# Transportation & Maritime Infrastructure Studies

Financial District and Seaport Climate Resilience Master Plan

## Overview

This appendix supplements the *Financial District and Seaport Climate Resilience Master Plan – Chapter 5: Maritime*. This appendix provides additional detail on the technical analyses and studies to understand the existing maritime facilities and functions, as well as how vulnerable they are to sea level rise, what the future maritime needs of the area are, and key considerations for designing resilient maritime assets.

Moreover, while the master plan does not include a specific proposal to replace the FDR Drive viaduct, given the long time horizon of the master plan, it was important to ensure the compatibility of the master plan with potential alterations to the roadway. The project team conducted high-level analysis of how the roadway could be reconfigured in the future to ensure that the flood defense will not limit the City's options for the future of the FDR Drive viaduct, as described herein.

## 1. Introduction

The Financial District and Seaport neighborhoods are a major hub of maritime activity, including ferries, historic ships, sightseeing excursion vessels, and other forms of waterborne transportation. At the end of the 20th century, only a fraction of the maritime uses that once thrived along the Financial District and Seaport waterfront remained. However, in more recent years, water-based transportation has been returning to the area, including the growth of commuter ferries and recreational services. Catastrophic events, such as the September 11 attacks, have also reinforced the critical importance of the waterfront for supporting emergency evacuation. Moreover, the study area is home to critical regional transportation connections that must be maintained while siting flood defense infrastructure.

In support of the Master Plan, the project team reviewed the transportation and maritime infrastructure (TMI) in the study area. This included evaluating the vulnerability of transportation and maritime assets to future flooding due to sea level rise, understanding the criticality of the functions and assets residing within the study area, and analyzing how to adapt transportation and maritime assets to withstand the impacts of future tidal flooding and coastal storms as part of the Master Plan.

## 2. Maritime

Several key questions guided the project team in planning for the future of the Financial District and Seaport's maritime uses. Key questions included:

1. What are the existing maritime facilities and functions and how vulnerable are they to sea level rise?
2. What are the future maritime needs in this area?
3. What needs to be considered when building resilient maritime facilities?

To address these questions, the project team developed a baseline understanding of existing maritime services, usage, and infrastructure in the study area using geospatial datasets and published mapping/data sources. This included obtaining and analyzing data to identify existing maritime uses in the study area, assess their vulnerability to sea level rise, looking to global precedents for resilient maritime uses, and identifying opportunities to include improved or expanded maritime uses in the engineering design of shoreline. The latter analysis included identifying specific locations for proposed improvements.

## 2.1 Existing Maritime Uses

In evaluating existing maritime uses in the study area, the project team looked at the following:

- Existing maritime uses including ferries, historic ships, excursion vessels, and the heliport
- Existing infrastructure at each facility
- Current and future transportation, infrastructure, and passenger/visitor needs for each facility identified in the study area
- Vulnerability of existing infrastructure to effects of flooding and future sea level rise
- Current physical condition of each facility based upon findings in recent inspection reports
- Expected lifespan of the facilities and infrastructure assets
- Anticipated future operations and capacity of existing facilities to support those operations
- Services provided and current operators using each facility
- Existing onshore and offshore space currently occupied by each facility
- Current ferry ridership
- Potential future maritime uses, such as freight and heavy-lift facilities

The maritime uses in the Financial District and Seaport primarily provide waterborne transportation across the city. This important function needs to be safeguarded in the face of climate change, while also accommodating potential future growth as the City's maritime needs change. The primary maritime assets in question include:

- **The Whitehall Ferry Terminal (WFT):** This terminal serves the Staten Island Ferry, the busiest passenger ferry route in the country. The Staten Island Ferry is a free ferry service that provides a critical link for about 70,000 daily passengers between Staten Island and Lower Manhattan (based on 2019 transit ridership figures).
- **The Battery Maritime Building (BMB):** The Battery Maritime Building is a national historic landmark and is home to passenger and freight ferry service to Governors Island, which is operated by the Trust for Governors Island. One of the slips is also operated by NYC Department of Transportation (DOT) and provides regional commuter ferry service.
- **The Pier 6 Downtown Manhattan Heliport**: This heliport provides landings for the New York Police Department (NYPD), emergency access, and a secure landing spot for important government officials, including the President of the United States. The heliport also provides private tourism flights and charter service to area airports and other local/regional destinations.
- **The Pier 11/Wall Street Ferry Stop**: Pier 11 is the busiest ferry landing in the NYC Ferry service and serves several other regional ferry operators.

- **Piers 15, 16, and 17**: Piers 15, 16, and 17 serve as public gathering spaces, including where people can view historic ships and board sightseeing cruises.

