSDOT]/FHA, 2005) identified that approximately 15 pipelines, 15 submarine cables and 1 tunnel cross the Creek at various locations, as reported in the USACE Navigability Determination in the late 1970s. These underwater structures limit the future deepening of the USACE navigation channel in those areas. The navigation chart identifies a cable and pipeline area extending from just upstream of the Pulaski Bridge to approximately a quarter of a mile west of the bridge.

Signage indicates a National Grid pipeline crossing at Manhattan Avenue across to Vernon Boulevard on the north side of the Creek.

Precise locations of cables and pipelines are not publicly available, which will need to be confirmed with utilities. There is a long history of intervention in the Creek and unknown or redundant utilities may still be “live” or create problems for construction. Construction of a barrier may require relocation of such utilities.

3.4.2 Combined Sewer Overflows and Stormwater Drainage

The sewage and surface water runoff collection system draining to the Creek is almost entirely a combined sewer system (Newtown Creek Long-Term Control Plan (LTCP), 2011) and is served by combined sewers draining either to the Bowery Bay or Newtown Creek Water Pollution Control Plants (WPCPs). Combined sewers discharge to regulators which discharge the flow to interceptor sewers which carry flow to the WPCP. When the capacity of the interceptors or the WPCP is exceeded, excess volume discharges to the Creek via CSOs. There are 12 CSOs within the Bowery Bay WPCP system and 10 within the Creek WPCP system that contribute overflows to the Creek. Major components of the Bowery Bay and Newtown Creek collection systems are shown in **Figure 3-5**, reproduced from the LTCP.



Source: Newtown Creek Watershed Facility Plan

FIGURE 3-5

Locations of Key Stormwater Infrastructure

There are two distinct combined sewer networks with the potential to discharge into the Creek. These two systems are tributary to the Bowery Bay WPCP and Newtown Creek WPCP. The CSO discharges into Newtown Creek are summarized in **Table 5-1**, reproduced from the LTCP.

TABLE 3-3
CSO discharges to Newtown Creek (from LTCP, 2011)

Regulator	Regulator Location	Waterbody	Outfall	Outfall Size	Drainage Area (ac)
BB-L1	Greenpoint Avenue and Newtown Creek	Newtown Creek, north shore, west of Dutch Kills	BB-011	24” diam.	17
BB-L2	35th Street W/O Review Avenue	Newtown Creek, north shore, west of Dutch Kills	BB-012	24” diam.	13
BB-L3	Borden Avenue and Dutch Kills	Dutch Kills, eastern shore	BB-004	6’-6” x 3’-3"	12
BB-L3B	30th Street and Huntington Ave	Dutch Kills, eastern shore	BB-009	11’-0" x 4’-6”	280
- BB-L3A	*Borden Pump Station Influent*	*Tributary to BB-L3B through Borden P.S.*			
- BB-L37	*Hunter Point Avenue and Van Dam Street*	*Tributary to BB-L3B*			
- BB-L38	*Hunter Point Avenue and 30th Street*	*Tributary to BB-L3B*			
- BB-L41	*Borden Avenue and 30th Street*	*Tributary to BB-L3B*			
BB-L3C	Behind Borden P.S.	Dutch Kills, eastern shore	BB-010	30” diam.	25
BB-L4	47th Ave between 28th and 29th Streets	Dutch Kills, head end	BB-026	9’-0” x 4’-6”	296
- BB-L39	*47th Ave and 30th Street*	*Tributary to BB-L4*			
- BB-L40	*47th Ave and 31st Street*	*Tributary to BB-L4*			
- BB-L42	*27th Street and Skillman Ave*	*Tributary to BB-L4*			
BB-L3C	Behind Borden P.S.	Dutch Kills, eastern shore	BB-010	30” diam.	25
BB-L4	47th Ave between 28th and 29th Streets	Dutch Kills, head end	BB-026	9’-0” x 4’-6”	296
- BB-L39	*47th Ave and 30th Street*	*Tributary to BB-L4*			
- BB-L40	*47th Ave and 31st Street*	*Tributary to BB-L4*			
- BB-L42	*27th Street and Skillman Avenue*	*Tributary to BB-L4*			
BB-L5	49th Ave and 27th Street	Dutch Kills, western shore	BB-040	24” diam.	8
BB-L6	Borden Ave and 27th Street	Dutch Kills, western shore	BB-042	12” diam.	1
BB-L7	E/S 11th Street, S/O 53rd Avenue	Newtown Creek, north shore, east of Dutch Kills	BB-043	54” diam.	37
BB-L8	W/S 11th Street and S/O 53rd Avenue	shore, east of Dutch Kills	BB-013	72” diam.	31
BB-L9	Vernon Blvd, S/O 54th Avenue	Newtown Creek, north shore, east of Dutch Kills	BB-014	22” diam.	12
BB-L10	5th Street and 55th Avenue	Newtown Creek, north shore, east of Dutch Kills	BB-015	15” diam.	5
NC-Q1	W/O Russel Street	Maspeth Creek, head end	NCQ- 077	2 @ 11’ x 7’	1,107
NC-Q2	56th Road and 43rd Street	Newtown Creek, north shore, east of Maspeth Creek	NCQ- 029	66" diam.	91
NC-B1, B1A	Johnson Avenue W/O Porter Avenue	English Kills, head end	NCB- 015	2 @ 15’-8” x 10’	2,275
NC-St. Nich Weir	Metropolitan Avenue and Troutman Avenue	East Branch, head end	NCB- 083	206” x 157” arch	1,901
NC-B2	Metropolitan Avenue and Onderdonk Avenue	East Branch, head end	NCB- 019	36" diam.	29

TABLE 3-3
CSO discharges to Newtown Creek (from LTCP, 2011)

Regulator	Regulator Location	Waterbody	Outfall	Outfall Size	Drainage Area (ac)
NC-B16	E/O Franklin Street	Newtown Creek, south shore near mouth of Creek	NCB- 023	24" diam.	15
NC-B15	Dupont Street and Commercial Street	Newtown Creek, south shore near mouth of Creek	NCB- 024	18" diam.	1.8
NC-B17	McGuiness Boulevard, N/O Ash Street	Newtown Creek, south shore east of Newtown Creek WWTP	NCB- 022	4'-6" x 6'-3"	23
High Relief	McGuiness Boulevard, N/O Ash Street	Newtown Creek, south shore east of Newtown Creek WWTP	NCB- 021	36" diam.	15
Newtown Creek WWTP	Newtown Creek WWTP Overflow	Whale Creek Canal	NCB-002	3 @ 7'x 8'	N/A
Total Combined Sewer Area (Acres)					**6192**

Notes:
BB denotes the collection system tributary to the Bowery Bay WPCP catchment; NC denotes the collection system tributary to the Newtown Creek WPCP

In addition to CSOs, there are numerous stormwater-only discharges to the Creek. There are 5 permitted storm drains as presented in **Table 3-4**. The LTCP notes that 218 non-CSO discharges were identified in a survey of the shoreline, including storm drains, highway drains, and other direct discharges. As drainage and surface water management are studied in detail at a complete feasibility study stage, gravity drainage outfalls should be looked at to ensure they are sealed during flood events in order to maintain the integrity of the flood defenses and prevent flood water ingress into the areas being protected. For example, flap valves may need to be provided or replaced and would need to be maintained.

TABLE 3-4
Newtown Creek Stormwater Outfall Discharges

Stormwater Outfall	Outfall Location	Waterbody	Outfall size
NCB-629	Scholes Street	English Kills	60-foot diameter
NCB-630	Meeker Avenue	Newtown Creek	15-foot diameter
NCB-631	North Henry Street	Newtown Creek	90-foot diameter
NCB-632	Grand Avenue Bridge	Newtown Creek	54-foot diameter
NCB-633	Grand Avenue Bridge	Newtown Creek	60-foot diameter

Source: LTCP, 2011.

3.4.3 Water Quality

Newtown Creek today is an industrial waterway with a shoreline that is mostly formed from bulkheads. However in the early 19th century it was a sluggish tidal inlet, surrounded by wetlands and upland farms. As the surrounding land was developed for residential and industrial use, the drainage of the creek's watershed was transformed into an engineered system of combined, sanitary, and separately sewered areas. Today, much of the area immediately adjacent to the Creek drains directly into it, and it also is the discharge point for CSOs that receive flow from the far upland areas of the watershed.

The creek, which today lacks any natural hydrologic inflow, and remains a creek in name only, is actually a long main stem with several smaller tributary canals, which are also completely industrial in nature. The area became heavily used by manufacturing plants in the second half of the 19th century, and it remains zoned for manufacturing today. Decades of unregulated and extensive industrial discharges to the Creek have left its sediment severely polluted and it is currently one of the USEPA's Superfund sites, as well as a recognized "Brownfield Opportunity Site" within NYC. The poor water quality of the Creek is caused by frequent CSO discharges, currently being addressed by the NYCDEP LTCP, and the fact that the creek is largely stagnant, with extremely low rates of exchange with the East River, into which it discharges. The Newtown Creek Wastewater Treatment Plan, adjacent to the Creek, receives flow from a large area of Brooklyn and Manhattan.

The New York City Water Quality Standards designate Newtown Creek as a Class SD area, for which the best use is fishing. This classification requires that the water quality in the creek be maintained as suitable for fish survival, and it is applied to areas in which natural or man-made conditions keep the waters unsuitable for secondary contact recreation and the growth of fish communities. This standard requires that a DO concentration of never less than 3.0 milligram per liter (mg/L) be maintained. The SD designation applies to other heavily industrialized water bodies in the city, such as the Arthur Kill, Kill van Kull, and Gowanus Canal. This level of DO will ensure survival of fish biota, but is below the level considered necessary (4.0 mg/L) for minimally healthy fish communities. Because the SD designation does not allow for contact recreational activity, it does not include a standard for bacteria counts.

The New York City Harbor Survey program has collected data on water quality in the waters surrounding the city for more than a century, and it maintains several sampling stations in the creek and its vicinity**.** The survey reports indicate a generally improving state of water quality for the Inner Harbor, of which Newtown Creek is one tributary, the result of decades of improvement in wastewater treatment and CSO controls. The physical configuration of Newtown Creek, however, restricts the amount of tidal circulation that can dilute and remove pollutants, especially in the portions near the head end of the creek system, leaving its water quality particularly vulnerable to impacts from CSO discharges.

The narrow cross-section along the extended length of the Newtown Creek canal system limits its capacity for exchange and dispersal of pollutants, and there is no flushing system in place, as at the Gowanus Canal. The DEP Watershed Facility Report for Newtown Creek contains a comparison of water quality in the Gowanus Canal and Newtown Creek, finding that the diversity of biota in the Gowanus is greater and more robust, indicating the important role of the flushing tunnel in raising the quality of the water in the Gowanus Canal. Without any such device at Newtown Creek, the NYCDEP LTCP plans to ameliorate the water quality of the system with three engineering approaches:

- Introduction of Green Infrastructure elements to the watershed to reduce inflow during storm events.
- Modification of regulator chambers to improve conveyance of combined sewage to the local interceptors.
- Aeration of the Creek with a mechanical forced-air system to improve the concentration of DO within the system in order to meet water quality standards and reduce odors.

The creek remains significantly below the mandated water quality standard and is designated by New York State as an Impaired Waterbody. In addition to its degraded DO condition, Newtown Creek contains several sediment mounds created by CSO discharges that comprise an aesthetic nuisance; they are visible and can emit noticeable odors at low tide. Floatable pollution from CSO discharges and direct runoff is also a pollutant of concern, and the DEP currently operates a floating boom to capture discharged waterborne debris.

3.5 Known Environmental Contamination Issues

3.5.1 Superfund Context

Newtown Creek was designated a Superfund National Priority Site around 2011. A complete condition survey, was performed in April 2009 by the USACE New York District (the last survey prior to that was performed in 1991). The entire channel was last dredged in 1951 with the removal of 80,000 cubic yards of material. In the 1950s and 1960s, portions of Dutch Kills and English Kills were dredged. The channel has been subject to various industrial contaminant inputs along the river over the past several decades. As a result, the material to be removed may be too contaminated to dredge and place in approved upland sites. NYCDEP is the local sponsor.

According to the USEPA and NYSDEC documentation[1], the U.S. Coast Guard documented an oil spill entering Newtown Creek in the late 1970s, which was found to extend over more than 50 acres (with an estimated 17 million to 30 million gallons of petroleum product released) and extensive subsurface petroleum contamination was documented extending from the former Exxon/Mobil refining facility located along the eastern portion of the Creek (further inland of the proposed storm surge barrier). Discrete areas of chlorinated solvent contamination were also identified in this vicinity during subsurface investigations.[1,2]

Petroleum product recovery activities are currently being employed in conjunction with NYSDEC and USEPA oversight within five distinct areas along the Brooklyn side of the creek, generally situated between the Greenpoint Avenue and Pulaski Bridges (further east of the proposed surge barrier improvements): the former ExxonMobil Terminal, the BP Terminal; the mixed-use commercial/industrial/residential area southwest of the BP Terminal (the ExxonMobil Off-Site Plume); the former Paragon Oil Terminal (currently the Peerless Importers/Empire Merchants distribution facility); and the Apollo Street Creek Parcels (located between the BP Terminal and the former Paragon Oil Terminal).

According to USEPA reporting,[2] sediment sampling throughout the Creek indicated concentrations of elevated metals; polycyclic aromatic hydrocarbons (PAH) and phthalates; polychlorinated biphenyls (PCB); and volatile organic compounds (VOCs). In September 2010, Newtown Creek was listed as a Superfund Site on the National Priorities List. In July 2011, USEPA signed an Administrative Order on Consent (AOC) with six Potentially Responsible Parties (PRPs). The AOC finalized start of the Remedial Investigation/Feasibility Study (RI/FS) process, and the RI is currently under way. Improvements to reduce CSO and stormwater discharge to the Creek are also being implemented.[2]

At the time of this study, Superfund Remediation plans for Newtown Creek were not yet established. It is understood that contamination is worst upstream approaching the Creek's eastern terminus. The western edge, closest to the East River, and where the potential in-water storm surge barrier locations are considered, has much less contamination. Any storm surge barrier and its upland infrastructure would require close coordination with the ongoing Superfund remediation efforts and would have to comply with all local and federal guidance on disturbance within the affected areas.

3.5.2 Municipal E-Designations Context

At a municipal level, New York City has created a system of "E-designations" to identify properties that have additional environmental review and compliance requirements based on a potential for adverse conditions present on a site or based on site development. They are triggered by land use review and rezoning actions subject to the City Environmental Quality Review (CEQR).

There are three basic types of E-designations including hazardous materials, air quality, and noise. Air quality and noise e-designations are intended to implement or identify redevelopment requirements associated with the additional measures necessary to avoid future potential impacts (i.e., building attenuation standards to achieve acceptable indoor noise standards or restrictions on the fuel or location of emission stacks to avoid a future stationary source air quality impact). Hazardous material E-designations are identified for land parcels that have a likelihood of existing environmental impairment and require the fee-owner of a property to conduct a subsurface testing protocol and remediation, where appropriate, to the satisfaction of the New York City Mayor's Office of Environmental Remediation (OER) before the issuance of a Building Permit and Certificate of Occupancy. These designations would be most applicable to use of

[1] Source: http://nysdecgreenpoint.com/ProjectHistory.aspx.

[2] Source: http://www.epa.gov/region2/superfund/npl/newtowncreek/.

upland parcels as part of the implementation of a storm surge barrier system and related flood prevention improvements.

There have been extensive land use and zoning actions that have generated a comprehensive coverage of e-designations. These include the Greenpoint-Williamsburg, Hunters Point Subdistrict, and Long Island City rezoning initiatives and there are numerous hazardous materials E-designations, primarily on blocks west of the Pulaski Bridge and McGuinness Boulevard, and along the East River waterfront (including areas of the proposed the storm surge barrier improvements).

Although previous studies suggest the majority of petrochemical and solvent contamination and other former heavy industrial uses are located in the central and eastern portions of the Creek; there is some potential that subsurface disturbance associated with the proposed storm surge barrier system could encounter contaminated media (e.g., soil, sediment and ground/surface water), which would require characterization, disposal and possibly remediation in accordance with applicable regulations (potentially including coordination with OER if subject to hazardous materials E-designation requirements). Moreover, as redevelopment and rezonings continue in upland areas near the eastern portion of the Creek, it is anticipated that additional parcels will receive hazardous materials E-designations to address areas of potential contamination (e.g., from former/current industrial and automotive uses).

3.5.3 Environmental Site Investigation

A desktop review of environmental site conditions was conducted as part of the study. A summary of potential hazardous materials along the concept option alignments and suggested future investigations is provided in H.

3.6 Navigation

3.6.1 Land

Main road connections at the study site include the interstate highway (Queens Midtown Expressway), connecting to Manhattan via the Midtown Tunnel, and arterial roads, including Creek crossings at the Pulaski and JJ Byrne Memorial Bridges. Truck and bike routes both extend across the Creek at the Pulaski and JJ Byrne Memorial Bridges.

Public transit connections include bus, subway, and ferry routes. The G subway line connects the Hunters Point and Greenpoint neighborhoods north and south of the Creek, while the 7 line connects Queens/Long Island City to Manhattan. The G subway line runs beneath the Creek at the end of Manhattan Avenue.

3.6.2 Marine

Newtown Creek is an active component of New York Harbor that has maintained a high level of commercial activity throughout the history of the port. The Creek is a narrow tidal extension of the East River and, in some locations, also serves as a boundary between the boroughs of Brooklyn and Queens. The surrounding area is high industrialized and the tributary offers reliable marine transportation access to the various commercial and industrial firms, which line its banks.

The existing federal navigation project provides for a channel 23 feet deep and 130 feet wide from East River to 150 feet north of Maspeth Avenue, with a triangular area at the north side of the entrance. A turning basin 23 feet deep at Mussel Island becomes shallower and narrower approaching Metropolitan Avenue. A survey conducted on behalf of the USACE in 2009 reveals that while the federal channel depth of 23 feet has been identified, shoaling, and sedimentation has reduced the controlling depth to approximately 17 feet on the western portion and approach channels of the Creek.

The banks of Newtown Creek support some 40-plus businesses, which rely on the marine transport of various petroleum products, earth materials, scrap metal, and refuse. The cargo passing through the tributary is predominantly via tug and barge, however, most businesses operate barges on seasonal rather than weekly schedules as a way to supplement regular truck and pipeline shipments. In 2005, the Federal

Highway Administration conducted a navigation analysis of Newtown Creek as part of the Kosciuszko Bridge Project. The report includes a review of current vessel traffic through the channel as well as an overview of vessel sizes and types. Based on a review of the report, typical vessel types and sizes are given below.

TABLE 3-5
Newtown Creek Vessel Characteristics

	Air Draft (feet)	Water Draft (feet)	Length (feet)	Beam (feet)
Barge	10 to 35	5 to 15	50 to 300	25 to 60
Tugboat	15 to 50	6 to 13	35 to 100	15 to 35

Source: FHA, 2005.

In addition to frequent commercial barge use, the NYCDEP operates a fleet of sludge vessels that call at the Newtown Creek WWTP. A fleet of three new vessels has recently come into operation. The vessels typically make one call at the WWTP per day, though in summer this can increase to twice daily as sludge production goes up. The WWTP does have 24 hours sludge holding capacity in the event that vessels are unable to call, such as in storm conditions. It is expected that longer term improvements at the plant will eventually lead to a higher percentage of solids in the sludge and, hence, a decrease in vessel frequency.

The new fleet of vessels is designed to navigate under the Pulaski Bridge, without the need for the bridge to open. The barges are self-propelled. Key characteristics are summarized in Table 3-6. Typically the vessels operate in at least 17.5 to 18.5 feet of water for safe navigation. The new vessels have an increased beam to accommodate the air draft restrictions without reducing capacity. The wider beam means that vessels are marginally less maneuverable.

TABLE 3-6
NYCDEP Vessel HUNTS POINT Vessel Characteristics (newer vessel)

Air draft (feet)	43 (mast down)
Length (feet)	290
Beam (feet)	70
Draft (feet)	14.5

TABLE 3-7
NYCDEP Vessel RED HOOK Vessel Characteristics (older vessel—no longer in service on Newtown)

Air draft (feet)	63 (mast down)
Length (feet)	360
Beam (feet)	53
Draft (feet)	21

Information on navigation operations was obtained in consultation with DEP vessel operators. Vessels typically approach from the southwest and this operation can be marginally more challenging in an ebb current in the East River. Vessels occasionally approach from the north, from Ward Island, using the west channel of the East River (i.e., on the west side of Roosevelt Island). This is typical of most vessel traffic due to bridges and air draft restrictions on the east channel. Once the vessels are south of 34th Street on Manhattan, they turn with a wide radius to approach the Creek entrance from the southwest. Due to shallow conditions on the north side of the Creek, vessels avoid the area close to Hunters Point South.

One-way traffic operations are in effect on Newtown Creek and vessels rely on AIS data to identify and communicate with other vessels. Other key traffic includes vessels calling at aggregate and scrap metal facilities and 4 oil terminals on the Creek. The existing NYCDEP berth at Commercial Street to the south of the Creek has been upgraded and this can provide a standby berth if the channel is occupied. There is also a sludge pipeline to this berth that allows sludge loading in the event that the vessel cannot access the Creek. This could provide a convenient point of operation in the event that the barrier were closed in anticipation of an approaching surge event.

The minimum preferred navigation channel width is 150 feet as defined by the width at Pulaski Bridge. The navigation channel narrows between 2nd Street and Vernon Boulevard. An additional restriction to navigation—such as a barrier—would preferably be located on a straight section of channel to allow vessel traffic to approach as perpendicular as possible, particularly given the reduced maneuverability of the wider barges, so as to allow adequate forward visibility of approaching vessels.

Although some recreational marine activity has been observed in Newtown Creek in recent years, it currently represents an insignificant amount of vessel traffic when compared to commercial and industrial use. Typical recreation use includes small vessels, which do not require special navigational accommodations to access or utilize the Creek. Many of these moorings are located along the north bank of the Creek between Vernon Boulevard and the Pulaski Bridge.

Additional discussion of navigation considerations is presented in Section 6 in the in-water storm surge barrier assessment.

3.7 Built Environment

A series of maps characterizing the built environment and urban design considerations were created as part of the existing conditions inventory. They are presented in Appendix E. These include: blocks and lots, land use, ownership, retail frontage, recent and upcoming development sites, open space, zoning and historic and/or cultural assets, view corridors, Design Flood Elevation conditions, roadbed widths, rights-of-way, loading docks, curb cuts, built/vacant lots, single-story buildings and connectivity.

4 Project Overview Storm Surge Barrier System Components

4.1 In-Water Storm Surge Barrier Gate Types

There are a variety of in-water storm surge barrier gates that may be used, depending upon site conditions. All barrier gate types would be expected to offer the same level of protection and performance as far as storm severity because the design standards for defense elevation would be the same. Rather, unique site conditions such as width limitations, subsurface depths and conditions, siltation rates, navigation use, speed of closure, or operation and maintenance requirements make some gate types better suited to a specific location than other gate types. Whole life costs, both capital and operating/maintenance, as well as adaptability to future expansion to accommodate sea level rise are two other considerations that factor into gate selection.

Table 4-1 below summarizes how different storm surge barrier gate types perform against different attributes typically considered in selecting a gate most suitable to a given location.

TABLE 4-1
Comparison of Storm Surge Barrier Gate Types
Note: G=green (good performance), Y=yellow (moderate performance), R = red (not possible/worst performance)

	Miter Gate	Flap Gate	Vertical Rotating Gate	Vertical Lift Gate	Horizontal Rotating Gate	Caisson Gate	Inflatable Gate
Gate width >100 feet	R	G	G	G	G	G	G
Gate width >300 feet	R	G	R	R if lowered* G if raised*	G	R	Y**
Gate depth > 35 feet	G	G	G	G	G	G	R
Avoid spatial requirements (gate recess, etc.)	G	G	G	G	R	Y	G
Ease of operation	G	G	G	G	G – if large width R	R	Y
Ease of maintenance	G	R	Y	G	G	Y	Y
Navigation height restriction	G	G	G	– if lowered R – if raised G	G	G	G
Vulnerability to damage from navigation impact	G	Y	Y	Y	Y	G	R
Time for barrier to close	G	G	G	G	G – if large width R	R	Y
Landscape impact	G	G	G	R	Y	Y	G

** There are two designs or operational configurations. The first configuration has a gate submerged in a recess which lies below the channel bed and is raised to the required flood defense position. The alternate configuration retains the gate above water by towers/supports on either side and is lowered to the flood defense position with the gate sealing against the sill/channel bed.*

***Precedent projects using inflatable gates have a maximum width for each gate that approaches 300 ft. For larger widths, multiple gates are linked together.*

In addition to the characteristics compared above and the key features of each gate type described in the following sections, there are a number of engineering or design assumptions that were considered in both assessing the particular gate type best suited for a given in-water barrier location, or which are assumed to apply across any location.

Siltation is a consideration in selecting an appropriate gate as certain types, such as a flap gate, are more susceptible to operational and maintenance issues caused by the substantial accretion of silt on top of or adjacent to the gate. Although most gate types can be designed in such a way that the hydraulics are sized to account for onerous siltation conditions, this will have significant operational and whole life cost implications associated with it. However, based on the study team's understanding of the existing conditions, and the current limited frequency of dredging undertaken by USACE in Newtown Creek (Creek), it has been assumed that the rate of siltation is not a significant factor. The proposed gates identified by this study are less susceptible to siltation, and hydraulics can be sized to clear the anticipated level of silt accretion.

Scouring of the river bed can also be a problem for any in-water structures. However, based on the study team's understanding of the likely flow velocities through the barrier, the minimum 150-foot width being adopted for navigation, the relatively limited tidal range, and the flow control created by the existing Pulaski Bridge, it has been assumed that scour immediately upstream and downstream of the storm surge barrier is unlikely to be a significant factor. This is reinforced by the fact that the in-water storm surge barriers would probably be built over creek bed capping installed as part of any future Newtown Creek Superfund remediation work that extends beyond the Pulaski Bridge toward the East River.

An additional factor influencing gate choice is the excavation depth required for a gate sill and base foundation. Given the contaminated nature of the Creek's existing channel bed, and the likely remediation and capping plans, gate types selected for the locations have sought to minimize the depth of excavation/dredging in order to minimize to the degree possible, the excavation and mobilization of contaminated material within the waterbody, and the disturbance of potential future Superfund remediation.

Consideration has also been given to the anticipated vertical height of any storm surge barrier and resultant vulnerability to wind loading or challenges to closing a gate in high-wind hurricane conditions. Gates with a very large "sail" area, such as a vertical lift gate, can be problematic in extreme high wind conditions. The section that follows introduces the various gate types in use globally and in the United States, and lists key advantages and disadvantages for each.

4.1.1 Miter Gate

Miter gates consist of double leaf gates where the leaves rotate about their quoins/hinges, and close against an underwater sill, to meet and form an angle pointing in the direction of the tidal surge. Miter gates are commonly used on canals and smaller waterways and generally represent the simplest storm surge barrier option with the lowest cost and ease of operations.

Ipswich Tidal Floodgate, UK – single 50-foot gate.

Miter gate in closed position.

Miter gate in open position.

FIGURE 4-1
Miter Gate

The gates are operated by hydraulic rams which are designed together with the gate to have the size and strength required to clear general siltation and sediment out of the way so long as it is not excessive.

Advantages miter gates offer include the following:

- They have no restriction on navigation clearance height.
- They have a relatively simple design and construction.
- Their closure time is relatively quick, requiring shorter lead-up time before closure and coordination with vessel operators.
- Their operation and maintenance is comparatively easy, requiring a single operator and having no confined space-entry requirements.
- They offer a proven concept with good reliability and simple back-up procedures to close gates.
- They normally require little upland area, which can minimize cutting into the existing bulkhead and land behind it, and thus enable the barrier to be located where space is constrained by existing development and land use. Construction and whole-life costs are generally lower in comparison to other barrier gate types.

Miter gates present a few disadvantages or limitations to their use, including:

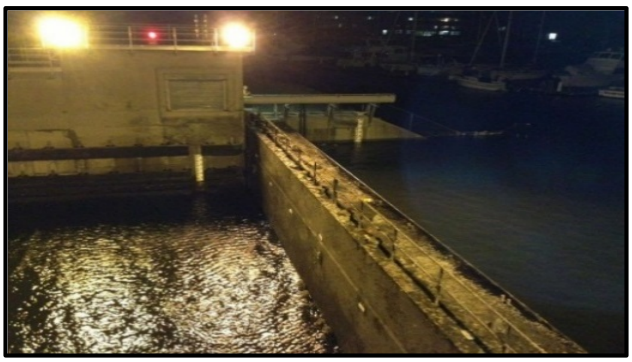
- Gate width is generally limited up to about 100 feet, which precludes their use in all of the locations considered for a barrier location at the Creek as the minimum navigation width required is 150 feet.
- They can only operate one way and cannot deal with reverse head, although this is unlikely to be an issue for the functionality that the gate is required to provide. Control is problematic when operating under flow or wave conditions.

4.1.2 Flap Gate

Flap gates rely on a submerged bottom hinged arrangement at the sill and a gate that is raised either by hydraulic rams or by lifting wires. In the open position, the gate generally lies in a horizontal position flat on the channel bed.

Stamford Hurricane Barrier, CT– single 90-foot gate.

Aerial view of barrier with gate in open position lying flat on channel bed. Source: USACE, 2008



Barrier flap gate in closed position during Hurricane Sandy surge event in October 2012. Source: USACE

FIGURE 4-2
Flap Gate

Flap gate advantages include the following:

- Large gate spans are feasible, meaning they can accommodate any of the locations considered at the Creek.
- They present no restriction on navigation clearance height.
- The gate design is relatively simple, although civil works construction can be complex such as the installation of an underwater foundation to support the gate hinge and gate recesses. They are suitable for use in deep water.
- Their operation is relatively easy, requiring an average closure time of about 20 minutes and only one or two operators, depending on size.
- They offer a proven concept with good reliability.
- They provide reasonable control when operating the gate in flow or wave conditions.
- They normally require little upland area, which can minimize cutting into the existing bulkhead and land behind it, and thus enable the barrier to be located where space is constrained by existing development and land use.

Flap gates present a few disadvantages or limitations to their use, including:

- There are potential issues with the gate recess silting up or silt deposition on top of gate while it is in open position, although this is believed to be less of a concern at the potential the Creek locations.
- Flap gates are difficult to inspect, maintain, and replace, particularly the submerged hinges.
- The gate can only operate one way, although this is unlikely to be an issue for the functionality that the gate is required to provide at the Creek.

4.1.3 Vertical Rotating Gate

There are two types of vertical rotating gates: rising sector gates and falling radial (or tainter) gates. Rising sector gates normally lie open in a horizontal position within a recess in the sill below the channel bed level. To close for the vertical flood defense position, the gate is raised by rotating it 90 degrees. In contrast, a falling radial gate is held in the raised open position above normal water levels and is lowered by rotating it down until it seals against the sill provided to close the gate.

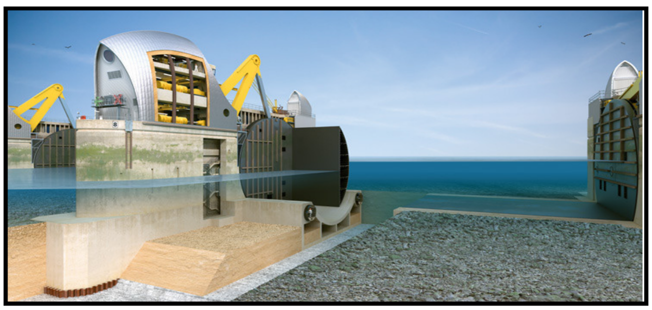
The vertical rotating rising sector gate’s advantages include the following:

- Large gate widths up to 200 feet are feasible. Such a gate width would accommodate most (but not all) of the locations considered for the Creek.
- They present no restriction on navigation clearance height.
- They are ready for immediate deployment and have a relatively fast closure time of around 5 minutes. Their operation is relatively easy, and depending on size, may require only one or two operators.
- They can accommodate reverse head and/or flow, thus having the ability to provide both storm surge defense and retention of a raised water level upstream of it. Reasonable control is possible when operating the gate in flow or wave conditions.
- They offer a proven concept with good operational reliability. The gate can be rotated out of the water for inspection and maintenance.
- They normally require little upland area, which can minimize cutting into the existing bulkhead and land behind it, and thus enable the barrier to be located where space is constrained by existing development and land use.

Thames Barrier, London, UK – combination of 4No. 200-foot and 2No. 103-foot wide vertical rising sector gates.

Environment Agency

Overall aerial view of barrier



Visualization of sector gate in closed (left) and open (right) positions

FIGURE 4-3
Vertical Rotating Gate

Vertical rotating rising sector gates present a few disadvantages or limitations to their use, including:

- The gate design and associated mechanical and civil works are relatively complex with high tolerance required for construction of the sill and gate recess.
- There can be potential issues with silting up of the gate recess or debris/objects accumulating within it that can damage the gate or inhibit its opening.
- Confined space entry is required for operators to inspect and maintain the gate's internal mechanisms.
- The sill is relatively deep to house the gate and would require a greater amount of excavation and disturbance of remediated and capped material.

4.1.4 Vertical Lifting Gate

Vertical lifting gates are a widely used type of storm surge barrier gate, and generally have a satisfactory record of operation. There are two designs or operational configurations. The first configuration has a gate submerged in a recess which lies below the channel bed and is raised to the required flood defense position. The alternate configuration retains the gate above water by towers/supports on either side and is lowered to the flood defense position with the gate sealing against the sill/channel bed. Given the contaminated nature of the existing channel bed, the remediation and cap activity planned anticipated as part of future Superfund remediation works, and the preference to minimize disturbance to the remediated channel bed, the lowered vertical lifting gate (drop gate) is the more suitable configuration of this gate type for the Newtown Creek locations.

The vertical lifting gate's advantages include the following:

- Large gate spans, up to around 360 feet wide are feasible, so they can accommodate any of the locations considered at the Creek.
- Their operation is relatively easy, requiring an average closure time of about 20 minutes and one or two operators, depending on size.
- The raised gate is accessible for maintenance, so no confined space entry is required apart from any internal gate inspection and maintenance. Working from height is an issue that needs managing.
- They offer a proven concept with good reliability.
- Reasonable control is possible when operating the gate in flow or wave conditions.
- They normally require little upland area, which can minimize cutting into the existing bulkhead and land behind it, and thus enable the barrier to be located where space is constrained by existing development and land use.

Hull Barrier, UK – single 100-foot-wide vertical lifting gate that is lowered into position.

Barrier lifting gate in semi-lowered position above water.

Lifting gate in normal open position rotated 90 degrees to maximize navigation clearance.

FIGURE 4-4
Vertical Lifting Gate

Vertical lifting gates present a few disadvantages or limitations to their use, including:

- The raised gate configuration (drop gate) imposes a clearance height constraint for navigation. The higher the water level within the channel, the greater the gate height required above navigation clearance, which can increase the size and complexity of the structure.

PROJECT REF: GOWANUS CANAL AND NEWTOWN CREEK STORM SURGE BARRIERS STUDIES • EDC CONTRACT NO. 58100001

- The raised gate configuration is subject to wind load.
- There are potential operational and maintenance issues with the wearing of gate guide wheels and with underwater marine growth affecting gate movement.
- The vertical lifting gate may be sensitive to hydrodynamic-induced vibration.

4.1.5 Horizontal Rotating Gate

The horizontal rotating gate comprises circular sector or radial gates that rotate on a vertically mounted pivot and close in a horizontal plane. In the open position the gate leaves retract and lie within a recess alongside and clear of the navigation channel. Larger gates generally use floating gates that are pushed across the channel and then filled with water to lower them onto the constructed sill and channel bed.

Lake Borgne Barrier, New Orleans – the barrier is a single, 150-foot-wide, vertically hinged horizontal rotating sector gate.

Overall aerial view of barrier. Source: USACE, 2012

Horizontal sector gates in normal open position recessed into areas adjacent to the channel and clear of navigation. Source: USACE, 2012

FIGURE 4-5
Horizontal Rotating Gate

The horizontal rotating gate's advantages include the following:

- Large gate spans, in excess of 600 feet wide, are feasible, so they can accommodate any of the locations considered at the Creek.
- They present no restriction on navigation clearance height.
- They are suitable for use in deep water.

- Rapid closure time of between 5 to 10 minutes is possible for smaller gates (including those circa 150 feet wide), though larger gates can take up to 60 minutes.
- Location of gates in “dry dock” recesses allow offline maintenance in the dry.
- They offer a proven concept with good reliability.

Horizontal rotating gates present a few disadvantages or limitations to their use, including:

- Use of infill areas within the channel would be required to create the necessary recesses unless the recess were into the adjacent upland areas of the canal. Depending on the size of the infill, there may be opportunities to create new recreational space or habitat if all of the infill is not used to house the recessed gates.
- Confined space entry is required to undertake internal gate inspection and maintenance for larger size gates.
- The gate design is relatively complex.
- If the gate runs on wheels across the sill, then the build-up of silt can be both an operational and maintenance issue. However, this is not believed to be a major problem in the Creek and the hydraulics would be sized to clear the anticipated level of silt accretion.

4.1.6 Caisson Gates

There are three types of caisson gates: floating, sliding, or hinged caisson (or barge). A floating caisson gate is moored to a pier, then moved into position by tugs and filled with water to lower it into the constructed recess. This gate type is often used for large size dry docks. In contrast, a sliding caisson gate is a floating gate located in a recess to suit, pushed or pulled across the channel and then filled with water and lowered to seal onto a sill. A hinged caisson gate is operated in a similar fashion but can be rotated around into position using either a side or bottom hinge.

The caisson gate’s advantages include the following:

- They can accommodate large gate widths.
- They present no restriction on navigation clearance height.
- A floating caisson gate can be maintained away from the channel without interfering with navigation.
- Except for a hinged caisson gate, they are suitable for reverse head.
- A floating or hinged caisson gate requires little upland area.

Royal Chatham Docks, UK – single sliding caisson gate circa 100 feet wide

Sliding caisson gate post refurbishment being lowered into normal open position. Source: Beckettrankine.

Lake Borgne Barrier, New Orleans – single barge gate 150 feet wide.

Barge gate in normally closed position on left alongside horizontal rotating sector gates. Source: USACE, 2012

FIGURE 4-6
Caisson Gate

Caisson gates present a few disadvantages or limitations to their use, including:

- Bottom hinged gates are not suitable to deal with heavy silt build up on top of the gate while in the open position.
- In general, they are not suitable for deep waters, which depending upon post-Superfund remediation depths, could preclude this gate option.
- They offer very little or no control when operating the gate in flow or wave conditions.
- Relatively complex operating equipment is required, such as having a tug on-hand to maneuver the caisson gate into position.
- Slide gates require relatively complex civil works, particularly those associated with the construction of the required gate recess.
- Sliding caisson gates require a large upland area to accommodate the recess and would require cutting into the existing bulkhead/waterway edge.

- Floating caisson gates normally require confined space entry for inspection since they are large hollow steel structures, similar to barge gates, with internal piping requiring internal structural and mechanical inspections.
- Very slow deployment/closure speed of around 30 minutes is required, and closure for floating caisson gates can take up to half a day or longer due to tug availability and high operational manpower requirements.

4.1.7 Inflatable Rubber Dam

An inflatable rubber dam consists of a rubber bladder attached to the bottom of the channel that is inflated to form a dam/barrier across the channel opening. They are used widely throughout the world but currently with limited application as storm surge barriers. Inflation can be with air, water, or a combination of both. In the open position, the rubber bladder is deflated and lies relatively flat in the recess provided on the channel bed.

Ramspol Barrier, Holland – 3No. 246-foot-wide, inflatable rubber dams.

Overall aerial view of barrier.

Rubber dams in deflated open position.

Rubber dams in inflated closed position.
Image source: Waterschap Groot Salland

FIGURE 4-7
Inflatable Rubber Dam

The inflatable rubber dam's advantages include the following:

- They can accommodate spans up to 300 feet wide, though a series of inflatables would be used to bridge the total expanse.
- They present no restriction on navigation clearance height.
- They offer a proven concept with good reliability.
- They normally require relatively little upland area, which can minimize cutting into the existing bulkhead and land behind it, and thus enable the barrier to be located where space is constrained by existing development and land use.
- They provide a direct transfer of hydraulic load.
- They can be erected and deflated in flowing water.
- They do not require hinges or a drive system.
- They are not sensitive to siltation.

Inflatable rubber dams present a few disadvantages or limitations to their use, including:

- They are generally not suitable for waters deeper than 30 feet, which would preclude locations at the Creek.
- They have a lengthy closure speed of around 55 minutes.
- It is difficult to inspect, maintain, and replace the rubber dam element, and confined space entry is required.
- They are more vulnerable than other types of barriers to navigation or debris impact when in the deployed position.

4.2 Upland Defense Types

There are a variety of upland defense structures that may be used, depending upon unique site conditions for a given location. An important consideration is whether the structure can be left permanently in place or must be deployed and then removed between flood events to allow for access.

Permanent structures consist of earthen berms and vertical floodwalls inland and shoreline stabilization (bulkheads and rock revetments) along the shoreline. For the inland features, earthen berms are nearly always more cost effective but require a larger footprint, so can take away from active recreation areas, although passive recreation may be accommodated. Vertical floodwalls require a significantly smaller footprint but are more costly and require a subsurface foundation. Vertical floodwalls are typically constructed of concrete or sheet pile, though a variety of vendor products are available (such as vinyl piles, glass walls, etc.). Along the shoreline, rock revetments are generally more cost effective and offer in-water habitat, but have a larger required footprint. Bulkheads offer more opportunities to integrate active recreational features as a result of the narrower footprint.

A variety of deployable structures may be used. The specific site conditions such as width, clearance, subsurface conditions, and operation and maintenance requirements make some deployable types better suited to a specific location than other types. **Table 4-2** summarizes how different deployable upland defense types perform against different considerations.

TABLE 4-2
Comparison of Deployable Upland Defense Types
Note: G=green (good performance), Y=yellow (moderate performance), R = red (not possible/worst performance)

	Slide or Roller Gate	Swing Gate	Demountable Panels
Opening width >80 feet	R	R	G
Avoid spatial requirements (clearance to open)	G	R	G
Ease of maintenance	Y	Y	G
Ease of operation/implementation	G	G	R
Storage requirements	G	G	R
Visual Impact	Y	Y	G
Cost	R	R	Y

The following section discusses each of the upland defense structures and lists key advantages and disadvantages for each.

4.2.1 Earthen Berms/Levees/Revetments

Earthen levees typically have a 10-foot wide top width and 2:1 ratio side slopes at a minimum. It is typical to have an additional 15 feet of clearance on each side of the levee toe for inspection, maintenance, and flood-fighting access. They need a properly prepared foundation, which may require over excavation, utility relocations, and additional right-of-way (ROW) acquisition. Earthen levees are constructed of engineered soils to resist issues with stability, seepage, and settlement. The riverward side requires erosion protection, such as riprap or grass.

FIGURE 4-8
Earthen Berms

The advantages of using earthen berms include:

- They offer a proven concept and have been shown to be reliable with adequate inspection and maintenance.
- They tend to be the most cost-effective levee solution when onsite space and soil materials are available.

Use of earthen berms also present a few disadvantages, including:

- They typically occupy a large footprint that could require relocations and ROW.
- There are potential issues of cutting off local drainage that would have to be captured and routed through/under the levee.
- Construction will likely require significant imported soil materials to meet specifications. This could translate into traffic issues with number of trucks, staging, and dust control.
- Earthen berms are discontinuous at crossings.

FIGURE 4-9
Revetments

4.2.2 Vertical Floodwalls

Vertical floodwalls are typically constructed of reinforced concrete or steel sheet piles. It is typical to have an additional 15 feet of clearance on each side of the floodwall for inspection, maintenance, and flood-fighting access. Reinforced concrete floodwalls need a properly prepared foundation, which may require over excavation, utility relocations, and additional ROW. An underground footing is required that has a width greater than the surface wall, unless a sheet pile “I-Wall” is used. Steel sheet pile floodwall depths and sections depend on existing subsurface soil conditions, but are deeper than the footing of a concrete wall. The depth of embedment may require utility relocations. Vertical floodwalls are engineered to resist stability, seepage and settlement issues. The materials used for construction typically provide erosion protection without additional revetment.

FIGURE 4-10
Vertical Floodwall

Advantages to using vertical floodwalls include the following:

- Vertical floodwalls offer a proven concept that is reliable with adequate inspection and maintenance.
- They require a smaller footprint compared to an earthen berm.

Disadvantages the vertical floodwalls present include the following:

- Typically, the foundation preparation and driven sheet piles require relocations and ROW acquisition. Pile driving can present vibrational risks to nearby buildings.
- There are potential issues cutting off local drainage that would have to be captured and routed through/under the floodwall.
- Construction requires imported materials, which could translate into traffic issues with number of trucks and staging.
- Vertical floodwalls are discontinuous at crossings.

4.2.3 Deployable Structure: Slide or Roller Gate

Slide or roller gates are typically constructed with a reinforced concrete foundation and/or reinforced concrete or steel superstructure. Additional space is required adjacent to (in-line with) the gate to store it while in the open position. Clearance inspection and maintenance is also required in front of the open gate. The reinforced concrete foundation may require over excavation, and utility relocations. Slide or roller gates are engineered to resist stability, seepage, and settlement issues. The materials used for construction typically provide erosion protection without additional revetment.

Sliding or roll-across gate

FIGURE 4-11
Slide Gate

Advantages of a deployable slide or roller gate include the following:

- Slide or roller gates offer a proven concept that is reliable with adequate inspection and maintenance.
- Closure speed is relatively fast (circa 15 minutes), and time requirements are relatively short. When accounting for manning and closure checks, time requirements can be up to 2 hours, especially for the larger gates. Manning time requirements could take longer, depending upon traffic diversions and road closures put in place as part of any traffic operations and management plan.
- The gate opens in-line with the closed position, minimizing the perpendicular onsite space required.

Disadvantages a deployable slide or roller gate present include the following:

- They are only practical for a limited closure width (up to 80 feet with two adjacent gates).
- There are potential operational and maintenance issues with the wearing of gate guide wheels and the foundation plate due to traffic.
- Construction will require imported materials, which could translate into traffic issues with number of trucks and staging.

4.2.4 Deployable Structure: Swing Gate

Swing gates are typically constructed with a reinforced concrete foundation and steel gate structure. Additional space is required adjacent to (both in-line and perpendicular) the gate to operate and store it while in the open position. Clearance for inspection and maintenance is also required. The reinforced concrete foundation is typically robust and may require piles, over excavation, and utility relocations. Swing gates are engineered to resist issues with stability, seepage and settlement. The materials used for construction typically provide erosion protection without additional revetment.

Advantages a swing gate presents include the following:

- Swing gates offer a proven concept and are reliable with adequate inspection and maintenance.
- Closure speed is relatively fast (circa 15 minutes), and time requirements are relatively short. When accounting for manning and closure checks, time requirements can be up to 2 hours, especially for the

larger gates. Manning time requirements could take longer, depending upon traffic diversions and road closures put in place as part of any traffic operations and management plan.