In developing a baseline understanding of existing maritime conditions in the study area, the project team came up with the following key takeaways**:**

- The study area is a major hub of maritime activity today and this activity is expected to continue into the future
- Ferries and other vessels currently using the area and infrastructure include:
  - Staten Island Ferry
  - Governor's Island Ferry
  - NYC Ferry
  - Seastreak
  - NY Waterways
  - NY Water Taxi
  - Excursion and recreational vessels
  - Historic ships managed by the Seaport Museum
  - Boats of police, fire, Coast Guard, contractors, and other supporting marine services will make use of slips in the area intermittently when required
- Maritime uses in the study area are highly vulnerable to sea level rise and flooding
- Much of the maritime infrastructure will reach the end of its useful life in the coming years
- Many of the maritime facilities lack space/capacity to allow future operational changes

## 2.2 Sea Level Rise Vulnerability of Maritime Assets

To understand the impacts from climate change that each asset faces, the project team reviewed technical drawings to document each facility's existing above-ground elevations. The project team then compared building elevations with current and future sea level rise to determine when, how, and to what degree each asset will be affected. The analysis below uses the following terms to describe some of the effects of sea level rise:

- *Submerged Daily* - Refers to the condition where the surface of an asset (i.e. pier deck, promenade surface, etc.) is inundated by waters of the East River, for all or a portion of the daily tidal cycle, without the influence of storm surge.
- *Daily Overtopping* - Refers to the condition where wave energy is transmitted over the deck of a maritime asset, during all or a portion of the ordinary daily tidal cycle.
- *High Frequency Storm Surge* - Refers to a storm surge of less than 1 foot. Evaluation of water surface elevation records at the Battery reveals that storm surges of less than 1 foot occur multiple times per month.
- *Low Frequency Storm Surge* -Refers to a storm surge of greater than 1 foot. Evaluation of water surface elevation records at the Battery reveals that storm surges of more than 1 foot occur multiple times per year.
- *Frequent Overtopping -* With regard to overtopping, the frequency and intensity of wave overtopping of the Study Area's maritime assets were evaluated as a function of each structures' freeboard (F) (distance between the deck surface and the water surface elevation) relative to a wave height (H) of 3 feet, using the ratio F/H ("Overtopping Vulnerability Ratio"). Specifically, the freeboard was determined based upon known structure deck elevations and the MHHW elevation associated with a particular sea level rise

projection.  A wave height of 3 feet was selected based upon a wave generation calculation for the East River.  Based upon "rule of thumb" coastal engineering principles, a vulnerability ratio of less than 1.5 was defined as being sufficient to qualify a structure as being vulnerable to "frequent overtopping."

### 2.2.1 Whitehall Ferry Terminal

If no action is taken, by the 2050s, daily tides will reduce the clearance between the top ferry deck and roof of the terminal. This could require steeper boarding ramps which can be challenging for all users. By the 2080s, the lower level will be submerged daily, which will not only affect lower-level boarding, but operations of the whole facility.

The floor elevations of the Terminal vary, with the lowest elevation (lower level boarding floor) having an elevation of +7 feet NAVD88.  While NYCDOT's Flood Mitigation project is being designed to protect for infrequent storm surge (up to 10-11 feet NAVD88), it does not address the operational impacts of gradual sea level rise.

Further detail regarding the impacts of sea level rise are provided below and in Figure 1.

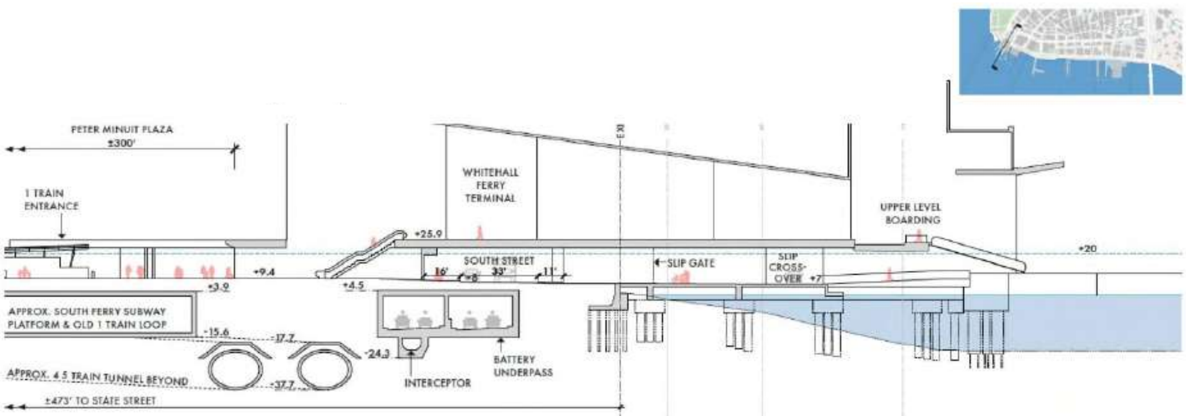


*Figure 1. Whitehall Ferry Terminal Sea Level Rise Vulnerability Analysis (Elevations in Feet NAVD88)*

Anticipated impacts by the 2050s (+30 inches sea level rise):

- Freeboard of lower-level loading floor reduced to ~2 feet at MHHW
- Increased vulnerability of Plaza and Terminal Building to high frequency storm surge flooding due to more frequent overtopping of adjoining bulkhead and associated nuisance spray/flooding along promenade and sidewalk.
- Impact of wave action upon seaward-facing structural walls
- Reduced clearance between upper ferry deck and slip roof
- Lower-level boarding logistics affected—bridge submerged frequency
  - Possible ADA non-compliance
  - Lower level exposed to wave action
- Upper-level boarding bridge logistics affected

Anticipated Impacts by the 2080s (+58 inches sea level rise):

- No freeboard for lower-level loading level at MHHW (floor is inundated daily at highest tide stage)
- Daily overtopping of bulkhead and associated Plaza flooding

- Frequent flooding of the Terminal's easternmost interior spaces, including lower level loading, first floor crossover, storage spaces, accessways, and emergency egress stairs
- Daily flooding of Gallows' MEP rooms and other finished Gallows' spaces
- Increased frequency and intensity of wave action impacting seaward-facing structural walls
- Reduced clearance between top ferry deck and slip roof
- Lower-level loading logistics substantially affected—bridge submerged frequently
    - Possible ADA non-compliance
    - Lower-level exposed to wave action
    - Likely abandonment of lower-level loading
- Upper-level loading logistics affected

Anticipated Impacts by the 2100 (+75 inches sea level rise):
- Lower-level loading floor inundated through approximately one third of every day
- Ongoing further impacts of 2080s performance issues, including complete abandonment of lower-level boarding level.

### 2.2.2 Battery Maritime Building

The terminal is one of the lowest-lying assets in the area, with a loading level floor elevation that ranges from approximately +5 to +7 feet NAVD88. If no action is taken, the boarding area of the Battery Maritime Building will experience monthly tidal flooding by the 2050s, leading to significant impacts and frequent service closures. Further detail is provided below and in Figure 2.

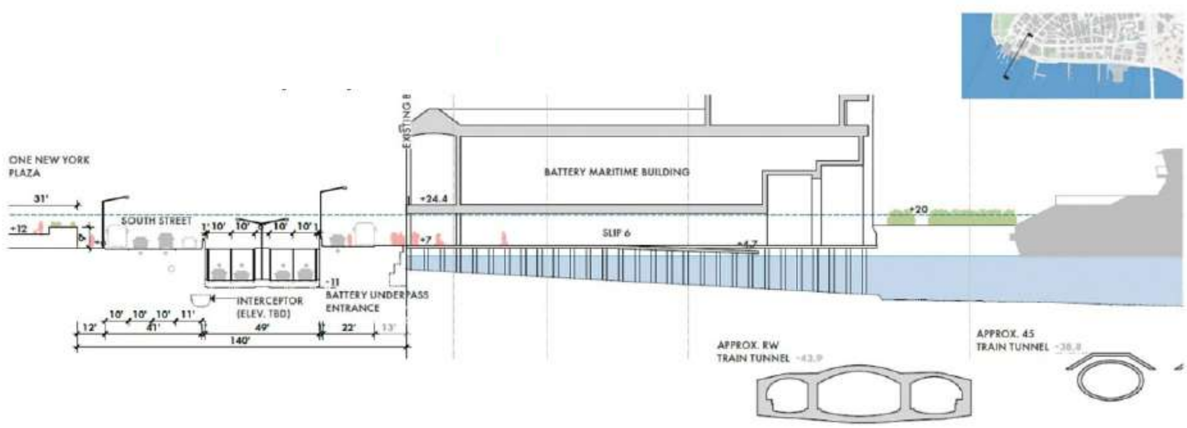


*Figure 2. Battery Maritime Building Sea Level Rise Analysis (Elevations in Feet NAVD88)*

Anticipated Impacts by the 2050s (+30 inches sea level rise):
- Freeboard of lower-level loading floor reduced to ~2 feet at MHHW
- Impact of wave action upon seaward-facing structural walls
- Increased vulnerability of Plaza and Terminal Building to high frequency storm surge flooding due to more frequent overtopping of adjoining bulkhead and associated nuisance spray/flooding along promenade and sidewalk.
- Reduced clearance between upper ferry deck and slip roof
- Non-elevated utilities are affected
- Lower-level boarding logistics affected—bridge submerged frequency

- o Possible ADA non-compliance, existing accessibility issues at Slips 5 and 6 worsen
- o Lower-level exposed to wave action

- Accessibility at Slips 5 and 6 worsens
- More frequent overtopping of adjoining bulkhead and associated nuisance spray/flooding along promenade and sidewalk.

Anticipated Impacts by the 2080s (+58 inches sea level rise):

- No freeboard for lower-level loading level at MHHW (floor is inundated daily at highest tide stage)
- Daily overtopping of adjoining bulkhead and associated Plaza flooding
- Frequent flooding of the Terminal's lower-level interior spaces
- Substantial wave forces regularly impact seaward-facing walls of enclosed spaces
- Non-elevated utilities are infeasible
- ADA accessibility infeasible at Slips 5 and 6 without modifications. Slip 7 periodically ADA inaccessible
- Access to second floor affected
- Regular ferry service likely becomes infeasible

Anticipated Impacts by the 2100 (+75 inches sea level rise):

- Lower-level loading floor inundated through approximately 1/3 of every day
- Terminal is entirely non-functional

### 2.2.3 Pier 6 Downtown Manhattan Heliport

The Pier 6 deck and terminal elevation is approximately +6.5 feet NAVD88. By the 2050s, the deck of Pier 6 will be flooded monthly by high frequency surge and wave events, rendering it non-functional. Further detail is provided below and in Figure 3.