- There are no vertical clearance issues.

FIGURE 4-12
Swing Gate

Disadvantages of using a swing gate include the following:

- They are only practical for a limited closure width—up to 80 feet with two adjacent gates.
- Construction will require imported materials which could translate into traffic issues with number of trucks and staging.

4.2.5 Deployable Structure: Demountable Panels

Demountable panels are typically constructed of reinforced concrete foundations, steel intermediate posts, and aluminum panels. The reinforced concrete foundation may require piles, over excavation, and utility relocations. Demountable panels are engineered to resist issues with stability, seepage and settlement. The materials used for construction typically provide erosion protection without additional revetment.

FIGURE 4-13
Demountable Panels

Advantages demountable panels present include the following:

- There are no limits to closure width (although there is a limit to individual panel widths and column spacings).
- Demountable panels offer a proven concept and are reliable with adequate storage, inspection, and maintenance.
- Tends to be the most cost-effective closure solution when onsite space is tight.

Disadvantages of using demountable panels include:

- Closure speed and time requirements are longer: approximately 2 hours for smaller systems and up to 4 hours for the larger systems. More manpower required for installation as compared to swing/slide gate operation. Any installation, especially for larger ones where a crane is required, will present health and safety challenges in hurricane force wind conditions. Early closure may be dictated, leaving little scope for last minute emergency access to the zones in front of the upland defenses.
- Typically the foundation preparation requires utility relocation and ROW acquisition.
- Construction will require imported materials, which could translate into traffic issues with number of trucks and staging.

The **Table 4-3** shows typical implementation times and equipment requirements for the three deployable systems discussed.

TABLE 4-3
General Guidance of Implementation and Use of Closure Structures within Floodwalls

Type	Dimensions	Implementation Time* (does not include delivery)	Manpower	Equipment Needed**
Post/Panel System (small)	Height: <5 feet Length: <50 feet	2 hours	3-man crew	Truck (delivery) Forklift (installation)
Post/Panel System (large)	Height: 5 feet to 15 feet Length 50 feet to 200 feet	4 hours	12-man crew	Truck (delivery) Crane (offload) 2 Forklifts (installation)
Slide gate	Height: <15 feet Length: <40 feet (or 80 feet with center column)	2 hour	3-man crew	Truck (installation) Forklift
Swing gate	Height: <15 feet Length: <40 feet (or 80 feet with center column)	2 hour	3-man crew	Truck (installation)

* Additional activity to make the structure watertight (i.e. polyvinyl chloride (PVC) sheeting and sandbags) are not included.

**The best option truck used for delivery of the posts and panels would include a flatbed with a truck-mounted crane. The slide gate and swing gate trucks would need to include tools as needed to complete the closure.

4.3 Lessons-Learned

This section identifies and documents lessons learned and best practices from other storm surge barrier projects in the USA and overseas, which are applicable to the potential barriers being considered for the Creek.

The lessons learned and best practices have been categorized under the topic areas listed below, which generally determine the key requirements and their impacts upon the design and delivery of storm surge barrier schemes.

FIGURE 4-14
Conceptual image of barrier in Newtown Creek from SIRR.

The topic areas are as follows:

- Land use
- Navigation and transport
- Bathymetry and geomorphology
- Topography
- Hydrology, hydraulics and hydrodynamics
- Climate
- Engineering and design
- Environment
- Operation and maintenance
- Regulatory impacts

Generally all of the lessons learned and best practices detailed below are applicable to both the Gowanus Canal and Newtown Creek studies. Where relevant, individual reference is made where it specifically relates to one of the two locations.

For ease of reference, the various barrier projects used as references regarding lessons learned are as follows:

- Lake Borgne Barrier (IHNC), New Orleans, U.S.
- Ipswich Barrier, Suffolk, UK
- Boston Barrier, Lincolnshire, UK
- Thames Barrier, London, UK
- Hull Barrier, Yorkshire, UK
- Ramspol Barrier, Netherlands
- Saint Petersburg Barrier, Russia
- Mose Barrier, Venice, Italy

It should be noted that there are three storm surge barriers in the eastern United States that are not on this list of information: the Fox Point Hurricane Barrier, Independence, Rhode Island; the New Bedford Harbor Hurricane Barrier, Massachusetts; and the Hurricane Barrier, Stamford, Connecticut. The project team has had no access to lessons learned of any note from these locations, but it is worthwhile noting that the

United States has, through these hurricane barriers that were built following the 1938 Long Island Hurricane and subsequent hurricane flooding in the 1950s, some of the oldest storm surge barriers in the world.

4.3.1 Land Use

It is important to identify the land use—past, present and future—adjacent to a proposed barrier location as it can prove to be either a showstopper as regards location, result in very high costs for the remediation of contaminated land, or have significant influence as to the cost or impacts of the barrier scheme whether short-term during construction or long-term after construction.

- The Ipswich Barrier scheme undertook the construction of the defenses required to tie the barrier into high ground as an earlier phase of the works. This has enabled these works to be designed to form part of the adjacent Griffin Wharf development proposals on its west bank before the development is completed (see **Figure 4-15**). This has avoided the cost of reconstructing the landscaped area as well as compensation claims for disruption, blight to property sales, etc. during construction. This is something to consider, particularly with respect to the Hunters Point South and Greenpoint developments at the mouth of the Creek.

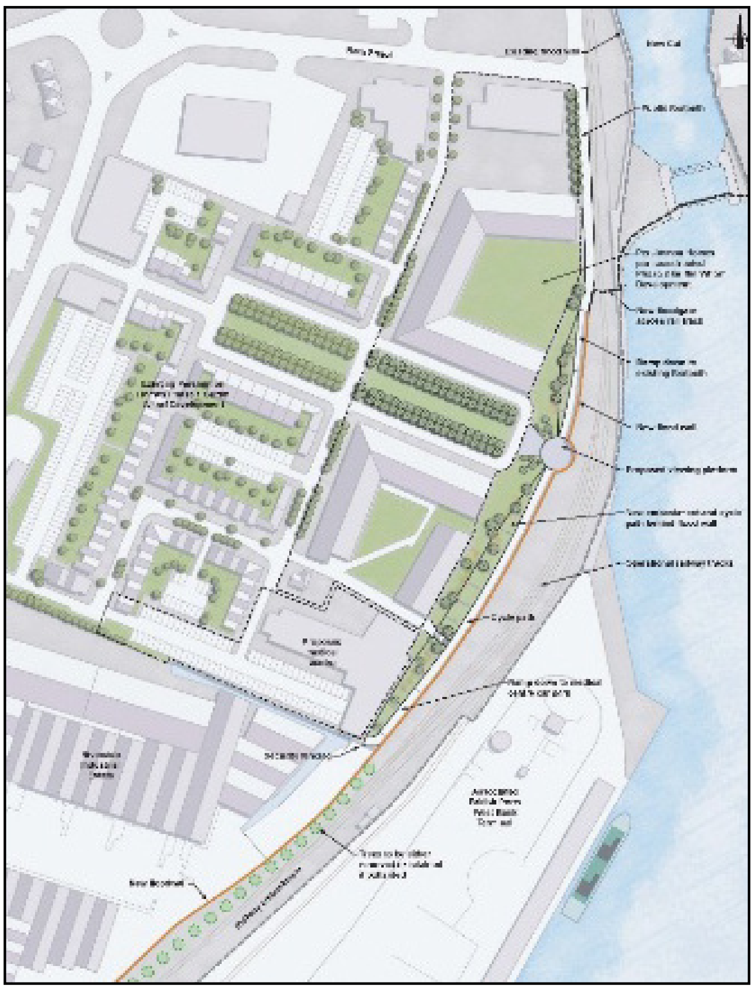


FIGURE 4-15
Plan of Ipswich Barrier West Bank Works which were undertaken as early works prior to barrier construction.

- For the above Griffin Wharf development in Ipswich, new apartments are to be constructed which have unimpeded views to the River Orwell estuary. Following consultation with the developer at an early stage of the barrier project, the barrier location was modified so as not to impede these views and hence avoided the compensation claim for blight and loss of property value that the developer would otherwise have sought. Again this could be relevant when considering the planned new developments at the mouth of the Creek.

- It is important to ascertain what future developments/land use are proposed in the study area for the barriers, and that consideration is given to the location of the barrier such that, if possible, it does not prevent their future implementation, e.g., the Ipswich Barrier and its control building have been located to the south away from the proposed alignment for a potential future road bridge crossing. Alternatively there is the opportunity of combining the barrier with the construction of a road or rail bridge as per the Saint Petersburg Barrier (**Figure 4-16**) or Tees Barrage. This is a consideration for the Creek where there could be potential to integrate a cycle/pedestrian bridge link as part of the Manhattan Avenue option.

FIGURE 4-16
Saint Petersburg Barrier, Russia includes a roadway.

- For flood defense schemes, there is generally a limit to the extent of flood risk area that can be justified for improved flood protection. Sometimes these schemes require land from, or cause major impact to, landowners who lie outside of the protected area i.e. lots of impact but no benefit. This can often result in substantial claims for compensation or objections from those affected which in turn can involve extended legal action and therefore substantial costs and project delays.
- Storm surge barrier schemes generally involve an interface with existing services such as electricity, gas, telecommunications, water, sewerage, oil, etc. It is important to understand as early as possible the importance of those services, their condition, and the scale of likely diversion works that will be required as it can have a significant impact on the barrier location and/or cost. The cost of these diversion works can be disproportionately high versus the cost of the barrier construction, as demonstrated by the Ipswich Barrier scheme where the enabling works to divert two 50 year old 132 kilovolt cables is costing circa $17 million in comparison to the $33 million contract to construct the barrier. This could be a key issue for the Creek barrier due to the cables and pipelines located along the bed of the Creek, which potentially may need to be diverted.
- Early identification of high risk areas of contaminated land from past records, site history and usage, are important as the potential remediation cost and/or environmental impacts can be so significant that the barrier location, form or layout has to be substantially changed to minimize any disturbance to the contaminated land, or to avoid contaminants leaching/being mobilized into the surrounding water table. For both Gowanus and Newtown the extent of contamination with the Superfund sites will need to be taken into consideration.

4.3.2 Navigation and Transport

Storm surge barriers, being located in a waterway, by their very nature interface to varying degrees with the navigation traffic that uses the waterway. This can vary from large commercial sea-going vessels to small recreational craft. The passage of this navigation traffic through the barrier is a critical requirement which impacts upon the barrier location, type, dimensions, operation and cost.

- In order to limit the vulnerability of the barrier to impact and damage from vessels passing through it, training walls on the approaches to the barrier, and impact protection such as dolphins and fendering, are necessary (see Lake Borgne Barrier, **Figure 4-17**). The scale of these protective measures, and hence cost, increases significantly the larger the size of vessel to be designed for. On the Boston Barrier scheme in the UK, the preferred barrier location was significantly influenced by avoiding interaction with the large commercial shipping using the Port of Boston's facilities.

FIGURE 4-17
Lake Borgne barrier, New Orleans showing training walls for navigation.

- It is important to understand the alignment of the navigation channel in relation to the location and orientation of the barrier opening. One should seek to locate the barrier on a relatively straight section of channel—if it is on a bend then issues arise regarding risk of impact and/or damage to the barrier; the protection measures (long term maintenance / replacement costs), and the vessels themselves. Problems also arise with navigational safety, e.g., lack of line of sight of navigation traffic approaching the barrier from the opposite direction.
- Early identification of existing constraints on navigation width/draft/height and flows within the river channel enables one to determine a starting point for a minimum barrier width, e.g. Pulaski Bridge for Newtown Creek (**Figure 4-18**).

FIGURE 4-18
Pulaski Bridge on Newtown Creek restriction width of navigable channel.

- It is important to understand the size and operating regimes for the navigation traffic using the waterway which the storm surge barrier will span across. Dimensions of the vessels including beam, draft, height, and length, are required, as well as details of the frequency and timing of when they pass through the barrier location. This information is vital for understanding the requirements for the permanent barrier dimensions as well as the size of temporary passage/bypass channel to be provided during the barrier construction.
- Early engagement with the Coastguard, Harbor or Port Authority, and other river users (commercial and recreational), will ensure that the key navigation information and constraints are established at the start of the concept/outline design development. On the Lake Borgne Barrier project, a lesson learned was that engagement with the Coastguard should have been sooner than it was. On the Boston Barrier scheme, the team did not initially engage fully with some recreational river users until later on when significant impacts (and hence mitigation) were identified. In both these two instances, modifications were required resulting in delay and/or additional cost.
- When assessing the location of the barrier, it is important to consider the barrier's buildability and how it can be constructed so as to avoid or minimize unnecessary interference with the normal traffic and commerce of the waterway. One should seek to position the barrier within the waterway channel such that it enables partial closure of the waterway and the construction of the whole or part of the gated barrier structure or abutments in the dry, e.g., within a sheet piled cofferdam. This is particularly relevant for barrier locations where the waterway channel width is relatively small and the scope to provide a sufficiently large enough temporary bypass channel is very constrained, e.g., the Ipswich and Boston Barriers and the potential barrier locations further upstream in the Creek.

4.3.3 Bathymetry and Geomorphology

It is important to understand the bathymetry and geomorphology of the river channel and to determine its shape/characteristics.

- An early bathymetric survey of the area, if not already available from the port or harbor authority, provides a sound baseline to highlight any natural change to the geomorphology of the existing river channel bed prior to the construction of the storm surge barrier. It provides important information so that cross sectional and other design data is available to inform the development of a conceptual or outline design, e.g., the depth and profile of any berms to be constructed as part of the tie-in walls to the barrier structure.

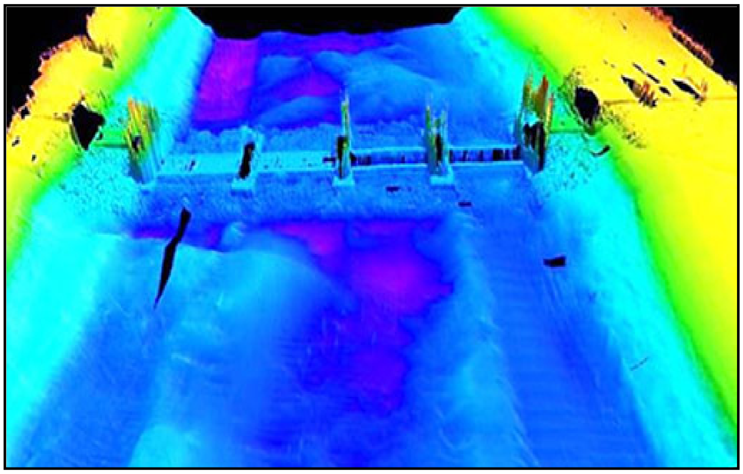


FIGURE 4-19
Typical bathymetric survey output.

- The impact of a storm surge barrier scheme on the geomorphology of the existing watercourse is an important issue that needs to be carefully considered throughout the scheme's development. Any significant sediment deposition/accretion or scour/erosion, increased dredging requirements either for the barrier operator or the local port/harbor authority, and increased scour protection all incur substantial whole life costs (e.g., as demonstrated by the ongoing extensive erosion protection works required at the Eastern Scheldt Barrier). Therefore there is a need to look at the barrier design and layout to minimize siltation occurring especially in the navigation channel such that it minimizes maintenance dredging requirements. It is also advisable to consider preventing silt build up in the barrier opening through regular operation of the barrier gate. Preliminary modelling as undertaken for the Boston Barrier (**Figure 4-20**) can be very useful to quickly ascertain whether sediment accretion or erosion is a significant issue in the vicinity of the barrier.

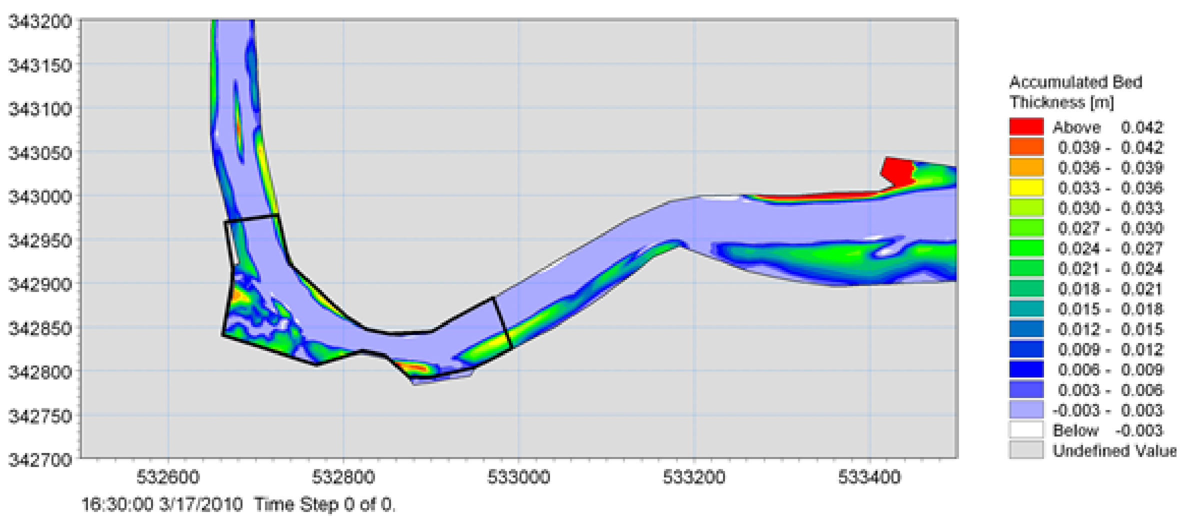


FIGURE 4-20
Sediment transport modeling for the Boston Barrier (UK)

4.3.4 Topography

Fundamental to any storm surge barrier scheme is the construction of the flood defenses that link back to higher ground on both sides of the waterway. It is important to establish that the higher ground is consistently above the required defense height and that there are no low spots which would allow the barrier and its defenses to be outflanked by the flood waters.

A lesson learned from the Boston Barrier scheme is that, if LiDAR topographical survey information is used, the level of accuracy of that information should be understood and the potential level of uncertainty established. Where the levels are critical, on site spot survey checks to verify the level information is advisable.

4.3.5 Hydrology, Hydraulics and Hydrodynamics

A clear understanding is required of the hydrology, hydraulics and hydrodynamics that can affect or be affected by the construction of a storm surge barrier across the river channel.

- A basic requirement for a storm surge barrier scheme is that during an event there is sufficient upstream storage available for any fluvial flows arriving behind the barrier and which can back up whilst the barrier gate is closed and the tidal surge event precludes any discharge downstream of the barrier. This can be problematic where the ability to create sufficient storage capacity is limited and a large scale pumping station may be required to pump this water over the barrier and defenses during the surge event to avoid fluvial flooding occurring. This has had to be considered as a potential future requirement for the Ipswich Barrier should sea level rise and rainfall intensity increase as predicted. This is relevant, for both Newtown Creek and Gowanus Canal, where the extent of upstream waterway, and hence storage capacity, is relatively small.
- In many cases the construction of the barrier will permanently reduce the overall channel width and cross sectional area at its location. As a result, it is important to check that this reduction will not significantly impact upon the discharge of a large fluvial flood event such that the risk of fluvial flooding upstream of the barrier is increased.
- The accuracy of flood forecasting is also important to establish as it affects closure response times as well as the number of times that the barrier is closed—in particular those closures which occur but were not actually required as the event was less than predicted due to forecasting error. For the Mose Barrier in Venice closure model testing has been undertaken over an extensive period and this has allowed the forecasting accuracy to be significantly improved long before the completion of its construction.
- When considering the width of the barrier opening it is important to consider the hydraulics and flow velocities through the barrier such that it is safe for all the types of vessel passing through it. A lesson learned from the Boston Barrier scheme was that, in determining these flow velocities, the cross sectional area of the barrier opening should be reduced by the area occupied by the beam and draft of the vessel.
- Undertaking physical modelling of the proposed barrier can prove to be very effective as demonstrated by its use on the Lake Borgne and Ipswich Barrier projects (see **Figure 4-21**). It has enabled the designers to test and see the effects of complex wave loading scenarios, check to see whether any gate vibration is induced under different scenarios, and to better determine the extent of river bed scour protection required. For the Ipswich Barrier, the $200,000 cost of the physical model was more than offset by the $375,000 cost saving as a result of it demonstrating that the proposed scour protection could be reduced. A key lesson learnt was that this physical modelling should be undertaken early enough for results to feed into the detailed design. On the Ipswich Barrier it has proved to be a powerful piece of visual proof to reassure and/or convince navigation stakeholders that the effects of the barrier should not have a significant impact upon them. For the Thames Barrier significant scale modelling and testing was undertaken to ensure that the barrier had a minimum effect on the river hydrodynamics.

FIGURE 4-21
Ipswich barrier physical model.

- A lesson learned from the Lake Borgne Barrier is that one should consider the merits of an in-situ hydraulic test as part of the construction to prove the design and performance of the barrier gate rather than the use of sensors to monitor performance under load afterward during post-construction storm events. The use of an in-situ hydraulic test as part of the commissioning process has been adopted for the Ipswich Barrier; however, it is generally only feasible where the complete barrier gate and its associated structure are built within a single cofferdam, which is designed to hold water within it to a level that provides an adequate check of the gate's performance under load.

4.3.6 Climate

Climate has an impact on the design parameters for a storm surge barrier. This includes the need to consider what allowances are appropriate to allow for potential climate change factors such as sea level rise, increased storminess, and increased rainfall intensity. The determination of these allowances is generally dictated by guidance provided by the relevant lead flood authorities. However there are some others factors such as wind and ice to consider depending on the barrier gate type or location.

- The design levels for water levels and wave effects are dependent on the climate effects, as well as on the design life and the level of reliability that the design must deliver.
- For wind there is a need to ensure that adequate provision is made in the gate design for resistance to wind loads and that dynamic loading effects are considered. This is especially relevant if considering a vertical lift type gate such as the Hull Barrier (**Figure 4-22**) or the Bayou Bienvenue gate. Safe access in windy conditions to exposed areas of the gate for its operation and maintenance also needs consideration.
- Depending on where the barrier is located in the world, how one deals with ice and ensuring it does not compromise the operation of the barrier gate can be important. For the Saint Petersburg Barrier scheme heating pads were considered in order to release the sluice gates which might have been frozen onto their concrete substructures. An air bubble system has been installed to keep the water at the gates, which defend the permanent dry docks for the large radius sector gates, from freezing. This is a potential issue that may need to be considered for the proposed storm surge barriers at Newtown Creek and Gowanus Canal.

FIGURE 4-22
Hull Barrier

4.3.7 Engineering, Design and Construction

There are various lessons learned and best practice examples described under other topic headings that are integral to the development of the design of storm surge barriers and the associated engineering solutions. Some additional lessons learned specific to this topic area are described below.

- In developing a storm surge barrier design solution, it is important that there are clear reliability and design standards defined early on in the process, as they can have a significant effect on the proposed solution. As evidenced by the amount of work that has been undertaken on existing barriers worldwide, the review of the barrier's likelihood of failure and required emergency operating procedures has resulted in an enormous amount of remedial work, such as retrofitting extra closure mechanisms.
- The design process should be driven by a set of functional requirements that reflect the required outcome of the project in terms of its performance. The primary functional requirements will be to open and close on demand, and be able to withstand the design loadings. Secondary functional requirements may be provided to set the following: design life; acceptable levels of risk, reliability and consequence; maintenance strategy; buildability strategy; and aesthetics, environmental and ecological targets. The process should be set out in a project design basis document.
- Design should also consider issues that affect reliability, such as 'defense in depth' in terms of providing multiple sources of power to the barrier machinery, and to spatial separation such that common mode failures can be gauged to have a sufficiently low level of risk of occurrence. Recovery scenarios should also be considered if the primary system fails; for example on the Thames Barrier, despite having multiple power sources, the gates can still be hand-cranked (albeit slowly) closed.
- On the Lake Borgne Barrier project, there has been a post-construction review of the operation and maintenance requirements for the barrier and queries were raised about the inspection and maintenance of fracture critical design members within the barrier gates. This highlighted the importance of considering in the design how these members would be accessed for future inspection and maintenance and that, where possible, one should seek to minimize the number of these members being located under water or in a more aggressive wet/dry zone. It also highlighted the importance of designers being involved throughout the preparation of the operations and maintenance manual for the barrier.
- Consideration should be given to the transition between different defense structures and the differential settlement that can occur between them particularly in locations where there is a step

change in the depth of foundations (i.e. shallow vs deep). The lesson learned on the Lake Borgne Barrier project was that this should be considered early on in the design process.

- It is important to establish as early as possible the barrier gate requirements such as opening and closing times, ability to open or close under a reverse head, speed and ease of closing, and the ability to provide a dual function such as a barrage or velocity control. These requirements will have a significant influence on the selection of the type of gate for the barrier. For the Lake Borgne Barrier, the selection of a vertically hinged horizontal sector gate was influenced by the need to close the gate as late as possible to allow for late-arriving navigation traffic such as fishing vessels to pass through the barrier and seek shelter in the protected area behind it.
- Early contractor involvement has proven to be beneficial on both the Ipswich and Boston Barrier schemes in setting out an outline construction methodology that informs stakeholder engagement, and assessment of potential temporary impacts that will be caused by the construction. Their involvement also enables any potential key buildability issues to be addressed.
- The use of precast or modular units, where possible, to minimize working in the wet and to reduce the working time required at the barrier site is generally beneficial in reducing the construction period and costs. This has been adopted on a number of barrier projects such as the Thames Barrier and more recently the Lake Borgne Barrier.
- Preparation of a materials logistic plan to ensure that the right materials are stored and delivered at the time that they are required to the project site(s) can be beneficial to avoid delays and costs during construction. It can also potentially reduce the amount of land take required for site working areas.

4.3.8 Environment

There are numerous environmental factors and impacts to be considered when constructing a storm surge barrier. Some of the key areas and issues that are regularly encountered, need to be addressed and potentially require mitigation are listed below.

- Fish passage – the change in wet cross section, and flow velocity through the barrier, as well as a change in the salinity gradient in the river channel upstream of the barrier can have a detrimental impact on the passage of fish in the affected water body. This can influence the width and depth of the barrier opening and/or require the construction of a fish pass alongside the barrier—estimated fish pass cost for the Boston Barrier is circa $2 million.
- Compensatory habitat – the footprint of a storm surge barrier scheme, particularly within the river channel, involves the destruction or disturbance of existing habitat. This, coupled with the potential increased erosion of marginal habitat such as saltmarsh due to holding or advancing the flood defense line, often dictates that the scheme is required to create compensatory habitat in the adjacent area. This can be both very costly and difficult to find appropriate sites nearby.
- Water quality – it important to consider the impacts on tidal flows particularly into and out of the channel upstream of the barrier both during and after construction. Throttling of the flow can cause a reduction in the water quality (e.g., reduced level of dissolved oxygen); or change in salinity due to the upstream fluvial fresh water flows becoming more predominant. For the Lake Borgne Barrier scheme, an environmental requirement was imposed on the Bayou Bienvenue gate construction that dictated a minimum through flow was to be maintained at all times.
- Invertebrates – should the barrier result in significant accretion or erosion of river bed sediments or permanent submersion of intertidal mud flats, this can have a detrimental impact on the habitat of invertebrates in the affected river bed.
- Transportation of contaminated sediments – it is important to establish what level of contamination is present in the existing sediments and material that occurs on the bed of the river channel. Any dredging

of those sediments can create significant issues with their mobilization in the water body due to the disturbance created by the dredging operation, and transportation/migration into nearby environmentally designated sites, or areas dredged by others such as a port authority. All of this has significant cost implications including disposal costs, stringent containment measures, and compensation for increased dredging costs/delays/operational impacts on the port due to the contamination caused.

- It is beneficial to undertake a scoping exercise early on in the process to establish any environmental impacts that could significantly affect the development of the barrier scheme and its delivery.

4.3.9 Operation and Maintenance

The flooding of New Orleans from Hurricane Katrina was, to some extent, due to a lack of an integrated management plan for what was a series of individual flood schemes with differing levels of defense and, in some cases, lack of appropriate maintenance. The reliability of the storm surge barrier to operate and close on demand is therefore fundamental to the success of the scheme in reducing the risk of flooding to the infrastructure and properties behind it. The operation and maintenance (O&M) of the barrier is vital to ensure this reliability, and would draw heavily on the project design basis document referred to in Section 4.3.7 above.

- It is critical to establish at a very early stage in the development of a storm surge barrier scheme who the authority/organization is that will be responsible for the O&M of the barrier. It is important that that organization is involved in defining the design requirements and how the operation and maintenance of the barrier is to be undertaken in the future. With the Lake Borgne Barrier scheme, although O&M was considered during the design, the ultimate authority responsible for the O&M, the Southeast Louisiana Flood Protection Authority, was not fully involved in the design development. As a result, when it came to the handover of the barrier and its associated assets, they had issues regarding the works and the O&M requirements/liabilities they would be taking on.
- The early preparation of an outline control philosophy for the proposed barrier as well as a Barrier Management Plan can be very helpful to understand interfaces with navigation traffic as well as help define the roles and responsibilities of the authority designated to take over the operation and maintenance of the barrier. A good example of a Barrier Management Plan for a smaller size barrier is that produced for the Ramspol Barrier which is very clear in defining how the barrier is to be operated and maintained, and is based on the use of a temporary team of operatives with appropriate skills and training, and with back-up provision in an emergency.
- It is important to consider how the inspection and maintenance of the barrier and its associated assets is to be undertaken in a safe and secure manner. Consideration needs to be given to identifying the spatial requirements, ensuring ease of access to undertake tasks, health and safety, replacement and stocking of parts and strategic spares, etc. The refurbishment works recently undertaken on the Hull Barrier provide a good example of how insufficient consideration for future maintenance at design stage can result in significant additional costs and risks. For the Hull Barrier, side paneling to the barrier structure had to be removed, a special crane attachment designed for delivering the new parts inside the barrier, and the construction of a mock up away from site to ensure that the replacement plant could be fitted safely and securely in the confined space available (**Figures 4-23** and **4-24**).
- It is worth considering including an extended maintenance contract (say 5 years) as part of the capital construction contract to ensure an effective handover of knowledge and expertise to the operating authority's own staff. This is being adopted for the delivery of the Ipswich Barrier.
- The design and selection of materials should be considered from a whole life cost perspective and where a higher cost specification is justified in minimizing future maintenance. This can be especially relevant if capital funding is available for construction but long term revenue funding to pay for the future O&M costs is constrained and/or difficult to obtain.

- For smaller-sized storm surge barriers, the barrier operation could potentially be undertaken by a third party who already have a permanent presence and necessary skilled operatives at the site, or they could provide emergency back-up, in order to reduce the costs of manning the barrier. At Ipswich the port authority, Associated British Ports, operate the Wet Dock Lock floodgate on behalf of the Environment Agency, the flood defense authority, as port operatives are already present for operating the port's lock gates. Depending on the location and size of the barrier this could be considered in conjunction with those operating the Pulaski Bridge.

FIGURE 4-23
Hull Barrier remedial works.

FIGURE 4-24
Hull Barrier remedial works.

4.3.10 Regulatory Impacts

The delivery and construction of the Lake Borgne Barrier and its associated works, has been achieved in a relatively short timescale when compared to the delivery periods of over 20 years from inception (normally started due to an unwelcome trigger event which causes significant damage) to completion for other barrier projects both in the USA and worldwide. This has been due to the streamlined delivery program and because political pressure was brought to bear on providing a solution as rapidly as possible to demonstrate to the nation that what had been a national disaster would not happen again. It is worthwhile noting that, statistically speaking, there is no such thing as an absolute and therefore a small residual risk of a similar event remains.

It is potentially worthwhile to consider how programs for the delivery of the Creek and other planned storm surge barrier projects in the area can be streamlined by proposing a process of regulatory inspections and staged approvals of design and construction plans and having this concept accepted by the regulatory bodies.

This page was intentionally left blank.

Part II:
Concept Option Development and Evaluation

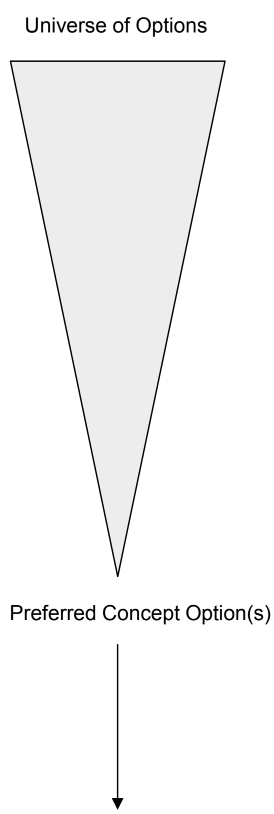
This page was intentionally left blank.

5 Evaluation and Analysis Framework

5.1 Overview of Concept Option Screening and Project Analysis Process

The study team developed and applied a two-part evaluation process to screen potential concept options and ultimately arrive at a preferred concept option for Newtown Creek (Creek) (see **Figure 5-1**). Principles guiding the framework's development include the following:

- Develop a transparent tool for multiple audiences to understand the study process and leverage the work for future efforts.
- Provide a documented approach to filter potential alignments toward the preferred concept option for each site.
- Capture engineering, community/public, and implementation considerations.
- Ensure compatibility with U.S. Army Corps of Engineers (USACE) accepted approaches and translatability to USACE terminology.
- Reflect the broad range of local New York City (City) benefits, interests, and policy goals.



- **Two-stage Comparative Evaluation Process**
  - **Part I: In-water barrier screening**
    - Coarsely evaluate and compare potential barrier locations
    - Funnel study towards more feasible barrier locations around which to develop the upland defense schemes
    - Address key siting considerations
  - **Part II: Comparative alignment screening**
    - Evaluate potential concept options (in-water + upland connections) relative to each other to identify preferred concept option
    - Consider costs, benefits, reliability and implementation
    - High-level assessment. Quantify or evaluate metrics and convert to relative comparative scores where applicable
- **Project Analysis**
  - High-level hydrodynamic modeling: storm surge, flushing and rainfall assessment
  - Preliminary benefit-cost analysis
  - Local funding strategies
  - Implementation and permitting

FIGURE 5-1
Study Evaluation Framework

The criteria reflect the broad range of local New York City benefits, interests, and policy goals. At the same time, to best position the study's outputs for a transition to USACE, the study team's evaluation framework and criteria are aligned to those criteria used by USACE in its project evaluation. The criteria framework uses categories that are consistent with terminology used by USACE in its planning regulations, namely efficiency, effectiveness, completeness, and acceptability. Effects evaluated are categorized within the four USACE accounts as defined in USACE Planning Regulation: National Economic Development (NED), Regional Economic Development (RED), National Ecosystem Restoration (NER), and Other Social Effects (OSE). The criteria and metrics proposed in the framework for the Creek storm surge barrier study are intentionally broad. The suggested criteria address both specific USACE needs and requirements and the feedback from USACE to capture as broad an array of benefits as possible. The filtering process responds to USACE's desire to see documentation explaining how alternative concept options dropped out of consideration.

The Part I screening made a coarse assessment of potential in-water barrier locations based on key siting considerations. The Part I screening funneled the study toward more feasible in-water barrier locations around which to develop the upland defense alignments.

The Part II screening then compared the concept option alignments against one another along a series of cost, benefit, reliability, and implementation criteria. The Part II screening identifies the strengths, weaknesses, and key tradeoffs among the concept options (see **Table 5-1** and **Figure 5-2**).

From this evaluation process, the study team, in collaboration with the New York City Economic Development Corporation and Office of Recovery and Resiliency, and with incorporation of feedback from the interagency workshops, identified a preferred concept option for each site.

The preferred concept option underwent more detailed project analysis, including hydrodynamic modeling to define the zone of protection and a preliminary benefit-cost analysis, the results of which are summarized in this report. The project analysis identified potential local funding strategies In addition, phasing, timing and permitting were considered as part of developing a potential roadmap for future project implementation should a storm surge barrier project at Newtown advance beyond this conceptual study phase.

5.1.1 Part I In-water Storm Surge Barrier Screening

The Part I In-Water Barrier threshold screening documents demonstrate—at a coarse level—how the team identified potential barrier sites, given considerations of anticipated costs and benefits, the level and extent of protection offered by the barrier, the ability to be constructed given site constraints (physical depth and width, contamination, property availability, land-tie in complexity, etc.), the ability to protect navigation, and the ability to be permitted. The categories, criteria and factors assessed during the Part I screening are presented in the **Table 5-1**.

TABLE 5-1
Part I In-water Storm Surge Barrier Screening Components

Category*	Criterion	Factors Assessed
Economic Efficiency	Anticipated costs and benefits	Order of magnitude in-water barrier costs Connection to upland defenses (proxy for upland defense alignment costs) Potential zone of protection (proxy for damages avoided)
Engineering Effectiveness	Level and extent of protection	Protection provided at design flood elevation (barriers equally effective at all sites)
Completeness	Ability to be constructed	Barrier depth and width Construction staging Physical in-channel constraints Operations and maintenance access Interface with waterfront usage and development, including visual impact

TABLE 5-1
Part I In-water Storm Surge Barrier Screening Components

Category*	Criterion	Factors Assessed
Acceptability	Ensures/protects navigability	Temporary during construction Permanent post-construction
	Ability to be permitted	Infill/land reclamation considerations Preliminary water quality considerations

* These are the four evaluation categories defined in established USACE planning regulations.

5.1.2 Part II Concept Option Comparative Screening

The Part II Comparative Alignment Screening compares the full concept option alignment (in-water storm surge barrier plus upland connections to the tie-in with the 17-foot elevation). The Part II screening takes a high level review of the concept option alternatives to compare how they perform against the various criteria. At this screening stage, the criterion scoring is indicative and relative based on preliminary analysis and quantification of some information as well as the team's professional experience. The cost and benefits criteria are consistent with what the USACE would evaluate, such as life cycle costs and expected avoided damages. These criteria also go beyond USACE NED requirements, capturing metrics important to New York City residents, such as percentage of capital costs borne by the private sector, percentage of costs leveraging other publicly financed projects, protected jobs and affordable housing, share of green infrastructure, protection of critical infrastructure and impact on public safety. The Part II screening also looks at questions of reliability and implementation as far as ownership, responsibility, funding potential, interface with private property, waterfront access and other factors. The Part II screening criteria are presented in **Table 5-2**.

TABLE 5-2
Part II Comparative Concept Option Screening Components

Category	Sub-Category (USACE Plan Evaluation Account)	Criterion
Costs	Capital costs (NED)— *National Economic Development*	Total capital cost Percentage of capital cost borne by private investments (i.e. raised sites) Percentage of capital cost borne by other public investments (i.e. Department of Parks and Recreation (DPR) projects)
	Operating costs (NED)	Total operations and maintenance costs
Benefits	Avoided damages (NED)	Net present value (NPV) of avoided damages
	Economic (RED)— *Regional Economic Development*	Flood insurance savings Number of jobs protected
	Environment (NER)— *National Ecosystem Restoration*	Flushing performance Impact on habitat Share of green infrastructure
	Social (OSE)— *Other Social Effects*	Protection of people Protection of housing Protection of non-residential space (total square feet industrial, commercial, institutional) Protection of critical facilities (rail yards, docks, etc.)

TABLE 5-2
Part II Comparative Concept Option Screening Components

Category	Sub-Category (USACE Plan Evaluation Account)	Criterion
		Synergies with existing and planned transportation network (transit, road, on-road bike lanes)
		Impact on public safety
Reliability	Completeness	Extent of in-place versus deployable/temporary
Implementation	Regulatory (Acceptability)	Complexity of legal/planning approval process
	Community support (Acceptability)	Ability to attract funding
		Extent of blockage or interference with development sites
		Minimizes access disruptions for existing residents and businesses
		Maintains waterfront access
		Maintains view corridors
		Promotes appropriate development/redevelopment of uplands
		Improves neighborhood connections
	Ownership / Control (Acceptability)	Number of private property owners involved/percentage of alignment publicly owned
		Reliance on third-party future development commitments

5.2 Costs and Benefits Framework

The costs and benefits framework employed in this study for the preliminary benefit-cost analysis is a subset of the evaluation structure. The NED cost and benefits criteria, capital and operating costs, and avoided damages are consistent with USACE's approach to benefit-cost analysis when making decisions around funding. The benefits criteria in the study's framework also go beyond USACE NED requirements, capturing metrics important to New York City residents, such as protecting jobs, people, and housing, as well as flood insurance savings. Additional types of benefits are alluded to and suggested for analysis at a full feasibility study stage. While USACE studies may capture and document these other categories, under current policy, they do not factor into project funding considerations that are based around a project's benefit-cost ratio. These criteria are useful to building public support as well as generating interest and priority for funding from other sources. These additional benefits criteria are cross-walked to the corresponding USACE Plan Evaluation Account in **Table 5-3**.

TABLE 5-3
Costs and Benefits Framework

Category	Sub-Category (USACE Plan Evaluation Account)	Criterion
Costs	Capital costs (NED)— *National Economic Development*	Total capital cost (includes hazmat remediation exclusive of Superfund in-water work)
	Operating costs (NED)	Total operations and maintenance (O&M) costs
Benefits	Avoided damages (NED)	Net present value (NPV) of avoided damages
	Economic (RED)— *Regional Economic Development*	Protected jobs and businesses Reduced flood insurance costs Avoided mandatory floodproofing costs

TABLE 5-3
Costs and Benefits Framework

Category	Sub-Category (USACE Plan Evaluation Account)	Criterion
	Social (OSE)— *Other Social Effects*	Protected existing and projected populations Protected existing and projected housing Protection beyond current standards

5.3 Project Assumptions

The study team adopted a baseline set of assumptions in order to complete the project analysis and develop an implementation and phasing plan. Discussion around these assumptions, including discussion of alternatives, uncertainty and potential next steps, is presented throughout sections of this report. These baseline assumptions include the following:

- *Funding source*: USACE is the primary funding source. Therefore, the phasing and implementation plan is therefore developed around key steps and requirements in the USACE implementation process. Funding and financing analysis has focused on ways to reduce and/or identify the sources for the City's share of any project.
- *Timing:* A 15-year horizon, linked to completion of the Newtown Creek Superfund remediation work, is envisioned before any project would be physically realized, because it is understood that USACE would not begin construction until the remediation work is completed. This assumption could be revisited as Newtown Creek Superfund planning progresses. In the case that the demarcation for remediation activities lies upstream of the Pulaski Bridge, and would therefore not affect a storm surge barrier's construction zone, it is conceivable that a storm surge barrier could be constructed in advance or parallel to remediation works. Timing for feasibility and pre-construction activities could follow two pathways: 1) commencing from as early as first quarter 2016 and flowing forward from the upcoming NY NJ Harbor & Tributaries Feasibility Study should the Newtown Creek Storm Surge Barrier project be included in the study scope; or 2) commencing at a later date, but potentially preceding Superfund remediation, as a separate feasibility study that might be considered. The base year for benefits is the year benefits start to be realized.
- *Benefits and baseline condition assumptions:* The benefit-cost analysis relies on current existing conditions, which is in alignment with USACE methodology. Any new development that happens between today and when a project could be constructed, such as the Greenpoint and Hunters Point South development parcels, would be built to Federal Emergency Management Agency requirements for flood insurance and would not increase the avoided damage benefits. As far as environmental conditions, in addition to completion of the Superfund remediation work, ongoing NYCDEP combined sewer overflow abatement efforts will have made improvements to water quality and, in general, both waterways will be in a dynamic ecosystem state.
- *Governance and oversight:* The Red Hook Integrated Flood Protection System, as well as other ongoing NYC resiliency projects, will be in process or completed prior to a Newtown Creek project's construction. As part of these broader Citywide efforts, the City will have established a lead operating agency and be familiar with and/or have established any required approval processes (e.g., permitting and interagency coordination mechanisms) for flood defense systems.
- *Project delivery approach*: A design-bid-build delivery approach is pursued.

This page was intentionally left blank.

6 Storm Surge Barrier Feasibility

6.1 Siting Considerations

To identify feasible in-water storm surge barrier locations and suitable gate types, the in-water barrier assessment examined a number of siting criteria and factors that included the level and extent of protection, anticipated costs and benefits, navigation, constructability, and permitting. Key drivers for these criteria categories included the following:

- **Level and extent of protection:** Though not a differentiator among potential barrier locations because the barrier performance will be set by the DFE and therefore common to all potential barrier locations and types, the level and extent of protection is an important consideration because it aligns with USACE considerations and it dictates the gate size requirements that need to be accommodated. As noted previously, in the case of this Newtown Creek Storm Surge Barrier Study, the height of the barrier above water is specified at 21 feet. This reflects the conservative DFE calculated from the +14.9-foot North American Vertical Datum of 1988 (500-year flood) base flood elevation plus 3 feet for freeboard allowance plus 3 additional feet for sea level rise as detailed in Section 1.2.
- **Navigation:** A major driver behind siting considerations is the ability to protect existing navigation and use of the waterways as well as accommodate future activities. To the degree possible, any storm surge barrier system should minimize adverse impacts to waterway users. This includes both during and post-construction. The navigation assessment included profiling existing vessels, identifying where activity is heaviest, looking at currents and vessel maneuvering behavior, and examining width and height constraints. A City goal is to ensure that industrial waterway users still have access where it is needed and desired, and for Newtown Creek (Creek) in particular, the waterfront access is a geographical strength. As far as growth, the existing bridges' navigation restrictions and the limited dredging make much growth unlikely. As a conservative assumption for this stage of conceptual evaluation, the in-water barrier assessment has sought to maintain existing navigation channel width and/or introduce no additional navigation constraints to the degree feasible.
- **Constructability:** The existing physical conditions at the study site are important to constructability. Factors considered in evaluating a location's potential construction challenges included identification of in-channel constraints, depth (including potential future post-Superfund remediation depths), width, and interface with upland areas, including potential tie-ins, staging, and access locations.
- **Permitting:** Permitting challenges likely to be encountered include water quality and infill of the waterway channel bed. As with navigation considerations, preference for any barrier location and gate type is not to adversely affect the flushing capacity by preserving the current waterway width to the degree possible.
- **Anticipated costs and benefits:** While a full preliminary cost-benefit analysis was performed on the preferred concept option during the project analysis phase of the study, a preliminary assessment of anticipated costs and benefits was included at the in-water barrier screening stage both for consistency with USACE's Economic Efficiency category and to get a preliminary notion of whether one or more in-water barrier location options may be significantly out of line with the others as far as capital cost requirements or the potential value per unit of protection, and could present a fatal flaw. At this stage, the primary consideration was order-of-magnitude capital costs for the in-water barriers. Likely zones of protection and the relative length of upland defenses to natural elevation tie-ins were noted qualitatively.

In addition to the above, the in-water storm surge barrier assessment also started to identify opportunities for potential new public amenity areas or habitat creation.