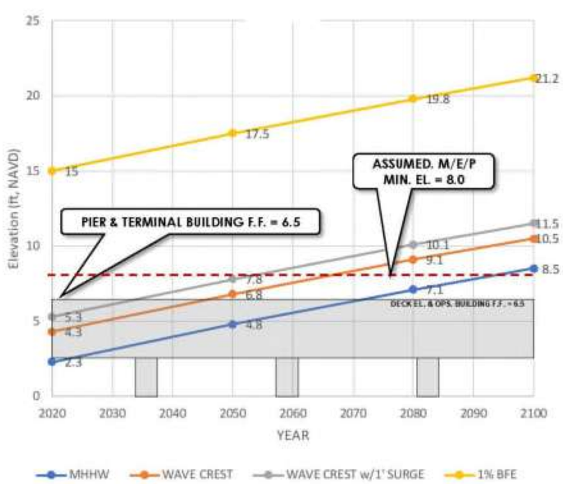



*Figure 3. Pier 6 Heliport Sea Level Rise Vulnerability Analysis (Elevations in Feet NAVD88)*

Anticipated Impacts by the 2050s (+30 inches sea level rise):

- Freeboard of pier deck and terminal building reduced to ~1.5 feet at MHHW
- Increased impact of wave action upon seaward-facing structural walls of terminal building

- Increased vulnerability of pier deck, adjoining plaza area and terminal building to high frequency storm surge flooding and wave overtopping.

Anticipated Impacts by the 2080s (+58 inches sea level rise):

- No freeboard on pier deck at MHHW (floor is inundated daily at highest tide stages)
- Daily wave overtopping of adjoining bulkhead and associated Plaza flooding
- Frequent flooding of the Terminal's interior spaces
- Substantial wave forces regularly impact seaward-facing walls of enclosed spaces
- Non-elevated utilities are infeasible
- Regular heliport service likely becomes infeasible, as it will be inundated for a portion of every day

Anticipated Impacts by the 2100 (+75 inches sea level rise):

- Lower-level loading floor inundated through approximately on half of every day
- Heliport is entirely non-functional

### 2.2.4 Pier 11/Wall Street Ferry Stop

The Pier 11 deck and terminal elevation is approximately +7 feet NAVD88. By the 2050s, the deck of Pier 11 will be flooded monthly by high frequency surge and wave events, rendering it non-functional. Further detail is provided below and in Figure 4.

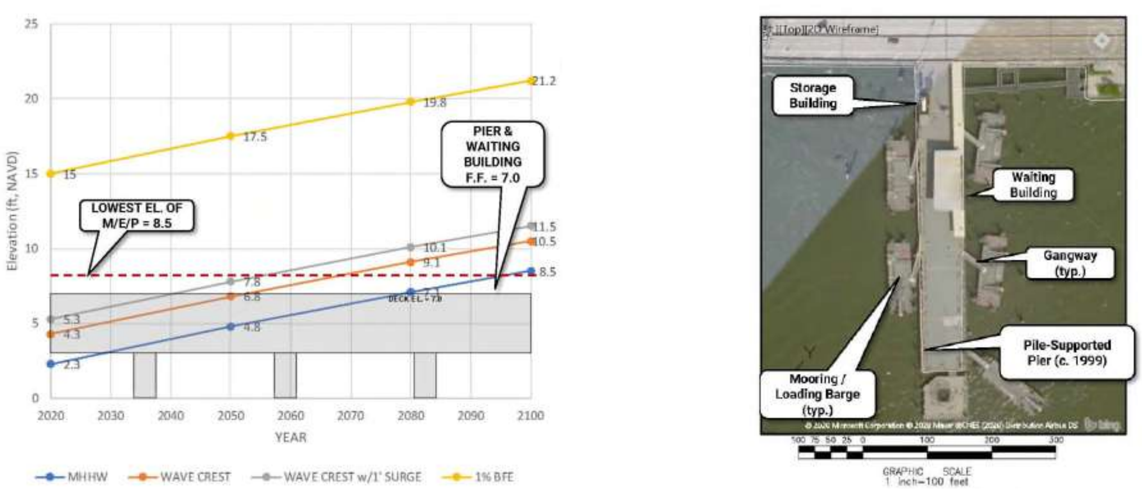


*Figure 4. Pier 11 Sea Level Rise Vulnerability Analysis (Elevations in Feet NAVD88)*

Anticipated Impacts by the 2050s (+30 inches sea level rise):

- Freeboard of pier deck and terminal building reduced to ~2 feet at MHHW
- Increased impact of wave action upon seaward-facing structural walls of terminal building
- Increased vulnerability of pier deck, adjoining plaza area and terminal building to high frequency storm surge flooding and wave overtopping.
- ADA accessibility and general functionality of gangways to floating loading barges is affected, and requires modification.

Anticipated Impacts by the 2080s (+58 inches sea level rise):

- No freeboard on pier deck at MHHW (floor is inundated daily at highest tide stages)
- Daily wave overtopping of adjoining bulkhead and associated Plaza flooding
- Frequent flooding of the Terminal's interior spaces
- Substantial wave forces regularly impact seaward-facing walls of enclosed spaces
- Non-elevated utilities are infeasible
- Regular service is likely to be infeasible.

Anticipated Impacts by the 2100 (+75 inches sea level rise):

- Pier deck inundated approximately one third of every day
- Ferry service is entirely non-functional

Loss of functionality will occur as early as the 2050s due to regular wave overtopping of the deck, building and pier inundation during high-frequency surge events, and difficulty achieving ADA access to barges at elevated water levels.

### 2.2.5 Piers 15, 16, and 17

Piers 16, 17 and the most landward and seaward portions of Pier 15 have deck elevations of approximately +7 feet NAVD88. The effects of sea level rise for these assets will be equivalent to those described above for Pier 11.

The seaward portion of Pier 11 has an elevation of approximately +11 feet NAVD88, and Pier 17 is similarly elevated. These higher elevation piers will not be negatively impacted by daily tidal conditions this century; however, they will remain vulnerable to tidal surges and wave impacts associated with low frequency storm events.

Further detail is provided below and in Figure 5 and Figure 6**Error! Reference source not found.**.

*Pier 15*

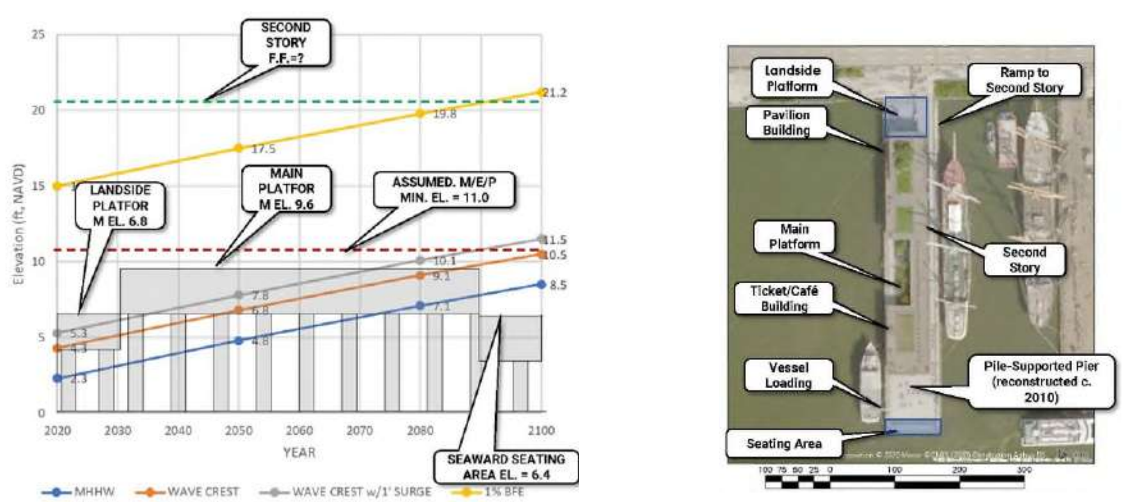


*Figure 5. Pier 15 Sea Level Rise Vulnerability Analysis (Elevations in Feet NAVD88)*

Anticipated impacts include:

- Landside platform and seating area inundation during low-frequency surge events (lower deck only, except in 2100)
    - 2020: 5.5-foot (NAVD88) inundation of main platform
    - 2100: 11.5-foot (NAVD88) inundation

Loss of functionality will occur for landside access and the seating area as early as the 2050s and for the main platform deck as early as the 2080s due to regular wave overtopping of the deck, building and pier inundation during high-frequency surge events, and potential difficulties with vessel loading.