6.2 Newtown Creek Storm Surge Barrier Assessment

6.2.1 Alternative Barrier Sites

Based on site visits and initial observation of waterfront properties, the waterway profile, and vessel traffic, the study team identified three potential in-water barrier locations. Then, based on specific size requirements, and efforts to minimize operation and maintenance requirements, to keep excavation as shallow as possible, and to accommodate vessel traffic and minimize gate closure time requirements, potential gate types were identified that appear to be best suited for each location. The gate type evaluation is summarized in **Table 6-1**. This evaluation is limited only to the selection of potential gate type. Evaluation of overall barrier location feasibility is described in Section 6.2.2 and summarized in **Figure 6-9**. Ultimately, the three locations and their respective in-water storm surge barrier type were identified and screened through the Part I assessment.

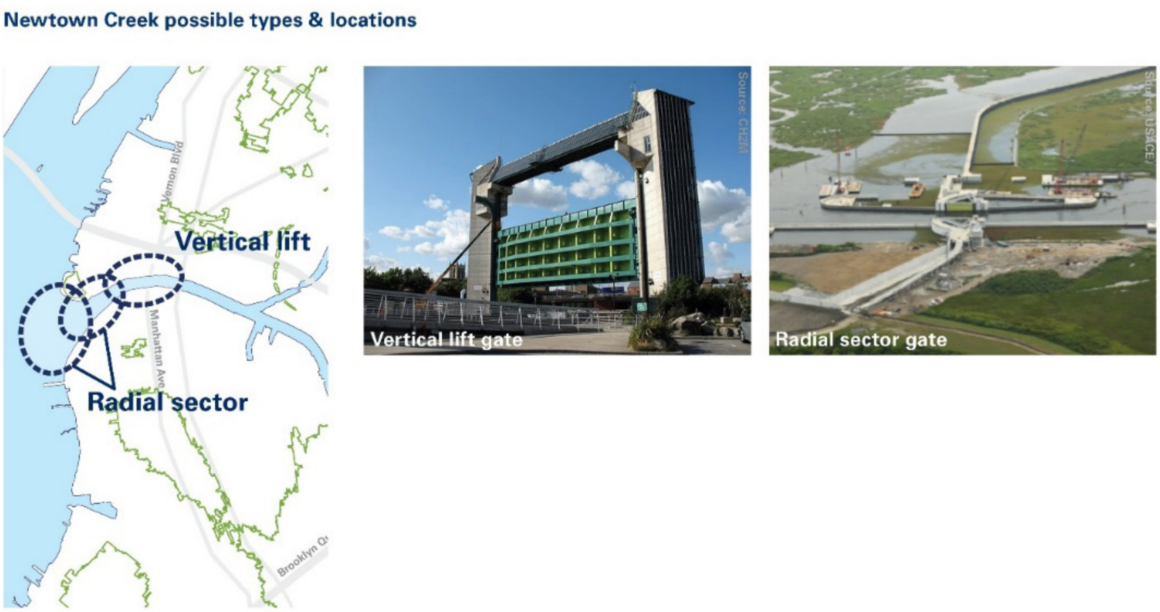


Image source: Environment Agency (vertical lift gate) and USACE (radial sector gate).

FIGURE 6-1
Alternative Newtown Creek Barrier Sites

TABLE 6-1
Gate Type Evaluation for Newtown Creek Alterative Barrier Locations
Note: Green = preferred gate type, Yellow = gate type could work, but likely better options, Red = likely fatal flaw

	Miter Gate	Flap Gate	Vertical Rotating Gate	Vertical Lift Gate	Horizontal Rotating Gate	Caisson Gate	Inflatable Gate
Option 1: 2nd Street	RED rating dictated by this type of gate not being suitable for the width required.	Could be rated RED if temporary bypass channel during construction not acceptable to navigation users.	Could be rated RED if temporary bypass channel during construction not acceptable to navigation users.	RED rating dictated by visual impact or restriction of navigation clearance height unacceptable	--	Operational reliability is weaker than others.	RED rating dictated by gate depth required not being feasible.

TABLE 6-1
Gate Type Evaluation for Newtown Creek Alterative Barrier Locations
Note: Green = preferred gate type, Yellow = gate type could work, but likely better options, Red = likely fatal flaw

	Miter Gate	Flap Gate	Vertical Rotating Gate	Vertical Lift Gate	Horizontal Rotating Gate	Caisson Gate	Inflatable Gate
Option 2: Manhattan Avenue	RED rating dictated by this type of gate not being suitable for the width required.	RED rating dictated by requirement to close creek to navigation during construction.	RED rating dictated by requirement to close creek to navigation during construction.	Could be rated RED if restriction of navigation clearance height unacceptable.	Could be rated RED if land take unacceptable.	Could be rated RED if land take unacceptable.	RED rating dictated by gate depth required not being feasible.
Option 3: Mouth of Creek	RED rating dictated by this type of gate not being suitable for the width required.	Could be rated RED if temporary bypass channel during construction not acceptable to navigation users.	Could be rated RED if temporary bypass channel during construction not acceptable to navigation users.	RED rating dictated by visual impact or restriction of navigation clearance height unacceptable	--	Operational reliability is weaker than other options.	RED rating dictated by gate depth required not being feasible.

The section that follows summarizes the findings for the Newtown Creek storm surge barrier assessment. More detailed information for the Part I screening and gate selection can be found in Appendix A.

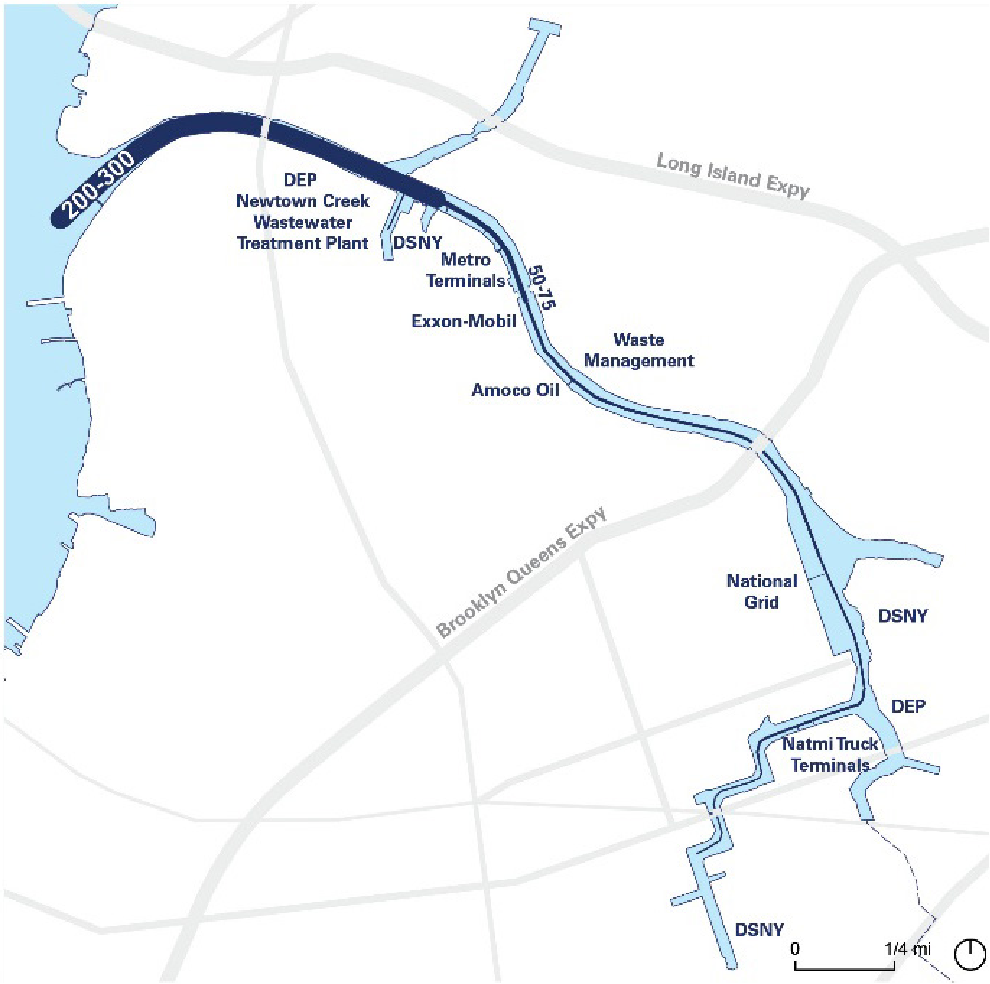
The three alternative barrier sites evaluated, moving east to west, for a potential Newtown Creek storm surge barrier system were:

1. Manhattan Avenue crossing to Vernon Boulevard with a 150 feet wide vertical lift gate. Given the urban neighborhood setting and a desire to preserve the existing width within the Creek for navigation and water quality purposes, while avoiding land take and deep excavation, this location's gate selection points to a vertical lift gate. However, this gate type would impose a navigation constraint due to vertical clearance that could be untenable to the navigation community. Future study could consider alternative gate types for this location as necessary where more detailed due diligence and investigations are performed.
2. 2nd Street crossing to the Greenpoint Landing development site and Box Street Park with a 150 feet wide vertically hinged horizontal sector gate. A horizontal sector gate is suggested for this location because of its advantages as far as minimal requirements for sill excavation depth, operation and maintenance reliability, navigation and visual impact and its ability to futureproof for sea level rise. Construction staging for a horizontal sector gate would enable construction in two halves to maintain navigation during construction.
3. Mouth of Creek with a 200- to 225-foot-wide radial sector gate. The same considerations as at the 2nd Street – Greenpoint Landing location suggest that a long radius horizontal sector gate would be most suitable.

6.2.2 Siting Assessment

6.2.2.1 Navigation

Vessel traffic on Newtown Creek is heaviest closest to the mouth and lessens as you move upstream beyond the DEP wastewater treatment plant. However, minimizing interference with vessel traffic by moving upstream would necessitate a trade-off with an in-water barrier's ability to maximize protection of the residential and commercial community, which is clustered at the Creek's mouth. This trade-off has meant that the siting of the barrier has considered how best to accommodate and minimize impact to waterway users. The 150 feet width of the Pulaski Bridge has been adopted as a conservative barrier gate width constraint that all concept options would maintain as a minimum.



Source: AIS vessel tracking data, Moffat & Nichol, Sept. – Oct. 2014.

FIGURE 6-2
Relative Vessel Traffic Volumes

The 2nd Street location, with a 150-foot-wide gate, offers the best option from a navigation perspective. It is on a straight section of the Creek and has room for a horizontal sector gate, which could be constructed in two halves, enabling navigation during construction.

A barrier sited at the mouth of the Creek would present significant navigation challenges due to strong currents within the East River and vessel maneuvering to enter the Creek. As a result, a much wider and costlier gate would be required.

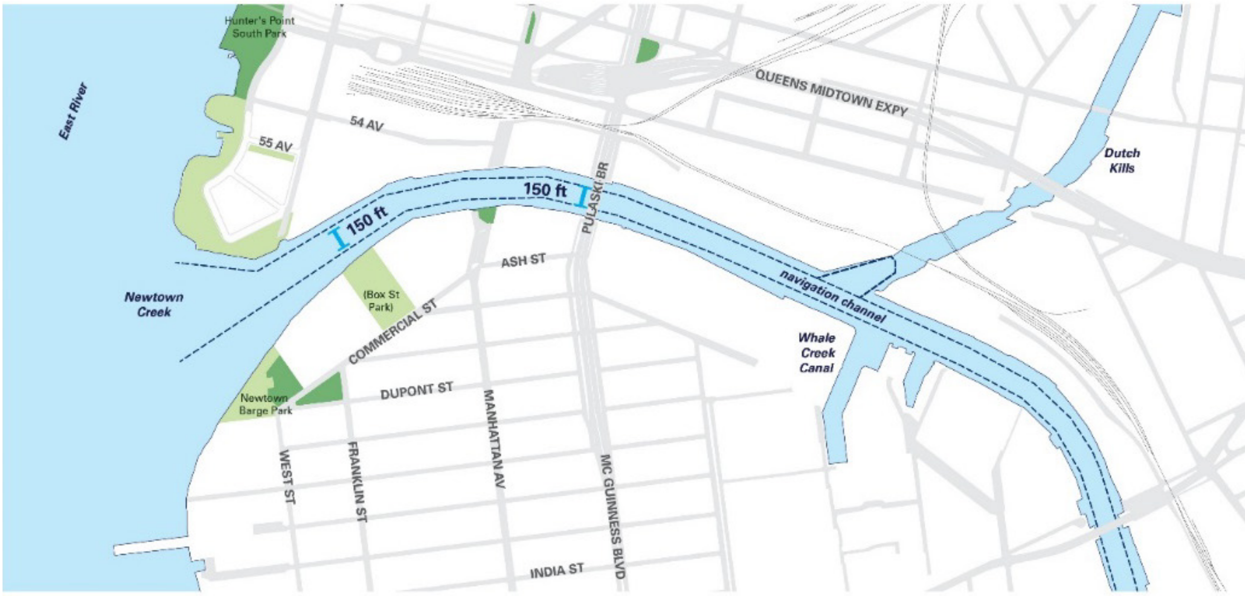


FIGURE 6-3
Pulaski Bridge 150-foot Width Constraint

The Manhattan Avenue location is less attractive for navigation purposes. The location is on a bend, which can affect visibility. The need to avoid infill to maintain channel width points toward the use of a vertical lift gate. However, navigation would be impacted during construction as temporary closures would be required for erecting a vertical lift gate at the Manhattan Avenue location. Any closures would have to be coordinated in advance and efforts made to ensure closure periods are as brief as possible (no more than a few days at a time), especially considering New York City Department of Environmental Protection's (DEP) requirements for plant access.

Use of a vertical lift gate would also impose height clearance restrictions. DEP's new vessels have been designed to be able to travel under the Pulaski Bridge when the bridge is closed. The heights of other vessels vary. Tug boats for example have vertical clearances that can range between 30 to 35 feet or exceed 50 feet. The Kosciuszko Bridge on the Brooklyn Queens Expressway has a fixed height clearance of 125 feet. Were that clearance adopted as a conservative assumption, the vertical lift gate would require a vertical height of around 175 feet, including the gate height, although this might be lessened if the gate is stored in a rotated position (e.g., the Hull Barrier in England). In addition to the issues associated with wind loading, such a large structure raises concerns around footprint size, constructability, and cost.

6.2.2.2 Constructability

The current channel depth at all three Newtown Creek barrier locations is around 20 feet. This depth, combined with the 21-foot barrier height, means that a potential barrier would require a height of 41 feet. Future Superfund remediation plans are not yet defined, although the level of contamination in the Creek is understood to be lowest out by the mouth where the alternative locations are situated. Even with 10 to 15 feet of additional depth post-remediation, the gate height requirement at all three locations would still fall within the upper range of global precedence.

FIGURE 6-4
Potential Staging Areas

Construction staging areas around the alternative barrier locations are limited. Some construction would be done via the water, with pre-fabricated sections floated in. Where infill would be created, for example, at the 2nd Street location, the infill itself may offer additional staging area. At the Manhattan Avenue location, there are adjacent areas potentially available on both the north and south sides of the Creek.

From the perspective of waterfront usage and development interface, the mouth of the Creek and the 2nd Street locations present significant interface issues with planned development parcels and parks. These include planned and anticipated developments at both Hunters Point South and Greenpoint as well as Box Street Park, the Greenpoint Waterfront esplanade, and the planned waterfront park on the Queens (north) side of the Creek.

The Manhattan Avenue location avoids the major residential interface challenges, although there is the potential for rezoning and mixed-use redevelopment along the water’s edge on the Queens side of the Creek and raised floodwalls would run along the channel or tie into development parcels in order to maximize overall protection afforded by the line of defense. In addition, some moorings and parking would be lost at the end of 53rd Avenue on the north side of the Creek.

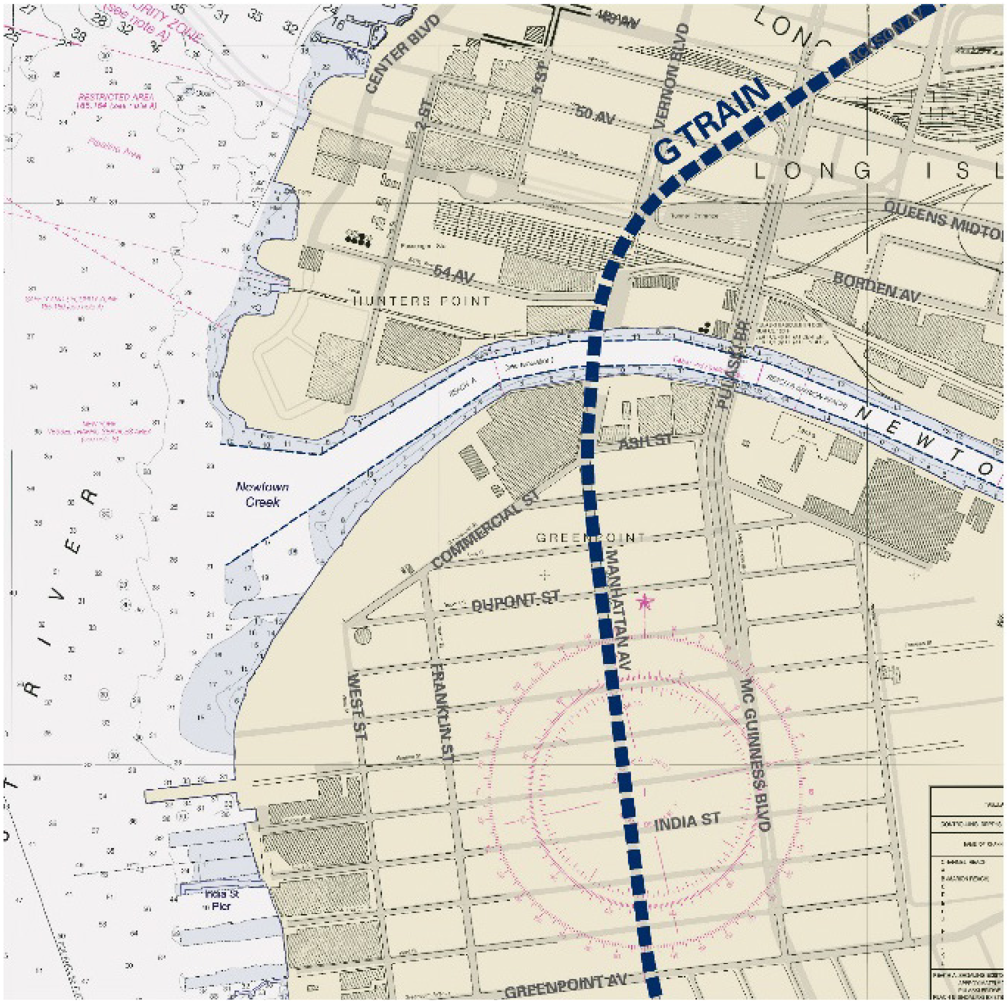


FIGURE 6-5
In-Channel Constraint

The Manhattan Avenue location faces an additional obstacle to constructability that the alternative locations do not. It would require integration or interface with the G-train subway line that runs below it, potentially adding costs and complexity to its design and construction. In addition, there may be a National Grid pipeline crossing as signage at the site suggests. In the case that any Newtown Creek storm surge barrier project advances beyond this conceptual stage, detailed investigations and coordination with utility companies and the MTA would be required.

Finally, each of the options have some potential as far as public amenity or recreational creation. Depending upon the size of potential infill at either the mouth of the Creek or the 2nd Street location, some of the infill could be designated for recreational areas or potentially tied into the existing and planned waterfront parks. At the Manhattan Avenue location, there is a potential opportunity to incorporate a future pedestrian or bicycle swing bridge connecting Greenpoint and Hunters Point South by using an extension from the barrier abutments.

6.2.2.3 Permitting

From a permitting perspective, the Manhattan Avenue location presents the fewest challenges as far as preliminary infill and water quality considerations. The location and use of a vertical lift gate with dimensions equal to that of the Pulaski Bridge enables the Manhattan Avenue location to maintain close to the current Creek width. It is therefore expected to have no significant impact on water quality.

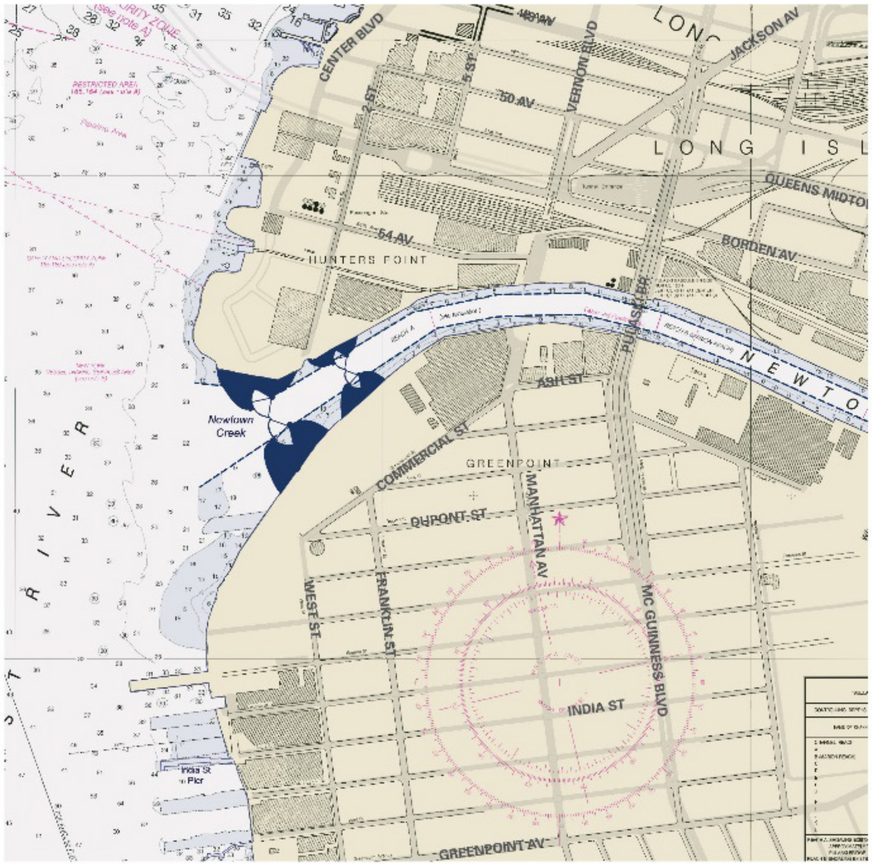


FIGURE 6-6
Illustrative Infill Requirements

The mouth of Newtown Creek option poses major permitting challenges. It would require significant infill, potentially reducing the waterway width by around 67 percent. Such a reduction in channel width may increase sediment accretion and would significantly constrain tidal exchange, likely resulting in detrimental impact to water quality. This could potentially be mitigated by incorporation of a very wide barrier, though this adds engineering complexity and increases capital costs.

The 2nd Street barrier location at Newtown Creek would require some infill, though sized at the same width constraint of the Pulaski Bridge, its impact on water quality is relatively small, as described further in Section 9. Any significant adverse impact could potentially be reduced through incorporation of a wider gate if needed, though at potentially greater cost. The 2nd Street locations falls in between the Manhattan Avenue and mouth of Creek locations as far as severity of permitting challenges.

6.2.2.4 Anticipated Costs and Benefits

As far as economic efficiency considerations, the Manhattan Avenue in-water barrier is the lowest cost barrier based on barrier width requirements at the locations. The 2nd Street alternative about 1.5 times greater and the mouth of the Creek alternative three times greater. However, for the full Newtown Creek concept option alignments, the Manhattan Avenue location ultimately exceeds most 2nd Street alignments for total cost once the upland defenses are taken into account, where the Manhattan Avenue alignment runs back toward the East River shoreline in order to maximize the zone of protection. The additional floodwall costs required for the Manhattan Avenue in-water barrier location are a little greater than the cost difference between the barrier at Manhattan Avenue and the 2nd Street location.

FIGURE 6-7
Current Land Use at Newtown Creek Study Area

As far as potential zones of protection and the number of people, households and jobs that could be protected by a potential flood defense system, there is little difference between the alternative barrier locations. The residential and commercial activity is clustered toward the mouth of the Creek along the East River waterfront, and any upland defense alignment would likely tie back to the waterfront in order to maximize the protected area.

6.2.3 Storm Surge Barrier Screening Results

Based on the Part I screening, the location at the mouth of the Creek falls out of consideration given the challenges and complexities it would face or impose if erected. Both the 2nd Street and Manhattan Avenue barrier locations present challenges, though different in nature. The 2nd Street in-water barrier location is preferable from a navigation perspective while the Manhattan Avenue location is preferable from an urban design and integration perspective. Both locations were carried forward for concept option development.

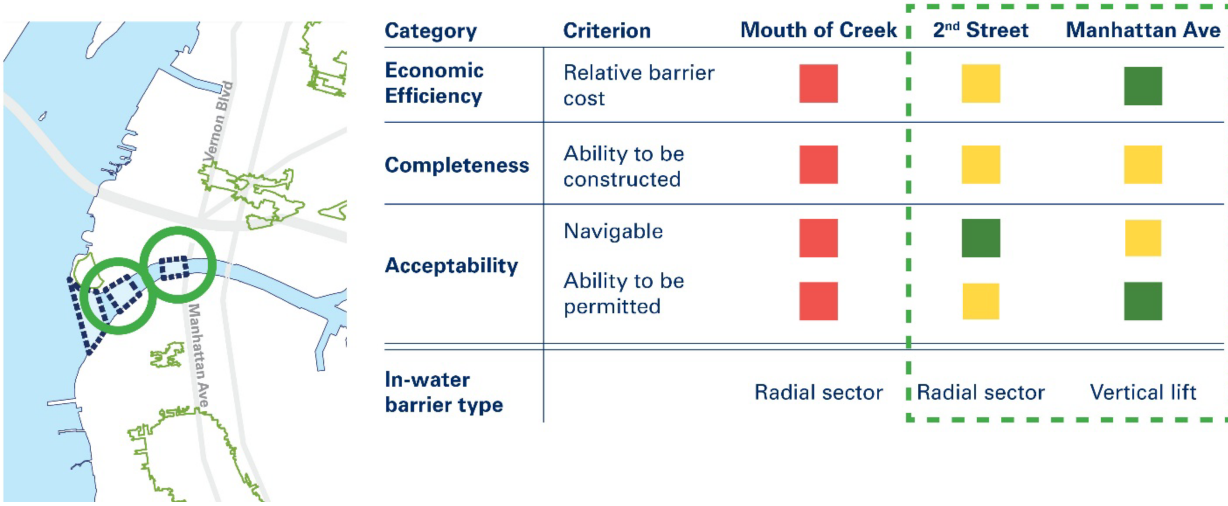


FIGURE 6-8

Part I Screening for Newtown Creek In-Water Storm Surge Barrier Site Alternatives

7 Storm Surge Barrier Concept Engineering

7.1 Overview

Following the shortlisting of the potential barrier options in Section 6.2.3 to those located at 2nd Street and at Manhattan Avenue, the engineering and construction aspects of each option were considered in more detail. A high level planning cost estimate for these two alternatives was prepared for comparison purposes together with an assessment of the associated risks and uncertainties. The results of this work are summarized in Sections 7.2 and 7.3 and have been taken forward to inform the evaluation of the concept options in Section 8.

7.2 2nd Street In-water Barrier Option

7.2.1 Key Details

The height of the barrier has been set at +21-feet North American Vertical Datum of 1988 (NAVD88) as detailed in Section 2.4, which incorporates the 500-year flood level of +15 feet plus an allowance of 3 feet for sea level rise and 3 feet of freeboard. This precautionary approach is normal practice and is adopted as it can be very difficult and costly to retrospectively extend a barrier gate and its structure in the future.

Image source: USACE
FIGURE 7-1
Precedent Barrier: Lake Borgne Surge Barrier in New Orleans

The sill level has been set at a depth of 20 feet so as to lie flush with the existing bed level. The barrier gate depth is therefore 41 feet.

The width of the barrier gate/opening is to be between 150 feet and 170 feet wide so as to provide the same channel cross sectional area as the Pulaski Bridge, and to maintain the navigation channel width.

The type of barrier proposed at 2nd Street is a vertically hinged horizontal sector gate of steel fabrication, similar in size and construction to the gate used at the IHNC Lake Borgne Surge Barrier in New Orleans.

The barrier structure is likely to be reinforced concrete with a sill/base slab approximately 150 feet by 150 feet with the side abutments formed to create recesses on either side to accommodate the sector gates when they are in the open position.

7.2.2 Conceptual Works

7.2.2.1 Permanent Works

A control building will be required to house the necessary mechanical and electrical operating plant for the barrier and from the barrier can be managed. Clear vision into the barrier opening and both upstream and downstream of Newtown Creek (Creek) will be important.

Steel sheet pile bulkheads would be required to the immediate north and south of the main barrier structure, with infill between them, in order to tie in with the adjacent quayside and upland flood defenses on the north and south sides of the Creek.

Landscape works which tie in with the Greenpoint Landing and Hunters Point South developments will be required. It is likely that this would need to be of reasonably high quality specification to match that of the adjacent developments.

Access roads will need to be provided for operational and maintenance access to both the north and south side of the barrier.

Navigation measures, including lights, signage, marker posts, and fendering (bumpers), and dolphins will be required to guide vessels through the open barrier and to protect the barrier structure against vessel impacts.

In order to reduce the risk of flooding from storm water runoff backing up within the Creek while the barrier is closed in a storm surge flood event, it is envisioned that a pumping station would be required as part of the works.

Due to the infill and hence loss of channel bed as part of these works, it is also envisioned that compensatory habitat creation to offset the loss would be required.

7.2.2.2 Temporary Works

During construction provision will need to be made for temporary lighting, fendering, etc. necessary for vessels to pass safely around the works in the temporary bypass channel created for them to use until the barrier is completed.

During certain construction activities it is highly likely that some closures of the Creek to navigation will be necessary.

A key part of the construction will be the dewatering of the cofferdams in which to create a dry working area to construct the barrier structure. It is not envisioned that this will be a significant issue as there are impermeable soil layers relatively close to the surface which the cofferdam piling can key into.

Even post any Superfund remediation work along the Creek, it is likely that containment measures may need to be put in place to control the risk of contaminants that become mobilized during dredging and migrating along the Creek and into the East River.

7.2.2.3 Future Works

As sea level rise takes place the barrier will be closing on a more regular basis and the probability of higher intensity rainfall events coinciding with a storm surge flood event will increase. As a result there is a strong possibility that over time more pumping capacity will need to be provided to deal with the increased volume of storm water run-off that will accumulate behind the barrier during a surge event.

7.2.3 Conceptual Cost Estimate

7.2.3.1 Allowances

An allowance of 25 percent of the estimated construction cost has been made in these high level estimates for the contractor’s preliminary costs.

A contingency allowance of 30 percent of the estimated construction cost has been included.

Other costs: 25 percent, including land purchase, compensation, ground investigation, appraisal studies, permitting, design fees, contract supervision fees, client management fees, etc.

A general utility relocation allowance of 10 percent was included in the cost estimate.

7.2.3.2 Assumptions

For this option it has been assumed that the bulk of the barrier structure will be constructed in a single cofferdam with the southern section completed once the main barrier is open and the temporary navigation bypass channel can be closed.

It has been assumed that the underlying soils are suitable for an average depth, size, and number of foundation piles to support the barrier structure.

7.2.3.3 Capital Cost

The conceptual cost estimate prepared is a preliminary estimate with a circa 15 to 30 percent accuracy range.

Construction of the in-water barrier will require staging and access alongside heavily developed areas as the likelihood is that Hunters Point South and Greenpoint Landing developments will have been completed by the time construction of the barrier is commenced on site. This is expected to have significant impacts to traffic and residential access during construction. These challenges are incorporated into a preliminary allowance of 25 percent in the cost estimate.

The estimated capital cost for this barrier option is circa $121 million for a high-level cost build-up, including $15 million for a storm water pump station and additional contingencies. Appendix L provides the detailed buildup of the conceptual cost estimates for the in-water barrier costs in addition to the upland defenses.

7.2.3.4 Whole Life Cost

Operational requirements for the barrier include operating staff costs, power usage, and costs associated with scheduled testing (normally on a monthly basis) and manning during a flood event. This will be impacted by the frequency of operation of the gates, which in turn is affected by the accuracy of flood forecasting. It is presumed that no daily attendance is required with respect to navigation passing through the barrier. Daily versus monthly manning would obviously be significantly more expensive.

Barrier maintenance normally involves routine annual maintenance, as well as intermittent more major maintenance work at intervals at 5 years, 10 years, and 25 years. This includes the major refurbishment of the gate, which is likely to commence in year 25 in a phased approach. An allowance of between 1 to 2 percent of the capital cost for annual operation and maintenance is appropriate (or alternatively 5 to 10 percent of the capital cost of the gates; mechanical, electrical, instrumentation, controls, and automation; control building; access; and landscape works—based on the interface with the size and frequency of navigation vessels passing through the barrier and the anticipated small-scale sediment accretion/dredging requirements, the median of the range would be most likely.

The cost of 5 percent per annum is more appropriate when considering the major maintenance interventions. For comparison, the recent 25-year major refurbishment for the Hull Barrier (single 30-meter-wide vertical lift gate) cost more than $12 million.

7.2.4 Risks and Uncertainties

Given the conceptual pre-feasibility stage of this study, there are numerous project risks and uncertainties that would be further investigated and refined as part of any future detailed feasibility investigation. A number of these are described herein as items this study has identified and given initial consideration to potential impacts or implications, but which are not included in the order-of-magnitude cost items.

7.2.4.1 Barrier Width

The barrier width has implications for water quality due to its potential impact on the Creek's water exchange performance. While this study has made a conservative assumption to size barrier gates equal to the span of the Pulaski Bridge, with a width of 150 to 170 feet, to minimize potential impact to water quality, the tolerance by regulatory agencies for absolutely no worsening of flushing performance could require a wider gate be used. Such a requirement would be expected to increase capital costs. A wider gate could lessen the volume and area of required infill making permitting less of a challenge, but such a trade-off would not similarly benefit the cost differential as the scale of cost differences between wetland remediation/restoration on a per acre basis versus the capital costs of a barrier gate is significant.

7.2.4.2 Barrier Depth

The future Superfund remediation works are unknown at this time. As a result, there is uncertainty around post-remediation depths at the Creek. The level of contamination close to the Creek's mouth where the barrier could be sited is understood to be fairly low as compared to inland sections of the Creek, and significant dredging may not be required. However, where there are significant changes to the depth, additional infill and significant bulkheads may be required to elevate the channel bed in order to accommodate a more reasonable gate height. In the absence of current plans for Newtown Creek, **Figure 7.2** shows illustrative examples from Gowanus Canal where the depth change and implications on in-water barrier size and infill requirements can be estimated due to the published anticipated post-remediation conditions.

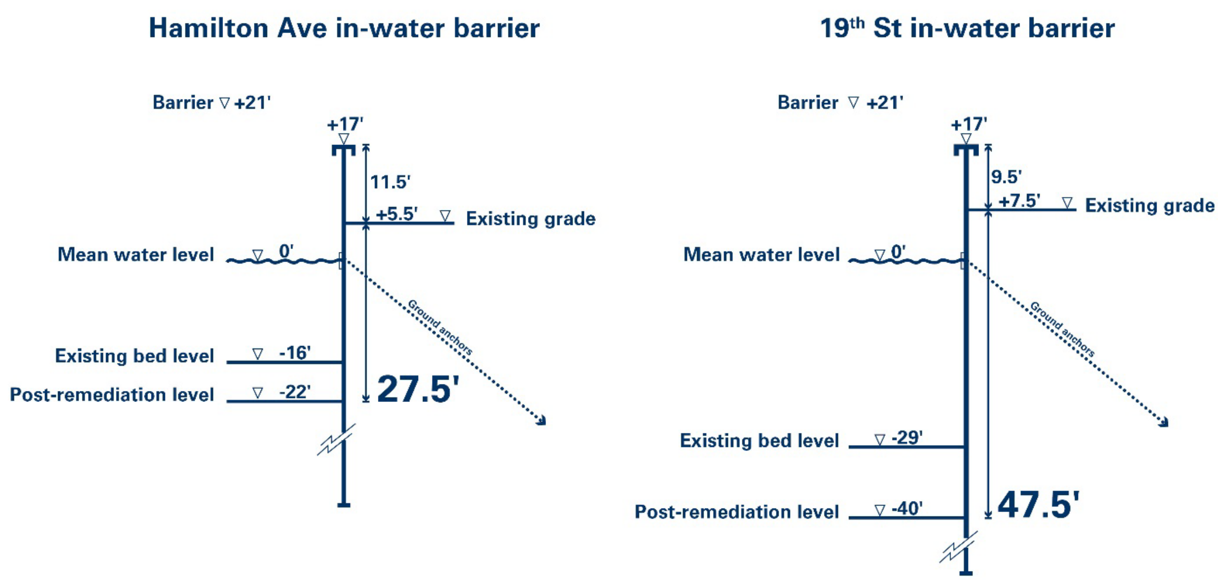


FIGURE 7-2
Example of Post-Superfund Remediation Channel Bed and Bulkhead Profile

7.2.4.3 Upstream Storage Capacity

The hydrodynamic modeling undertaken as part of this study included a high-level analysis of the likely rainfall that could occur during a storm surge flood event; and a preliminary assessment of the volume of storm water that could accumulate behind the barrier during such an event, and the capacity of the Creek to store such a volume. The findings indicated that, given the size of the catchment area and the limited capacity within the Creek, there would be insufficient storage capacity upstream of the barrier and that a storm water pumping station would be required to minimize the risk of storm water flooding to property protected by the barrier from tidal flood risk during a storm surge.

Allowance for a pumping station has been included in the capital cost estimate, but future investigations would be expected to look in greater detail at the factors that affect the number of barrier closures (such as predicted sea level rise, the barrier operation/control philosophy, and the storm surge forecasting accuracy); and the factors that affect the storm water run-off upstream of the barrier (such as increasing rainfall intensity, and the existing and future storm water sewer network and infrastructure for the area).

A combined probability analysis of these factors would then be required to better determine the flows and volumes of storm water that would need to be accommodated and the storage or pumping capacity required over time, using an adaptive approach, to provide the requisite standard of combined flood risk management. The costs associated with any increase in storage or pumping capacity over and above the $15 million included in the conceptual cost estimates has not been allowed for.

7.2.4.4 Service Diversions

Utility investigations, including those for sub-channel cable and pipeline facilities, and drainage outfalls, are another area that would require further more detailed appraisal and review in a future feasibility study. Based on the desk review completed for this scope, it is not believed that there are active cables that a 2nd Street in-water barrier would interfere with, but this would require confirmation during detailed design. While some contingency allowance has been included for minor utility relocations or protection (see Section 7.2.3.1), any more extensive works required to divert utilities or construct around utility corridors would result in an increase in capital costs.

7.2.4.5 Development Integration with adjacent Developments

An allowance has been included for landscaping works at the upland tie-in points where the in-water barrier at 2nd Street would interface with the Greenpoint Landing development and the Box Street and Hunters Point South parks. However, given the level of design and public amenity that may be planned or desired, the landscape integration costs could be significantly higher than those included in the conceptual cost estimate. Negotiations and legal challenges by property owners could also cause capital cost estimates to escalate as well.

7.3 Manhattan Avenue In-water Barrier Option

7.3.1 Key Details

As for the 2nd Street option, the height of the barrier has been set at +21 feet NAVD88 as detailed in Section 1.2, which incorporates the 500-year flood level of +15 feet plus an allowance of 3 feet for sea level rise and 3 feet of freeboard.

FIGURE 7-3
Precedent Barrier: Vertical Lift Gate in Hull, England

The sill level has been set at a depth of 20 feet so as to lie flush with the existing bed level. The barrier gate depth is therefore 41 feet.

The width of the barrier gate/opening is to be between 150 feet and 170 feet wide so as to provide the same channel cross sectional area as the Pulaski Bridge, and to maintain the navigation channel width.

The type of barrier proposed at Manhattan Avenue is a vertical lift gate of steel fabrication, similar in size and construction (but slightly higher) to the gate used at Hull in England.

The barrier structure would consist of two substantial reinforced concrete abutments on either side of the channel to support the main gate, supporting columns/towers with a concrete sill located on the channel bed onto which the gate will be lowered in the closed position.

7.3.2 Conceptual Works

7.3.2.1 Permanent Works

A control building will be required to house the necessary mechanical and electrical operating plant for the barrier and from the barrier can be managed. Clear vision into the barrier opening and both upstream and downstream of the Creek will be important.

Steel sheet pile bulkheads would be required to the immediate north and south of the main barrier structure, with infill between them, in order to tie in with the adjacent quayside and upland flood defenses on the east and west sides of the Creek.

Landscape works that tie in with development on either side will be required. It is would need to be of reasonably good quality specification to match that of future developments.

Access roads will need to be provided for operational and maintenance access to both the north and south side of the barrier.

The G train subway line runs below the alignment, and the barrier's abutments would be expected to interface with or be constructed around the G train infrastructure. Cable or service diversions that could be required have not been included in the capital costs estimates but are discussed in the Section 7.3.4.

7.3.2.2 Temporary Works

During construction, provision will need to be made for temporary lighting, fendering, and other requirements necessary for vessels to pass safely through the works in the temporary channel created for them to use until the barrier is completed.

During certain construction activities it is highly likely that some closures of the Creek to navigation will be necessary.

A key part of the construction will be the dewatering of the cofferdams in which to create a dry working area to construct the barrier structure. It is not envisaged that this will be a significant issue as there are impermeable soil layers relatively close to the surface which the cofferdam piling can key into.

Even post any Superfund remediation work along the Creek, it is likely that containment measures may need to be put in place to control the risk of contaminants, that become mobilized during dredging, migrating along the Creek and into the East River.

7.3.2.3 Future Works

As sea level rise takes place, the barrier will be closing on a more regular basis and the probability of higher intensity rainfall events coinciding with a storm surge flood event will increase. As a result there is a strong possibility that over time more pumping capacity will need to be provided to deal with the increased volume of storm water run-off that will accumulate behind the barrier during a surge event.

7.3.3 Conceptual Cost Estimate

7.3.3.1 Allowances

An allowance of 25 percent of the estimated construction cost has been made in these high level estimates for the contractor's preliminary costs.

A contingency allowance of 30 percent of the estimated construction cost has been made.

Other costs: 25 percent, including land purchase, compensation, ground investigation, appraisal studies, permitting, design fees, contract supervision fees, client management fees, etc.

A general utility relocation allowance of 10 percent was included in the cost estimate.

7.3.3.2 Assumptions

For this option it has been assumed that the barrier structure abutments will be constructed separately on either side of the Creek channel within their own cofferdam with navigation passing between these works. The concrete sill spanning between these two abutments would be precast and lowered onto foundation piles installed when clear of navigation.

It has been assumed that the underlying soils are suitable for an average depth, size and number of foundation piles to support the barrier structure, apart from the additional measures required for the interface with the G subway train infrastructure.

7.3.3.3 Capital Cost

The conceptual cost estimate prepared is a preliminary estimate with a circa 15 percent to 30 percent accuracy range.

Construction of the in-water barrier will require staging and access alongside the developed areas at the ends of Manhattan Avenue and Vernon Avenue. This is expected to have significant impacts to traffic and access to those industrial units during construction. These challenges are incorporated into a prelims allowance of 25 percent in the cost estimate.

The estimated capital cost for this barrier option is circa $90 million for a high level cost build up, including a $15 million allowance for a storm water pump station and contingencies. Appendix B provides the detailed build-up of the conceptual cost estimates for the in-water barrier costs in addition to the upland defenses.

7.3.3.4 Whole Life Cost

Operational and maintenance requirements and costs for the barrier will be of a similar order and capital cost percentages as those detailed in Section 7.2.3.4.

7.3.4 Risks and Uncertainties

As with the 2nd Street in-water barrier, project risks and uncertainties have been identified for the Manhattan Avenue barrier option. These would be further investigated and refined as part of any future detailed feasibility investigation. A number of these are described herein as items this study has identified and given initial consideration to potential impacts or implications, but which are not included in the order-of-magnitude cost items.

7.3.4.1 Barrier Width

The barrier width has implications for water quality due to its potential impact on the Creek's water exchange performance. While this study has made a conservative assumption to size barrier gates equal to the span of the Pulaski Bridge, with a width of 150 to 170 feet, to minimize potential impact to water quality, the tolerance by regulatory agencies for absolutely no worsening of flushing performance could require a wider gate be used. There is not a significant amount of extra space at the Manhattan Avenue location once abutments and support columns are considered. Should the width of the waterway need to be maintained in order to be acceptable for water quality purposes, land taking may be required in order to move the barrier footings out of the channel.

7.3.4.2 Barrier Depth

The uncertainty for barrier depth described for the 2nd Street barrier in Section 7.2.3.2 applies to the Manhattan Avenue barrier location as well.

7.3.4.3 Upstream Storage Capacity

The uncertainty/risk surrounding upstream storage capacity and need for additional storm water storage and pumping station capacity described in Section 7.2.4.3 for the 2nd Street barrier location applies to the Manhattan barrier location as well.

7.3.4.4 Service Diversions

Utility investigations, including those for sub-channel cable and pipeline facilities are another area that will require detailed investigations and review in a future feasibility study. Based on the desk review completed for this scope, there may be a National Grid pipeline crossing or other cables running in the vicinity of the barrier location. Due diligence to determine the nature and location—whether active or abandoned—of any service lines running through the corridor will be required and diversions or removal accounted for in detailed design work.

While some contingency allowance has been included for minor utility relocations or protection (see Section 7.3.3.1), any more extensive works required to divert utilities or construct around utility corridors would result in an increase in capital costs.

7.3.4.5 G Train Subway

The G train subway line runs below Newtown Creek in the alignment of the Manhattan Avenue barrier. Any design and construction would require coordination with MTA as there would be interface between the abutments and the tunnel. Detailed design would need to consider the potential for settlement, vibration and distributed load/bearing impacts and include works to mitigate such potential impacts. Development Integration with adjacent Developments

7.3.4.6 Development Integration with Adjacent Developments

This is less a factor for the Manhattan Avenue location than it is for the 2nd Street option given existing development plans, but as future rezoning actions may occur, this risk factor may increase for the Manhattan Avenue option as well and the same considerations would apply.

8 Concept Options

8.1 Newtown Creek Concept Options

Advancing from the Part I in-water barrier screening, four alternative concept options were developed and evaluated for Newtown Creek (Creek) around the two potential barrier locations. Each concept option developed presents different strengths and weaknesses. These differences highlight trade-offs and challenges that add to the overall understanding of the opportunities and complexities entailed in adopting a storm surge barrier system as part of the City's overall approach to flood defenses and resiliency.

FIGURE 8-1
Newtown Creek Alternative Concept Option Alignments

The four concept options are:

- 2nd Street shoreline
- 2nd Street site integration
- Manhattan Avenue site integration
- Manhattan Avenue right-of-way (ROW)

For this conceptual stage of development, concept options are presented in plan form. The types of upland defense that may be suitable for given locations along portions of the alignment are indicated. Key trade-offs, strengths, and weaknesses for each concept option are presented in this section. The complete Part II comparative evaluation is summarized in spreadsheets in Appendix K.

8.1.1 2nd Street Shoreline Concept Option

The Second Street shoreline option minimizes the reliance on deployable barriers and maximizes the zone of protection offered by any of the Newtown Creek concept options. This concept option includes land reclamation on either side of the in-water barrier at the end of 2nd Street on the Queens (north) side of the creek and at 37 Commercial Street (the Greenpoint Landing development site) on the Greenpoint (south) side of the creek. A shoreline stabilization approach is incorporated in Hunters Point South and Greenpoint, making the line of defense entirely independent of future development. The shoreline stabilization could consist of concrete floodwall or steel sheet pile with riprap on the water side, coming to a height of 8 to 11 feet above grade. Landscaped berms could integrate into existing parkland at the southern end of Gantry Plaza State Park (Queens) and Transmitter Park (Brooklyn). Floodwalls would run along the park side of Center Boulevard between 49th and 48th Avenues; along the centerline of 48th Avenue between Center Boulevard and 5th Street; integrated along the fence line of Hunters Point Park; and along the centerline of Greenpoint Avenue from the terminus at Transmitter Park to Franklin Street. Operable gates would provide vessel access to the ferry landings and piers, including at Hunters Point South, the DEP emergency dock at Newtown Barge Park, and the India Street ferry pier. Deployable barriers are required at 2 street crossings and 1 intersection (double) crossing, where the line of defense turns perpendicular to the shoreline and cuts back to meet the +17-foot North American Vertical Datum of 1988 (NAVD88) elevation contour. The line of defense for this concept option hugs the shoreline but stays out of the water to avoid regulatory requirements and associated costs.

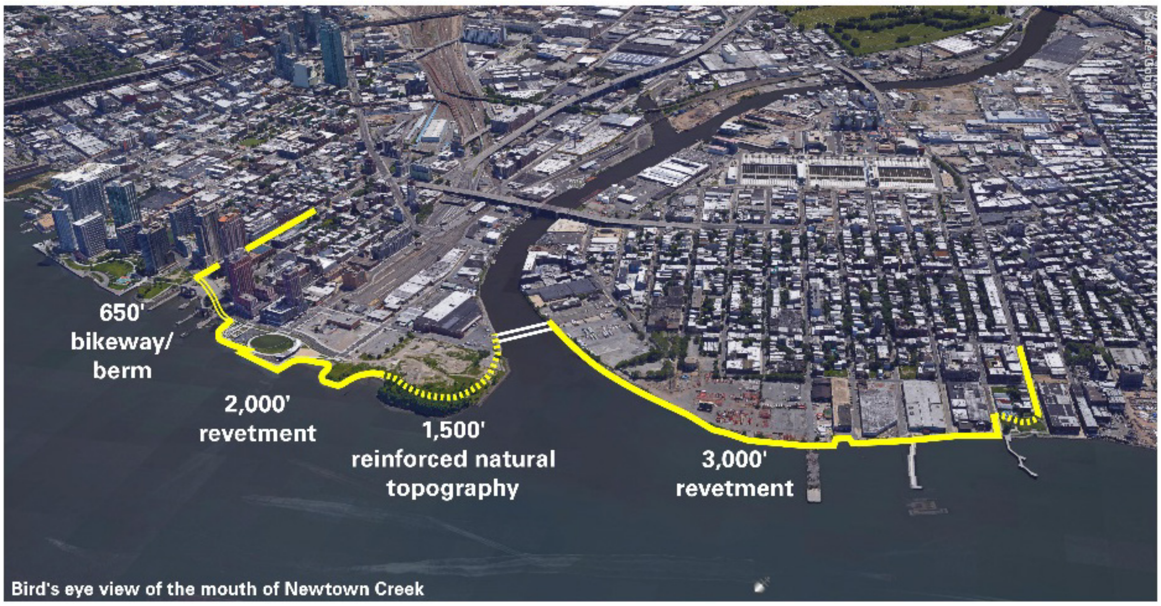
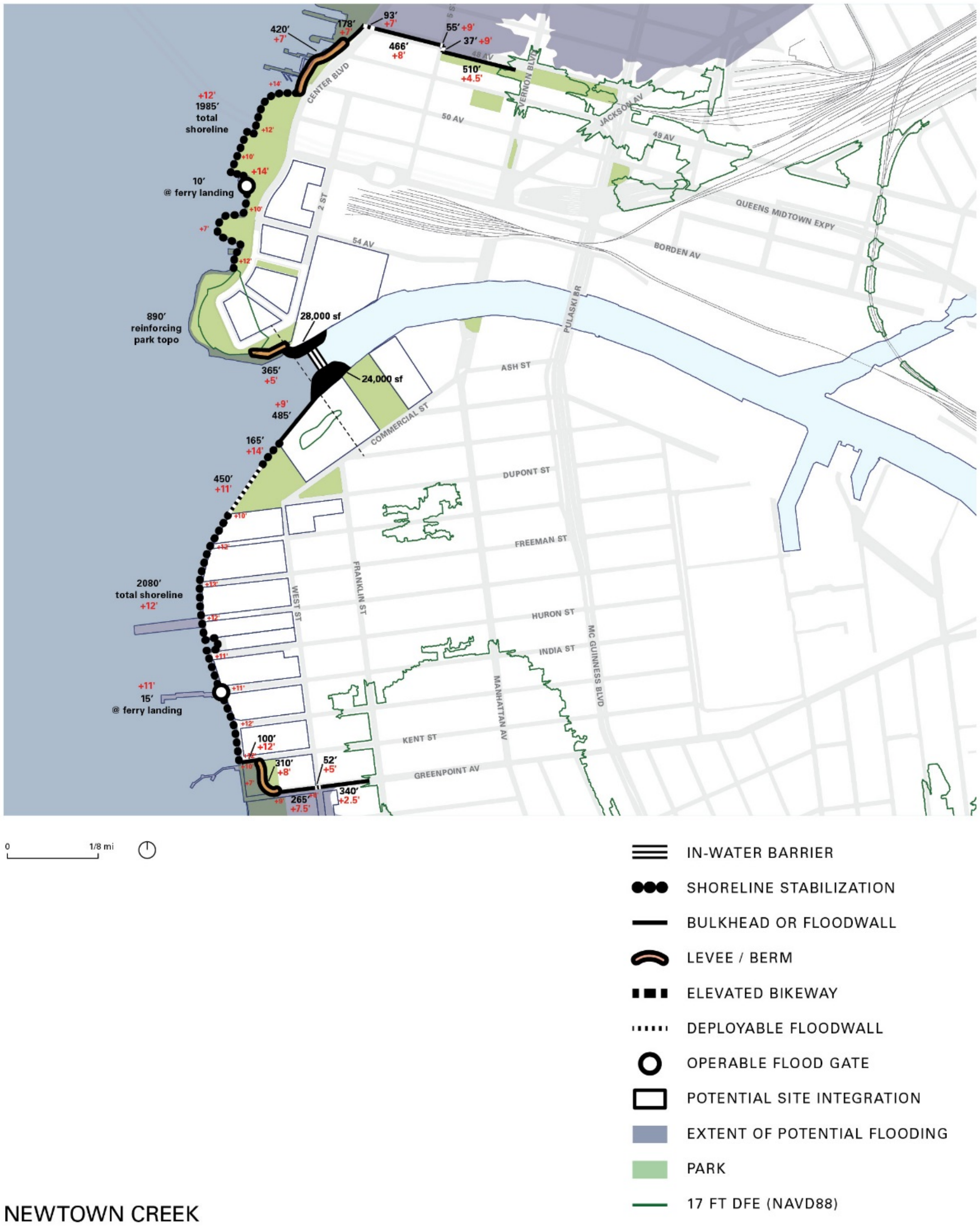


FIGURE 8-2

View of the 2nd Street Shoreline Concept Alignment Potential Components

FIGURE 8-3
Potential Concept Option Components and Required Height Along the Alignment

Second St / shoreline option



Note: Heights for the flood defense components indicated in the plan above are averages for the indicated segments and not spot elevations.

FIGURE 8-4
2nd Street Shoreline Concept Option

A variation on the 2nd Street shoreline alignment could move the line of defense back to the eastern edge of the Hunters Point South Park/western edge of Center Boulevard. This would lessen impacts to waterfront access and parkland, leaving the East River accessible, while still affording the same protection to the residential and commercial properties.

FIGURE 8-5
2nd Street Shoreline Concept Option Alignment Variation

As noted above, a key strength of the 2nd Street shoreline alignment is that is minimizes the reliance on deployable components. Instead, it relies on floodwalls and permanent structures with a long design life. In addition, it tries to minimize interventions in the urban fabric by tying into natural or landscaped topography and placing the line of defense along the shoreline wherever possible. In this way, the 2nd Street shoreline achieves high reliability, and maximizes the zone of protection, capturing the entirety of the residential, commercial and industrial properties within the study site.

The 2nd Street shoreline alignment minimizes disruption to residential and commercial activities and potential adverse impacts to public safety by staying out of the public ROW to the extent possible. Another strength of this concept option is it offers the greatest opportunity to incorporate green infrastructure as part of the upland defense system. The use of berms and shoreline stabilization are likely.

This alignment's operation and maintenance costs and requirements could be comparatively lower. The upland defense line runs along the East River shoreline—not the active waterfront within the Creek.

A key trade-off that arises by keeping the alignment at the shoreline and minimizing community disruption is that this concept option would adversely impact view corridors and waterfront access. This alignment potentially requires a wall on the water-facing side of the future Greenpoint waterfront esplanade and along the waterfront park system in Queens. The future Greenpoint waterfront esplanade will be elevated to between +12 to +13 feet (NAVD88) and the Box Street and Newtown Barge Parks, both of which are about to commence construction, will be circa +12 and +13 feet at their highest elevations. Approaches to future retrofits for parks, including the Greenpoint waterfront esplanade, to meet this study's design flood elevations (DFE) of +17-foot NAVD88 were explored with New York City Department of City Planning (NYCDCP) and New York City Department of Parks and Recreation (NYCDPR) around potential design solutions. Coordination with DPR will be critical should a Newtown Creek storm surge barrier project advance beyond this study.

FIGURE 8-6
2nd Street Shoreline Concept Option's Key Strengths and Weaknesses

The major weakness of the 2nd Street shoreline alignment is the anticipated complexity of the legal and planning process. Much of the challenge is associated with the in-water barrier placement. As noted previously in Section 6, a horizontal rotating in-water storm surge barrier would require infill, which will trigger New York State Department of Environmental Conservation involvement. Depending upon how the gate is sized and the volume of infill required, environmental permitting could be very difficult or require extensive mitigating activities. At the same time, the infill might create opportunities for new recreational areas.

Beyond the infill permitting challenge, the in-water barrier would tie into the upland connection in front of the planned Greenpoint Landing site. This is likely to trigger legal action and opposition due to adverse impacts with planned waterfront access and waterfront views that would now look out onto the barrier structure. Community resistance due to adverse design impacts on park areas and waterfront access is also likely and would require discussions around trade-offs for protection. The incorporation of upland defenses within existing parks could mean taking away active space, which is heavily contested by the communities. Parkland alienation issues could also be triggered.

Finally, although the 2nd Street Shoreline alignment tries to keep to publicly controlled lands as much as possible, a portion of the Greenpoint waterfront, where the esplanade will be built represents an example of one of the City's shared public-private approaches to introducing and improving public amenities. The esplanade is being funded by private developers who own the waterfront parcels, but the esplanade at the water's edge is part of the re-zoned parkland and is a public amenity. The esplanade has been certified already by NYCDCP as part of the Greenpoint Waterfront Access Plan certification, making it difficult for NYCDCP to go back to the drawing board and ask for changes at this stage in the process. In the future, once the esplanade has been transferred to DPR control, DPR could explore design solutions to retrofit and incorporate a higher DFE into the esplanade as opposed to erecting a floodwall on its waterfront side.

8.1.1.1 Protection of People and Jobs

The zone of protection for all of the Newtown Creek concept options, except for the Manhattan Avenue ROW concept option, is very similar, because the alignments tie back toward the East River waterfront. For the 100-year flood event, the Newtown Creek 2nd Street shoreline concept option, as well as would protect roughly 740 acres, home to about 7,500 people. This concept option protects more than 22,000 jobs, two-thirds of which are in industrial sectors. With around 1,400 businesses in the area's 740 acres, the density of businesses is more than 2.5 times that of the waterfront (measured as the Sandy inundation area), and 60 percent greater than the city as a whole. With almost 1,400 buildings and more than 19 million square feet of built area, the area is 45 percent more densely built than the general New York City waterfront, as measured by the 2007 Flood Insurance Rate Map 100-year flood zone.

For the more extreme 500-year flood event, modeling results show that a much larger area of 1,267 acres would be protected, home to 15,600 residents, with similar age, income, and racial/ethnic characteristics as those protected from the 100-year event. More than 42,000 jobs and 2,500 businesses are protected in the area captured within the 500-year flood plan, at higher densities (34 jobs and 2 businesses per acre) than in the 100-year protected area. The area also contains more than 2,700 buildings and 37 million square feet of built area.

8.1.1.2 Conceptual Engineering and Planning Cost Estimate

Engineering and construction risks were considered for this alignment. A high level planning cost estimate for this alternative is provided for comparison purposes.

The predominant defense type outside of the in-water barrier is the bulkhead along the shoreline. Floodwalls are also incorporated and it is assumed that the soil is suitable to support this construction.

This alignment minimizes the potential utility conflicts assuming few utilities are currently located in the existing bulkhead corridor. Construction of significant underground infrastructure to support the concrete floodwalls is expected. It is assumed that this will be possible and that utility conflicts can be addressed and are accounted for with a utility allowance of 5 percent in the conceptual cost estimate.

While some of the bulkhead is likely to be constructed from the waterside, access will be required between the commercial businesses and the water to construct the remainder. It is assumed that sufficient space will be made available via a temporary easement from the business owners. Wall construction will require staging along the streets and it is assumed that the streets can be shutdown to traffic during these periods. Access to the commercial businesses will need to be addressed and is a consideration at the north and south limits of the system. A 5 percent access allowance factor is included in the cost estimate.

The preliminary conceptual cost estimate for the upland defense portion of the 2nd Street Shoreline concept option is roughly $108 million. This figure excludes any land acquisition. Risks and other factors, as described above, and similar to those described for the in-water barrier conceptual engineering, could escalate the figures. The total cost estimate for the complete 2nd Street Shoreline concept option, combing both the in-water storm surge barrier and the upland defenses, is approximately $229 million. Appendix B provides the detailed build-up of the conceptual cost estimates.

8.1.1.3 FEMA Certification Considerations

Portions of this alternative at the north and south limits are aligned adjacent to private commercial property. It is assumed that work will be done within existing road ROWs and no easements (which would be a Federal Emergency Management Agency (FEMA) requirement) will need to be obtained. At both terminus points the system ends at existing ground that is sufficiently high to provide an acceptable tie-in point for FEMA mapping purposes.

While the number of deployable measures are limited in this alternative, they are included. FEMA would require that the adopted Operation and Maintenance Plan detail all aspects of these features, including the flood warning system in place to allow sufficient time for implementation.

8.1.2 2nd Street Development Integration Concept Option

The 2nd Street development integration concept option follows a similar path as the 2nd Street shoreline alignment, except that the line of defense moves inland to the mid-block point where operable gates or post and panel deployable barriers would connect to elevated sites. For the mid-block closures, operable gates would be faster to close and less labor intensive, but could introduce a more industrial aesthetic than would demountable panels. The key strength of the 2nd Street development integration concept option is that it could lower the capital costs by maximizing leverage of third-party investment, in this case through potential elevated sites.

FIGURE 8-7
View of the 2nd Street Development Integration Concept Alignment Potential Components

This concept option is more hypothetical than some of the others. There is heavy reliance on third-party development commitments, which given current planning stages, may make achieving +17-foot NAVD88 impossible for some sites. Entire sites or partial site raising might be pursued, and berms or other landscaped upland defense components could provide protection at the water-facing side of the site and then connect to the mid-block gates or barriers.

At the time of this study, not all development plans and future elevations were known. However, once the future Greenpoint waterfront esplanade is constructed at a +12- to +13-foot elevation (NAVD88), the required additional elevation in some locations may not be substantial, depending upon the design plans for parcel interface with the esplanade.

Because of Americans with Disabilities Act compliance requirements that dictate maximum allowable differences in grade between adjacent parcels/buildings or between a parcel/building and the adjacent road or waterfront, the Greenpoint waterfront esplanade needed to be designed to be contiguous and at the same or very similar grades from parcel to parcel. This meant that each property owner needed to match (or closely match) the elevation of adjacent properties at the waterfront. Based on existing grade elevation, these mid-block gates in Greenpoint would be about 5 to 6 feet in height. Preliminary discussions were conducted with NYCDCP, NYCDPR, and NYC Housing, Preservation and Development to explore initial concepts of how parcels might integrate with a storm surge barrier system. A study recommendation is for the City to continue to explore policy options for site elevation and integration.

FIGURE 8-8

Illustrative Concept Option Component: Post-and-Panel or Operable Gates at Mid-blocks

Note: Heights for the flood defense components indicated in the plan above are averages for the indicated segments and not spot elevations.

FIGURE 8-9

2nd Street Development Site Integration Concept Option

FIGURE 8-10
Development Status

Beyond the potential capital cost savings to the City that this option could bring, other strengths of the 2nd Street development integration alignment are that it would maintain view corridors and waterfront access, and that it avoids a majority, though not all, of the adverse interface impacts with the Greenpoint waterfront esplanade and the waterfront parks projects, both planned and existing.

FIGURE 8-11
2nd Street Development Site Integration Concept Option's Key Strengths and Weaknesses

As with the 2nd Street shoreline alignment, this concept option also faces complex legal and planning process challenges due to the location of the in-water storm surge barrier. In addition to those, in order to satisfy the rules to meet 44 Code of Federal Regulations—a requirement for FEMA certification—non-private easements would be required to be negotiated with the private property owners. The portions of the elevated sites functioning like earthen levees or berms would need to be under public operation and control as part of the storm surge barrier defense system.

Other weaknesses of the 2nd Street development integration alignment relate to the large number of deployables/operable gates. The increased reliance on deployable components increases the potential for system failure. Any operational error or component failure that results in a section of the defense line not sealing will leave the zone of protection vulnerable. In addition, closure leading up to a storm event would require coordination with multiple parties prior to deployment, and there could be some impact to public safety in a storm event as far as circulation and blockage of street ends and equipment staging requirements. This concept option may have higher operations and maintenance costs due to testing, storage, and deployment labor requirements.

The population, households and jobs protected by this concept option are almost equal to those protected by the 2nd Street shoreline concept option.

8.1.2.1 Conceptual Engineering and Planning Cost Estimate

Engineering and construction risks were considered for this alignment. A high level planning cost estimate for this alternative is provided for comparison purposes.

The predominant defense type outside of the in-water barrier and the elevated sites is the floodwalls located at the north and south tie-in locations. It is assumed that the soil is suitable to support the concrete floodwalls.

Construction of significant underground foundations to support the concrete floodwalls is expected; however, the extent of the floodwall is limited. A utility relocation allowance of 10 percent was included in the cost estimate to account for this issue.

Construction of the floodwall and deployables will require staging and access along streets adjacent to existing commercial businesses. It is assumed that temporary easements at these businesses and in the roadways will be available. The construction will occur near the end of the streets so impacts to traffic is expected to be relatively minimal and can be staged along successive streets. The access issues are incorporated into an access allowance of 10 percent in the cost estimate.

The preliminary conceptual cost estimate for the upland defense portion of the 2nd Street Development Integration concept option is roughly $61 million. This figure excludes any land acquisition, and risks and other factors as described above and similar to those described for the in-water barrier conceptual engineering, could escalate the figures. The total cost estimate for the complete 2nd Street Development Integration concept option, combining both the in-water storm surge barrier and the upland defenses is circa $183 million. Appendix L provides the detailed build-up of the conceptual cost estimates.

8.1.2.2 FEMA Certification Considerations

This site incorporates the raising of the properties adjacent to the shoreline with deployables tying the raised parcels to each other. This option will have significant hurdles with FEMA certification. First, FEMA will only consider full system certification so this site raising would need to be complete before certification is pursued. Based on the range of ownership of the parcels being used, this timeline would be very uncertain. In addition, FEMA requires that a flood protection system be owned and maintained by a community participating in the National Flood Insurance Program or an agency created by such a community. In this case that ownership would not exist. This option envisions that a corridor through the property would be designated as the theoretical prism of the levee and a permanent easement would be granted. The use of this easement would need to be limited so to allow for access, inspection, and maintenance. This approach would need to be coordinated with FEMA if determined to be viable from a private ownership (granting the easement) perspective.

This alternative contains a significant number of deployable measures. FEMA would require that the adopted Operation and Maintenance Plan detail all aspects of these features, including the flood warning system in place to allow sufficient time for implementation. Details of the manpower and time needed for the implementation would likely be required.

8.1.3 Manhattan Avenue Shoreline and Development Integration Concept Options

A variation of the preceding concept options, the Manhattan Avenue development integration or shoreline alignments move the in-water storm surge barrier up the Creek to the Manhattan Avenue location where a lift gate would be incorporated. This alignment avoids the interface with Greenpoint Landing and the anticipated DEC permitting challenges due to required infill for the 2nd Street in-water barrier. However, as discussed in Section 6, this in-water barrier option could adversely impact navigation by imposing a height constraint on vertical clearance. Floodwalls would need to be erected along the Creek to connect back toward the East River in order to maximize the zone of protection. On the Greenpoint side of the Creek, this would require integration and interface with 77 Commerce but could then tie into Greenpoint Landing’s elevated parcel. On the Queens side, there are a number of parcels that are expected to be rezoned for mixed-use residential use in the next few years. A floodwall in front of these parcels would impede waterfront access so would be expected to require design integration and coordination with potential waterfront plans.

FIGURE 8-12

Manhattan Avenue Shoreline and Development Integration Concept Option Variations.

In general, the strengths and weaknesses of this alignment mirror those of the Manhattan Avenue development integration or shoreline alignments, depending on which variation were pursued. The Manhattan Avenue development integration concept option would maximize potential cost savings to the City by maximizing developer contributions for site elevation, while the Manhattan Avenue shoreline alignment would minimize interface with development parcels and reliance on deployables, but affect waterfront accessibility. An additional strength of an alignment incorporating the Manhattan Avenue in-water barrier is the potential to incorporate a pedestrian/bike connection between Greenpoint and Hunters Point, helping to integrate the two communities on either side of the Creek.

The population, households and jobs protected by this concept option are almost equal to those protected by the 2nd Street shoreline concept option.

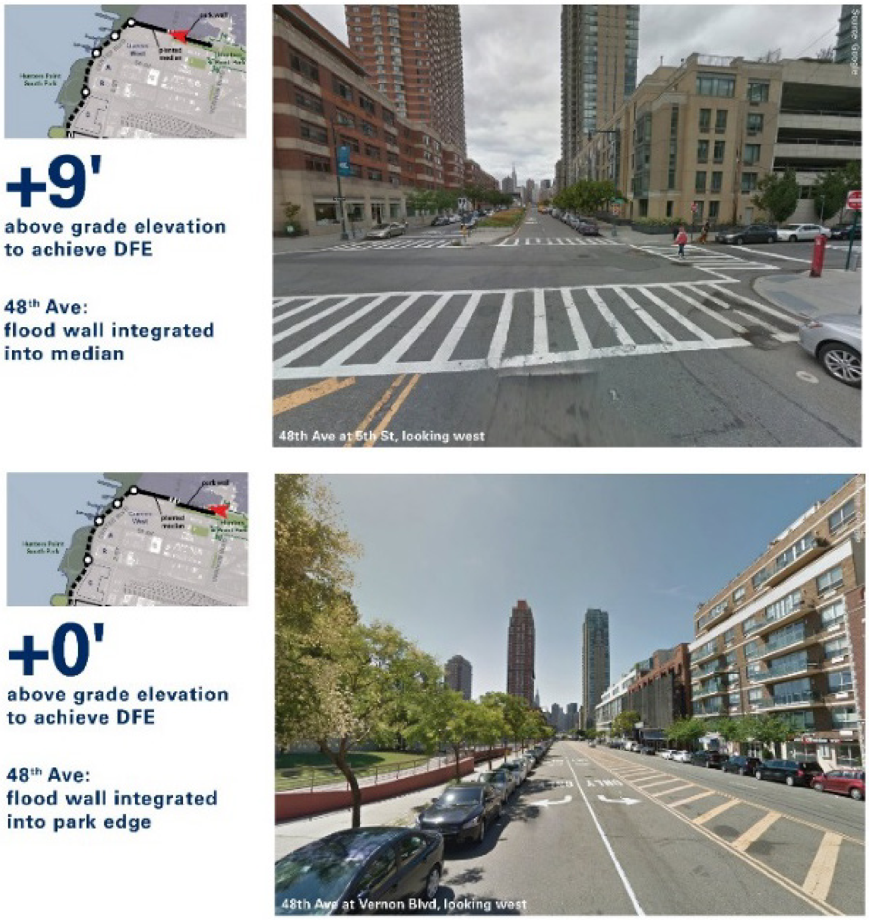
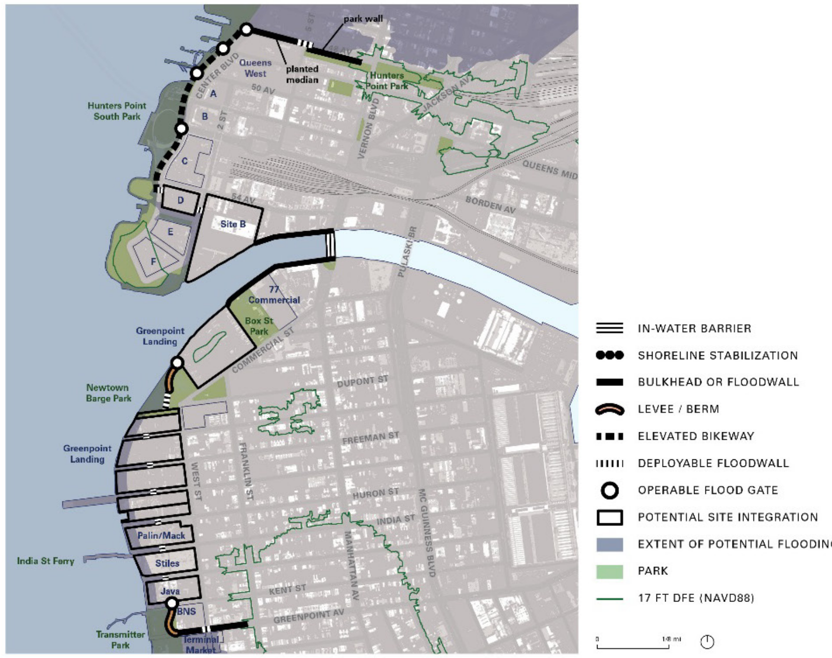


FIGURE 8-13
Illustrative Concept Option Components

- **Avoids permitting complexity of 2nd St**
- **Lower capital costs**
- **Complex legal / planning process**
- **Higher O&M costs and requirements**
- **Reliance on third-party commitments**
- **Uncertainty around FEMA certification**



Note: Key strengths and weaknesses for the Manhattan Avenue Shoreline alignment are presented in Appendix K. In general, they are similar to those of the 2nd Street Shoreline alignment.

FIGURE 8-14
Manhattan Avenue Development Integration Concept Option's Key Strengths and Weaknesses

8.1.3.1 Conceptual Engineering and Planning Cost Estimate

Engineering and construction risks were considered for this alignment. A high level planning cost estimate for this alternative is provided for comparison purposes. The alignment along the shoreline (not set inland along the raised sites) is considered in this assessment. Detailed cost build-ups for both alternatives are included in Appendix L.

The predominant defense type outside of the in-water barrier is the bulkhead along the shoreline. Floodwalls are also incorporated and it is assumed that the soil is suitable to support this construction.

This alignment minimizes the potential utility conflicts assuming few utilities are currently located in the existing bulkhead corridor. Construction of significant underground foundations to support the concrete floodwalls is expected. It is assumed that this will be possible and that utility conflicts can be addressed and are accounted for with a utility allowance of 5 percent in the conceptual cost estimate.

While some of the bulkhead is likely to be constructed from the waterside, access will be required between the commercial businesses and the water to construct the remainder. It is assumed that sufficient space will be made available via a temporary easement from the business owners. Wall construction will require staging along the streets and it is assumed that the streets can be shutdown to traffic during these periods. Access to the commercial businesses will need to be addressed and is a consideration at the north and south limits of the system. A 5 percent access allowance factor is included in the cost estimate.

The preliminary conceptual cost estimate for the upland defense portion of the Manhattan Avenue shorelines concept option is roughly $152 million. This figure excludes any land acquisition, and risks and other factors as described above and similar to those described for the in-water barrier conceptual engineering, could escalate the figures. The total cost estimate for the complete Manhattan Avenue shoreline concept option, combining both the in-water storm surge barrier and the upland defenses is circa $242 million. The Manhattan Avenue site integration concept option variation would have upland defense costs circa $106 million and total concept option costs circa $196 million. Appendix L provides the detailed build-up of the conceptual cost estimates.

8.1.3.2 FEMA Certification Considerations

Portions of this alternative at the north and south limits are aligned adjacent private commercial property. It is assumed that work will be done within existing road ROWs and no easements (which would be a FEMA requirement) will need to be obtained. At both terminus points the system ends at existing ground that is sufficiently high to provide an acceptable tie-in point for FEMA mapping purposes.

While the number of deployable measures are limited in this alternative, they are included. FEMA would require that the adopted Operation and Maintenance Plan detail all aspects of these features, including the flood warning system in place to allow sufficient time for implementation.

8.1.4 Manhattan Avenue Right-of-Way Concept Option

The final concept option for Newtown Creek is the Manhattan Avenue ROW alignment. This concept option maintains the line of defense in the public street ROW as much as possible to maximize public control. The Manhattan Avenue ROW alignment would run along the western side of the street. This would result in loss of on-street parking on one side of the street, but both bicycle lanes could be maintained. The line of defense would vary in height between 2 feet and 4 feet above grade level for most of the Greenpoint segment, except for a 6.5-foot-high section between the Creek and Ash Street. Low permanent floodwall segments that could double as planters are envisioned with post-and-panel segments at intersections. On the Queens side, taller segments of floodwall would wrap around the rail yards and then range between 6 feet and 1 feet as the alignment runs to +17-foot NAVD88 elevation along Vernon Boulevard at 49th Avenue.

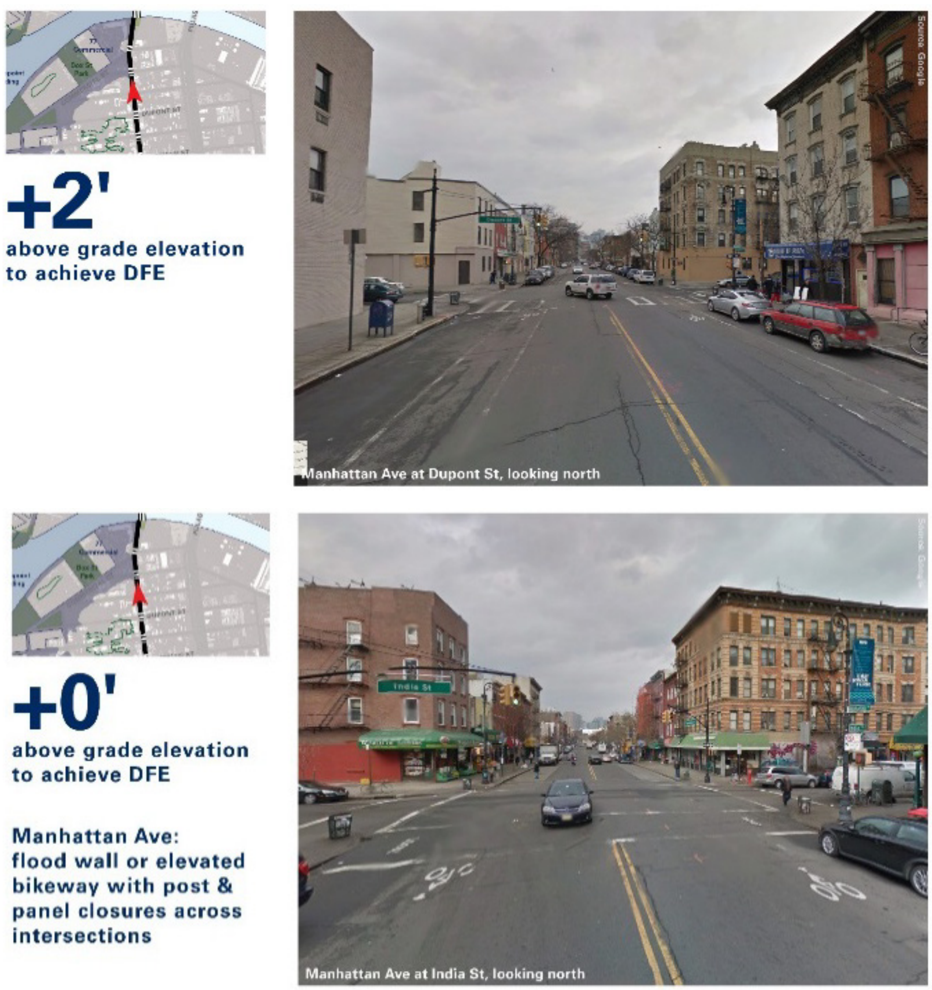


FIGURE 8-15
Illustrative Concept Option Components

A variation on this alignment could shift the line of defense west, running along the Creek and then turning south along Franklin Street in Greenpoint and turning north in Hunters Point to wrap around the rail yards along 2nd Street and Borden Avenue back to Vernon Boulevard where it turns north and runs to the +17-foot NAVD88 elevation at 49th Avenue. Both Manhattan Avenue and Franklin Street have vibrant commercial activity and much street activity. The advantage of Manhattan Avenue is that it is a wider ROW so might be able to accommodate the upland defenses better than Franklin Street.

FIGURE 8-16

Manhattan Avenue ROW Concept Option Alignment Variation

Manhattan Ave / right-of-way option

Note: Heights for the flood defense components indicated in the plan above are averages for the indicated segments and not spot elevations.

FIGURE 8-17
Manhattan Avenue ROW Concept Option

The key strength of the Manhattan Avenue ROW concept option is that it maximizes public control by moving the alignment into public ROW. It also presents the shortest alignment, meaning lowest capital costs. In addition, by shifting upstream to the Manhattan Avenue in-water storm surge barrier location, the legal and permitting complexities of the 2nd Street location are avoided and the potential for the Brooklyn-Queens pedestrian/bicycle connection becomes possible.

The key weakness of this concept option is that the zone of protection is significantly reduced, leaving a large portion of the residential and commercial community vulnerable, although the majority of the industrial activity inland would remain protected by the Manhattan Avenue ROW concept option. Other weaknesses include the heavy reliance on deployable defense components and the associated coordination, maintenance and operations challenges. The Manhattan Avenue ROW concept option would also adversely affect businesses and pedestrian circulation along a major retail corridor, and is likely to see public opposition. Day-to-day, this concept option poses challenges to New York City Department of Transportation (NYCDOT) and other City agencies street maintenance and operations activities. In addition, there would be adverse impacts to public safety during a storm event as streets are closed off and circulation patterns are affected.

8.1.4.1 Conceptual Engineering and Planning Cost Estimate

Engineering and construction risks were considered for this alignment. A high level planning cost estimate for this alternative is provided for comparison purposes.

The predominant defense type outside of the in-water barrier is the floodwall located north and south of the in-water barrier. It is assumed that the soil is suitable to support the concrete floodwalls.

Construction of significant underground infrastructure to support the concrete floodwalls is expected. Because the walls are aligned within a heavily developed area, it is assumed that this will meet significant challenges. A utility relocation allowance of 25 percent was included in the cost estimate to account for this issue.

Construction of the floodwall will require staging and access through heavily developed areas. This is expected to have significant impacts to traffic and business and residential access during construction. These challenges are incorporated into an access allowance of 20 percent in the cost estimate.

The preliminary conceptual cost estimate for the upland defense portion of the Manhattan Avenue ROW concept option is roughly $61 million. This figure excludes any land acquisition, and risks and other factors as described above and similar to those described for the in-water barrier conceptual engineering, could escalate the figures. The total cost estimate for the complete Manhattan Avenue ROW concept option, combining both the in-water storm surge barrier and the upland defenses is approximately $151 million. Appendix L provides the detailed build-up of the conceptual cost estimates.

8.1.4.2 FEMA Certification Considerations

This alternative is aligned adjacent to private commercial property. It is assumed that work will be done within existing road ROWs and no easements (which would be a FEMA requirement) will need to be obtained. At both terminus points the system ends at existing ground that is sufficiently high to provide an acceptable tie-in point for FEMA mapping purposes.

This alternative contains a significant number of deployable measures. FEMA would require that the adopted Operation and Maintenance Plan detail all aspects of these features, including the flood warning system in place to allow sufficient time for implementation. Details of the manpower and time needed for the implementation would likely be required.

- Lower capital costs
- Maintains view corridors and waterfront access
- Higher O&M costs and requirements
- Reduced protected area
- Major disruptions to community and commerce
- ? Relatively simple legal / planning process

FIGURE 8-18
Manhattan Avenue ROW Concept Option's Key Strengths and Weaknesses

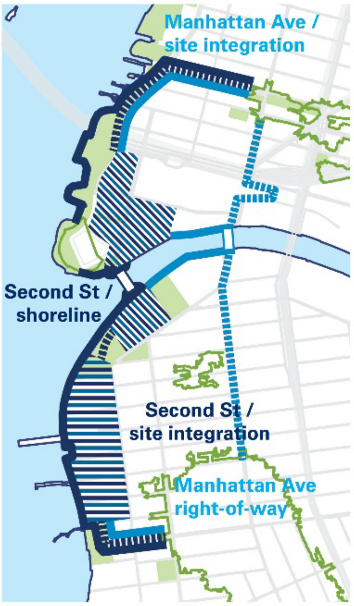
8.2 Preferred Concept Options Advanced to Project Analysis

8.2.1 Evaluation Screening Outcomes

A summary of the comparative screening is shown in **Figure 8-19**. Given the nature of the urban setting and the pace of new construction, there is no easy solution for Newtown Creek—all of the concept option alternatives presented challenges and trade-offs.

A shoreline approach appeared to provide the greatest opportunities to maximize the zone of protection, reliability, and avoiding adverse impacts to commercial activity. Additionally, this concept option did not rely as heavily on third-party commitments and had fewer responsible parties involved than did the site integration concept options. This shoreline concept option also could be considered with the in-water barrier at either the 2nd Street or the Manhattan Avenue location. Based on the evaluation screening, discussions with NYCEDC and ORR, and feedback from City agencies, the shoreline concept options with an in-water barrier at either 2nd Street or Manhattan Avenue were selected as the preferred concept option for additional analysis.

The site integration concept option, also with an in-water barrier at either 2nd Street or Manhattan Avenue, captures nearly the same zone of protection and the benefits are assumed to be the same for purposes of discussion throughout this report This concept option was also further explored as an alternative concept option in discussions with City agencies and investigations into funding and financing approaches.



	Criterion	Second St shoreline	Second St site integration	Manhattan Ave site integration	Manhattan Ave right-of-way
Cost	Total cost	Red	Yellow	Yellow	Green
	Ability to leverage other investments	Yellow	Green	Green	Yellow
	O&M costs	Green	Red	Red	Red
Benefit	Protects jobs	Green	Yellow	Yellow	Red
	Protects homes	Green	Yellow	Yellow	Red
	Utilizes green infrastructure	Green	Yellow	Yellow	Red
	Minimizes impact on public safety	Green	Yellow	Yellow	Red
Reliability	Extent of in-place vs deployable barriers	Green	Red	Red	Red
	Number of responsible parties	Green	Red	Red	Green
Implementation	Complexity of legal/planning approvals	Red	Red	Red	Yellow
	Disrupts access for residents & businesses	Green	Yellow	Yellow	Red
	Maintains view corridors	Red	Green	Green	Green
	Maintains waterfront access	Red	Green	Green	Green
	Reliance on third-party commitments	Yellow	Red	Red	Green
	Improves neighborhood connections	Yellow	Yellow	Green	Green

**Site integration* = incorporation of defense line segments into private parcels, funded by developers*

- *Current development approvals and site status precludes realization of full site integration concept option.*
- *Benefits criteria ratings could be green or yellow, depending on defense line placement between East River and West Street*

Preferred Concept Option (*Manhattan Ave barrier possible*)

Alternate Concept Options* (*for comparative, policy exploration purposes*)

FIGURE 8-19
Summary of Part 2 Comparative Screening for Newtown Creek Concept Options

Should a potential Newtown Creek storm surge barrier project advance beyond this conceptual study, a whole host of investigations and due diligence, ranging from utility and geotechnical surveys to environmental site investigations, would be conducted. There are also a number of topics that require interagency coordination, policy determination, or decisions that would also need further investigation and discussion. These include the following:

- Determining the in-water barrier location will require careful consideration of the advantages and disadvantages. As noted previously in Section 6, both the 2nd Street and the Manhattan Avenue locations could afford a potential solution, but each presents trade-offs. A horizontal rotating sector gate at 2nd Street would require infill, which will trigger DEC involvement. Depending upon how the gate is sized and the volume of infill required, environmental permitting could be very difficult or require extensive mitigating activities. In addition, the upland tie-ins would interface with planned park and private development sites. The potential for integration with development plans and waterfront parks, including legal actions, policy determinations and engineering design are issues that will require additional investigation and determination. On the other hand, a vertical lift gate at Manhattan Avenue could impose navigation air draft constraints that are untenable to the vessel community. Consultation of the navigation community will be important for any future feasibility study. In addition, close coordination would be required with MTA and utility owners in order to investigate and accommodate the G-train and any other in-channel utility or pipeline connections.
- Plans for Superfund remediation within the Creek are not yet determined. Coordination with the U.S. Environmental Protection Agency (USEPA), NYCDEP and other parties involved with the Newtown Creek Superfund remediation work should take place. For the 2nd Street Shoreline alignment, the topic of focus is ensuring that the bulkhead improvements are designed to accommodate the in-water storm surge barrier. For the Manhattan Avenue shoreline alignment, the in-water barrier interface is still

important, but the topic of focus expands to the ability to leverage any USEPA bulkhead replacement efforts more broadly as the alignment would include floodwalls along the northern and southern sides of the Creek. To the degree that coordination with USEPA and the planned remediation efforts could happen sooner than later, there might be opportunities to design and construct the bulkhead improvement such that they could more easily accommodate floodwalls or in-water barriers rather than having to undergo costly retrofits and reinforcement or rebuild efforts at a later date.

- Engagement with the Newtown Creek communities to explain the challenges and trade-offs associated with erecting a flood defense system in such a vibrant and dynamic community will be a vital component of building allies and public acceptability for a storm surge barrier project to be successful. Community and developer resistance is likely to be encountered due to adverse design impacts on park areas, waterfront access, planned view corridors, or any changes to parking. The incorporation of upland defenses within existing parks could reduce active space—an issue heavily contested by the communities. Parkland alienation issues could also be triggered. Design solutions can seek to minimize adverse interface impacts, but some worsening to the public experience planned waterfront amenities is likely.
- FEMA certification requires that a flood protection system be owned and maintained by a community participating in the National Flood Insurance Program or an agency created by such a community. Where any site elevation components are pursued as part of a flood defense scheme or components of a flood defense system are incorporated across privately owned parcels, easements will need to be obtained in order to ensure 24-hour access to berms, barriers or operable gates and for maintenance activities. In places where defense systems run across private property which is locked and has restricted public access, there are typically two gates, with the public agency operator having its own key and point of entry.
- In addition to the requirements for maintenance, inspection, testing and timely deployment, the storage of demountable components is a consideration to any upland defense alignment that incorporates them. There might be space within the City properties nearby that could accommodate storage of posts, panels, and other equipment. Alternatively, the City might consider acquiring nearby property for storage and operations and maintenance activities.
- For a flood defense components in the public street ROW, fire and life-safety access, as well as to day-to-day City operations, such as snow plowing, street cleaning, garbage collection, utility access and maintenance, and a host of other day-to-day operations would be impacted by any permanent defense components. A future feasibility study and detailed designs would need to coordinate with NYCDOT, City of New York Department of Sanitation (DSNY), and other responsible parties to understand the operational implications and identify any accommodations that might be incorporated into flood defense system designs.

Part III:
Project Analysis

This page was intentionally left blank.

9 Hydrodynamic Modeling Assessment

9.1 Modeling Objectives

Hydrodynamic modeling and high-level flushing and rainfall analyses were conducted as part of the study in order to:

1. Provide data on flood depth and extent for the existing “no barrier” condition, defined as the “baseline” condition, for surge events of varying return period. The outputs were used in order to determine baseline damages in the preliminary benefit-cost analysis.
2. Provide data on flood depth and extent for the preferred barrier option in the closed position at each location for surge events of varying return period. The outputs were used determine damages for each of the options and hence damages avoided, by comparison with baseline conditions in the preliminary benefit-cost analysis.
3. Undertake an assessment of the impact of the barrier on tidal exchange via flushing modeling by assessing changes in the residence time with and without the barrier in place.
4. Assess the likely impact of rainfall / surface water flooding on the land side of a closed barrier by performing a volume comparison that considers landside storm runoff for a range of rainfall events.

The avoided damages analysis was achieved via a combined regional surge modeling and local flood modeling approach interfaced at the project shoreline. In this way, the surge time series along the project shoreline were extracted from the regional surge model and fed to the local flood model that simulates surge propagation overland. The resulting flood depth and extent were used as inputs into the economic analysis model to determine the associated flood damages.

The flushing analysis was achieved using a local flow model nested within a sub-regional flow model and run coupled to an advection and diffusion (Transport) module while the rainfall/surface water analysis was addressed via a desktop assessment. Details of each of the approaches and graphic presentation of modeling results for all modeled scenarios are provided in Appendix F.

9.2 Modeling Scenarios

For the purpose of bracketing the likely cost variation of flood damages, surge/flood simulations for a range of return periods as summarized in **Table 9-1.**

The various return period events were determined based on Federal Emergency Management Agency (FEMA)/New York City Panel on Climate Change (NPCC2) extreme water levels at the Battery. These water levels are compared with other sources in **Table 9-2**.

Since the NPCC2 study applied the same modeling methodology, storm and associated inputs of FEMA (2014) for the baseline set (without considering sea level rise), their results of return period-based extreme water levels (tide + surge + wave setup) are consistent with those of FEMA (2014) as shown in **Table 9-6**. These levels are higher than those given in the U.S. Army Corps of Engineers (USACE) North Atlantic Coast Comprehensive Study (NACCS) (2015).

For future extreme water level incorporating future sea level rise (SLR), the NPCC2 (2015) study conducted additional simulations using the 90th percentile SLR projections for 2020s, 2050s, and 2080s. The 90th percentile SLR scenario was considered a conservative approach in NPCC2.