*Pier 16*

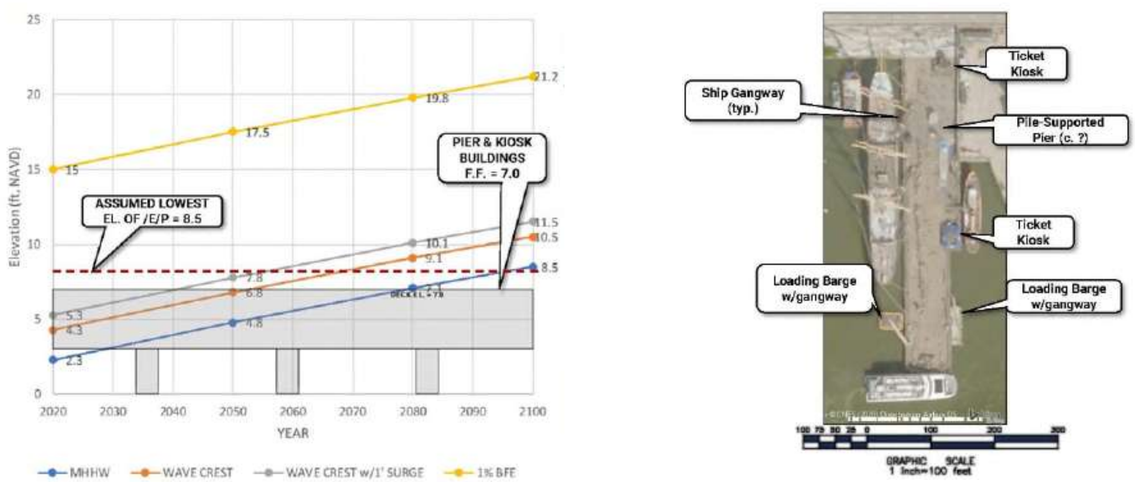


*Figure 6. Pier 16 Sea Level Rise Vulnerability Analysis (Elevations in Feet NAVD88)*

Anticipated Impacts by the 2050s (+30 inches sea level rise):

- Freeboard of landside platform and seaward seating area reduced to ~1.5 feet at MHHW
- Increased vulnerability of pier deck and adjoining plaza area to high frequency storm surge flooding and wave overtopping.

Anticipated Impacts by the 2080s (+58 inches sea level rise):

- No freeboard on landside platform and seaward seating area pier deck at MHHW (floor is inundated daily at highest tide stages)
- Daily wave overtopping of adjoining bulkhead and associated Plaza flooding
- Challenges for achieving ADA compliance of vessel loading
- Regular access to the central, elevated portion of the pier is limited.

Anticipated Impacts by the 2100 (+75 inches sea level rise):

- Landside platform and seaward seating area inundated approximately one half of every day
- No reliable access to the central, elevated portion of the Pier
- Vessel loading challenges.

## 2.3 Global Precedents for Resilient Maritime Uses

The project team looked to various global precedents of resilient maritime facilities for applicability of setting, use, and design features to understand potential options for the Whitehall Ferry Terminal, Governor's Island Ferry and other maritime uses along the waterfront. The project team paid special attention to the following:

- Existing ridership and data to project future ridership
- Number of slips and in-water space required for each maritime use
- Amount of land required to support each maritime use
- How facilities maintain functionality in areas with a large tidal range, which can serve as a model for how to adapt maritime uses to future sea level rise (see Figure 7)


*Figure 7. Master Plan Tidal Range Compared to Global Precedents*

Various applicable precedents are summarized in Table 1.

*Table 1. Global Precedents for Resilient Maritime Uses*

| Global Precedent | Setting/Use Features | Design Features | Applicability to Study Area |
|---|---|---|---|
| Colman Dock Terminal (Seattle) | High volume traffic, two-level large and small vessel accommodation, passenger and vehicles, urban setting | Second story passenger terminal, first story garage, lift bridge used to accommodate large tidal range, separate facilities for short-range (small) and long-range (large) vessels, entire facility built on pier | Accommodating a wide variety of vessels at a large tidal range in an urban setting |
| SeaBus Terminals (Vancouver) | High volume traffic, two-level vessels, passenger-only, urban setting | Floating terminal, gangway access, elevated connection to city-proper | Floating terminal accommodates tidal variability, emphasis on connectivity to urban fabric and accessible |

| Global Precedent | Setting/Use Features | Design Features | Applicability to Study Area |
|---|---|---|---|
| | | | "get-downs" to maritime uses |
| Inter-Harbor Passenger System (Lisbon) | High volume traffic, two-level vessels, passenger-only, urban setting, 10+ ferry stops | Upland terminals, exclusively barge moorings with gangways, side loading of vessels | Accommodating large passenger ferry ridership |
| Long Wharf (Boston) | High volume traffic, multiple vessel types, two-level vessels, passenger-only, urban setting | Upland terminal, upper- and lower-level loading from floating barges (upland loading from barge-mounted platforms), mooring accommodates high surge events, side loading of vessels | Navigating elevation changes while maintaining accessibility, accommodating high surge events |
| Isle of Man Terminal (Liverpool) | High volume traffic, pedestrian and vehicular, multiple vessel types, multi-level vessels, urban setting | Upland and floating terminal, separate moorings for large and small vessels, lift bridge vehicle gangways to accommodate large tidal range | Accommodating a wide variety of vessels in an urban setting, navigating elevation changes while maintaining accessibility, floating terminal accommodates tidal variability |

## 2.4 Future Maritime Needs Space Considerations

To understand the future needs of maritime uses in the study area, the project team examined the expected lifespan of existing maritime facilities, as well as historic trends and growth projections, to determine the potential for future changes in operations. The project team also examined the potential for new uses, such as waterborne freight. Once estimates of future ferry ridership for each facility were developed, the project team identified where additional slips, or spaces for ferries to dock, may be needed to accommodate future growth and long-term adaptability. The project team also examined additional space needs, such as passenger loading and waiting areas.

Due to the uncertainties involved in projecting the needs associated with future maritime uses, the project team developed two scenarios: low and moderate growth (see Figure 8). These projections are intended to give a broad sense of potential needs, acknowledging that demand for ferry services can be heavily affected by investments in the expansion of services and pricing. These projections are based on existing peak hour ridership for each service and apply growth factors based on historic trends or, in the case of the Governors Island Ferry, future development projections. The project team then analyzed the operations of each terminal to determine if additional slips would be needed to accommodate the demand. In addition to ferries, the project team also accounted for additional space for emergency maritime evacuation, potential future freight services, and growth of visiting ships and other excursion vessels. The facilities to be developed will also need to include docking capacity for both bow-loading and side-loading vessels.

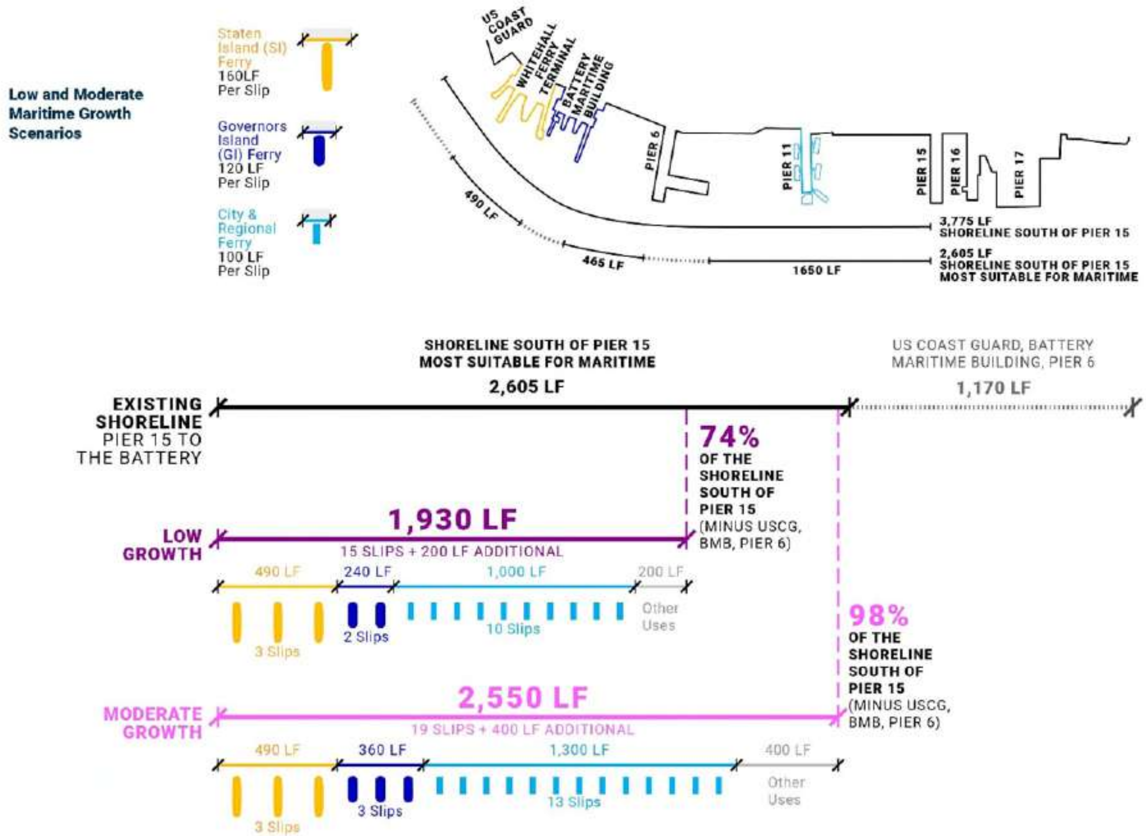


*Figure 8. Low and Moderate Maritime Growth Scenarios*

*Staten Island Ferry*

A free service, the Staten Island Ferry provides a critical commuter link between Staten Island and Lower Manhattan as well as points beyond through additional transit connections. At 3,700 peak hour ridership currently, this is the busiest ferry route in the study area.[1] By 2050, the project team projected 4,300 peak hour ridership under a low growth scenario (0.5% growth rate) and 5,000 under a moderate growth scenario (0.95% growth rate).[2] Under either growth scenario, additional capacity at Whitehall Ferry Terminal is not necessary. However, the Ferry Terminal will need be rebuilt to some extent to accommodate an increasing tidal range to allow for adaptation to sea level rise over time, and to accommodate a flood defense system. DOT has also expressed an interest in additional passenger waiting and queuing space.

*Governors Island Ferry*

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[1] Current peak hour ridership is based on data provided from DOT on 2017 peak (3,488); the growth rate for annual ridership from 2017-2019 (5.45%) was applied to arrive at the 3,700 peak hour figure for 2019.
[2] 0.97% growth rate was provided by DOT, which was halved for the conservative growth rate (.5%).