For the present study, it is deemed appropriate to apply the 50 percent percentile SLR projection as a mid-range estimate to assess impacts of sea level change on project performance. This 50th percentile value is not provided in NPCC2 (2015) but has been linearly interpolated herein based on the published 10th (1.25 feet), 25th (1.83 feet), and 75th (4.17 feet) percentile values in NACCS (2015). The corresponding

50th percentile SLR value in 2100 is 3 feet, which was adopted for use in conjunction with the 100-year return period extreme water level incorporating sea level rise as shown in

For replicating the referenced flood exceedance levels at The Battery for the 1-year, 10-year, 100-year, and 500-year return periods for the existing condition, a scaling approach based on the Holland B parameter (generally varying between 0.5 and 2) in the parametric Holland model, which in terms determines the maximum wind speed in the Holland parametric model, was used. The simulation with the “correct” Holland B parameter value that results in the closest match with the referenced flood exceedance levels at the Battery was adopted and the same model setup used to conduct the barrier option runs.

For the SLR run, the selected SLR (3 feet in this case) was applied as a uniform uplift of the present-day offshore water level boundary conditions for the 100-year return period run.

In the ensuing model runs, the 1-year return period event was replaced by the 1.5-year return period to represent the damage initiating event as needed for the economic analysis of the flood damage.

TABLE 9-1
Summary of Modelling Scenario Mix

Modeling Task	Condition	Purpose	Return period (year)	SLR Scenario for surge modeling
Surge/Flood modeling	Baseline – present day condition – no barrier	To provide data on flood depth and extent for use as input to the economic analysis model to determine baseline damages	1	No
			10	No
			100	No
			500	No
			100	Estimated 50th percentile, NPCC2 (2015), target year = 2100
	Barrier closed	1) With Flood model: to provide data on flood depth and extent maps for use as inputs into the economic analysis model based on flooding-dependent damage functions; and to determine damages for each of the options and hence damages avoided by comparison with baseline conditions	1	No
			10	No
			100	No
			500	No
		2) For surge modeling: to assess the impact of the barrier on hydrodynamics outside/downstream	100	Estimated 50th percentile, NPCC2 (2015), target year = 2100
Local flow/ Flushing modeling	Baseline – present day condition – no barrier	To assess impact on water quality based on mechanical water exchange	Spring neap tidal cycle, operational condition	No
	Barrier open – normal conditions		Spring neap tidal cycle, operational condition	No
	Barrier open – stormwater volume stored behind barrier after surge event		Spring neap tidal cycle, operational condition	No

Note:
Two barrier options for Newtown Creek.

TABLE 9-2
Comparison of Extreme Water Levels, The Battery (ft NAVD88)

RP (year)	FEMA (2014)	NACCS (2015)		NPCC2 (2015)
	Newtown Creek	Mean	90% CL	
10	6.9	6.2	6.6	6.9
100	11.2	7.9	9.5	11.2
500	14.1	9.8	12.8	14.4

Note:

FEMA levels are stillwater elevations that account for tides, surge, and wave setup while NACCS (2015) and NPCC2 (2015) values are model outputs from coupled hydrodynamic-wave modelling and thus account for tides, surge, and wave setup as well.)

A total of two storm surge barrier system options were investigated for Newtown Creek. These are presented as the Barrier I and Barrier II options as shown in **Figure 9-1**. As discussed in Section 8, for the Newtown Creek study site, the shoreline alignment concept options, with either the 2nd Street or Manhattan Avenue in-water barrier locations, were identified as the most promising alternatives based on screening, discussion with NYCEDC and feedback from City agencies.

FIGURE 9-1
Barrier options, Newtown Creek: Left: 2nd Street Alignment (Barrier II); Right: Manhattan Avenue Alignment (Barrier I)

9.2.1 Flood Model

9.2.1.1 Flood Model Overview

The interface between the surge and the flood model occurs at the shoreline. The extent of the surge model is such that it includes an overlapping land area abutting the shoreline wherein the land topography is resolved schematically to minimize surge elevation rising vertically at the shoreline if it were represented as the land-water interface. The flow outputs at the shoreline were extracted from the surge model and fed into the flood model as boundary conditions. Flood Modeling was performed using Flood Modeller Suite.

9.2.1.2 Surge Inputs

Point locations for surge time series data were extracted from the Surge model and used as input locations for the Flood model. The time/stage storm surge data series associated with each surge data point location (See **Figure 9-2**) was applied to a polyline input boundary matching the adjacent shoreline and spread inland using the polyline as a boundary condition. A typical surge boundary time series is shown in **Figure 9-3**.

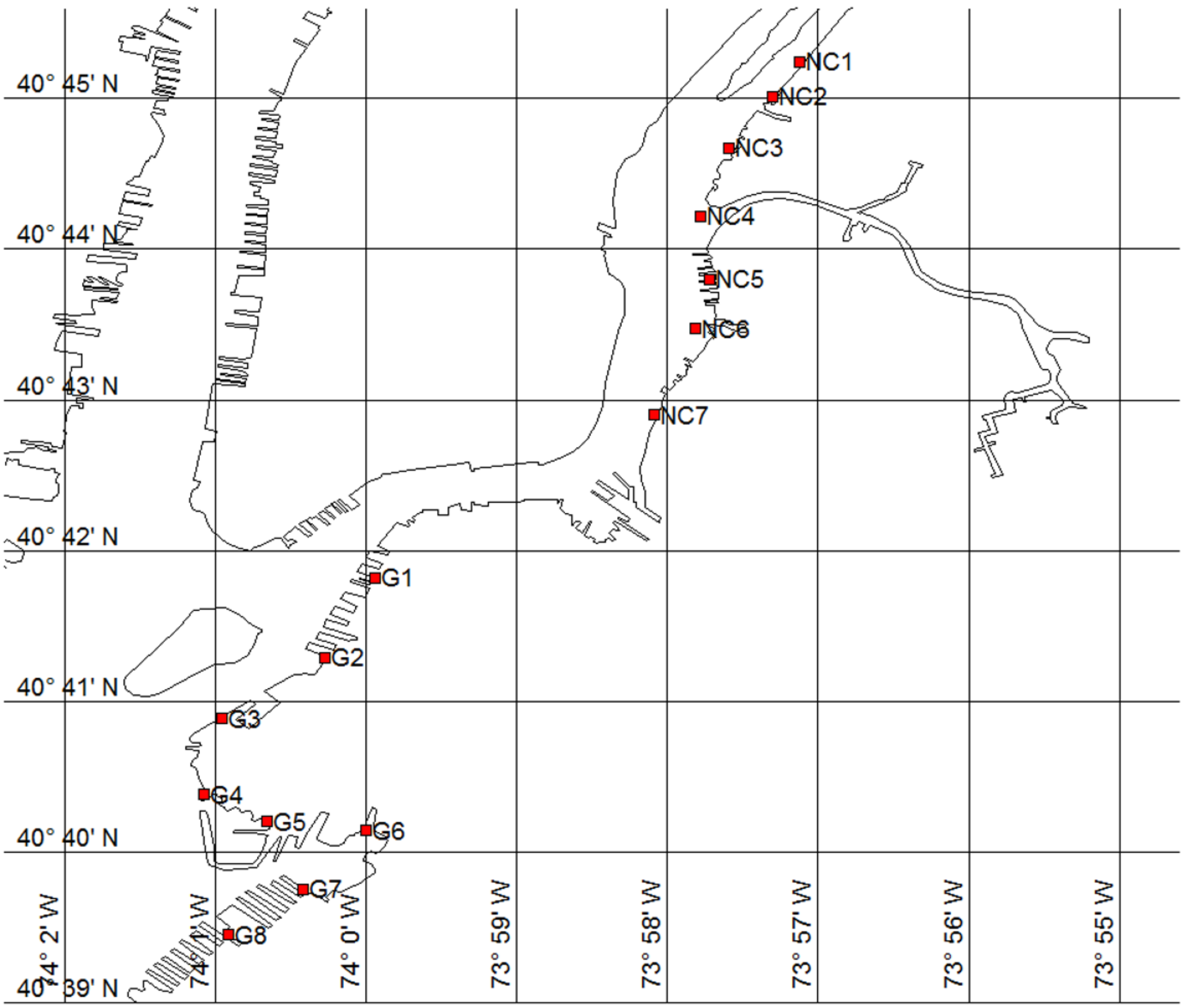


FIGURE 9-2
Newtown Creek Surge Input Locations-Baseline Conditions (NC series)

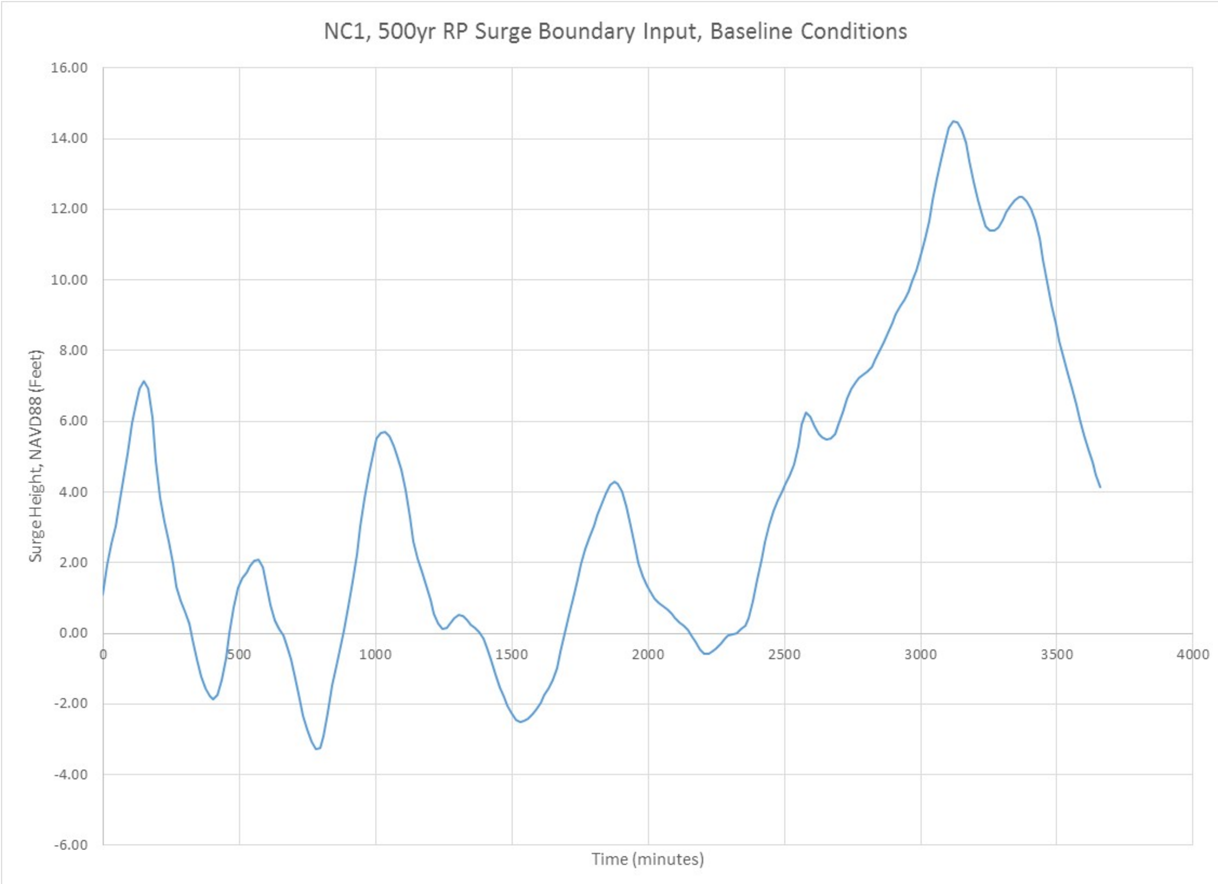


FIGURE 9-3
Typical Surge Boundary Input as a Time Series Plot

9.2.1.3 Topography

A three-foot bare earth Digital Elevation Model (DEM) of New York City was used as the topographic basis for the flood modeling. This DEM was produced November 2011 from 2010 New York City (NYC) LiDAR data to support the production of updated hurricane surge (SLOSH) inundation area and depth data for NYC Office of Emergency Management (OEM) and NYS OEM. The data is in feet, referenced to NAVD 88. The clipped DEM used for the baseline simulation is shown in **Figure 9-4**.

NYC Department of Information Technology provided the source 2010 LiDAR (.las) tiled data which was collected April 14 to May 1, 2010, by Sanborn and reviewed for quality assurance and control by the Center for Advanced Research of Spatial Information (CARSI) lab at CUNY Hunter College. Accuracy of the source LiDAR data is 9.24 cm RMSE vertical accuracy, 33 cm horizontal accuracy, and 8-12 points per square meter point density.

The USACE Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, produced this data at the request of the USACE New England District to meet the hurricane SLOSH data production schedule. Only class 2 (bare earth) points from the source .las tiles were used for production. No additional quality assurance or control was performed on the final DEM other than that already performed on the source .las data.

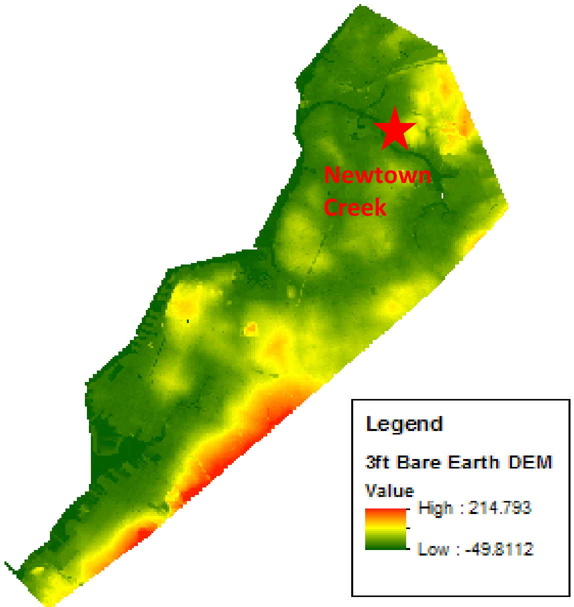


FIGURE 9-4
Bare Earth DEM

Minor DEM modifications were made to reflect "holes" in the DEM with very low elevations. These are likely a reflection of the filtering technique used on the DEM, shadows in the aerial photography used for DEM development, or active construction sites at the time of photography that resulted in low elevations.

A computational grid of 10 feet by 10 feet, based on the original 3-foot bare earth grid, was used in the software for all flood model simulations.

9.2.1.4 Model Parameters

All Newtown Creek FAST simulations used similar base model parameters. The baseline models were constructed using a 10 foot computational grid with a global starting water elevation set at the average elevation of the initial surge height in the time series input files. The default FAST Advanced Parameters were used, and the baseline simulations were individually run for durations sufficient to simulate the entire surge time series for each scenario.

During simulation of the 100 year + sea level rise (SLR) event and the 500-year event, the surge level is close to the ground level near the rail yard and thus enters the low-lying rail yard. Preliminary FAST model results indicated that flooding into Newtown Creek, around the barrier, might be possible due to this lower-lying ground at the rail yard location shown in **Figure 9-5**. To further investigate this question, additional modeling was performed using the ADI solver, a fully 2D hydrodynamic model. The results of this modeling (**Figure 9-5**) show that this flooding is localized and is likely to propagate no further than the rail yard. The green area is the baseline (no barrier) flood extent for the 100-year + SLR model run, and the blue area is the detailed 2D model results with Barrier 2 (the Manhattan Avenue shoreline alignment).

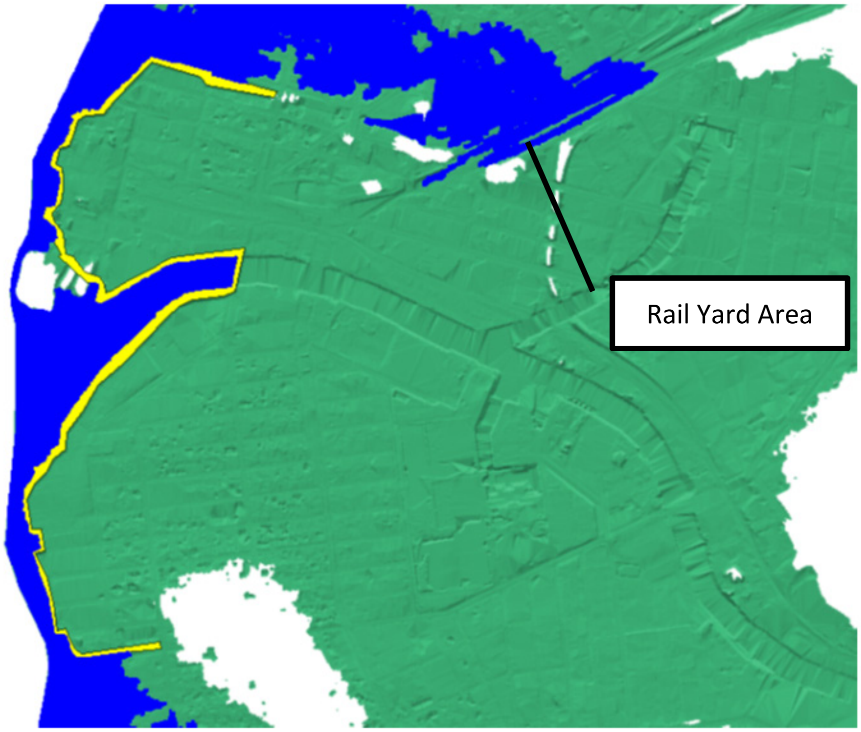


FIGURE 9-5
Detailed 2D Simulation Results for 100-year + SLR Barrier 2 Scenario

The topography of the FAST DEM was then modified for these two runs to produce similar results in the FAST model to the fully 2D model. Future analysis should fully define the topography in this area with a survey so that any future analysis is able to utilize more accurate elevation data in this area to fully evaluate if the surge is able to go around the barrier and into Newtown Creek at this location.

9.2.1.5 Model Validation

Surge inputs from Hurricane Sandy were input into the FAST model and the results compared against the FEMA Modeling Task Force (MOTF) Hurricane Sandy Impact Analysis field-verified MOTF Sandy Inundation extent. The comparison, **Figure 9-6**, shows that the FAST-simulated depth grid closely matches the recorded Hurricane Sandy inundation extents.

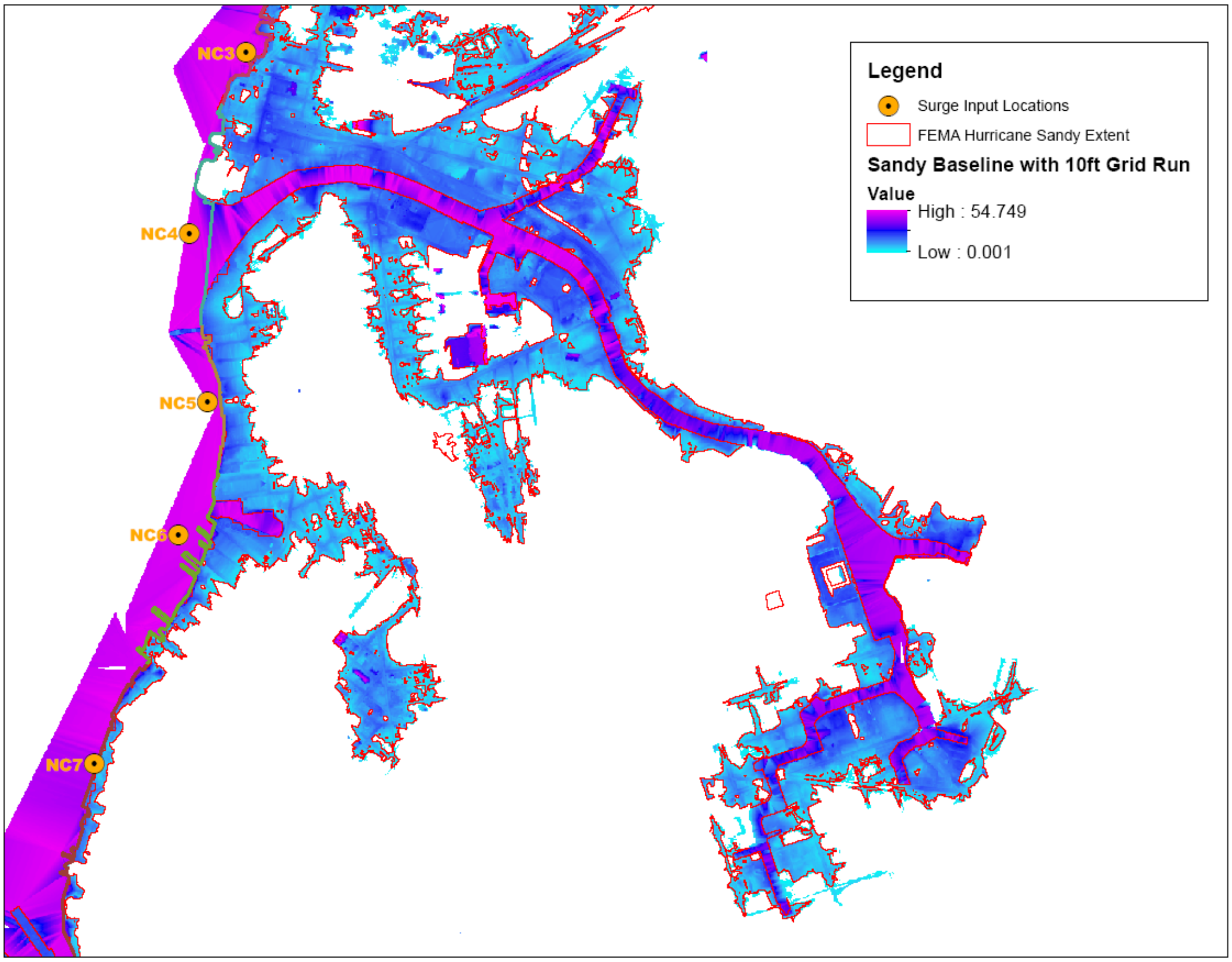


FIGURE 9-6
Comparison of the Flood Extent between Newtown Creek Hurricane Sandy FAST Simulation and FEMA Inundation Boundary

9.2.2 Flushing Model

9.2.2.1 Flushing Model Overview

The local flow model was driven by the boundary conditions provided by the sub-regional model as shown in **Figure 9-7** The local flow model was then coupled to the Transport model (advection and diffusion module) to compute the time for full exchange of the water within the water body under normal tidal conditions, i.e., over a typical 2-week spring/neap cycle, termed the "flushing/residence time" of the water body.

During the simulations, the water body behind/upstream of the canal mouth/barrier locations was assigned an initial unit tracer concentration. Combined sewer overflow (CSO) discharges were included as point sources with time varying flows with an assigned constant unit tracer concentration. The residual level of the tracer concentration in the defined water boundary was tracked through time. This was assessed for both the baseline "no barrier" case and with the barrier in place (open) case to assess the impact of the barrier on the flushing time due to any flow restriction.

In addition, the local flow model was applied to the condition when the barrier was open immediately after the passage of a surge event to investigate the flushing of the ponded water behind the barrier accumulated over the barrier closure period.

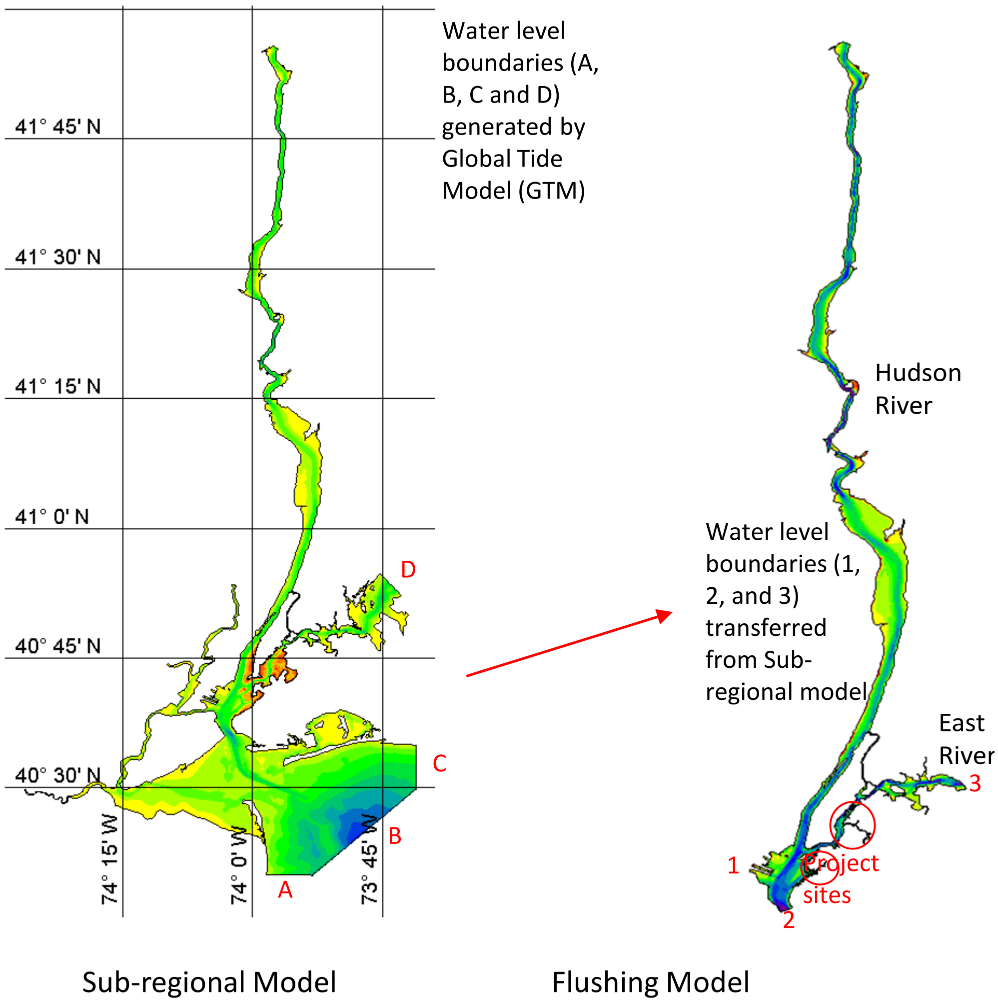


FIGURE 9-7
Boundary Transfer Protocol, Flushing Modeling

9.2.2.2 Flushing Model Calibration and Model Parameters

Ideally, model calibration of both the local flow and the transport model is to be conducted using measured flow and tracer dispersion pattern or available estimates of flushing time from prior hydraulic studies. However, both are unavailable for the Newtown Creek site at this time, the calibrated parameters based on model calibration at the Gowanus Canal site where measured flows and prior estimates of flushing time were available were adopted.

The CSO flow contributions (see **Figure 9-8** for distributions) were modeled as point sources using the average values based on the 2008 CSO flow time series received from New York City Department of Environmental Protection (NYCDEP).

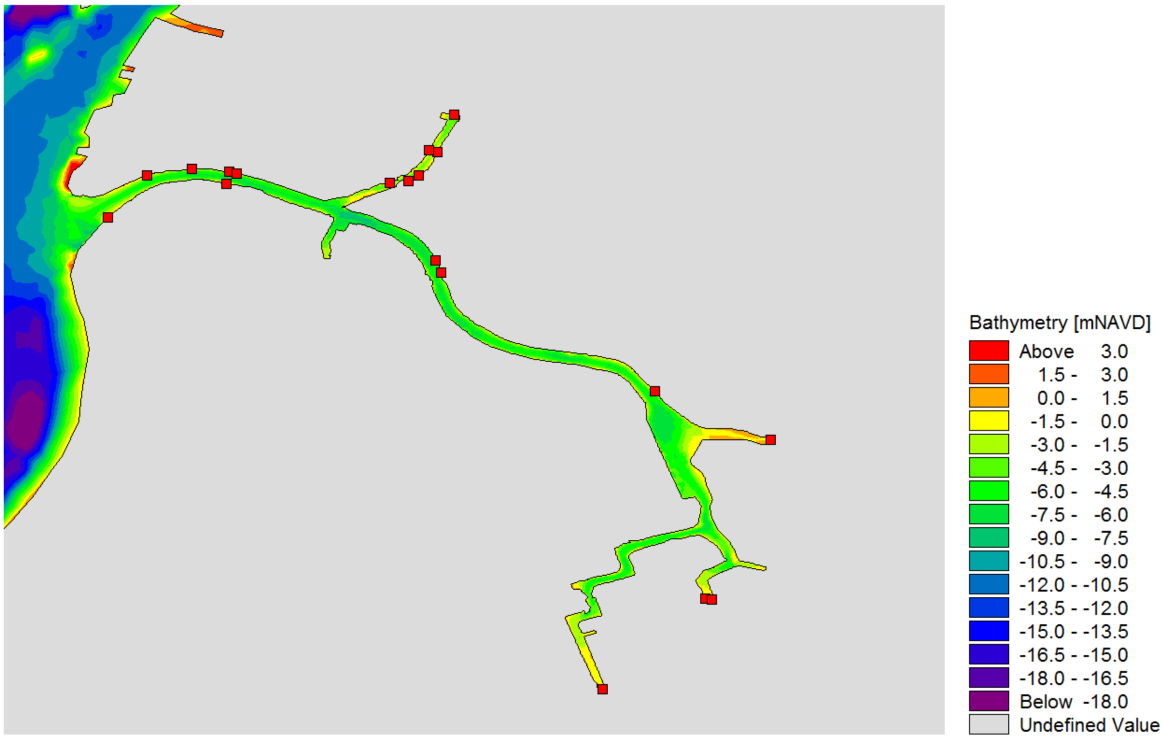


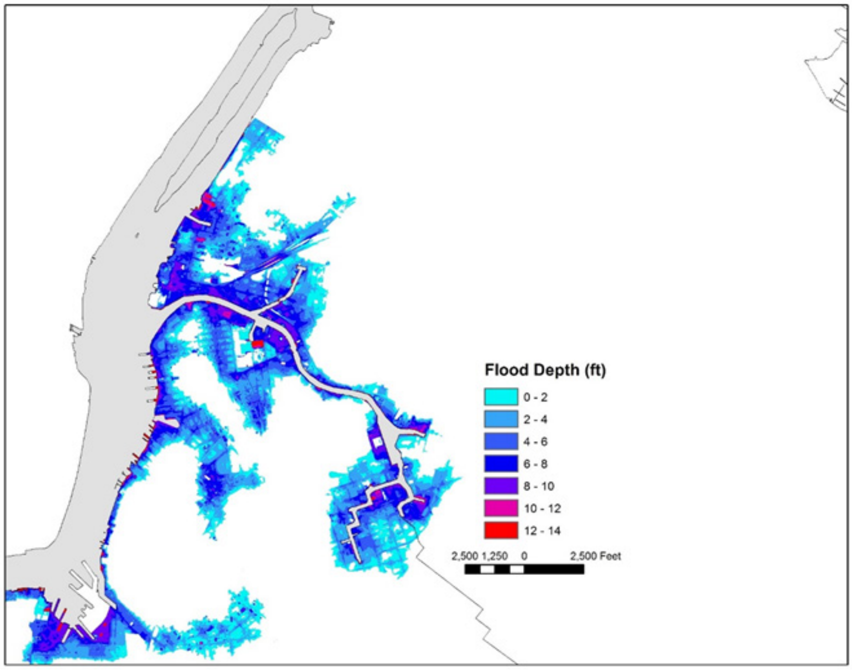
FIGURE 9-8
CSO Locations at Newtown Creek

9.3 Modeling Outputs

9.3.1 Flood Modeling

Appendix F contains figures showing the flood model results for all the baseline conditions and each of the two barrier scenarios. **Figure 9-9** compares the flood extents for the 500-year event between the baseline condition and Barrier 1 (Manhattan Avenue shoreline alignment) option. Note that the flood extent for Barrier 2 (2nd Street shoreline alignment) is very similar and therefore only that for the Barrier I option is shown here and Appendix F.

In addition, overlay maps of the flood extent between the baseline and each of the barrier options are also contained in Appendix F. Both the barrier options provide an effective level of protection through the 500-year event as illustrated in **Figure 9-10** for the highest surge event of 500-year return period.



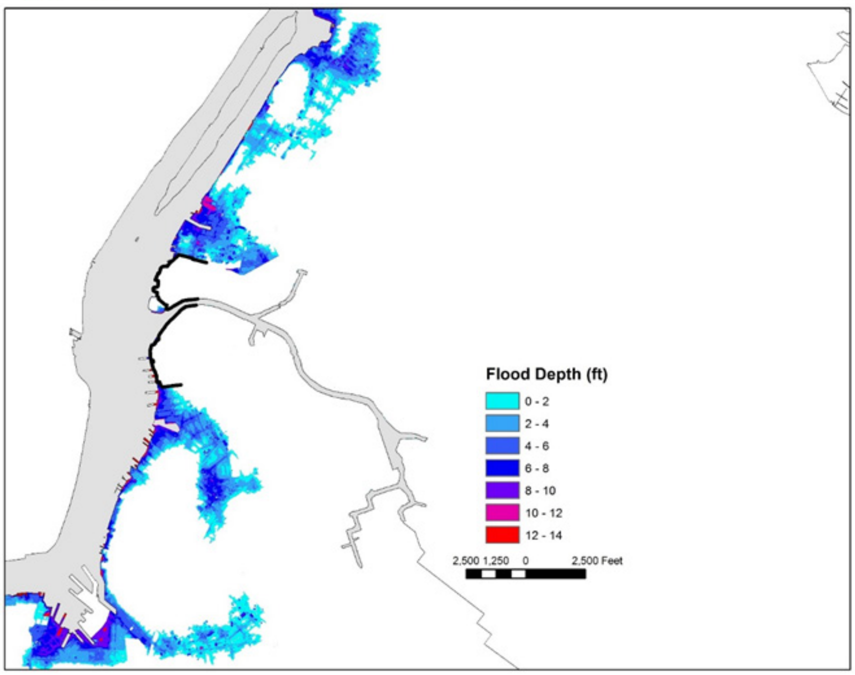


FIGURE 9-9

Comparison of Flood Extent, 500-year Event: Top: Baseline Condition; Bottom: Barrier Option I (Manhattan Avenue Alignment)

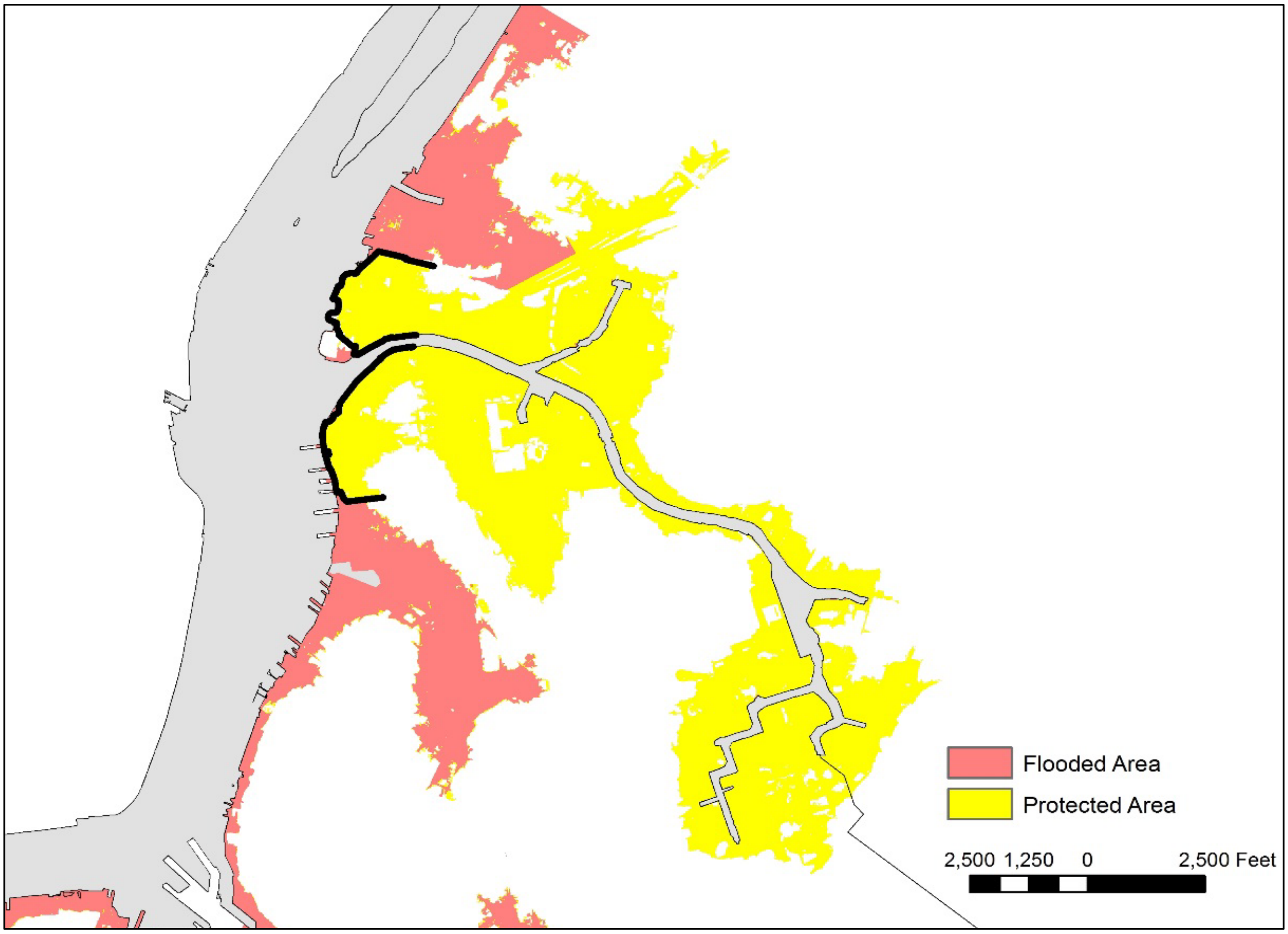


FIGURE 9-10

Protection Zone Based on Overlay of Flood Extents of 500-year Storm Event between the Baseline Condition and Manhattan Avenue Shoreline Alignment)

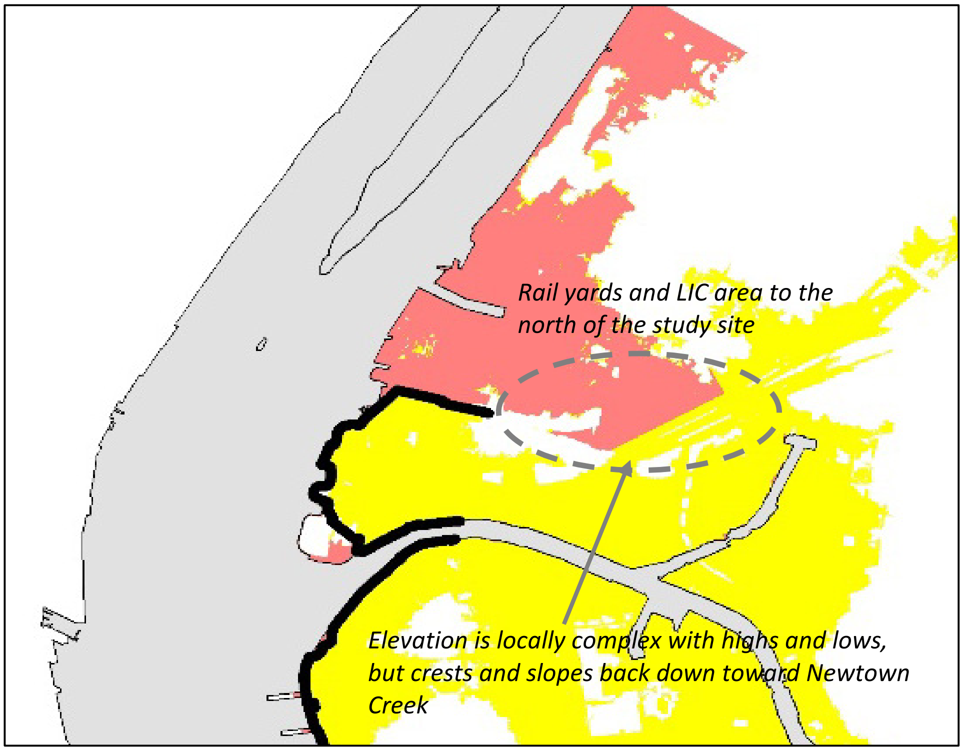
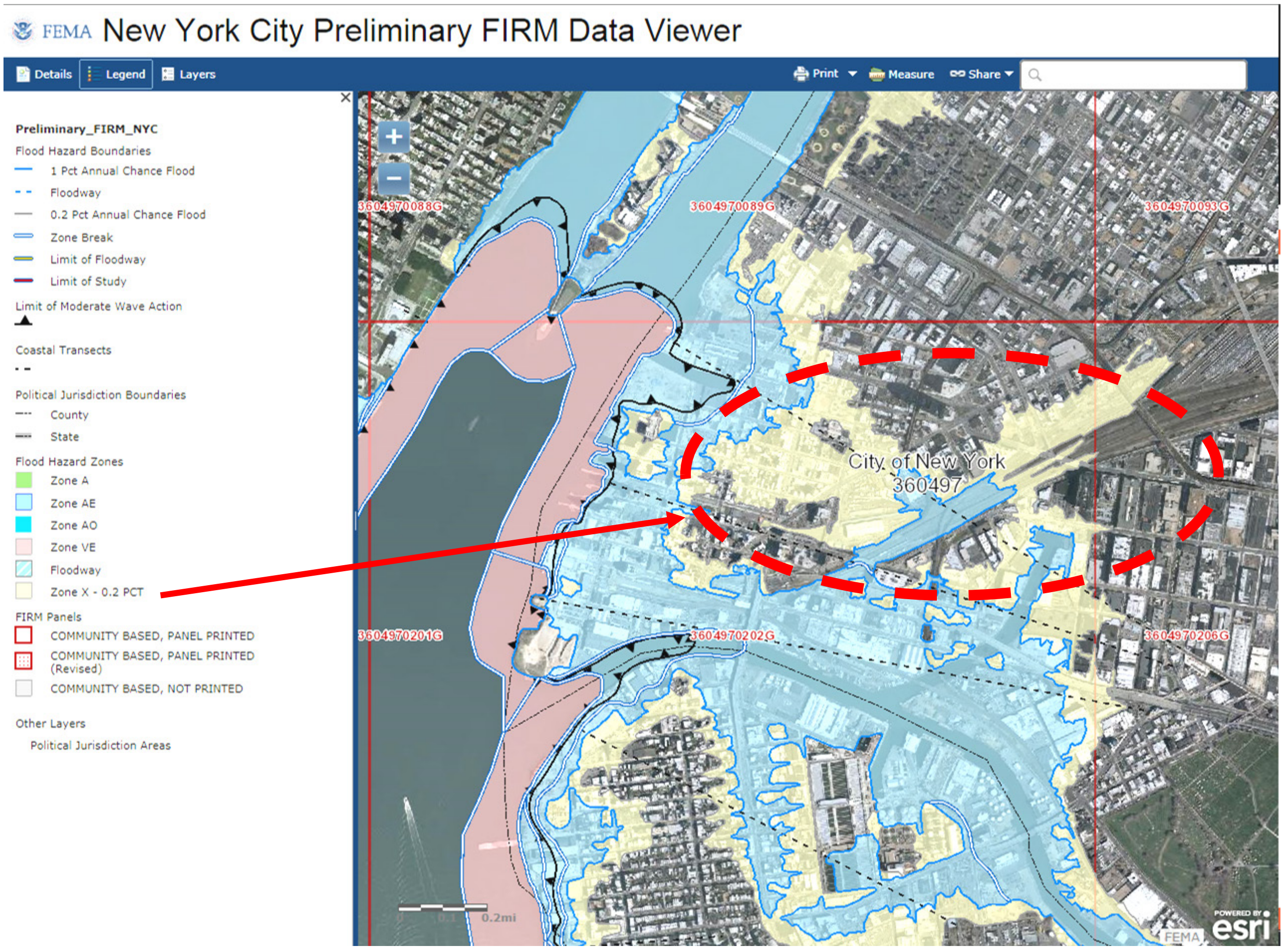


FIGURE 9-11
Future Risk: 100-year Storm Event + 3 foot SLR - Anable Basin and Queens Waterfront Flood Source

9.3.2 Future Risk and Sea Level Rise Adaptation

Assessment of the storm surge barrier flood protection system's performance in differing storm events is useful for identifying potential future risks and a need for adaption over the longer-term horizon. Based on findings from the 100-year storm event + 3 feet SLR scenario, as sea level rise progresses, future risk could arise. Low-lying areas north of the Newtown Creek study area are vulnerable to flooding from the East River as water moves south from Anable Basin into Long Island City. This could introduce a future back door entry point for water flow into Newtown Creek if the flood stages are large. As noted in Section 5.2.4, additional modeling using 2D dynamic flooding/inundation model (advanced hydraulics) found that for the 100+3SLR scenario, flooding is localized with flood depth less than 1 foot and is likely to propagate no further than the rail yard where it dissipates. Further definition of ground elevations in this area may reduce or eliminate this flooding. Future feasibility studies would conduct elevation spot-checks. Such a future risk is understood to present no issue for FEMA certification today. The area in question is Zone X based on FEMA p-FIRMS. Flood insurance requirements do not apply today.

Over the long-term horizon, this northern boundary would be an area to monitor and ultimately, SLR adaptation to a Newtown Creek flood defense system might be pursued. Future flood protection strategies to contain the north East River flood source could include a variety of approaches. The Newtown Creek defense line could be extended to the northeast along the rail yards. However, such a strategy would leave Long Island City and the Queens waterfront vulnerable. MTA is understood to be exploring flood protection measures for the rail yard. Depending on what these measures consist of, they might contain water and provide protection for Newtown Creek. Another approach might be development of a comprehensive Queens waterfront flood protection strategy with a tie-in to the Newtown Creek defense line. Finally, site elevation or flood defense measures might be incorporated into Long Island City redevelopment plans. This is an area where significant redevelopment potential and interest exists.



Source: Accessed online at
http://apps.femadata.com/preliminaryviewer/?&appid=687703427dd347018b8fa2bb0adee979.

FIGURE 9-12
FEMA P-FIRM Data Overlay for Area of Potential SLR Future Risk

9.3.3 Flushing Model

The results of the flushing model is presented in the form of flushing curves shown in **Figure 9-13**. For these runs, the barriers remain open throughout the 15-day simulation period. The green horizontal line denotes the e-folding time, which defined as the time required for the initial tracer concentration to reduce to a fraction of 1/e, where e is the base of the natural logarithm (=2.7183). The light brown line denotes the 4-day time limit within which the residual tracer concentration level reaches 1/e of its initial level considered as good flushing.

It is seen that the flushing of the baseline condition is already poor to begin with. For the barrier options, both show similar flushing capacity, increasing the flushing time relative to the baseline condition by ≅ 5 percent in terms of residual concentration level.

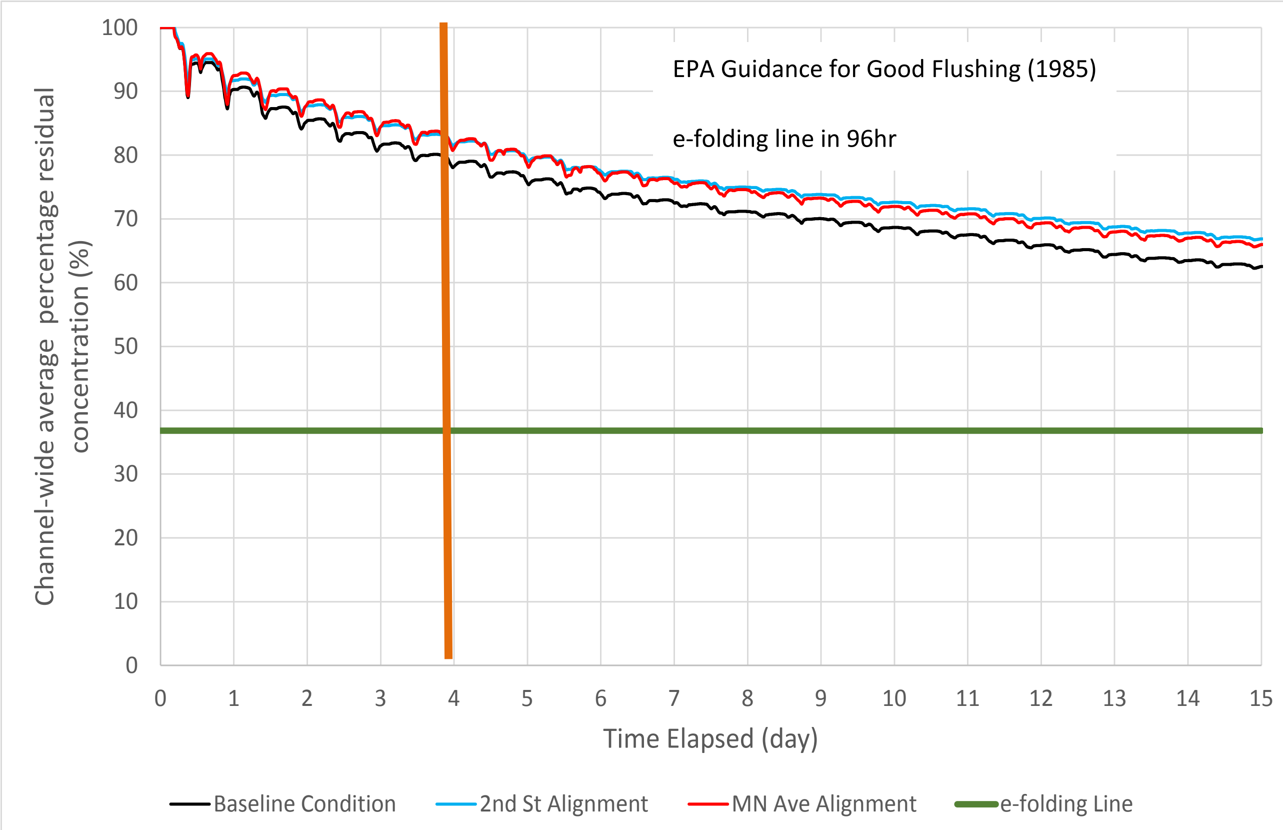


FIGURE 9-13
Comparison of Flushing Curves for Newtown Creek (MN = Manhattan)

An additional set of runs were conducted whereby the barriers are open after the passage of the surge event during which time the water level behind the barriers has risen due to rainfall runoff. For these runs, a 4-foot rise in the channel water level was assumed and the barrier gate opens over a span of 8 minutes.

The results are again presented in the form of flushing curves as shown in **Figure 9-13**, which indicates that the drawdown is rapid for both options due to the initial flow momentum associated with barrier opening.

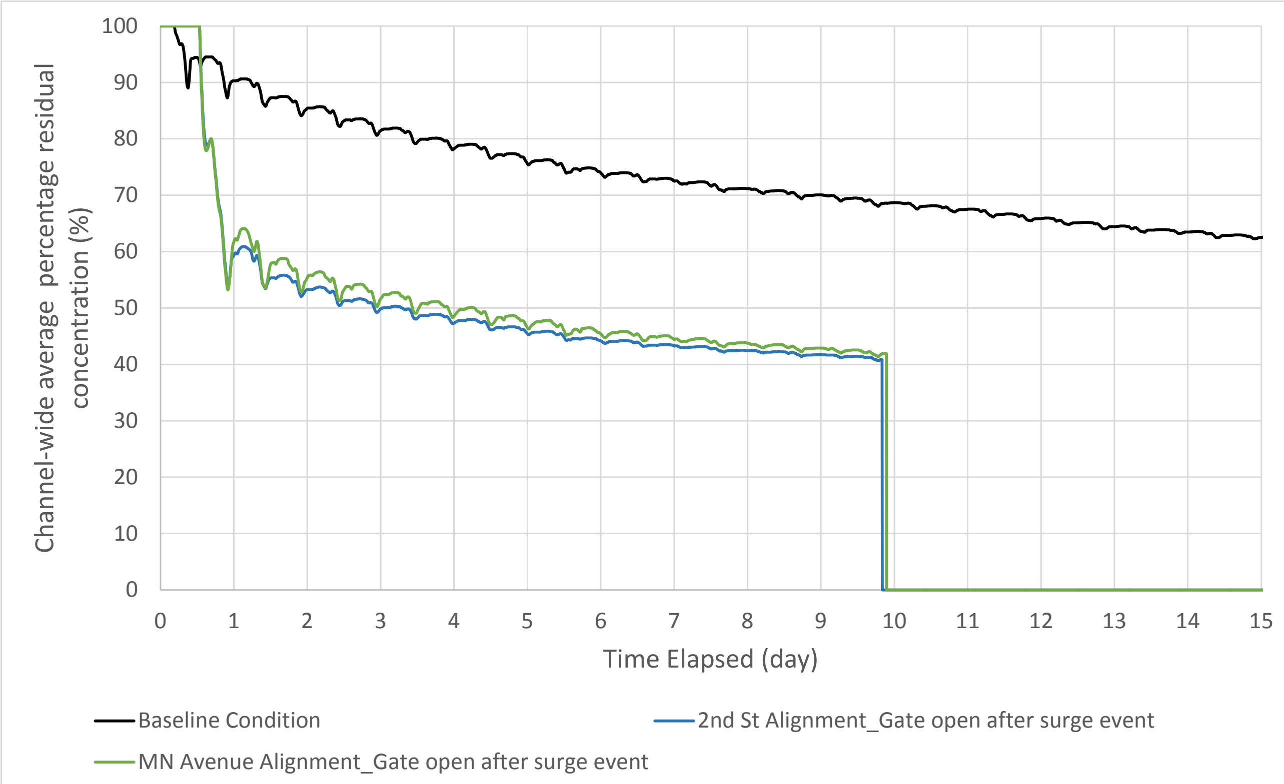


FIGURE 9-14
Drawdown of Tracer Concentration when Barrier is Open after the Passage of Surge Event (MN = Manhattan)

In summary, the introduction of in-water barriers at Newtown Creek appear to cause marginal worsening of circa 5 percent to tidal exchange. Future analysis could dictate that a wider barrier gate be included as part of a storm surge barrier flood defense system in order to further reduce impact to flushing performance. For the case of barrier opening after the passage of a surge event, the modeled results indicate that the accumulation of rainfall runoff behind the barriers leads to a rapid drawdown of the accumulated tracer concentration as a result of the initial flow momentum associated with barrier opening.

The flushing study has qualitatively assessed potential impacts to the flushing capacity of Newtown Creek. Detailed water quality modeling is recommended to be done as part of a future feasibility study both to appropriately size the in-water gate width and to analyze impacts to salinity, oxygen levels and pollutant loads.

9.4 Rainfall Impact Assessment

9.4.1 Overview

Landside rainfall impact analysis was performed to assess the potential for flooding problems behind the barrier when an event with a high storm surge (requiring the flood barrier to be closed for an estimated 12-hour period) is coupled with intense rainfall. For this high-level simplified analysis, a simple approach is taken by comparing the volume of rainfall discharged to each waterbody to the volume of storage available in each waterbody assuming different freeboards. The volume of rainfall is also reduced assuming that a portion of it is redirected to the respective WPCP. The approach is detailed and the results presented in the following sections.

9.4.2 Rainfall Volumes

In this analysis, direct rainfall runoff with 100 percent runoff and no infiltration was used to conservatively calculate the volume of rainfall being discharged to Newtown Creek from its tributary area.

Four return periods (RP) for rainfall intensity were considered based on the storm surge events analyzed in the numerical modelling study. These include 1 year, 10 year, 50 year, and 100 year. The rainfall intensity was determined using Technical Paper No. 40, Rainfall Frequency Atlas of the United States, May 1961 as summarized in **Table 9-3**. The 1-hour, 1-year storm event is similar in volume to the observed landside rainfall during Hurricane Sandy. Hurricane Irene was also analyzed with 7-inches of rainfall. Including the Hurricane Irene analysis, a total of 9 scenarios were considered.

TABLE 9-3
Rainfall Intensity in NYC

Rainfall Event (RP – year)	Rainfall (Inches)	
	1 Hour Storm Duration	6 Hour Storm Duration
1	1.2	2.0
10	2.2	3.6
50	2.8	4.5
100	3.0	5.5

The tributary areas summarized by NYCDEP (2008 and 2011) equal 7,441 acres for the Newtown Creek area. This areas include those serviced by CSOs, stormwater sewers, and areas of direct overland flow to the canals.

The rainfall was conservatively converted to runoff volume by directly and uniformly applying the rainfall to the tributary areas (rainfall x area). Rainfall volumes are summarized in **Table 9-4** for the Newtown Creek watershed.

TABLE 9-4
Rainfall Volumes for Newtown Creek Watershed

Rainfall Event (RP – year)	Volume (MG)	
	Newtown Creek	
	1 hour duration	6 hour duration
1	242	404
10	445	727
50	566	909
100	606	1,111

The seven inches of rainfall that relate to Hurricane Irene produce 1,414 MG at Newtown Creek.

9.4.3 Resulting Rainfall Considering Losses to WPCP

An assumption was made for this analysis that the water pollution control plants (WPCP) would be operating at full capacity for a period of 12 hours with no power failure. This volume would reduce the total rainfall volume listed in **Table 9-4**. State Pollutant Discharge Elimination (SPDES) capacities for each WPCP are given by NYCDEP (2008 and 2011). Newtown Creek WPCP and Bowery Bay WPCP service portions of the Newtown Creek watershed. The capacity considered for each WPCP was the SPDES capacity minus the dry weather flow.

Each WPCP covers multiple watersheds. Therefore, it was necessary to assume that only a portion of total water directed to each WPCP would be from the watershed. It was assumed that this was proportional to the percentage of flow that is normally discharged into each waterbody from the WPCPs. During a detailed drainage and surface water management study at a future stage of analysis, consideration would be expected to incorporate other resiliency projects to account for the impacts of additional surface water that may be directed to the Newtown Creek WPCP, for example water from Manhattan that may be pumped out of the areas protected by an East Side or Lower Manhattan project.

The total volumes handled by each facility and the proportion coming from each watershed based on the above assumption are summarized In **Table 9-5**.

TABLE 9-5
Volumes redirected to each WPCP

WPCP	SPDES Capacity (MGD)	Dry Weather Flow (MGD) from 2007	Total Volume (MG) for 12 hours	Watershed	% from Watershed	Volume (MG) from watershed
Newtown Creek	700	268	216	Newtown Creek	39.4%	85
Bowery Bay	300	109	96	Newtown Creek	4.7%	4

In summary, a total of 89 million gallon (MG) of rainfall would be redirected from the Newtown Creek watershed and sent to the WPCPs servicing that area.

Considering these losses the total volume of rainwater directed to each waterbody for the various cases considered are shown in **Table 9-6**. The 1-year, 1-hour storm event total represents the total rainfall similar to the rainfall volume that fell during Hurricane Sandy. A 7-inch total rainfall, similar to the rainfall volume produced by Hurricane Irene, produces 1,325 MG at Newtown Canal.

TABLE 9-6
Rainfall Volumes Discharged into Newtown Creek

Rainfall Event (RP – year)	Volume (MG)	
	Newtown Creek	
	1 Hour	6 Hour
1	153	315
10	355	638
50	479	820
100	517	1,022

9.4.4 Available Storage in Waterbodies

The volume of available storage in Newtown Creek was calculated based on the surface area of the waterbodies. Assuming various freeboards the available storage is summarized in **Table 9-7**.

TABLE 9-7
Available Storage

Freeboard (feet)	Storage Volume (MG)
	Newtown Creek
1	49
2	98
3	147
4	196

Figure 9-15 depicts the rainfall volumes (summarized in **Table 9-6**) compared to the storage volume at the four freeboards (summarized in **Table 9-7**) for Newtown Creek. In these figures, the black horizontal lines

represent available storage volume in the waterbody assuming different freeboards. The colored lines represent the net rainfall volume discharging into Newtown Creek behind the surge barrier for different recurrence intervals at different storm durations.

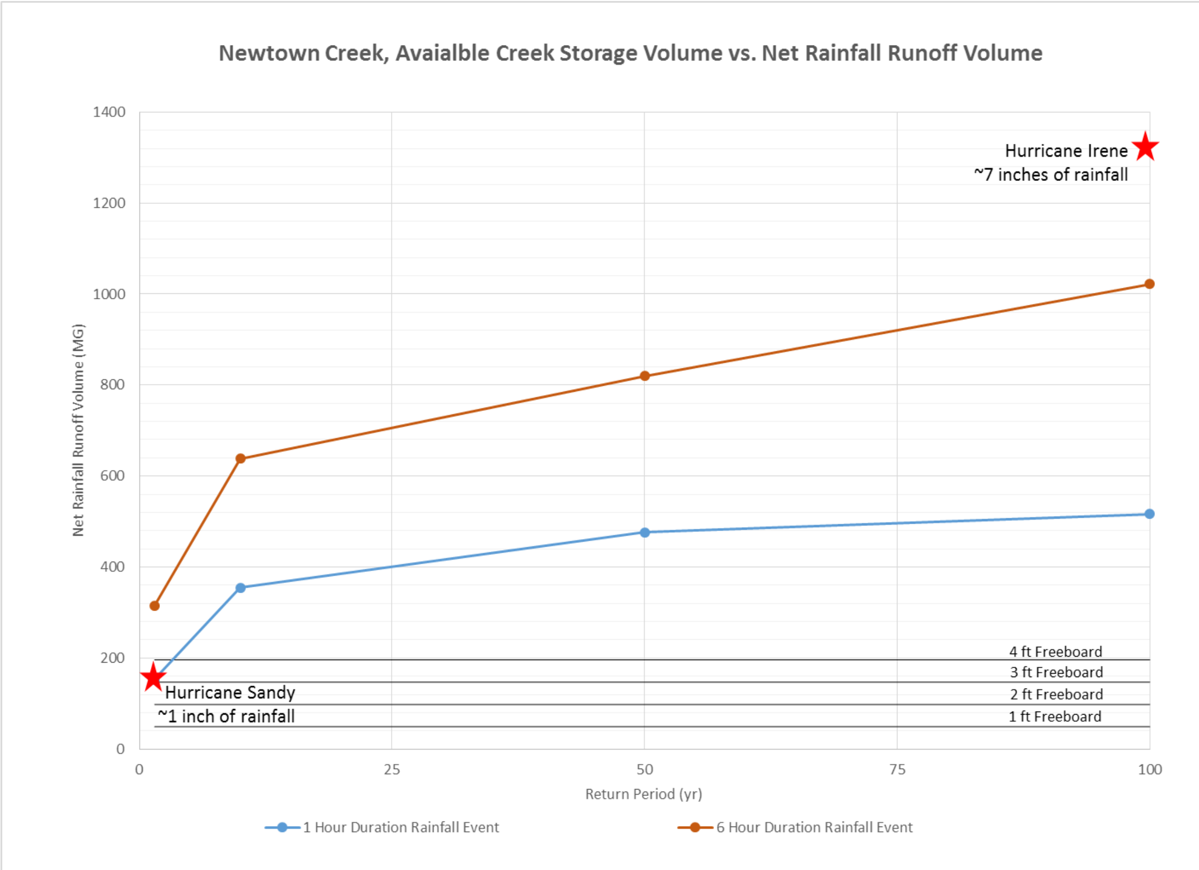


FIGURE 9-15
Newtown Creek Rainfall Volume for Various Return Periods Compared to Available Storage

9.4.5 Conclusions

From the comparison in the above section, this simplified analysis shows that Hurricane Sandy's landside rainfall would likely not have caused flooding behind a closed barrier. Hurricane Irene, however, would likely have caused flooding. Longer and larger storms likely cannot be contained within the Creek. In this simplified analysis, storms larger than the 1-hour, 1-year event rainfall volume were not contained within the Creek system.

It is recommended that any future studies should analyze potential rainfall impact behind the barrier in more detail to better define the flood risk behind a closed flood barrier and potential need for pumping stations at the barrier locations.

This page was intentionally left blank.

10 Preliminary Benefit-Cost Analysis

10.1 National Economic Development (NED) Benefit-Cost Analysis

10.1.1 Overview and Approach

This section documents the economic analysis of flood risk to structures and building contents performed as part of the Newtown Creek Storm Surge Barrier Study. The objectives of this effort were as follows:

- Estimate storm surge-related flood risk to structures and building contents and potential damages reduced by implementation of storm surge barrier conceptual design options in each study area.
- Estimate expected flood damages to structures and contents by methods generally consistent with U.S. Army Corps of Engineers (USACE) flood risk assessment guidelines albeit at a level of detail appropriate for a pre-feasibility study.
- Calculate the net benefits and benefit to cost ratios associated with alternative concept design options as modeled.
- Provide data on potential costs and benefits of options to facilitate informed decision making regarding advancement to more detailed study/design and potential for assistance through USACE programs.

10.1.1.1 Economic Flood Risk Study Area

The initial inventory area for each waterbody was defined based on the limits of the Federal Emergency Management Agency (FEMA) 2013 Preliminary Flood Insurance Rate Map's (Flood Insurance Rate Map [FIRM]) 500-year floodplain. However, the nature of the storm surge-induced flooding necessitated definition of the upstream and downstream limits of the study area along the East River. To determine these limits, the hydrodynamic modeling team was tasked with estimating the area that would be impacted by construction of any of the proposed protection projects, including both beneficial impacts to protected upland structures and any potential adverse impacts to structures waterward of the project. The hydrodynamic modeling results were presented in the Task 3-4 Report. During simulation of the 100 year + SLR event and the 500-year event, the surge level is close to the ground level near the rail yard and thus enters the low-lying rail yard. Preliminary FAST model results indicated that flooding into Newtown Creek, around the barrier, might be possible due to this lower-lying ground at the rail yard location. To further investigate this question, additional modeling was performed using the ADI solver, a fully 2D hydrodynamic model. The results of this modeling showed that this flooding was localized and is likely to propagate no further than the rail yard. Future analysis should fully define the topography in this area with a survey so that any future analysis is able to utilize more accurate elevation data in this area to fully evaluate if the surge is able to go around the barrier and into Newtown Creek (Creek) at this location.

Hydrodynamic modeling results for the baseline and with-barrier conditions identified that: 1) any of the storm surge barrier concept options modeled would provide protection from storm surge-induced flooding at all modeled storm events effectively eliminating residual flood risk to structures protected by the barriers for the purposes of this preliminary analysis; and 2) no significant adverse effect on flood elevation to structures waterward of the barriers is expected. As such, the economic flood risk study area for this analysis was defined as the area encompassing those structures that would be protected by construction of each storm surge barrier option. **Figure 10-1** presents the Newtown economic flood risk study areas in terms of structures that would be protected by the conceptual storm surge barrier options. At Newtown Creek, both barrier options considered protected the same subset of structures. The Newtown economic flood risk study area included 2,048 structures.

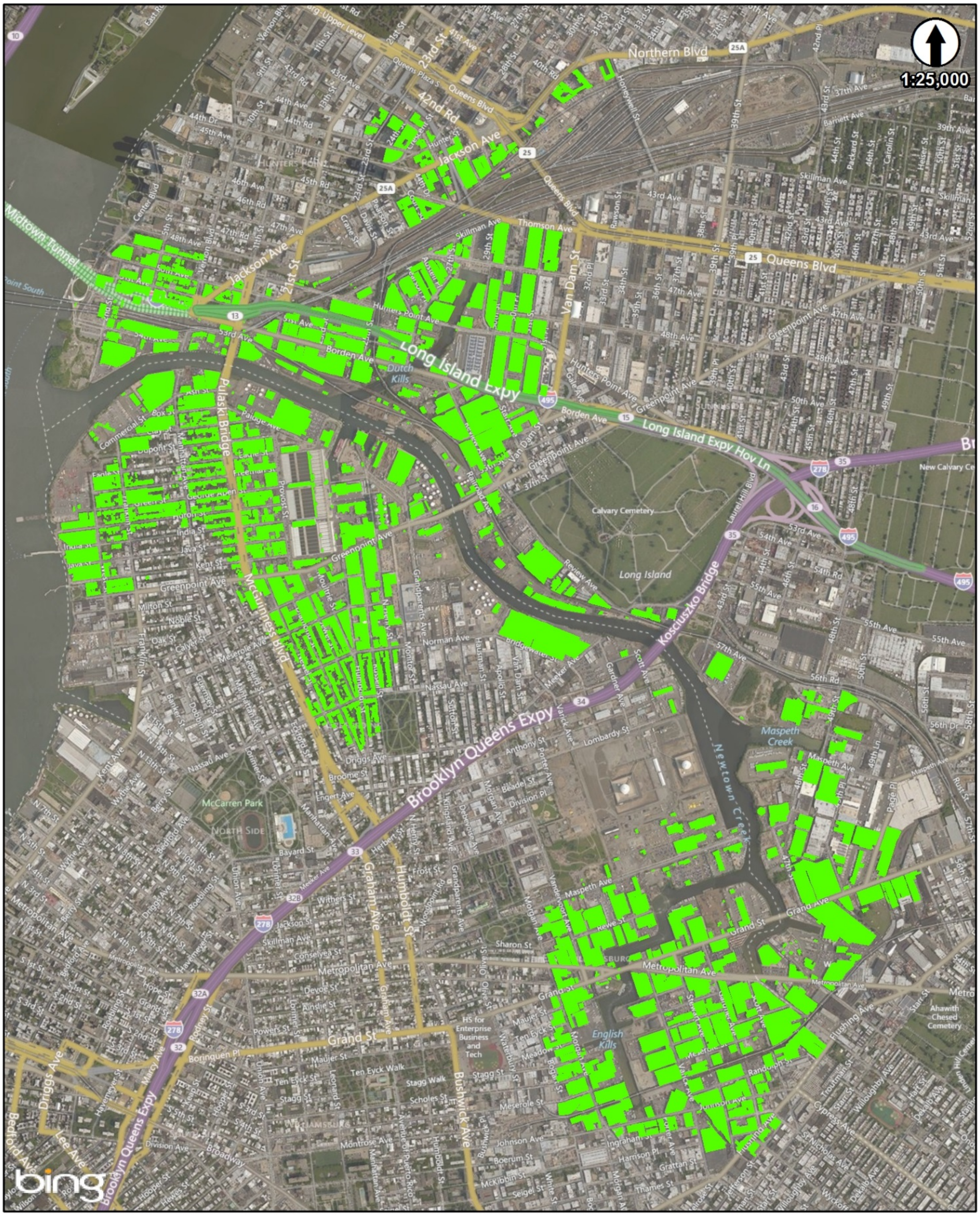


FIGURE 10-1
Newtown Creek Economic Flood Risk Study Area

10.1.1.2 Methodology

Damage estimates were calculated using Version 1.4 of the USACE-certified Hydrologic Engineering Center Flood Damage Assessment model (USACE, 2015) (HEC-FDA). HEC-FDA integrates available hydrologic, hydraulic, geotechnical, and economic relationships to estimate flood risk in terms of expected annual damage (EAD). EAD is a measure of average annual impact, accounting for the risk of inundation across the full frequency curve, rather than for a single event.

Figure 10-2 illustrates the primary relationships that HEC-FDA uses in a typical application to generate estimates of EAD. As shown in the top left quadrant, hydraulic inputs are used to define the flow-exceedance relationship with uncertainty. The top right quadrant illustrates a rating curve that is defined by hydraulic modeling, and allows exceedance-flow and stage-flow to be related. As shown in the lower left quadrant, HEC-FDA combines hydraulic and economic inputs to define the stage-damage relationship. Finally, the lower right quadrant shows that these linked hydraulic and economic relationships allow computation of an exceedance-damage function. Integration of this function results in the EAD over the period of analysis.

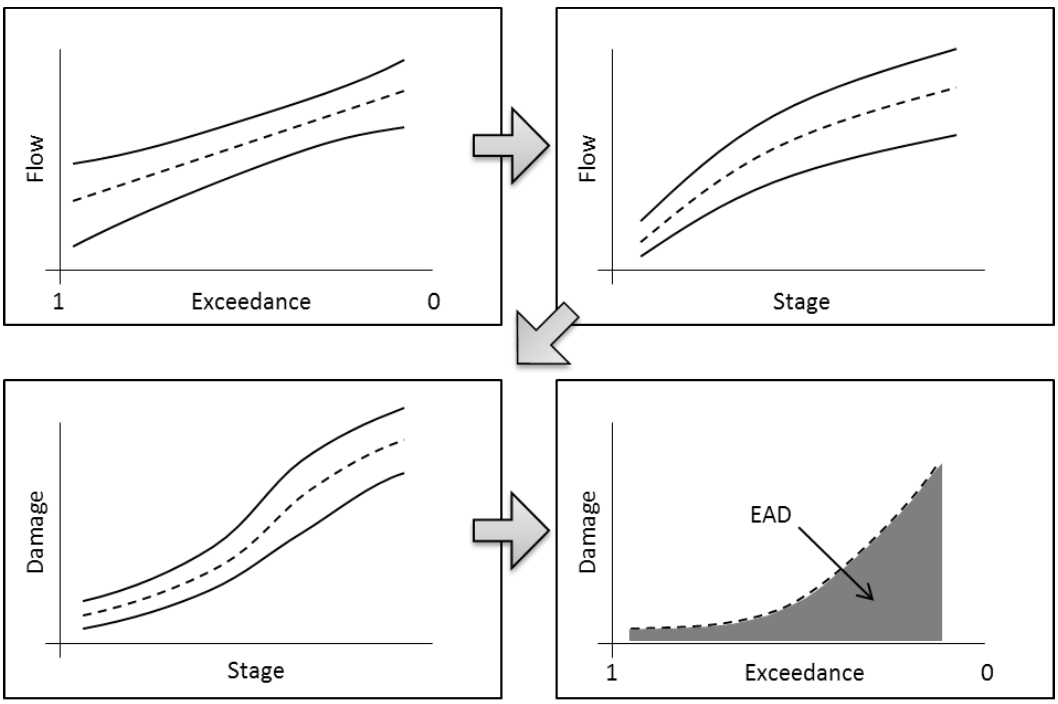


FIGURE 10-2
Summary of HEC-FDA Flood Risk Analysis Framework

As applied for this study, a separate HEC-FDA model was set up that corresponded to each of the economic flood risk study areas analyzed. Because the study area for each model was defined by the structures that would be completely protected by a project, estimated flood damages in the without-project condition (WOPC) were equivalent to the potential flood risk reduction benefits of project implementation. While simplified compared to a typical USACE feasibility study that would have a single study area and assess expected flood risk, flood risk reduction benefits, and residual damages in that defined area, this approach was considered appropriate to provide a preliminary assessment of flood risk in the study areas and to assess the potential for positive net benefits of a flood risk management option. For Newtown Creek, one model run was done to estimate damages (potential benefits) which applied to both Option 1 and Option 2—the line of defense with either the 2nd Street or Manhattan Avenue in-water barrier location.

The following subsections summarize the hydrodynamic and economic input parameters to the HEC-FDA flood risk modeling methodology as applied for this study.

10.1.1.3 Hydrodynamic Data

The hydrodynamic modeling team developed a WOPC inundation model using a two-dimensional (2D) inundation model that generated a set of floodplain depth grids for five modeled return-period events (the 1.5-, 10-, 50-, 100-, and 500-year events). Using a geographic information system (GIS), the average depth of flooding within the footprint of each structure was calculated for each return period event. The HEC-FDA model relies on the inundation modeling results and user specification of the uncertainty in the relationships between frequency and stage, as described below.

HEC-FDA requires input of depth-grid profiles for eight return period flood events. Typically, the eight events include the 2-, 5-, 10-, 25-, 50-, 100-, 250, and 500-year events. As noted above, the hydrodynamic modeling team provided results for five events, substituting the 1.5-year event for the 2-year event. The remaining three events (5-, 25-, and 250-year) were interpolated linearly. By using linear interpolation, the geographic extent of flooding does not change from the more-frequent to the less-frequent event, only the depth of flooding at each structure changes.

During development of an HEC-FDA model, "reaches" must be defined. A reach is an area in the floodplain where structures experience similar flood characteristics or are similarly affected by the proposed alternatives. Each reach is then assigned a common reference point along the channel (index location) for the purpose of aggregating and reporting damages with consistent geographic extent for both the without-project and with-project conditions. In order to limit model complexity, only the minimum number of reaches are defined. Because the alternatives were assumed to provide 100 percent protection to any structure upstream and there was minimal elevation grade change throughout either waterbody, only one reach was needed in HEC-FDA for each study area.

As noted above, HEC-FDA requires an index location be specified for each reach. An index location is a channel cross-section for which a frequency-stage relationship can be defined. HEC-FDA uses the index location to aggregate damages for the entire reach. The hydrodynamic modeling team provided frequency-stage information for a number of locations. Due to the relatively flat nature of the channel at Newtown, the choice of index location made little difference in the computed results. At Newtown, the index was set just upstream of the Dutch Kills confluence.

HEC-FDA allows for the inclusion of uncertainty in the relationship between recurrence interval and depth at the index location in terms of either discharge or stage. Because the hydrodynamic modeling team provided depth-grids for specific return period events, rather than for specific discharges, this function was defined in terms of stage at each of the eight specific recurrence interval events using HEC-FDA's built-in order statistics tool. Because the exceedance-probability function was entered based on stage, no additional definition of the relationship between discharge and stage was required.

HEC-FDA computed confidence limit curves around the exceedance-stage relationship based upon the period of record at the Battery gage (93 years). **Figure 10-3** shows an example exceedance-stage relationship with uncertainty for Newtown Creek's WOPC.

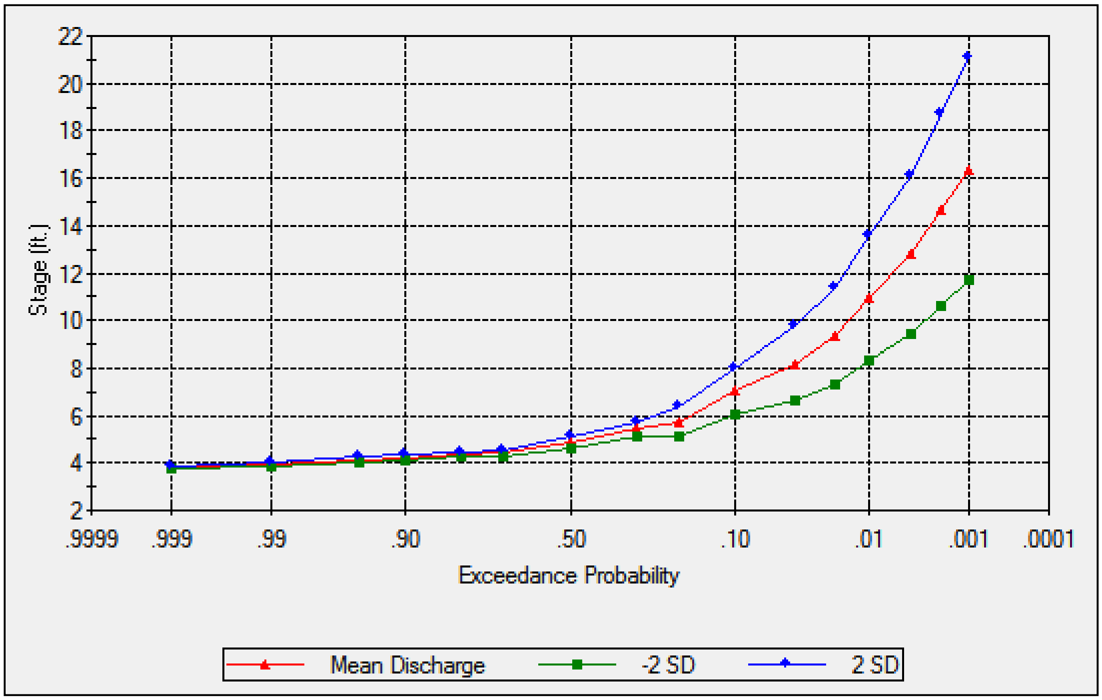


FIGURE 10-3
Example Exceedance-Stage Function with Uncertainty

HEC-FDA includes a levee component where the height of a levee (top-of-bank) and its geotechnical fragility curve may be entered for each reach. HEC-FDA assumes that the levee is located at the index location of the reach and controls failure or overtopping of the levee for the entire reach at that location. For the Newtown Creek model, the HEC-FDA levee feature was used to control the initiation of flooding through the top-of-bank parameter, but no geotechnical risk was included. Per coordination with the hydrodynamic modeling team, it was assumed that no damages occur for the provided 1.5-year return-period event depth grid. As such, the top of bank at the index location for each model was set to the channel water surface elevation corresponding to the 1.5-year return-period event. This parameter prevented HEC-FDA from initiating damages until after the banks are expected to overtop.

10.1.1.4 Economic Data

The economics component of HEC-FDA is where the user specifies and describes the inventory at risk of damage from flooding. For this study, the inventory included structures and building contents, and the related damage categories of cleanup cost, emergency assistance cost, and debris removal. The following subsections describe development of the economic data for input into HEC-FDA.

10.1.1.5 Inventory and Valuation

The structure inventory formed the basis for the primary damage category in the models. Public data sets for building outlines and lot-level assessor's information (New York City's Primary Land Use Tax Lot Output database 14v2) were combined into an inventory of structures within the provided 500-year inundation extent. GIS and online mapping tools were used to sample 5 percent of structures within a "sample zone" identified based upon preliminary alignment information available at that point in the study (April 2015). The sample included collection of additional characteristics necessary for estimation of depreciated replacement value and an adjustment of the first floor elevation above grade.

Following data collection and post-processing, estimation of structure depreciated replacement value (DRV) was completed using the Marshall & Swift Valuation Service (M&S) at a third quarter fiscal year 2015 price level.

The M&S process involves assignment of an M&S structure type, and selection of a replacement cost per square foot within that M&S type based on the construction material (i.e., masonry, wood, etc.) and the quality of the construction. Square footage is used in conjunction with the unit cost to estimate replacement cost. Next, depreciation is estimated, converted to a multiplier, and the replacement cost is adjusted to account for depreciation. M&S also includes price adjustments for locale.

For this analysis, M&S was used to estimate depreciated replacement value (DRV) of the sampled inventory. Structures in the sample were categorized as either Commercial, Industrial, Public, Mixed, or Residential. According to these classifications, typical unit costs were derived and applied to the un-sampled inventory. The M&S local adjustment factor for Kings and Queens counties is approximately 1.4. Depreciation was based upon the observations of the sampled structures and applied according to the five structure categories. Content value was estimated using Content-to-Structure-Value ratios from the FEMA's Hazards United States (HAZUS) model. Typically, residential occupancy types have a ratio of about 50 percent, and non-residential occupancy types had a ratio of 100 to 150 percent. Uncertainty in DRV was estimated for each of the five building categories based on the sampled buildings and variation in M&S unit costs by construction type and quality used in the valuation analysis. Uncertainty in the first floor elevation of each building was set at a typical value for all buildings: 0.5 feet. This parameter would likely decrease with a more complete survey that would occur in a feasibility-level analysis.

10.1.1.6 Depth-to-Percent Damage Functions

HEC-FDA relies upon depth-to-percent damage functions (DDFs) to tabulate impacts to the economic inventory. This is accomplished by linking the economic inventory to a location in the floodplain via the water surface profile grid identification numbers. This reconnaissance-level analysis relied on published and available DDFs.

DDFs are published by the USACE, as well as by FEMA through their Hazards U.S. HAZUS model. The DDFs used in HAZUS are typically sourced from previous USACE studies or data published by the Flood Insurance Administration. An additional source of depth damage functions for this study came from the USACE's recent report, the North Atlantic Coast Comprehensive Study (NACCS) (USACE, 2015).

HEC-FDA allows for specification of uncertainty about the DDF as either a triangular or normal distribution. In this analysis, uncertainty about the DDFs was included only if the source curve included uncertainty. HAZUS DDFs do not include uncertainty, and none was estimated. USACE functions for residential structures and contents used a standard deviation of percent damage. Single family residential DDFs were borrowed from the 2015 NACCS report. Most other DDFs were borrowed from those included in FEMA's HAZUS model. In total, there were 35 DDFs included in the model to account for a variety to structure occupancy types in the study areas.

10.1.1.7 Associated Damage Categories

Associated with inundation damage to structures and building contents are flood cleanup costs, emergency costs, and structure-related debris removal costs. Incorporation of these damage categories into the economic flood risk analysis for this study is described in the following subsections.

- *Cleanup:* Cleanup costs occur in the aftermath of flood inundation where interior debris, sediment, and moisture must be dealt with before residences and businesses can return to normal operation. This cleanup damage category is related to cleaning costs for the interior of structures. In general, the cost is based on returning the interior of the structure to a dry and normal condition (removing sediment, vacuuming water, drying). Cleanup costs were applied on a dollar-per-first-floor-square-foot basis to the residential, commercial, public, and mixed-use building inventory. Cleanup costs were not applied to industrial buildings under the assumption that industrial buildings do not require the same level of cleanup and often do not employ third-party specialized services. A cleanup cost per square foot of $3.65, with a standard deviation of $0.94, was applied to all relevant structure types based on approved costs in prior USACE studies (USACE, 2009).

- *Emergency costs:* Emergency assistance costs following a flood are estimated based on published FEMA assistance payments. FEMA public assistance payments can take the form of housing assistance, other needs assistance, or public assistance. Housing assistance includes things like temporary disaster housing grants, rental reimbursement, and temporary repair assistance. Other needs assistance covers disaster-related medical, dental, funeral, transportation, or other expenses not covered by insurance. Finally, public assistance covers the repair, replacement, or restoration of disaster-damaged public-owned facilities or facilities of certain private nonprofits. A previous USACE analysis of FEMA Disaster Expenditures across the nation resulted in an estimate of combined residential and public assistance payments of about $9,800 per flooded residential structure with a standard deviation of about 40 percent (USACE, 2009). This value was used to setup a damage function for residential structures, which was triggered at 1 foot of inundation.
- *Debris Removal:* Debris disposal can be a significant issue following most natural disasters, including floods. This analysis used FEMA's HAZUS model to inform estimates of exterior debris-removal cost. The HAZUS flood debris model focuses on building-related debris from structural components and finishes, and does not address contents removal or additional debris loads, such as vegetation and sediment. HAZUS uses a default data set based on the 2010 Census to estimate quantity and type of debris. The model was run for each of the five hydrodynamic model depth grids to generate an estimate of total debris tonnage by event. These tonnages were converted to an estimate of debris removal cost based on a typical mass-to-volume ratio of 4 cubic yards per ton (FEMA, 2010) and a unit cost for removal of $100 per cubic yard (Lipton, 2013). These results were then translated into a stage-damage function for insertion into HEC-FDA.

  To illustrate the estimated debris load, HAZUS estimated 4,400 tons of debris for the 100-year event, and 22,400 tons for the 500-year event, or removal costs of approximately $1.8 million and $9 million, respectively, at Newtown Creek.
- *Vehicle Damage:* Vehicles present in the study area during a flood would be susceptible to direct damage from floodwaters. To estimate these direct vehicle damages, HAZUS data were used to develop an inventory of vehicles and input a depth damage function into HEC-FDA. HAZUS data sets included an estimate of count and value of vehicles per Census block for night and day, and for three types of vehicles (cars, light trucks, and heavy trucks).

  For this analysis, the night and day counts were averaged, and the total vehicle value was scaled down in proportion to the ratio of inundation extent (floodplain area) to the total area of intersecting Census blocks. This scaling accounted for the fact that the HAZUS data set included the value of all vehicles within the Census block, and this analysis was only concerned with the value of vehicles within the inundated area. Next, total vehicle value by type was converted to a vehicle value per structure in the FDA structure inventory. This simplified approach allowed the depths reported at each structure to be applied to vehicles in the floodplain. The HAZUS depth damage curve for each vehicle type was inserted into FDA and the estimated vehicle value at each structure was entered as well.

  The total estimated value of vehicles associated with structures in the Newtown inventory was $141 million for cars, $97.8 million for light trucks, and $112.6 million for heavy trucks.

10.1.2 Project NED Benefits

After populating all necessary data components of the three HEC-FDA models, as outlined above, each was run to calculate EAD. The HEC-FDA process applies Monte Carlo simulation, an iterative statistical sampling procedure that allows estimation of the expected value of damages based on the supplied input parameters and their uncertainty. For each iteration of the model, the Monte Carlo process selects a different set of values for each input variable from within the range of uncertainty, and repeats this process until a sufficient number of iterations have been completed that the EAD estimate ceases to change significantly with each additional iteration. For the Newtown Creek HEC-FDA model, 10,000 iterations was sufficient to define the EAD.

The conversion of EAD to present value (PV) was based on the fiscal year 2015 Federal Interest Rate for Federal Water Resources Project Studies of 3.375 percent (USACE, 2014) and a 50-year period of analysis, which is typical for USACE analyses. The following sections summarize the results.

10.1.2.1 Key Assumptions

The bullets below summarize key assumptions in the HEC-FDA analyses for the Canal.

- The study area for each (and each associated HEC-FDA model) includes only those structures that would be protected by the storm surge barrier alternatives. The EAD reported by HEC-FDA for the WOPC is therefore equivalent to the risk reduction benefits associated with a given alternative.
- Because the area is already built out, the analysis assumed a constant structure stock throughout the period of analysis, and did not consider changes in building stock due to redevelopment within the 50-year period.
- Only the WOPC hydrodynamic modeling results are used in HEC-FDA because the alternatives are assumed to provide full protection (100 percent risk reduction) and there is no residual risk to the structure inventory in the model.

10.1.2.2 Expected Annual Damages and Potential Benefits

The following subsection presents the results for the Newtown Creek HEC-FDA model. The tables and text will refer to the results as EAD, though as described previously, these are equivalent to the benefits (damages reduced) for each alternative.

Table 10-1 presents the total number of structures in the Newtown Creek Protected Area (study area) and their estimated total value (structure DRV plus content value). It also presents EAD as both an annualized and a present value. The Newtown model estimated an EAD of $16.3 million and a PV of $391 million.

TABLE 10-1
Newtown Creek Analysis Summary

Alternative	Structures Protected	Total Value ($)	EAD	
			Annualized $	Present Value $
Barrier Options 1 and 2	2,546	$4,074,292,000	$16,316,300	$391,492,600

Table 10-2 presents a more detailed overview of the Newtown structure inventory, including DRV and content value by structure category. The Newtown inventory includes 2,546 structures with a total value of more than $4 billion.

TABLE 10-2
Newtown Structure Inventory Summary

Type	Count	Structure DRV ($)	Content Value ($)	TOTAL ($)
Commercial	190	$209,030,000	$193,292,000	$402,321,000
Industrial	871	$1,160,359,000	$1,225,779,000	$2,386,138,000
Mixed	195	$121,351,000	$121,351,000	$242,702,000
Public	124	$229,055,000	$242,932,000	$471,987,000
Residential	1,166	$380,762,000	$190,381,000	$571,143,000
TOTAL	**2,546**	**$2,100,557,000**	**$1,973,735,000**	**$4,074,292,000**

Table 10-3 presents impacts broken out by damage category, in terms of EAD and PV. The industrial structure category makes up the large majority of the damages, followed by commercial, then residential structures. Due to the high value of structures in the study area, the structure-related cleanup and emergency costs constitute a small percentage of total estimated damage.

TABLE 10-3
Newtown Impacts by Damage Category

Damage Category	EAD ($)	PV ($)	% of Total
Industrial	$9,556,000	$229,285,200	58.6%
Vehicle Damage	$1,812,400	$43,486,500	11.1%
Commercial	$1,659,200	$39,809,500	10.2%
Residential	$1,169,600	$28,062,300	7.2%
Public	$825,400	$19,804,100	5.1%
Mixed-Use	$977,400	$23,452,600	6.0%
Debris Removal	$122,700	$2,943,600	0.8%
Commercial - Cleanup	$51,400	$1,232,300	0.3%
Emergency Costs	$44,800	$1,074,000	0.3%
Residential - Cleanup	$36,800	$883,900	0.2%
Public - Cleanup	$41,200	$989,500	0.3%
Mixed-Use - Cleanup	$19,600	$469,100	0.1%
TOTAL	**$16,316,300**	**$391,492,600**	100.0%

Table 10-4 presents estimated structure and contents damages by event for the five events included in the hydrodynamic model. Note that these are event-specific damages, not EAD. The column headings for each event also note the average depth of flooding for structures that were damaged in the event. Damages at the 100-year event were estimated at $270 million, and damages at the 500-year event were estimated at $922 million. Average depth of flooding for damaged structures was 0.6 feet at the 10-year event and 2.5 feet at the 500-year event.

TABLE 10-4
Newtown Structure and Content Damage by Event

Damage Category	1.5-year		10-year		50-year		100-year		500-year	
	Count	Damage ($1,000)	Count	Damage ($1,000)	Count	Damage ($1,000)	Count	Damage ($1,000)	Count	Damage ($1,000)
Commercial	0	$0	15	$2,759	34	$14,451	77	$26,975	171	$108,692
Commercial - Cleanup	0	$0	5	$68	23	$447	47	$773	150	$3,772
Individual	0	$0	59	$13,485	210	$92,441	375	$184,670	811	$550,984
Mixed-use	0	$0	1	$1,943	6	$6,555	59	$15,580	167	$67,291
Mixed-use - Cleanup	0	$0	1	$40	3	$120	26	$212	128	$1,334
Public	0	$0	4	$33	26	$4,548	41	$16,999	112	$75,227
Public - Cleanup	0	$0	2	$1	19	$121	35	$980	97	$4,156
Residential	0	$0	3	$1,145	36	$3,114	459	$22,990	1069	$100,744
Residential - Cleanup	0	$0	1	$26	2	$31	59	$367	638	$3,784

TABLE 10-4
Newtown Structure and Content Damage by Event

Damage Category	1.5-year		10-year		50-year		100-year		500-year	
	Count	Damage ($1,000)	Count	Damage ($1,000)	Count	Damage ($1,000)	Count	Damage ($1,000)	Count	Damage ($1,000)
Residential - Emg. Costs	0	$0	1	$10	2	$19	59	$432	638	$5,806
TOTAL*	**0**	**$0**	**82**	**$19,510**	**312**	**$121,848**	**1,011**	**$269,978**	**2,330**	**$921,790**

Note:

The total count for damaged structures may be less than the total structures reported in previous tables. This is because some structures may not have experienced sufficient flood depth to initiate damage even though they were within the geographic extent of inundation.

10.1.3 Project Costs

Conceptual project costs were developed for each of the barrier options. The costs include in-water barrier construction costs (including a base allocation for stormwater pump station), upland defense construction costs, associated contingencies, and operations and maintenance (O&M) costs over 50 years, and at this conceptual stage convey a 15 to 30 percent level of accuracy. Costs were based upon benchmarking to similar-sized precedent projects and used industry unit cost factors as a starting point that were reviewed checked for sensibility to the New York City infrastructure construction market. Discussion of the conceptual capital cost development, assumptions, contingencies, risks, and uncertainties was presented in Section 7 and 8 and Appendix L. Costs were developed at fiscal year 2015 price level and use the same 3.375 percent USACE interest rate as used in the benefit calculations. Interest during construction (IDC) was included based on an assumed construction period of 24 months for all options. Construction spending was assumed to occur at a constant rate over the period. Costs are presented in **Table 10-5**. Detailed cost build-ups, including assumptions and unit cost factors for capital and O&M costs are included in Appendix L.

TABLE 10-5
Newtown Creek Options Cost Summary

Cost Component	2nd Street Shoreline	2nd Street Site Integration	Manhattan Avenue Shoreline	Manhattan Avenue Site Integration
In-Water Barrier	$121,570,401	$121,570,401	$89,671,944	$89,671,944
Upland Defenses	$107,512,114	$61,100,925	$152,337,071	$105,925,882
O&M: Upland	$3,275,878	$3,621,222	$4,126,644	$4,471,988
O&M: In-Water	$16,077,489	$16,077,489	$16,355,407	$16,355,407
Constr. Period (mo)	24	24	24	24
IDC (3.375%)	$7,447,591	$5,938,739	$7,867,838	$6,358,986
Total	$255,883,472	$208,308,776	$270,358,904	$222,784,208

10.1.4 Net NED Benefits and Benefit-Cost Ratio

For USACE planning studies, the NED plan is considered the one that maximizes positive net benefits (benefits less costs) and is typically the plan that the USACE would recommend for implementation. The NED plan is not necessarily the same as the plan that has the highest benefit-to-cost ratio. This approach reflects the federal objective, which seeks to maximize contribution to the net value of the national output of goods and services.

Table 10-6 presents the net benefits for each of the design options at Newtown Creek. At Newtown Creek, the *2nd Street Site Integration* option provides the greatest net benefits.

For USACE planning projects, the benefit-cost ratio (BCR) typically must exceed 1.0 in order to be eligible for project authorization. Additionally, the BCR of a project can influence construction budget prioritization at the national level. **Table 10-6** presents the BCR resulting from the analysis for each option.

As shown in the table, all four of the Newtown Creek options resulted in a BCR above 1.0, with the highest BCR associated with the *2nd Street Site Integration* option. This option also had the greatest net benefits.

The following section presents sensitivity analysis considerations related to reduction in uncertainty in the results for future analyses

TABLE 10-6
Newtown Creek BCR Analysis Summary

Newtown Options	Cost ($PV)	Benefits ($PV)	Net Benefits ($PV)	BCR
2nd Street Site Integration	$208,309,000	$391,492,600	$183,183,824	1.88
Manhattan Avenue Site Integration	$222,784,000	$391,492,600	$168,708,392	1.76
2nd Street Shoreline	$255,883,000	$391,492,600	$135,609,128	1.53
Manhattan Avenue Shoreline	$270,359,000	$391,492,600	$121,133,696	1.45

10.1.5 Sensitivity and Uncertainty

On the benefits side of the analysis, the study team identified structure valuation as an area where more detailed analysis during a feasibility study would reduce uncertainty in the benefits analysis. Even including the M&S regional adjustment factor of approximately 1.4, M&S had substantially lower typical unit costs for construction as compared to preliminary construction cost market research in the vicinity of the project area. Unit costs for construction are the basis for estimating structure replacement value and, subsequently, depreciated replacement value.

As an example of this underestimation, the M&S replacement cost for a “white box” industrial building, even after incorporating a local adjustment factor for the City, is just $67 per square foot. Market research with local experts for actual projects in the City yielded estimates of $150 to $180 per square foot. Similarly, while the M&S valuation for residential development is under $120 per square foot, local developers estimate actual hard and soft costs at around $275, and a cost estimator for a high-end development suggested more than $335. The local market research identified that construction unit costs in the vicinity of the project area averaged about twice as large as the costs used in this analysis (average adjustment factor of 2.2 for Industrial and Residential properties).

For the purposes of a brief sensitivity analysis, the benefits associated with structure and content damages were approximately doubled (multiplier of 2.2). **Table 10-7** presents the results of this sensitivity.

TABLE 10-7
Newtown Creek BCR Analysis Summary with Variation in Structure Valuation Methodology

Newtown Options	M&S BCR	Sensitivity BCR
2nd Street Site Integration	1.88	3.84
Manhattan Avenue Site Integration	1.76	3.59
2nd Street Shoreline	1.53	3.13
Manhattan Avenue Shoreline	1.45	2.96

On the cost side, as highlighted in Section 7, construction cost escalation could arise due to uncertainty around barrier width and depth, upstream storage capacity and surface water pumping requirements, service diversions, development parcel integration, land acquisition and potential legal challenges, any upland environmental remediation that might be necessitated, and for a Manhattan Avenue barrier location, potential G Train subway interface and design integration.

Additionally, a number of other items were identified for more detailed consideration in a future analysis or feasibility study, including:

- Additional consideration of the allocation of costs for surface water flood mitigation requirements (interior drainage, pumps, etc.), assumptions as to without-project conditions for local flooding, and the effects of these issues on project benefits.
- A more detailed evaluation of optimal level of protection for in-water and upland defense structures and the implications of varied barrier system elevations and configurations on project benefits.
- Refinement of debris and cleanup cost damage categories during a feasibility study through site-specific cost and damage estimates, as well as inclusion of additional damage categories that may require a separate modeling effort, such as local and regional traffic impacts.

10.2 Expanded Project Benefits

Beyond the avoided damages calculated in the preceding section, there would be numerous benefits resulting from the construction of a storm surge barrier system to protect the areas surrounding Newtown Creek. Evaluating these benefits is necessary in order to obtain funding, and each funding source recognizes specific types of benefits and often requires quantification of these benefits according to specific methodologies. While the USACE, which is primarily concerned with the national economy, will only fund a project if the value of the avoided damages to structure and contents is greater than the cost of building and maintaining the infrastructure, other funders, like the United States Department of Housing and Urban Development, allow for more social and environmental factors to be weighed against costs. City and community leaders may take a more expansive view of benefits in assessing a project's worth. Some of these expanded project benefits are quantified or described here, including those that may warrant further investigation as part of a future feasibility study. For purposes of translation, where applicable, these benefits are related back to the corresponding USACE planning account under which they would be grouped.

10.2.1 Protected Jobs and Businesses (RED)

A Newtown Creek Storm Surge Barrier can add flood protection to the measures the City is taking to ensure the Creek's viability as an industrial waterway. Over the past decades, the City has prioritized the preservation of industrial jobs, businesses, and land. From 2002 to 2013, the City spent more than $880 million from its expense and capital budgets in support of industrial sectors, and NYCEDC, Industrial Development Agency, and Brooklyn Navy Yard Corporation all have major programs to support these businesses[1]. In November 2015, City Hall and City Council renewed their commitment to industrial businesses as they announced the $115 million Industrial Action Plan. Like other industrial areas, Newtown Creek is home to businesses that are critical to the continued operation of the local economy and jobs that are accessible to New Yorkers who typically face barriers to employment. Unlike others, however, Newtown Creek possesses unique physical characteristics and plans for infrastructure upgrades that may increase the viability of industrial expansion.

Industrial sectors are important sources of employment opportunities for many New Yorkers, and businesses in the Protected Area[2] employ more than 8,500 people in these sectors.[3] In 2014, a report by the Independent Budget Office[4] found that industrial firms are more likely than others to hire employees

[1] NYC Independent Budget Office. 2014. "City Support for the Industrial Sector."

[2] Unless otherwise noted, "protected Area" includes all properties that would be inundated during a 500-year flood event without the project, but would not be inundated with the project, as identified through hydrodynamic modeling of the Second Street Shoreline barrier alignment.

[3] Unless otherwise noted, "industrial sectors" includes construction, manufacturing, transportation and warehousing, utilities, and wholesale trade.

[4] NYC Independent Budget Office. 2014. "A Profile of New York City's Industrial Workforce."

without college degrees, and a report by the City Council Land Use Division[5] found that more than 80 percent of employees in industrial sectors are people of color and more than 60 percent are foreign-born. While the Independent Budget Office report did find that industrial workers without college educations earn more than their counterparts in non-industrial sectors, this difference comes largely from the construction sector. Within the protected area, average earnings in industrial and non-industrial sectors are roughly the same at $69,000, but average industrial earnings compare favorably with those of other sectors with high proportions of workers without college degrees: retail trade, with average earnings of $45,000, and accommodation and food services, with average earnings of $51,000.

As one of New York City's few inland waterways, Newtown Creek is a unique and valuable asset for current businesses, and has the potential to host more industrial activity in the future. Recognizing the value of a working waterfront, the New York City Waterfront Revitalization Program establishes eight Significant Maritime and Industrial Areas (SMIAs) and reviews discretionary City actions within these areas for consistency with goals of retention of waterfront industrial activity. The Newtown Creek SMIA is the largest in terms of both employment and geography[6]. Its seven-mile shoreline represents approximately 30 percent of all SMIA shoreline and reaches deep into Brooklyn and Queens. Vessels enter the Creek more than 200 times per month,[7] using water-borne freight as an efficient, clean, and safe alternative to trucking.

Although the Newtown Creek area is home to many industrial businesses, significant improvements, including flood protection, are necessary for it to realize its full potential. While many freight-bearing vessels do enter the canal, fewer than half travel beyond its intersection with Whale Creek to the further reaches of Newtown Creek. Of the dozens of parcels abutting the Creek, there are 35 maritime facilities, but only 12 are currently active.[8] As recognized in Vision 2020,[9] New York City's comprehensive waterfront plan, shallow canal depth and poor quality bulkheads currently limit maritime activity. The plan cited the need for dredging and bulkhead repair in order to reactivate the Creek for maritime uses; both of these improvements will soon be realized as part of Superfund remediation. In addition to the potential for increased water-borne freight, the Creek's proximity to the Long Island and Brooklyn-Queens Expressways, as well as the Bushwick and Montauk Branches of the Long Island Railroad, suggest an opportunity for intermodal freight transfer. In addition to Creek-related improvements, local businesses also cite inadequate energy and telecommunications infrastructure as obstacles to growth.[10]

While dredging, bulkhead repair, and other infrastructure improvements may spur new industrial and maritime activity along Newtown Creek, they will not address the construction, insurance, and operating costs of businesses operating in this flood-prone area. Industrial businesses face financial challenges throughout the city, even with City support. Therefore, if the City seeks an industrial revitalization along this active but underperforming waterfront, a storm surge barrier can be another investment to alleviate the challenges faced by businesses in these important sectors.

Across all sectors, the 1,630 businesses and 19,000 employees in the Protected Area generate more than $4 billion in direct annual economic output and earn nearly $1.3 billion in compensation. Applying economic multipliers, this direct economic activity generates nearly 30,000 jobs, $2.1 billion in earnings, and $6.3 billion to total output (**Table 10-8**).

[5] NYC Council Land Use Division. 2014. "Engines of Opportunity."

[6] BOA Partners. 2012. "Newtown Creek Brownfield Opportunity Area Step 2 Nomination Report."

[7] Data collected by Moffat & Nichols for an ongoing bulkhead-raising study.

[8] BOA Partners. 2012. "Newtown Creek Brownfield Opportunity Area Step 2 Nomination Report."

[9] NYC Department of City Planning. 2011. "Vision 2020."

[10] BOA Partners. 2012. "Newtown Creek Brownfield Opportunity Area Step 2 Nomination Report."

TABLE 10-8
Economic Impact of Businesses in Protected Area

	Employees (FTE)	Employee Earnings	Output
Direct	18,900	$1,299 M	$4,034 M
Indirect	5,900	$457 M	$1,272 M
Induced	5,100	$332 M	$950 M
Total	**29,800**	**$2,087 M**	**$6,256 M**
Multiplier	*1.58*	*1.61*	*1.55*

Notes:
FTE = full-time equivalent
M = million

10.2.2 Protected Existing Populations, Housing and Buildings (OSE)

For the 100-year flood event, modeling results show that either Newtown Creek barrier option would protect roughly 740 acres, home to about 7,500 people. Relative to New York City overall, this population has a smaller proportion of both children (11 percent are under age 18, compared to 21 percent across the city) and seniors (7 percent older than age 65 compared to 12 percent across the city). The population also has a smaller percentage of racial and ethnic minorities, as 69 percent are white non-Hispanic, compared to just 33 percent of the city. There are relatively fewer low- and moderate-income residents in the area compared to the city overall, with 20 percent and 28 percent of families earning below $40,000 and $60,000 a year respectively, compared to 36 percent and 51 percent for the city as a whole. With more than 19 million square feet (ft^2) of built area, the area is 45 percent more densely built than the general New York City waterfront, as measured by the 2007 FIRM 100-year flood zone.

For the more extreme 500-year flood event, modeling results show that a much larger area of 1,267 acres would be protected. This area is home to 15,600 residents, with similar age, income, and racial/ethnic characteristics as those protected from the 100-year event. The area also contains more than 37 million ft^2 of built area.

10.2.3 Protected Growing Communities and Future Development (OSE)

The protected area includes portions of the Hunters Point and Greenpoint residential neighborhoods, which are home to more than 15,600 people. Most residents live in older buildings that are likely susceptible to flood damage: more than 85 percent of buildings and 65 percent of residential units were built before 1961, when the adoption of the New York City Zoning Resolution led to buildings more resistant to flood damage.

Beyond the current population, the area is poised for rapid population growth. Both Hunters Point and Greenpoint have experienced major residential rezonings in the past decade, and the development environment has been strong, with more than 2,800 new residential units built from 2004 to 2014 in the Protected Area. The area still contains more than 38 million ft^2 of unused residential development rights on soft sites[11]. If fully built out and occupied at the same population density of the existing housing stock, this could mean a fourfold increase in population to more than 77,000 people. Most of this growth would occur within the 100-year flood zone, expanding its population from fewer than 8,000 today to more than 60,000 at full build-out.

Although new buildings will be built to flood-resistant standards and elevated one foot above the 100-year flood elevation, their residents and owners would still see the benefits of a storm surge barrier. First, a barrier built to a 17-foot elevation would provide a higher level of protection than the minimum required by the New York City Building Code (see below). Next, a barrier would allow residents to remain in place during a storm without fear of adjacent streets being flooded. Finally, a barrier would ensure the continued

[11] Soft sites are defined as lots where the built floor area is less than 25 percent of the allowable residential floor area.

operation of entire neighborhoods during storms. Many important neighborhood assets, such as retail along Manhattan Avenue and Franklin Street, face significant flood risk, and protecting them would benefit neighborhood residents regardless of whether their own buildings are exposed to damage.

10.2.4 Protection beyond Current Standards (OSE)

While Appendix G of the New York City Building Code requires flood-resistant construction for new or substantially improved buildings in the 100-year flood zone, the storm surge barrier would offer extra flood protection since it incorporates additional freeboard and an adjustment for sea level rise. The 2015 New York City Panel on Climate Change report projects that, due to climate change, the 100-year flood in the 2050s may reach an elevation up to 2.5 feet higher than today's 100-year flood. A building built to code today would flood under these circumstances, but a storm surge barrier built to the 17-foot design elevation would still offer protection. Similarly, today's standards do not protect against the less frequent but more severe 500-year flood event, with a 15-foot elevation, while the flood barrier would.

While the avoided damages modeling results do take into account the protection of existing structures from these lower-frequency but higher-intensity events, they do not include any avoided damages to structures that are not yet built. This benefit of a higher level of protection would also apply to infrastructure assets, such as the Queens-Midtown Tunnel and the Newtown Creek Wastewater Treatment Plant.

10.2.5 Reduced Flood Insurance Costs (RED)

In New York City, flood insurance is available both through the public National Flood Insurance Program (NFIP) and through private insurers. NFIP premiums are based on FIRMs, which are produced by FEMA and are intended to reflect the risk of flooding. Properties within an NFIP Community—a community that has adopted certain land use and construction standards to prevent flood damage—are eligible for NFIP coverage, and all properties with a federally-backed mortgage within the FEMA Special Flood Hazard Area (SFHA); the area inundated by a flood having a 1 percent annual chance of being equaled or exceeded) are required to carry NFIP policies. Assuming the Newtown Creek storm surge barrier is certified by FEMA, the FIRMs would be updated to reflect the reduced risk of flooding within the zone of protection. This would mean that a) no properties within the zone of protection would be required to carry flood insurance, since they would no longer be within the SFHA; and b) properties with voluntary NFIP coverage would have lower premiums than they would without the barriers.

Coverage beyond NFIP policy limits must be purchased in the private flood insurance market, either individually or as part of a manuscript policy. Private insurers do not need to rely solely on FIRMs and can establish their own rate-setting methods, so a change in FIRMs would not necessarily result in a reduction in private flood insurance premiums. On the other hand, private insurers would not necessarily require a change in FIRMs in order to recognize the reduction in flood risk due to the storm surge barriers. With or without FEMA certification and a resulting FIRM update, if the private insurance market is efficient, the reduction in flood risk should lead to a decrease in flood insurance premiums.

It is important to note that flood insurance is meant to cover some of the same damages quantified in Section 10.1.2.2, so adding these benefits together would be duplicative. However, the timing of these benefits is not the same: damage costs are modeled based on expected probabilities but are only incurred when flooding actually happens, while flood insurance costs are incurred regardless of actual flooding.

The 2014 NFIP Policy Database contains a sample of data on approximately 39,000 policies within New York City. Of these, 140 were located within the area protected from the 100-year flood event, as summarized in **Table 10-9** below:

TABLE 10-9
2014 NFIP Policies in Protected Area, 100-Year Flood Zone

	Properties	Policies	Takeup Rate	% Pre-FIRM	Avg. 2014 Premium & Fee	Total 2014 Premium & Fee	Pres. Value 50 Yrs., 3.375%[12]
1-4 Family	324	37	11%	86%	$1,300	$48,000	$1,200,000
Multifamily	191	31	16%	40%	$5,200	$160,000	$3,900,000
Non-Residential	646	72	11%	65%	$4,300	$312,000	$7,500,000
ALL	**1,161**	**140**	**12%**	**74%**	**$3,700**	**$520,000**	**$12,600,000**

As discussed above, a flood protection system, if certified by FEMA, could remove any mandatory NFIP requirements within the zone of protection, and any future flood insurance costs could be realized as savings. Assuming property owners do forego flood insurance coverage, the total premium and fee amounts in **Table 10-9** represent a lower bound of annual NFIP savings, and NFIP is only one source of flood insurance.

Actual NFIP savings may be significantly higher for the following reasons:

1. **Incomplete Data.** Due to incomplete or irregular addresses recorded in the NFIP Policy Database, there may be additional NFIP policies within the zone of protection that were not captured in this analysis.
2. **Premium and Fee Increases.** This analysis does not take NFIP premium and fee increases into account. As shown in **Table 10-10**, premium and fee increases are particularly drastic between 2014 and 2015 as a result of the 2012 Biggert-Waters Flood Insurance Reform Act and the 2014 Homeowners Flood Insurance Affordability Act. Although increases will certainly continue, the size of increases is unknown, and, therefore, they are not included in this analysis.

TABLE 10-10
2014-2015 Average NFIP Increases, Zone AE

	Premium Increase	Total Increase
Post-FIRM	9%	23%
Pre-Firm Primary Residence	14%	15%
Pre-Firm Non- Primary Residence	24%	37%

FEMA. 2015. “April 1, 2015, Program Changes.”

1. **Takeup and Coverage Rates.** In 2014, NFIP takeup rates among properties in the zone of protection was less than 15 percent. As awareness of flood vulnerability increases, this rate, as well as total coverage amounts, may also increase, leading to greater total costs and, therefore, greater potential savings.
2. **Future Development.** Flood insurance for future developments are also not considered here.

While the total premium and fee amounts in **Table 10-9** represent a lower bound of annual NFIP savings if property owners forego flood insurance, some owners may choose to maintain coverage despite the flood protection system. These owners would face greatly reduced NFIP rates, reflecting their reduced risk. In

[12] The current discount rate for water resources projects that is required for use on USACE projects per USACE Economic Guidance Memorandum EGM15-01. A 7-percent discount rate, used for FEMA-funded mitigation projects per OMB's Circular A-94, Section 8.b.1, yields a present value of $7.2 million for all properties.

Appendix M: NFIP Rating Example, for instance, the with-project NFIP premium and fee of $2,400 is 70 percent less than the without-project full-risk premium and fee of $8,000. Since the final premium depends on individual owner decisions and very specific building characteristics, it is not feasible to estimate these potential savings for all properties in the zone of protection.

Beyond NFIP policies, many buildings have coverage through private insurers, whose premiums and rating systems are proprietary. Private insurance is particularly significant among multifamily and non-residential buildings, which contain approximately 85 percent of the residential units and 95 percent of the built area within the zone of protection. A lack of public information about private flood insurance means that costs, takeup rates, and coverage amounts from the private market are unknown at this time.

10.2.6 Avoided Mandatory Floodproofing Costs

Appendix G of the New York City Building Code requires that all new or substantially improved buildings within the FEMA 100-year flood zone comply with flood-resistant construction standards. This places restrictions on allowable uses, and requires certain construction strategies in building areas below the base flood elevation: no residences are allowed, and all areas must be either wet- or dry-floodproofed, depending on the type of building. This can add to the upfront costs for constructing a building with a floodproofed or elevated ground floor, and can reduce net operating income through the loss of rentable area and as well as requirements to maintain floodproofing components. A storm surge barrier could reduce these costs by compelling FEMA to map the Protected Area out of the 100-year flood zone. However, since this study assumes that the Newtown Creek area will be fully built out before barrier construction begins, developers will not be able to forego floodproofing measures.

10.2.7 Additional Potential Benefits

Although not quantified here, there are additional potential benefits the storm surge barrier could convey to the City and its residents that should be studied in detail as part of a complete feasibility study, including the following:

1. **Avoided loss of life and injuries.** Hurricane Sandy proved that even in New York City, storms can be deadly. Forty-three New Yorkers lost their lives during Sandy, and tens of thousands were injured.[13] The benefit of avoiding loss of life and injury can be converted to dollar amounts using FEMA life safety values.
2. **Avoided evacuation costs.** Much of the Protected Area is in Hurricane Evacuation Zone 2, the second tier of areas to be evacuated in the case of a hurricane. Evacuation presents a particular challenge for those with limited mobility, such as children and older residents, who combined, make up nearly 20 percent of the population within the protected area.
3. **Avoided relocation costs.** Damaged buildings and infrastructure can force residents and business to temporarily relocate, incurring extra costs. This benefit can include not only direct relocation costs, but also loss of productivity and mental health effects.
4. **Avoided business interruptions.** In addition to damage to physical structures and goods, flooding can cause business interruptions that lead to losses of profits for owners and wages for some classes of workers, as well as spillover effects from these losses. Hurricane Sandy caused approximately $5.7 billion of net losses in economic activity,[14] including direct, indirect, and induced impacts. A more detailed feasibility study should deploy localized economic models to obtain an estimate of lost economic activity.
5. **Preserved services and protected infrastructure.** The Protected Area contains numerous facilities that provide valuable services, including the Newtown Creek Water Pollution Control Plant and multiple

[13] City of New York. 2013. "Hurricane Sandy After Action Report."
[14] City of New York. 2013. "New York City CDBG-DR Action Plan."

liquid fuel terminals. Even for those facilities that feature onsite flood protection, a storm surge barrier may offer a higher level of protection. This benefit can be converted to dollar amounts based on the value of the services provided and likelihood of disruption. In addition to these critical facilities, the avoided damages calculated according to USACE NED excluded damage to public infrastructure, including parks, roads, utilities, and other public facilities. During Sandy, some waterfront parks experienced significant damage, resulting in temporary closure and costly repairs. Electrical grids were damaged, and though investments have been made to fortify the network, a storm surge barrier would convey greater risk reduction.

6. **New recreation space at barrier footings.** A surge barrier could create opportunities for new, unique public open space. While this specific benefit would depend heavily on the final design, there is potential for a park along either side of the in-water barrier, which would offer the public a chance to observe vessels entering and leaving Newtown Creek, learn about flood risk, and cross the Creek between Brooklyn and Queens. This benefit can be converted to dollar amounts based on public health benefits, as well as willingness to pay models.
7. **A new connection across Newtown Creek**. Depending on the final design, there may be an opportunity to create pedestrian and/or bicycle access over the in-water barrier, connecting the burgeoning residential areas of northern Greenpoint and Hunters Point South. This benefit can be converted to dollar amounts based on public health benefits and reduced travel times.
8. **Green infrastructure secondary benefits.** Depending on the final design and alignment, there may be opportunities to incorporate green infrastructure or create habitat as part of a Newtown Creek Storm Surge barrier. These components which could generate ecological benefits or human recreational benefits that could be quantified and monetized through benefit transfer analysis, habitat equivalency analysis and willingness to pay models.

11 Implementation and Phasing

11.1 Implementation Overview

A variety of federal, state, and New York City permits and approvals may be necessary to implement a Newtown Creek storm surge barrier system as examined in this feasibility study. Detailed discussion of the anticipated regulatory framework is presented in Appendix I. This section summarizes the process and timeframe for implementation of the project.

In general, it is assumed that any future implementation of storm surge protection would be developed and implemented by the USACE with the City as the local participant. Therefore, the framework associated with USACE project development, review, and implementation provides the overriding framework for the development and approval of any future proposed storm surge infrastructure. Implementation procedures for New York State or City actions and approvals would be completed in coordination with the federal process. The actual implementation of the project is assumed to be aligned with completion of the federal Superfund remediation. For analysis purposes, this is assumed to be a fifteen year horizon such that project implementation would not begin until at least 2030. As shown in **Figure 11-1**, there are two possible scenarios for project implementation.

Pathway A presents a likely sequence if the Newtown Creek storm surge barrier project is integrated in the NY NJ Harbor and Tributaries Feasibility Study. Under Pathway A, the potential measure would be evaluated in the feasibility study that is expected to begin its prescribed three year timeline in 2016 with a 2019 completion date. Should a waiver be acquired, the Feasibility study duration could exceed the three year timeframe. From the feasibility study, the project would be reviewed by the Civil Works Review Board and a Final Chief's Report and the National Environmental Policy Act (NEPA) record of decision would be prepared and circulated with final sign-off anticipated in 2022. Project authorization, preconstruction engineering and design, and congressional authorization are expected to take about 3 years with authorization estimated by 2025. Project construction would be anticipated in about 2032 about 2 years thereafter to provide time for procurement and any baseline testing and evaluation of pre-construction conditions accounting for a stabilized condition after the Superfund remediation, anticipated to be completed by 2030. Under Pathway A, the project could be completed by 2035.

Pathway B presents a process that would be based on an independent project implemented by the USACE (although coordinated with other storm surge protection projects). Under this scenario, there are additional steps to get the process started, most notably, it is expected that by 2019, the NY NJ Harbor and Tributaries Feasibility Study would have identified the recommended project or projects for implementation, the Newtown Creek storm surge barrier would not have been a part of the recommended project, and the Newtown Creek study area would not be protected by the recommended regional project. The USACE would start by requesting Investigation Funding from Congress. With funding in place by 2020, it is assumed that the feasibility study would be initiated in 2021 and completed by 2024. From this point on, the process is the same as described above. Given the anticipated time until Superfund completion, under Pathway B, the project could also be completed by approximately 2035. These timing assumptions are best case. Funding decisions, from initiation to authorizations, could, in reality, take significantly longer to achieve.

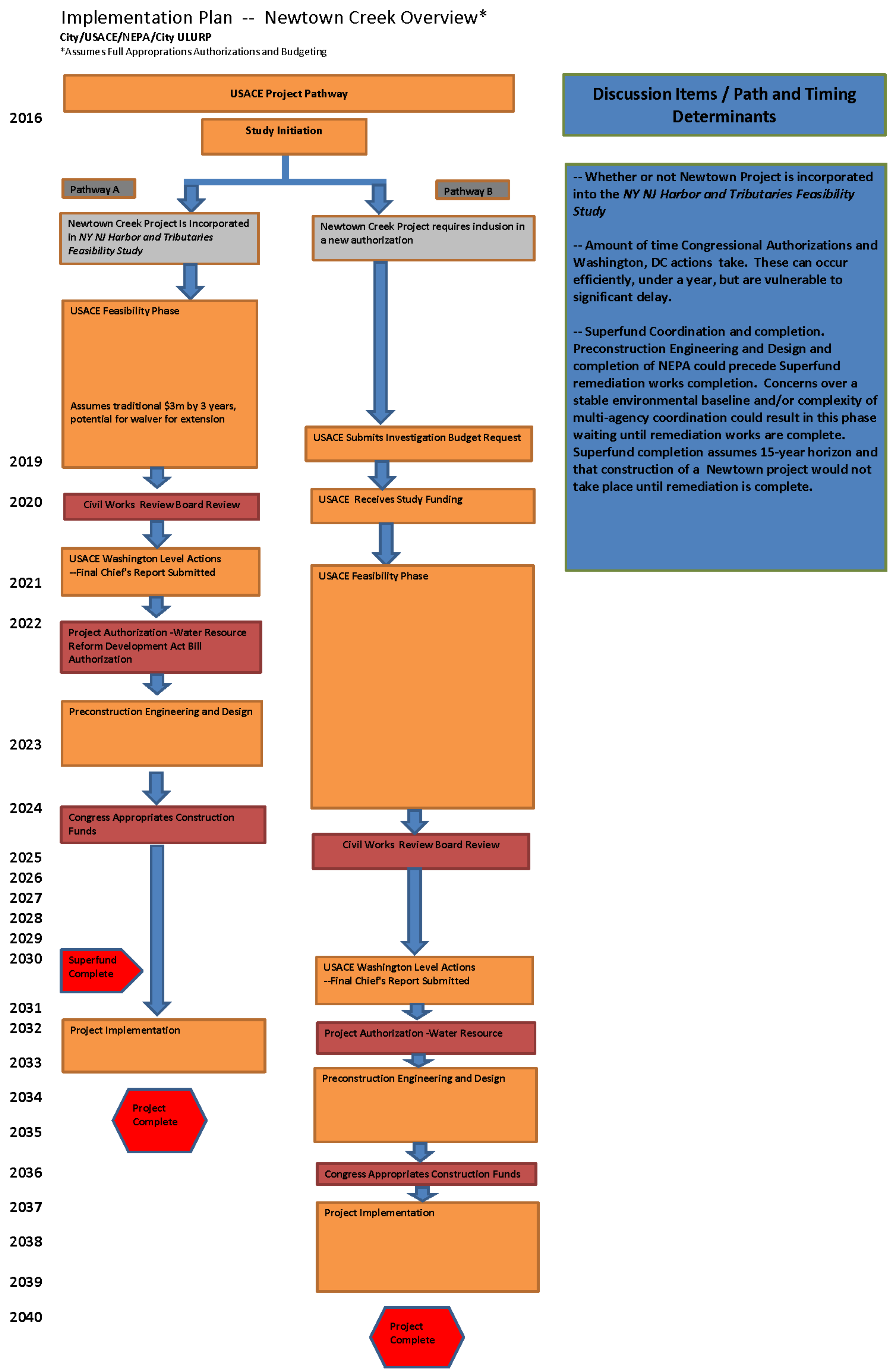


FIGURE 11-1
Newtown Creek Implementation Plan Scenarios

This page was intentionally left blank.

11.2 Detailed Phasing and Implementation Steps

Within each of the larger phases of project implementation, a significant number of steps and coordination points will be required. **Figures 11-1a, 11-1b, and 11-1c** provide a more detailed breakdown of the overall framework, including anticipated New York City actions that would need to be integrated and timed to match the federal process.

In fact, even before the formal USACE process gets under way (approximately in the period from 2016 to 2020), the City should be actively preparing and coordinating with the USACE during the initial lead up to USACE's start of the feasibility study (or during the feasibility study if the project is included in the NY NJ Harbor and Tributaries Feasibility Study). These steps could include business and resident stakeholder outreach, political consensus building, studying funding opportunities such as an assessment district, early action opportunities such as willing seller land acquisition, inter-agency coordination, and ongoing USACE coordination (i.e., providing ongoing support to the cost-benefit assessment that underpins project feasibility) and discussions around level of risk reduction and the potential for a Locally Preferred Plan in the event the City's policy objective for design high and level of risk reduction exceeds that of the USACE's recommended project.

11.2.1 Study Initiation

During this initial phase, USACE will undertake preliminary problem identification assessment that will yield first whether the project is included in the NY NJ Harbor and Tributaries Feasibility Study or if separate authorization for feasibility studies would be required specific to the Newtown Creek storm surge project.

As shown in **Figure 11-1a**, the City would need to formally request assistance from USACE for the study initiation phase to begin. During this time, it would be expected that the City would continue its early coordination and consensus building. With the USACE preliminary investigations under way, the City should begin to consider defining what local actions would be necessary to support the project. The City could also begin to define areas for mitigation banking in anticipation of future requirements that may result from the environmental impact study (EIS) findings.

At the end of this phase, USACE would prepare a Review Plan (Feasibility Study Scope of Review) and Project Management Plan (PMP) outlining USACE and City tasks. The City would commit to its intent to sharing costs of the feasibility study and future construction, and both the City and USACE would sign a cost-sharing agreement.

The timeframe for this phase is estimated to be complete in 2016, reflecting previous and ongoing discussions between applicable parties, if the project is included in the larger NY NJ Harbor and Tributaries Feasibility Study and from approximately 2019 to 2021 as an independent USACE study.

This page was intentionally left blank.

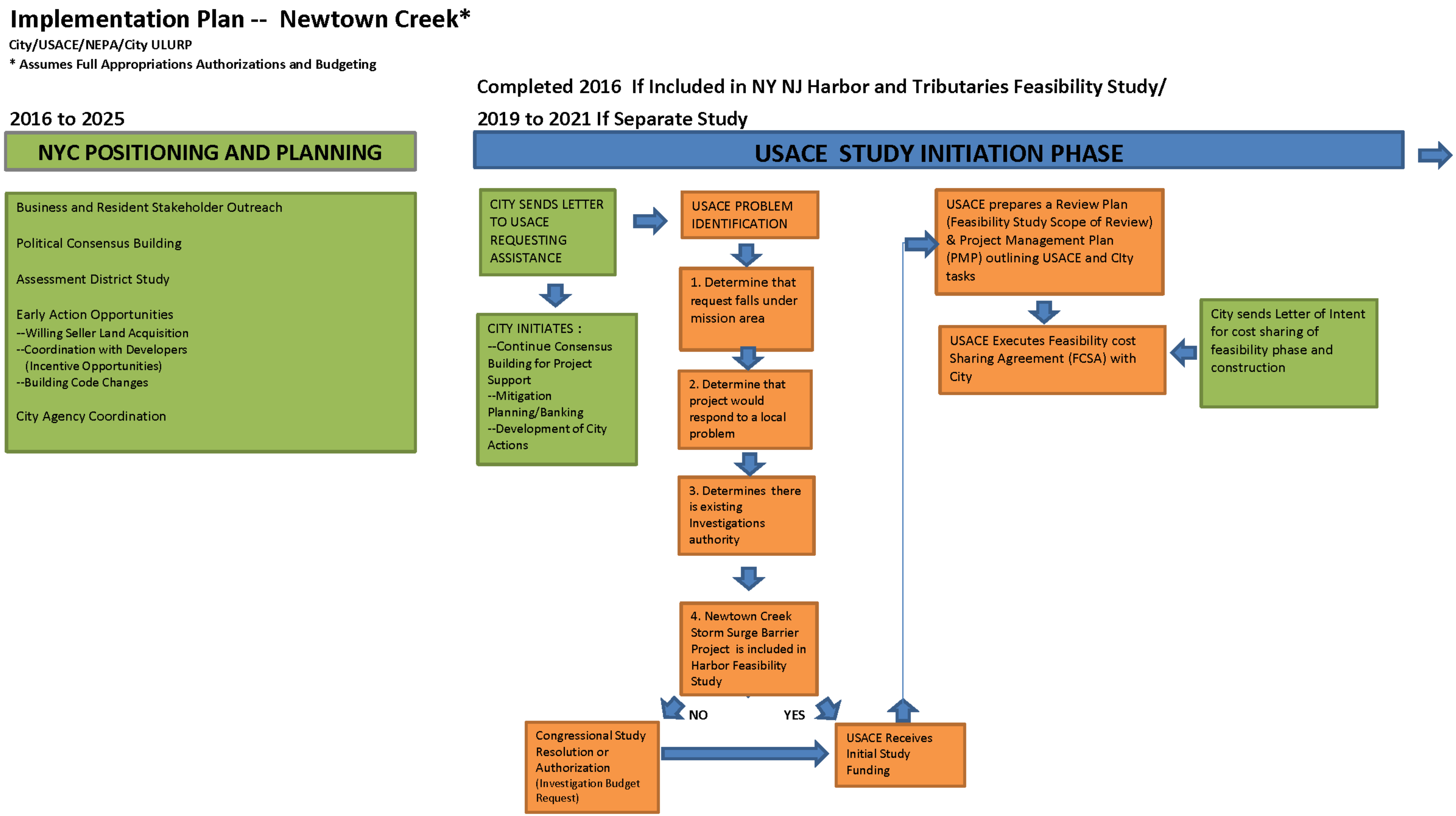


FIGURE 11-1A
Newtown Creek Study Implementation

This page was intentionally left blank.

11.2.2 Feasibility Study

As shown in **Figure 11-1b**, the feasibility study is closely integrated with the supporting NEPA review process, including project scoping, alternatives development, evaluation and assessment, and identification of the preferred alternative (See Task 3 detailed description of the NEPA process and EIS content). The City's role is to participate in the scoping process and to define any locally preferred alternatives.

This phase of the process concludes with the USACE preparing and issuing the Final Feasibility Report/NEPA Document and, after a 30-day period, the District Engineer signs the final report and submits to Washington, D.C., to start the Civil Work Board phase of the project.

The timeframe for this phase is between 2016 and 2019 if the project is included in the larger NY NJ Harbor and Tributaries Feasibility Study, and from 2021 to 2024 as an independent USACE study.

This page was intentionally left blank.

Implementation Plan -- Newtown Creek

2016 to 2019 If Included in NY NJ Harbor and Tributaries Feasibility Study/
2021 to 2024 If Separate Study

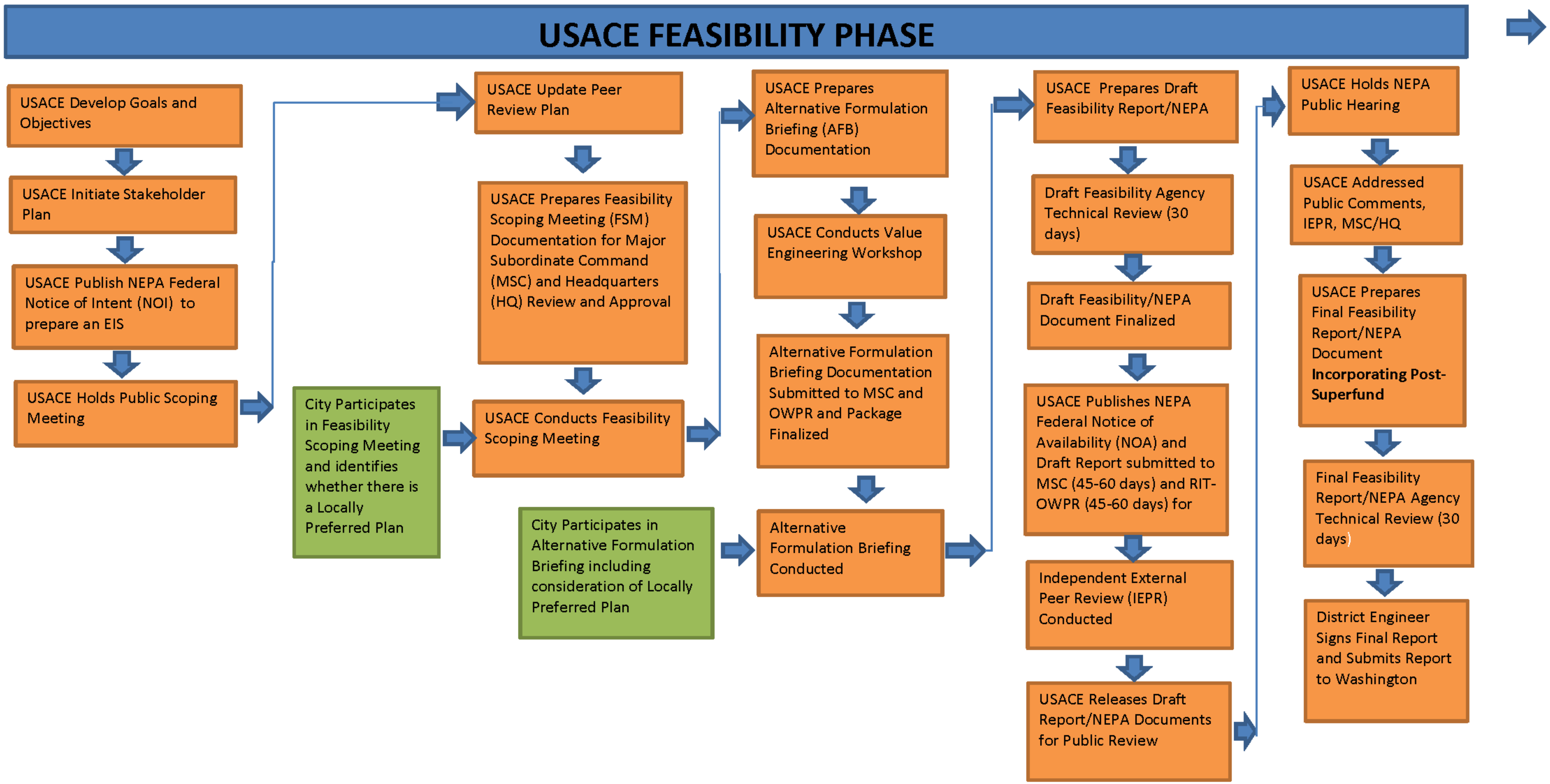


FIGURE 11-1B
Newtown Creek Feasibility Phase

This page was intentionally left blank.

11.2.3 Washington, D.C./Civil Works Review

Completion of the Final Feasibility Report initiates a USACE Headquarters-based review period that incorporates project review by the Civil Works Review Board (see **Figure 11-1c**). The final NEPA documents are prepared with responses to comments generated and Headquarters prepares Final Chief's Report, which is submitted to Congress, the Office of the Assistant Secretary of the Army for Civil Works, and the Office of Management and Budget (OMB). This phase concludes with project authorization through a Water Resource Reform Development Act bill.

During this period, it is anticipated that the City would be establishing and initiating local actions such that they could begin local approval processes (i.e., the Uniform Land Use Review Procedure [ULURP]) to be timed with USACE authorization to proceed. Specifically, this would include pre-ULURP activities, such as finalizing the City's proposed actions, coordination with borough and community board officials, and undertaking City Planning's BluePrint process as necessary for any proposed land use actions.

This phase is expected to take about 2 years and would be completed by 2022 under the NY NJ Harbors and Tributaries Feasibility Study or 2027 for the independent study.

This page was intentionally left blank.

Implementation Plan -- Newtown Creek

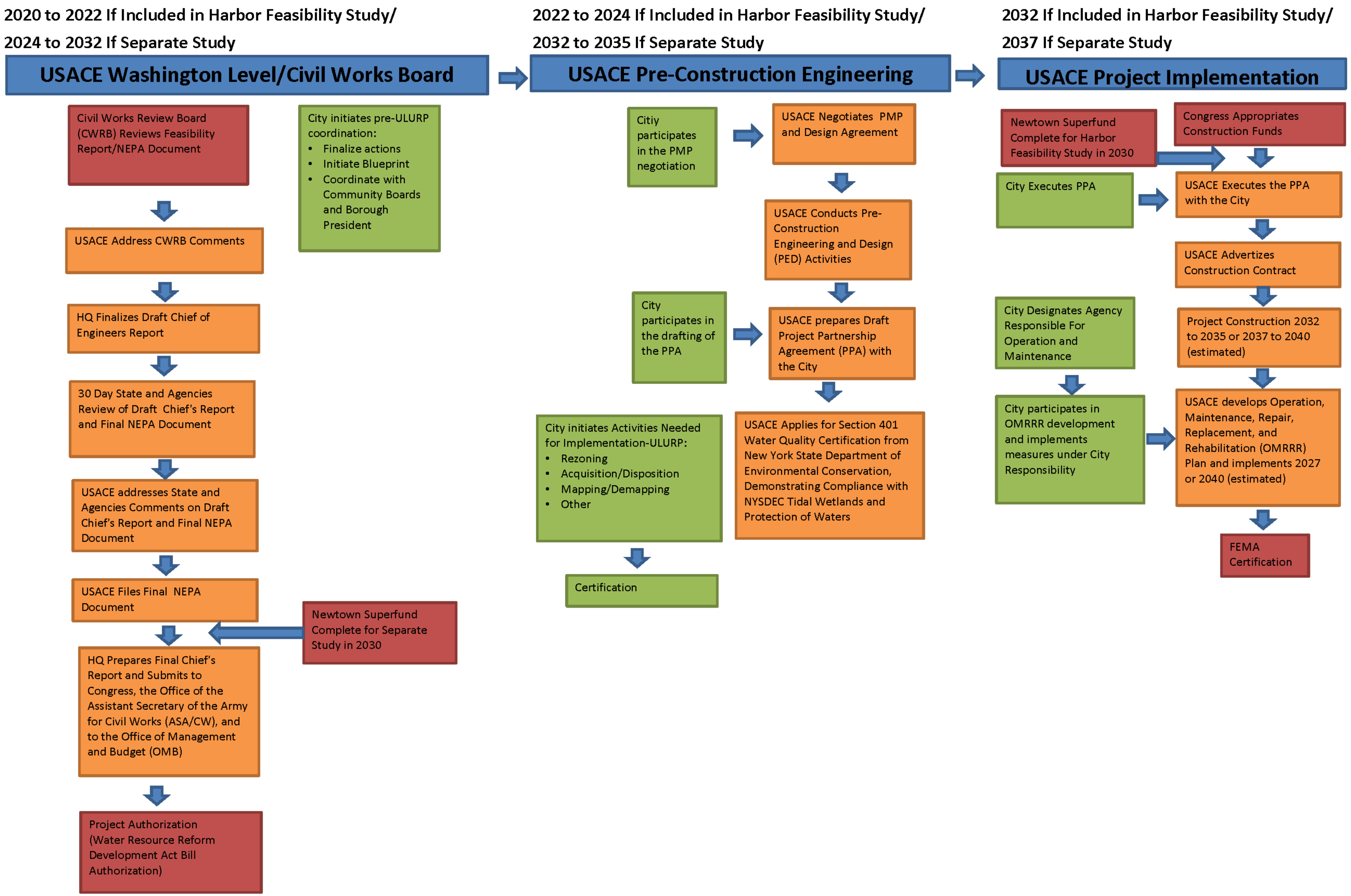


FIGURE 11-1C
Newtown Creek Review through Project Implementation Phases

This page was intentionally left blank.

11.2.4 USACE Preconstruction Engineering and Design

Once authorized, USACE begins the preconstruction engineering phase by completing the PMP and Design Agreement with New York City. As the engineering and design nears completion, USACE prepares a draft Project Partnership Agreement (PPA) with the City and upon execution, and initiates its application for Section 401 Water Quality Certification from the NYSDEC, which includes demonstrating compliance with NYSDEC Tidal Wetlands and Protection of Waters.

At this time, it would be expected that New York City would use the completed NEPA process as the fulcrum to initiate City actions requiring environmental review, most notably the ULURP process that will enable the City to proceed with any future rezoning, land acquisition or disposition, and any street closures and demapping actions.

As shown in **Figure 11-1c**, it is expected that this phase will take about 2 to 3 years, with a potential completion date of 2024 with the Harbor Study and 2029 as an independent project.

11.2.5 Project Implementation

With the Draft PPA and NYSDEC certification, USACE would then obtain congressional authorization for the project and, with that in place, can finalize and sign the PPA with New York City. Under both scenarios, as the scenario where the Newtown Creek project is not included in the NY NJ Harbor and Tributaries Feasibility Study will catch up to the other pathway during the Superfund work period, the anticipated 2030 completion of the Newtown Creek Superfund project would occur during this stage. USACE then advertises and secures the construction contracts and the project can get under way. The project has an anticipated construction schedule of about 2 years. The USACE and the City develop an Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRRR) Plan for implementation upon construction completion.

With the PPA executed, New York City must designate the agency responsible for O&M and the City participates in OMRRR development and implements measures under City responsibility.

With the project complete, FEMA can then certify changes to the flood elevation maps based on the new protection measures. Project Implementation is expected to take about 3 to 4 years in total, concluding by 2035 under both pathways.

This page was intentionally left blank.

12 Funding and Financing Approach

12.1 Local Funding and Governance

The estimated capital costs for the storm surge barrier system are $230 million[1], and under USACE funding guidelines, the City would be responsible for 35 percent of capital costs, or $80 million. The City would also be responsible for operations and maintenance (O&M) costs, with an annualized estimate of $864,000; the PV of this annualized cost[2] is $21 million. Thus, the total cost to the City of protecting this area—which generates almost 30,000 jobs, $2.1 billion in earnings, and $6.3 billion to total output (**Table 12-1**)—is just more than $100 million. Establishment of an assessment district and reduction of project costs by coordinating investments are two potential funding approaches the study team explored.

12.1.1 Funding Scenario: Assessment District

Many of the benefits of a storm surge barrier accrue to private property owners, and the City would therefore be justified in trying to capture some of this value to meet its obligations for 35 percent of capital funding and all O&M costs. A conceptual model of an assessment district suggests that this tool is a promising source of funds, as districtwide net benefits would far exceed the required assessment, and average assessment rates would be well under 1 percent of assessed value, even under the most costly scenario. The conceptual model was also used to test the sensitivity of the assessment rate to certain assumptions.

12.1.1.1 Base Case Model[3]

The funding potential of a special assessment district was tested under three different scenarios:

1. Size the assessment to fund all of the O&M costs;
2. Size the assessment to fund all of the local capital costs (i.e., 35 percent of total capital costs); and
3. Size the assessment to fund all of the O&M costs and local capital costs.

The results of this analysis (**Table 12-1**) show that full funding of O&M costs for a barrier system could be achieved through an assessment of properties equal to 0.1 percent of total assessed value. Funding the City's portion of capital costs would require an assessment roughly seven times greater.

TABLE 12-1
Assessment District Funding Scenarios

	Scenario 1: Fund All O&M Costs	**Scenario 2: Fund All Capital Costs**	**Scenario 3: Fund O&M and Capital**
Total Assessment	$13.5 M	$86.7 M	$100.3 M
Year 1 Assessment	$980,000	$7 M	$8 M
Total Assessed Value	$959 M	$959 M	$959 M
Year 1 Avg. Assessment Rate	0.10%	0.73%	0.83%

[1] This assumes the Second Street Shoreline alignment.

[2] Over a 50-year period with a 3.375 percent discount rate, the current rate for USACE water resources projects per USACE Economic Guidance Memorandum EGM15-01.

[3] The base case includes all properties in the Protected Area; assumes no future development or property value increases; applies a standard assessment rate to each property's non-exempt assessed value; assumes a 7 percent discount rate for property owners and a 6 percent interest rate for debt, with a 30-year term and 1.2 debt service coverage ratio; and counts as benefits only avoided property damages, not avoided business interruptions or other benefits.

The Protected Area contains properties with a wide range of types and values. This model assumes all properties contribute to an assessment district as a fixed percentage of their assessed value. **Table 12-2** contains the estimated assessment for sample properties, along with total estimated real estate taxes for comparison.

TABLE 12-2
Estimated Assessments for Sample Properties

Sample Property	*Est. fiscal year 2015 Real Estate Tax*	Scenario 1: Fund All O&M Costs	Scenario 2: Fund All Capital Costs	Scenario 3: Fund O&M and Capital
110,000 square foot warehouse building	$188,000	$1,800	$12,900	$14,700
3-story, 3-unit building in Greenpoint	$9,000	$50	$340	$390
12-story, 200-unit building on Hunters Point waterfront	$73,700	$570	$4,200	$4,700

In order to contextualize the cost of an assessment, it must be compared to the value it creates for property owners, which, in this model, is assumed to be equal to the value of avoided flood damages. Results in **Table 12-3** suggest that the value of flood protection to property owners is far greater than the cost of an assessment district. Assessment district funding for O&M should be strongly justifiable, and even complete capital and O&M funding appears justifiable under the assumptions of this model.

TABLE 12-3
Assessment District Return on Investment

	Scenario 1: Fund All O&M Costs	Scenario 2: Fund All Capital Costs	Scenario 3: Fund O&M and Capital
Total Assessment	$13.5 M	$86.7 M	$100.3 M
Total Benefits[4]	$225 M	$225 M	$225 M
Benefit/Assessment Ratio	16.6	2.6	2.2

12.1.1.2 Sensitivity Analysis

The assessment paid by each property owner will be sensitive to the total value of all properties in the district. To evaluate this sensitivity, the base case assumptions were varied in line with plausible alternative district inventories, including a fully built out Protected Area[5], a smaller Protected Area that includes only properties within the 100-year flood zone, and a district that exempted all residential area. Results in **Table 12-4** suggest the financial burden of an assessment district, and, therefore, its feasibility, will depend on key decisions regarding the total inventory of assessable properties.

[4] Includes all NED benefits; if only structures and content damages and cleanup costs are considered, the benefit/assessment ratios are 14.6, 2.3, and 2.0.

[5] Projection assumes all unbuilt developable square feet on soft sites are built and assessed at the same average rate as the inventory. Soft sites are defined as lots where the built floor area is less than 25 percent of the allowable residential floor area. Assumes no rise in property values.

TABLE 12-4
Assessment District Sensitivity Analysis

	Base Case	Full Build Out[5]	100-Year Flood Zone	Excluding Residential
Total Assessed Value	*$959 M*	$1,775 M	$539 M	$822 M
Year 1 Assessment Rate:				
Scenario 1: O&M	*0.10%*	0.06%	0.18%	0.12%
Scenario 2: Capital	*0.73%*	0.39%	1.30%	0.85%
Scenario 3: Capital and O&M	*0.83%*	0.45%	1.48%	0.97%

12.1.1.3 Areas for Further Study

While this initial evaluation suggests that the benefits created by a storm surge barrier justify at least some value capture from local properties, the establishment of an assessment district would require more detailed studies to address the following issues:

- **Legal process.** Presently, the only common form of assessment district in New York City is a business improvement district (BID), which typically funds security, sanitation, marketing, and other services in a business district, but may also issue debt to fund infrastructure. BIDs require support from local property owners and must be approved through a community process, culminating in legislation by City Council. A BID model could be implemented without authorization from the State of New York, but would require strong community support and would have a limited assessable inventory if it excluded residential properties. It is also possible to form other types of assessment districts, designed for specific purposes, but these would require legislation at the state level.
- **Distribution of benefits and financial burden.** This model shows that districtwide assessment costs compared favorably with districtwide avoided damages, but on the level of individual properties, this relationship likely will not hold. Many of the properties that are at greatest risk of flood damage, and, therefore, benefit the most from flood protection, do not have high assessed values. These properties would not be major contributors to the district if all properties were assessed at the same rate. Conversely, many new, high-value buildings will face little risk of flood damage, yet would contribute significantly to the assessment. The City must work with property owners toward a shared understanding that the actual benefits of flood protection extend beyond avoided building damage. Other benefits include avoided evacuations and business interruptions, as well as neighborhood-level effects, such as retail corridors remaining in service, and these benefits apply to newer, more flood-resistant buildings as well. Based on a more complete understanding of benefits, a value capture tool would need to balance the proportionality of assessment to benefit and the desirability of a districtwide strategy, as well as the property owners' capacity to absorb additional costs.
- **Relationship to other public policy goals.** Related to the distribution of financial burden, the City will need to balance funds raised for flood protection with funds raised or development regulations imposed to further other public policy goals, including industrial preservation and housing affordability.

12.1.2 Potential Value Capture Mechanisms

The strong development environment along the Brooklyn-Queens waterfront, as well as the public investments that will accompany new development, create opportunities for the City to plan now for an eventual barrier. The following are examples of actions the City could take to integrate investments with barrier planning in order to reduce project costs and foster better urban design outcomes. Reducing project costs could both decrease the total local expenditure and increase the project's benefit/cost ratio, improving the likelihood of receiving federal funding.

The ownership and development status of each parcel along the alignment determines what actions the City may be able to take, as summarized in **Table 12-5** and **Figure 12-1** and discussed below.

TABLE 12-5
Site Categories and Potential City Actions for Reducing Project Cost

Category	Potential City Actions	# Sites Along Alignment[6]
Public Ownership		
Public Improvements	Establish design standards for new parks and streets Invest in elevating existing parks and streets	9
City-Owned Sites for Disposition	Require development parcels to be integrated into flood protection system	1
Private Ownership		
Private Redevelopment Sites Requiring City Action	Require integration into flood protection	1
As-of-right Redevelopment Sites	Approach developer regarding site integration	8
Sites Recently Built or Under Construction	None	9

FIGURE 12-1
Development Site Categorization

Across all categories of sites, the first step toward any kind of integration of public and private sites into the barrier system is a decision by the City to establish a specific design flood elevation. This study analyzes a +17-foot NAVD88 elevation based on conservative assumptions of freeboard and sea level rise, and a final project approved by the USACE may be designed at a lower elevation. However, the City will miss any opportunity to coordinate investments in the meantime if it does not set an elevation standard.

6 All street ends combined are treated as a single public improvement; all future Hunters Point South development parcels are treated as a single site.

12.1.2.1 Publicly Owned Sites

- **Public Improvements**

The adoption of design standards for parks and street ends along the upland barrier alignment is a prerequisite for integrating sites into the barrier system. The opportunity for integration is particularly strong at sites that will be rebuilt between now and when a barrier would be built. This includes both major investments in parks and infrastructure related to real estate development projects—such as Newtown Barge Park, Box Street Park, and Phase II of Hunters Point South Park—as well as projects that are part of the regular cycle of park renovations and street upgrades, as shown in **Figure 12-2**.

FIGURE 12-2
Newtown Barge Park Illustrative Adaptive Redesign

Newtown Barge Park was designed to meet the adjacent grade of the Greenpoint Landing development sites on its northeastern and southern edges. The berm in the existing design is at an elevation of under +13-foot NAVD88, but it could potentially be redesigned to meet the storm surge barrier design flood elevation of +17-foot.

- **City-Owned Sites for Disposition**

For parcels like Hunters Point South Phase II (see **Figure 12-3**), which the City owns and plans to dispose of, integration of a site into a barrier system could be included as a requirement in a request for proposals. This requirement could yield great areawide flood protection benefits, and further study would need to identify any trade-offs between this flood protection and the parcels' buildable area, the viability of ground floor retail, and the quality of the public realm.

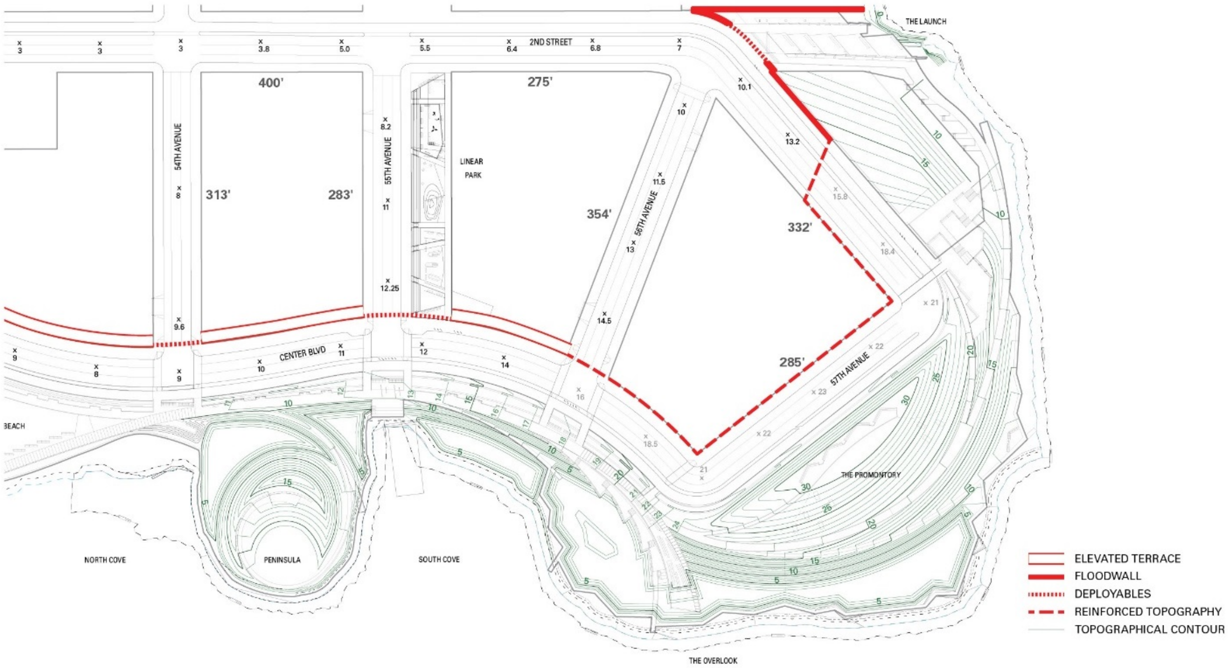


FIGURE 12-3
Hunters Point South Illustrative Development Site Integration

The Hunters Point South Phase II parcels offer multiple alternative opportunities for integration of a barrier system. An elevated terrace could be constructed between the buildings and Center Boulevard; a floodwall could run along the west side of Center Boulevard; or the road itself could potentially be reinforced and partially raised as long as the resulting slope is not too great. Each option has tradeoffs that should be analyzed by the City agencies as they implement this project.

12.1.2.2 Privately Owned Sites

Incentives or mandates for the integration of a barrier system into privately owned sites can potentially yield great project savings. If a site integrates into a barrier system, the cost of building a floodwall across the length of the site can be avoided; furthermore, since waterfront parks abutting development sites are designed to meet the elevations of these sites, the elevation of a private site can lead to the elevation of adjacent parkland as well. The City's legal authority in these areas must be investigated further.

- **Private Redevelopment Sites Requiring City Action**

For parcels that require a City action in order to be redeveloped, the Department of City Planning may be able to require site integration as a precondition to a rezoning. A coordinated strategy would be required in order to apply consistent rules across similar sites.

Presently, the only such site along the proposed barrier alignment is 13 Greenpoint Avenue. BNS Real Estate is pursuing a zoning text amendment related to access requirements in order to fulfill their proposal to redevelop this industrial/manufacturing site just west of Transmitter Park into an 11-story, 61,000 square foot mixed-use building. Even if it were confirmed that integration of this site were physically and legally feasible, redevelopment is likely too close to completion for the City to require a significant change. However, the City may be able to pursue this strategy for other coastal protection projects.

- **As-of-right Redevelopment**

For sites that could be redeveloped as-of-right, the City does not have the opportunity to require site integration as part of a rezoning process. However, it may be in the interests of both the developer and the public to integrate the upland defense into the site, rather than having a potentially restricting barrier built adjacent to the site. In these cases, the City could approach the developer to discuss options for site integration. If the public cost savings and urban design benefits of an elevated and redeveloped site are great enough, the City could provide financial or regulatory incentives for site elevation. There are eight such sites in Greenpoint along the East River waterfront.

Waterfront as-of-right development sites may be able to integrate into a barrier system without negatively impacting development value. As shown in **Figure 12-4**, a berm on the private lot, on the waterfront side of the building could contribute to protection of the neighborhood.

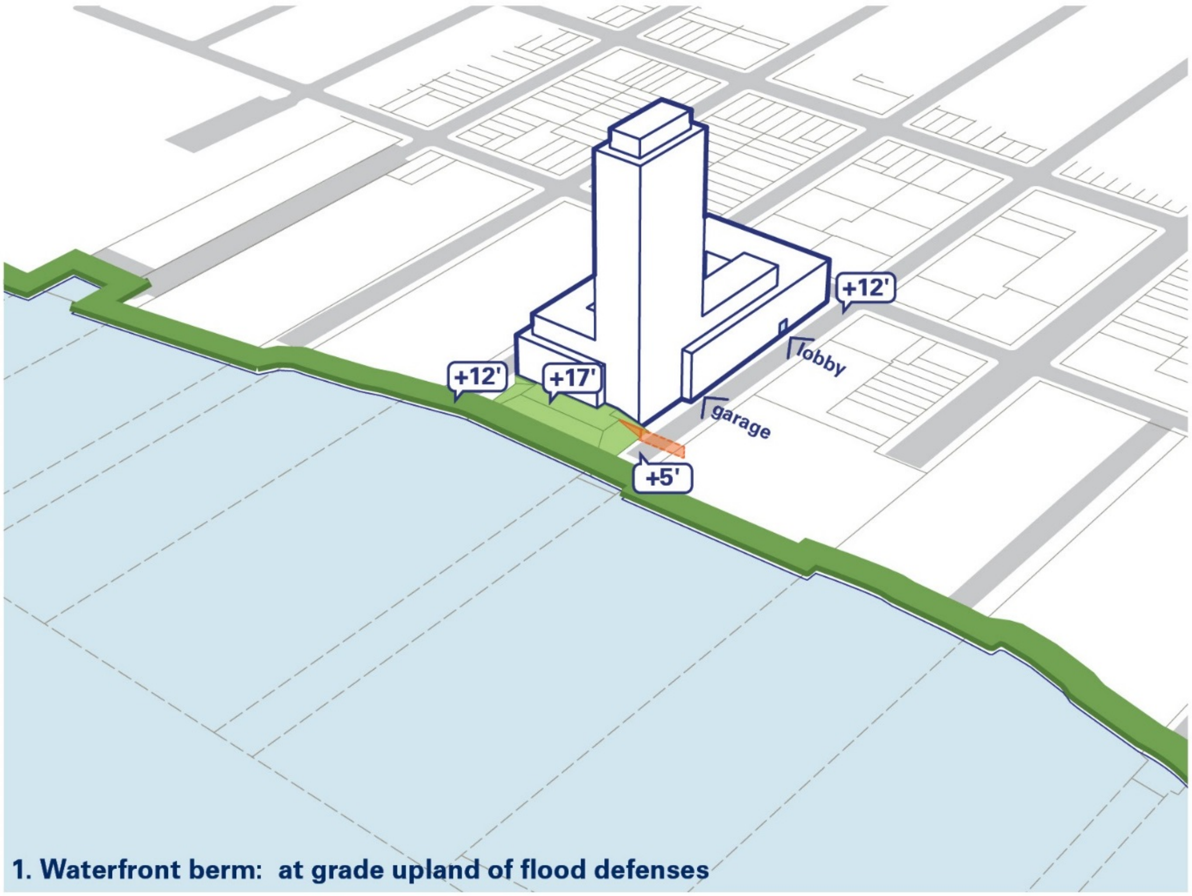


FIGURE 12-4
209 West Street Illustrative Development Site Integration Alternative A

Alternative design concepts could include a berm that wraps around the building or and an elevated terrace along the upland edge of the building (shown in **Figure 12-5**).

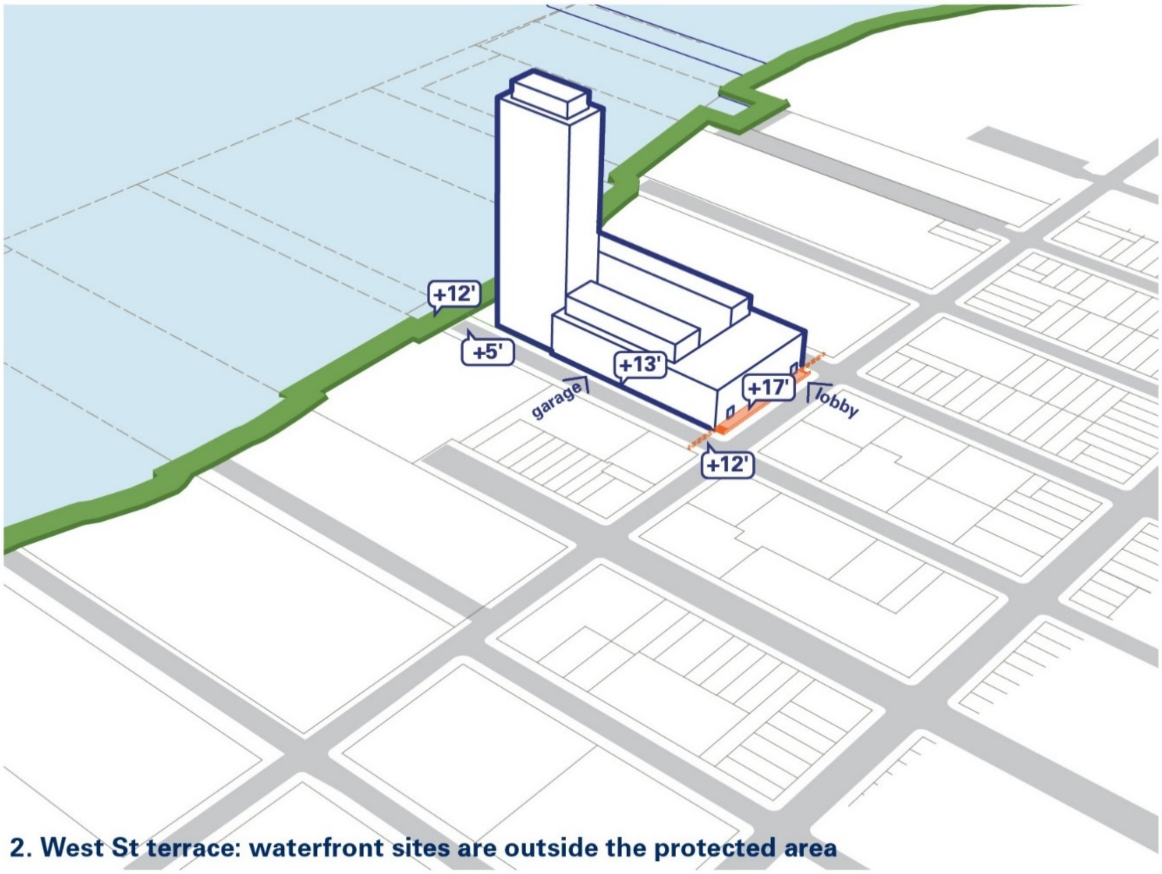


FIGURE 12-5
209 West Street Illustrative Development Site Integration Alternative B

- **Sites with No Known Plans for Rezoning or Redevelopment**

These are sites that would require a rezoning action in order to be redeveloped, but there are no known plans for redevelopment. If a rezoning were to occur, the City could adopt a policy of requiring site integration with a flood defense system.

- **Sites Recently Built or Under Construction**

These are sites that are under construction or recently built, and therefore no redevelopment is anticipated during the time period of barrier planning and construction.

13 Conclusions

13.1 Study Findings

Located at the heart of one of New York City's largest industrial zones and within blocks of some of its most rapidly growing residential neighborhoods, Newtown Creek (Creek) forms the border between Queens and Brooklyn, and, flowing into the East River, provides diverse waterfront opportunities, but also poses significant resiliency challenges. The low-lying lands on either side of Newtown Creek are subject to flood hazard, as waters from the East River are brought inland by Newtown Creek (Creek). Hurricane Sandy demonstrated these areas' vulnerability, with more than 350 acres of land along the Creek inundated by the storm. Newtown Creek is also a United States Environmental Protection Agency (USEPA) Superfund Site. Remediation plans are expected to be developed and pursued over the next decade.

- A storm surge barrier system could successfully limit risk at the Creek up through a 500-year storm event, based on a +17-foot North American Vertical Datum of 1988 (NAVD88) design flood elevation (DFE), and enable the City to achieve three essential goals:
  - Protecting Jobs and Businesses.
    - More than 18,000 people work in flood-prone areas surrounding the Creek. Nearly half of these jobs are in industrial sectors, performing critical functions within the local economy as well as providing employment opportunities for persons with low educational attainment, limited English language proficiency, and minority and immigrant populations.
    - Across all sectors, the 1,630 businesses and 19,000 employees in the Protected Area (all properties that would be inundated during a 500-year flood event without the project, but would not be inundated with the project) generate more than $4 billion in direct annual economic output and earn nearly $1.3 billion in compensation. Applying economic multipliers, this direct economic activity generates nearly 30,000 jobs, $2.1 billion in earnings, and $6.3 billion in total output.
  - Protecting Residents. The neighborhoods surrounding Newtown Creek are home to more than 15,000 residents, with most individuals living in older buildings, which were not built to flood-resistant standards. As new buildings are constructed in the coming decades, the area's population is poised to quadruple, with most of this growth happening in the 100-year flood zone.
  - Protecting Critical Infrastructure. As envisioned, a Newtown Creek storm surge barrier system could provide protection to the G train subway line, the rail yards bound by 2nd Street to the west and Bordon Avenue to the north, the Midtown Tunnel exit to the Long Island Expressway, and the New York City Department of Environmental Protection (NYCDEP) operated wastewater treatment plant.
- Any project at Newtown Creek will present challenges, require major investment, and require close coordination with agencies, regulatory bodies and the community to explain the risks and the trade-offs at stake in adopting a solution.
- The preferred concept option is the Shoreline Alignment with an in-water barrier at either 2nd Street or Manhattan Avenue.
  - It maximizes the potential zone of protection.
  - It minimizes disruption to residential and commercial activities and potential adverse impacts to public safety by staying out of the public ROW to the extent possible.

- It maximizes reliability, incorporating floodwalls and permanent structures with long design lives, tying into natural or landscaped topography wherever possible, and minimizing the use of deployable components.
- It is anticipated that it would provide a positive return on investment for the City and its partners. The preliminary Benefit-Cost Ratio (BCR) at this conceptual stage was found to range between 1.5 and 3.1. The range reflects the project benefit's sensitivity to the replacement structure values used in quantifying avoided damages and the variation in construction estimation data sets such as Marshall & Swift (M&S) as compared to local construction market intelligence.
  - Capital costs are estimated to range between $229 million to $242 million.
  - Operations and Maintenance (O&M) costs are estimated to be $807,000 to $854,000 on an annualized basis or $19.4 million to $20.4 million on a 50-year present value basis.
  - The present value of expected annual damages (EAD) for the 50-year period of analysis, the benefits, are $391.5 million or $16.3 million annualized.
  - Net benefits were estimated to range between $121 million and $136 million based on one data set. However, the value of avoided damages relies significantly on the real estate construction values used and could be substantially greater.
  - Construction estimation data sets, such as M&S, understate the value of avoided damages. A future detailed feasibility study should include research and verification of market construction values for New York City.
  - Greatest uncertainty and cost risks are likely to come from barrier gate sizing, stormwater pumping or storage requirements, utility and service diversions, environmental remediation separate from Superfund works, land acquisition, and legal challenges. These are areas that should be further investigated at a complete feasibility study stage beyond this initial study.
  - The benefits reflected in the BCR are limited to avoided damages. The future feasibility study stage should consider expanding the criteria to capture and monetize the broader set of benefits.
- The major weakness of the shoreline alignment is the anticipated complexity of the legal and planning process, reflecting not only New York State Department of Environmental Conservation (NYSDEC) in-water permitting requirements for a barrier and fill, but also the interface with planned residential water development projects and new park features. Planned residential and park developments at both Hunters Point South and Greenpoint, including the Greenpoint waterfront esplanade, Box Street Park and Newtown Barge Park, are designed at elevations below this study's DFE. In addition, a shoreline alignment would be expected to have some adverse impact on waterfront access and view corridors. These challenges and exploration of potential design solutions will necessitate further investigation and stakeholder engagement as part of a future complete feasibility study.
- Where a 2nd Street horizontal rotating in-water storm surge barrier is selected, it will require infill, which will trigger NYSDEC involvement. Depending upon how the gate is sized and the volume of infill required, environmental permitting could be very difficult or require extensive mitigation activities. Additionally, resistance is likely due to the required upland interfaces with planned park projects and private developments at the 2nd Street barrier site.
- Where a Manhattan Avenue vertical lift gate barrier is selected, it will require consultation with the navigation community to confirm acceptable vertical clearance requirements, coordination with the Metropolitan Transportation Authority (MTA) in the vicinity of the G-train subway line around which

abutments would need to be constructed, and engagement with utility owners to identify potential service diversions.

- The Department of Parks and Recreation will be a critical implementation partner. The integration of upland defenses with existing and planned parks may adversely impact view corridors and waterfront access, and could reduce active space—an issue heavily contested by the communities. NYCDPR will need to be engaged early on to consider design alternatives and opportunities to retrofit and integrate the flood defense scheme with the waterfront. Parkland alienation issues could also be triggered. Interface with the planned Greenpoint waterfront esplanade, a public-private public amenity initiative, and other planned waterfront projects will require consideration of design solutions.

- The alternate concept option is the Site Integration Alignment with an in-water barrier at either 2nd Street or Manhattan Avenue.
  - Like the preferred concept option, it also anticipated that it would provide a positive return on investment for the City and its partners. The preliminary BCR at this conceptual stage was found to range between 1.8 and 3.8, reflecting a cost reduction by transferring parts of the alignment to private developers.
    - Capital costs are estimated to range between $183 million to $196 million.
    - Operations and Maintenance (O&M) costs are estimated to be $821,000 to $868,000 on an annualized basis or $19.7 million to $20.8 million on a 50-year present value basis.
    - The present value of EAD for the 50-year period of analysis, the benefits, are $391.5 million or $16.3 million annualized.
    - Net benefits were estimated to range between $169 million and $183 million, based on one data set. However, the value of avoided damages relies significantly on the real estate construction values used and could be substantially greater.
    - Cost and benefit uncertainty and actions to refine assumptions are the same as those for the preferred concept option.
  - Given the likely timing of a potential Newtown Creek storm surge barrier project, the status of parcel development and approvals, and the additional anticipated approval complexities due to easement requirements for Federal Emergency Management Agency (FEMA) certification, the site integration alignment in its entirety is not viewed to be a realistic option. This alternative concept option was explored more with a view toward understanding trade-offs and identifying value capture mechanisms that the City could consider as part of its resiliency efforts. That said, there are specific opportunities on a site-by-site basis that merit further consideration, and a final design and barrier alignment may incorporate aspects from both the Shoreline and Site Integration concept options.

- As part of coordination and initial planning between the City and USACE for a full feasibility study, a policy decision will be required to set the DFE and the level of risk reduction for the project to achieve.
  - This study assumed a conservative +17-foot NAVD88 DFE for the upland defenses and a +21-foot NAVD88 DFE for the in-water barrier. This includes allowances for freeboard and sea level rise. Sea level rise allowances reflect the New York City Panel on Climate Change's 2015 findings that forecast mid-range (25^{th} – 75^{th} percentile) changes in sea level rise of 11-24 inches by the 2050s and 18-39 inches by the 2080s.
  - Federal policy may dictate that funded projects be built to a DFE lower than that assumed in this study. This could impact minimum design elevations and funding limits.

  - City preference for greater risk reduction may require a Locally Preferred Plan, in which the City is financially responsible for capital costs above and beyond the USACE plan. Alternatively, the City might consider a gradual approach, expanding the barrier and increasing the height over time.
- Over time, sea level rise adaptation of a flood defense system might be pursued.
  - Low-lying areas north of the study area are vulnerable to flooding from the East River as water moves south into Long Island City and could introduce a future back door entry point for water flow into Newtown Creek if the flood stages are high. Further definition of ground elevations in this area could result in a reduction or elimination of the estimated flooding. Future feasibility studies would conduct elevation spot-checks.
  - A Queens waterfront strategy to contain the East River flood source north of the Newtown Creek Study area could include the extension of the Newtown Creek defense line (but leaves Queens vulnerable), possible MTA rail yard protection measures that contain water from Newtown Creek, a comprehensive Queens waterfront flood protection strategy tie-in to a Newtown Creek system, or incorporation of protection measures into Long Island City redevelopment plans
- There appear to be potential opportunities for new public amenities. A bicycle/pedestrian connection could form a part of an in-water barrier at Manhattan Avenue or new recreational space might be possible atop infill at a 2nd Street barrier location.
- There are opportunities to incorporate habitat enhancement as part of a storm surge barrier system. Native plant communities might be added adjacent to a barrier or crevices and habitats designed into a barrier structure. Vegetated berms with salt marsh plantings or coastal shrub might also be possible.
- A high-level flushing analysis found that introduction of in-water barriers at Newtown Creek appear to cause marginal worsening of circa 5 percent to tidal exchange.
  - Future detailed analysis could dictate that a wider barrier gate be included as part of a storm surge barrier flood defense system in order to further reduce impact to flushing performance.
- The preliminary rainfall and storage capacity analysis performed found that longer duration storms likely cannot be contained within the Creek.
  - In this simplified analysis, storms larger than the 1-hour, 1-year event rainfall volume were not contained within the canal/creek system.
  - Stormwater pump stations will almost certainly be required as part of a storm surge barrier system. Conceptual cost estimates built up for this study have made an allowance for an additional stormwater pump station for all concept options, but the requirements could be significantly larger.
  - A detailed surface water and drainage study will need to be performed as part of a complete feasibility study.
- Given the industrial history of the study area, especially heavy industrial and automotive uses, future environmental site investigations will need to be performed as part of a feasibility study to determine whether hazardous material remediation may be required along the alignment. Primary contaminants of concern include petroleum, metals, solvents, plasticizers, coal tar and creosote.
- A complex regulatory arena, comprising federal, state and city reviews and approvals, will need to be navigated as part of any future project implementation.
- Future studies, investigations, and analyses that are anticipated to be scoped into a detailed feasibility study in order to refine cost and benefit estimates include, but are not be limited to:
  - Elevation spot checks of LIDAR data as part of storm surge modeling.

- Comprehensive drainage and water quality modeling, including combined probability analysis of storm surge and rainfall events.
- Sampling and detailed environmental site investigations on parcels along the storm surge barrier alignment.
- Utility investigations and as-needed service diversions or relocations studies.
- Real estate studies and plan.
- Expanded benefits quantification and monetization such as avoided relocation costs, avoided business interruptions, preserved services and protected infrastructure, and green infrastructure secondary benefits.

13.2 City Actions and Next Steps

Although USACE would likely not complete construction and implementation of a project until after the completion of Superfund remediation in 15-plus years, there is much that the City can do in the meantime to prepare for a storm surge barrier. Many of these actions apply not only to a Newtown Creek barrier, but could also apply to other flood control projects throughout the city, and should therefore be pursued independent of the timeline or feasibility of this project.

13.2.1 Establish Flood Protection Funding and Financing Mechanisms

The estimated capital costs for the storm surge barrier system are $230 million[1], and under USACE funding guidelines, the City would be responsible for 35 percent of capital costs, or $80 million. The City would also be responsible for O&M costs, with an annualized estimate of $864,000; the present value of this annualized cost[2] is $21 million. Thus, the total cost to the City of protecting this area—which generates almost 30,000 jobs, $2.1 billion in earnings, and $6.3 billion in total output —is just more than $100 million.

The City can take actions now to limit the total public expenditure necessary to fund the construction, operation, and maintenance of a barrier system. By creating a special assessment district for the properties that benefit from flood protection, the City can raise at least some of its portion of its funding obligations, and by aligning public investments and the regulation of private property with plans for the barrier, the City can reduce total project costs. Other actions can increase the likelihood of obtaining USACE funding, foster local support, and improve flood management tools.

13.2.2 Refine Cost Estimating Methodology with USACE

The avoided damages methodology applied in this study relies on the M&S valuation system, consistent with other USACE flood control projects, but likely underestimates actual avoided damages. This could result in an underestimation of the project's net benefits and BCRs, and reduced potential for federal funding. It is critical that the City, in consultation with the USACE, develop a cost estimating methodology that is in line with federal guidelines but also captures the true cost of construction in New York City.

This study's preliminary investigation into the differences between the M&S replacement costs and data from local developers found significant variation between estimated values. Substituting market-based cost estimates for the M&S replacement costs nearly doubled the total avoided damages and significantly increased the BCR.

Beyond the fact that the M&S valuation system employed for USACE purposes may underestimate total replacement costs, there are a number of factors that suggest that actual replacement costs may be greater than would be recognized by the USACE:

---

1 This assumes the Second Street Shoreline alignment.

2 Over a 50-year period with a 3.375 percent discount rate, the current rate for USACE water resources projects per USACE Economic Guidance Memorandum EGM15-01.

- **National and Local Cost Escalation**. Nationally, construction costs are escalating at rates significantly faster than inflation; New York City (NYC) construction costs are escalating at a rate faster than the national average.3 For a project that is still decades away from implementation, this escalation will have a significant impact on valuation.
- **Public Processes**. The prevalence of public reconstruction funding can introduce regulations and bureaucracy that increase costs directly and through project delays.
- **Post-Disaster Premiums.** Demand for construction labor and materials spikes after a disaster—M&S guidelines suggest that materials and labor can increase 30 percent to 50 percent following natural disasters.

It is understood that the NYC Emergency Management is presently undertaking an interagency effort to document and understand actual costs to the City from Hurricane Sandy, including replacement costs, service disruption impacts, and other factors. These values may be a potential data source for more accurate benefits calculations that could be incorporated into a detailed feasibility study.

13.2.3 Build Support

While construction of a barrier may still be decades in the future, it is not too early to begin building support among local stakeholders and congressional representatives.

13.2.4 Establish Administrative Processes

As climate change continues to increase the risk of floods, it will become increasingly important to efficiently approve, permit, and implement flood defense projects. Other flood defense projects currently under way, such as East Side Coastal Resiliency and Red Hook Integrated Flood Protection will be implemented far in advance of a Newtown Creek storm surge barrier; it is important that lessons learned from those projects are institutionalized. The Newtown Creek barrier system would be different than these other projects because it contains an in-water barrier, which presents unique challenges of implementation and operation.

13.2.5 Acquire Strategic Parcels or Easements

Certain strategic parcels will be necessary for barrier construction and maintenance. Establish a real estate plan that identifies where such parcels and land are anticipated to be required and monitor those parcels. Swift action by the City to acquire parcels or easements may lead to much smoother and less costly future implementation of the project.

13.2.6 Define Approach to Surface Water Flood Mitigation

While a Newtown Creek barrier can protect a vast area from storm surge, it will not alleviate flooding from stormwater. The Department of Environmental Protection must continue to refine its approach to stormwater management and implement solutions that are integrated with storm surge defense projects.

[3] NYC Building Congress. 2015. "New York City Construction Costs on the Rise."

14 References

American Society of Civil Engineers (ASCE). 1970. Design and Construction of Sanitary and Storm Sewers. ASCE Manual of Practice, No. 37. Revised by D. Earl Jones, Jr.

DOI. 2012. Preassessment Screen for Newtown Creek, Brooklyn and Queens, New York.

Federal Emergency Management Agency (FEMA). 2010. Debris Estimating Field Guide – FEMA 329. Federal Emergency Management Agency, Department of Homeland Security. Web. September. Accessed online at https://www.fema.gov/pdf/government/grant/pa/fema_329_debris_estimating.pdf.

Federal Emergency Management Agency (FEMA). 2013. Flood Insurance Study (Preliminary), City of New York, New York. p. 131.

Federal Emergency Management Agency (FEMA). 2013. Flood Insurance Study, City of New York, New York, Volume 1 of 1, December. p. 131.

Federal Emergency Management Agency (FEMA). 2014. Region II Coastal Storm Surge Study, September.

HDR. (2015). Gowanus Canal Flushing Time Estimates, memo dated June 1, 2015 (as received from NYCDEP).

Holland, G. 1980. "An analytic model of the wind and pressure profiles in hurricanes," Monthly Weather Review, Volume 108. p. 1212-1218.

Lipton, Eric. 2013. Cost of Storm-Debris Removal in City Is at Least Twice the U.S. Average. *The New York Times.* Web. April 24. Accessed online at http://nyti.ms/ZNxZsN.

MIKE by DHI. (2012). MIKE C-MAP bathymetry database.

MIKE by DHI. (2012). User manual, MIKE CMAP.

MIKE by DHI. (2014a). MIKE 21 Flow Model FM, user manual.

MIKE by DHI. (2014c). MIKE 21 Toolbox, user manual.

National Oceanic and Atmospheric Administration (NOAA). 1955. Rainfall Intensity-Duration Frequency Curves. Retrieved from http://www.nws.noaa.gov/oh/hdsc/Technical_papers/TP25.pdf.

New York City Department of Environmental Protection (NYCDEP). 2008. Gowanus Canal Waterbody/Watershed Facility Plan Report.

New York City Department of Environmental Protection (NYCDEP). 2011. Waterbody/Watershed Facility Plan Report Newtown Creek.

New York City Department of Environmental Protection (NYCDEP). 2011. Newtown Creek Waterbody/Watershed Facility Plan Report. Retrieved from http://www.hydroqual.com/projects/ltcp/wbws/newtown_creek.htm.

New York City Department of Transportation (NYSDOT)/Federal Highway Administration (FHA). 2005. Kosciuszko Bridge Project, Newtown Creek Navigation Analysis

New York City Panel on Climate Change (NPCC2). (2015). Annals of the New York Academy of Sciences, 1336, 2015, 1-151.

U.S. Army Corps of Engineers (USACE). 1996. EM 1110-2-1619 – Risk Based Analysis for Flood Damage Reduction Studies. U.S. Army Corps of Engineers. Washington, D.C.

U.S. Army Corps of Engineers (USACE). 2000. Economic Guidance Memorandum EGM 01-03, Generic Depth-Damage Relationships. CECW-PG. U.S. Army Corps of Engineers. December 4.

U.S. Army Corps of Engineers (USACE). 2000. Economic Guidance Memorandum EGM 01-03, Generic Depth-Damage Relationships. CECW-PG. U.S. Army Corps of Engineers. December 4.

U.S. Army Corps of Engineers (USACE). 2000. Engineering Regulation 1105-2-100, Planning Guidance Notebook. CECW-P. U.S. Army Corps of Engineers. April 22.

U.S. Army Corps of Engineers (USACE). 2004. Gowanus Bay and Canal Ecosystem Restoration Studies

U.S. Army Corps of Engineers (USACE). 2006. ER 1105-2-101 Risk Analysis for Flood Damage Reduction Studies. CECW-P, CECW-E. U.S. Army Corps of Engineers, Washington, D.C. January 3.

U.S. Army Corps of Engineers (USACE). 2009. City of Carpentaria Storm Damage Reduction Project – Economic Appendix. Los Angeles District, U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE). 2014. EGM 15-01 – Economic Guidance Memorandum, 15-01, Federal Interest Rate for Corps of Engineers Projects for Fiscal Year 2015. CECW-P. U.S. Army Corps of Engineers, Washington, D.C. 15 October.

U.S. Army Corps of Engineers (USACE). 2015. HEC-FDA Website and User Manual. Accessed online at http://www.hec.usace.army.mil/software/hec-fda/documentation.aspx.

U.S. Army Corps of Engineers (USACE). 2015. North Atlantic Coast Comprehensive Study: Appendix AL Engineering, Final Report, January. p. 14.

U.S. Army Corps of Engineers (USACE). 2015. North Atlantic Coast Comprehensive Study, Final Report. January.

U.S. Army Corps of Engineers (USACE). 2015. North Atlantic Coast Comprehensive Study: Appendix AL Engineering, Final Report, January. p. 14.

U.S. Environmental Protection Agency (USEPA). 1985. Coastal Marinas Assessment Handbook. U.S. Environmental Protection Agency, Region 4, Atlanta, GA, April. p. 614.

U.S. Environmental Protection Agency (USEPA). 2001. Nutrient Criteria Technical Guidance Manual, Estuarine and Coastal Marine Waters, EPA-822-B-01-003, October.

U.S. Environmental Protection Agency (USEPA). 2011. Gowanus Canal Remedial Investigation Report.

U.S. Environmental Protection Agency (USEPA). 2011. Gowanus Canal Superfund Feasibility Study.

U.S. Environmental Protection Agency (USEPA). 2013. Draft Phase 1 Remedial Investigation Field Program Data Summary Report.

UK Environment Agency. 2013. Benchmarking the latest generation of 2D hydraulic modelling packages, Report SC12002.

United States Department of Commerce. 1961. Technical Paper No. 40, Rainfall Frequency Atlas of the United States. May.

Vickery, P.J. and Wadhera, D. 2008. "Statistical Models of Holland Pressure Profile Parameter and Radius to Maximum Winds of Hurricanes from Flight-Level Pressure and H*Wind Data," J. Applied Meteorology and Climatology, American Meteorology Society, Vol. 47, October. p. 2497 – 2517.

Wu, J. (1980). Wind-stress Coefficients over sea surface and near neutral conditions - A revisit, J. Phys. Oceanography, 10, 727-740.

Wu, J. (1994). The sea surface is aerodynamically rough even under light winds, Boundary layer Meteorology, 69, 149-158.

Part IV:
Supporting Analysis and Background Documents

This page was intentionally left blank.