Ferries from Lower Manhattan and Brooklyn are the only way to access Governors Island. Currently, the Trust for Governors Island has exclusive use of one slip of the Battery Maritime Building, and shares use of one slip with a hotel operator that manages the upper floor uses. The ferry has a 1,700 peak hour ridership.[3] Future ridership projections are based on North Island and Academic Campus Build-Out Scenarios for 2023 from NYCEDC's Governor's Island Travel Demand Forecast, applying a 1% growth rate. With continued growth under the North Island development scenario, peak hour ridership would reach 2,200 in 2050. This additional ridership can be accommodated by continuing to use one slip. With the Academic Campus development scenario, 10,800 peak hour ridership is projected.[4] To accommodate this, three slips would be needed.[5] The Trust for Governors Island has noted that the Battery Maritime Building is not an ideal facility for ferry service, though the general location of the terminal suits their needs well.

*NYC Ferry*

The NYC Ferry Service was launched in 2017 and has expanded several times since. Pier 11/Wall Street is the busiest stop, currently serving six lines from Soundview to the Rockaways with a current peak hour ridership of 1,200.[6] By 2050, the project team projected 1,600 peak hour ridership under a low growth scenario and 2,600 under a moderate growth scenario.[7] The project team's analysis found that either of these growth scenarios could be accommodated within the existing footprint through increased frequency of service. There is also an interest in improving waiting and queuing space for the service.

*Other Private Ferry Systems*

The project team also developed future ridership projections for several other private ferry systems operating in the study area, including:

- The New York Water Taxi, stopping at Battery Park, Pier 11, and Pier 16, which provides regional service around NYC and the New York Harbor
- NY Waterway, stopping at Battery Maritime Building and Pier 11, which provides service to Midtown, Weehawken, NJ, Port Imperial, NJ, and Hoboken, NJ
- SeaStreak, which provides service from the Financial District out to Highlands, NJ and Atlantic Highlands, NJ

Together, these other private services provide 1,965 peak hour riders currently at the Battery Maritime Building and Pier 11.[8] By 2050, the project team projected 2,685 peak hour ridership under a low growth scenario,

[3] Provided by NYCEDC

[4] Build-out scenarios from EDC's Governor's Island Travel Demand Forecast, applying a 1% growth rate for North Island after full build-out in 2023, assumes no gondola.

[5] This assumes 1,200 vessel capacity at 80% utilization, and 3 landings per hour. The 2017 GI Transportation study was based on design target of 9,000 peak hour ridership operating at 100% utilization.

[6] Provided by NYCEDC

[7] NYCEDC shared 5YR projections (moderate 5% growth and high 10% growth) but noted that these would be unrealistic to project out further to 2050 because of terminal capacity constraints. The project team cut the moderate growth rate in half to 2.5% and added a low growth rate of 1% to be reflective of these space constraints as well as ridership demand.

[8] Provided by NYCEDC

necessitating one additional slip. Under a moderate growth scenario, the project team projected 4,240 peak hour ridership, which would require four additional slips.[9]

*Summary*

A summary of peak hour passengers and slip capacity under present-day, low growth, and moderate growth conditions can be found in Table 2.[10] As an important note, this analysis is based on vessel throughput capacity and not passenger loading/unloading efficiency.

*Table 2. Summary of Ferry Growth Projections*

| Service | Peak Hour Passengers (appx) | | | Capacity | | | |
|---|---|---|---|---|---|---|---|
| | **No Growth (Existing)** | **2050 Low Growth** | **2050 Moderate Growth** | **Existing Building Size / Waiting Area** | **Existing Slips** | **Low Growth Slips** | **Moderate Growth Slips** |
| **Staten Island Ferry (inbound)**<br>**(outbound)** | **1,300**<br>**2,400** | **1,500**<br>**2,800**<br>(0.5%) | **1,700**<br>**3,200**<br>(0.97%) | **280,000 SF**<br>Enclosed Terminal | **3** | **3**<br>(No increase needed) | **3**<br>(No increase needed) |
| **Governors Island Ferry**<br>**(inbound)**<br>**(outbound)** | <br>**110**<br>**1,650** | (NI scenario)<br>**100**<br>**1,700** | (AC scenario)<br>**1,000**<br>**10,800** | **6,400 SF**<br>Enclosed Waiting Area | **1** | **2**<br>(+1) | **3**<br>(+2) |
| **Other Private @ BMB**<br>*NY Waterways, Seastreak*<br>**(inbound)**<br>**(outbound)** | <br><br>**4**<br>**65** | <br>(1%)<br>**6**<br>**85** | <br>(2.5%)<br>**9**<br>**140** | | **1** | **1**<br>(No increase needed) | **1**<br>(No increase needed) |
| **NYC Ferry (inbound)**<br>**(outbound)** | **145**<br>**1,200** | **200**<br>**1,600**<br>(1%) | **300**<br>**2,600**<br>(2.5%) | **6,500 SF**<br>Sheltered Waiting Area | **5** | **5**<br>**(No increase needed)** | **5**<br>**(No increase needed)** |
| **Other Private @ Pier 11**<br>*(NY Waterways, TWFM Ferries, NYCWT, Capital Cruises)*<br>**(inbound)**<br>**(outbound)** | <br><br>**130**<br>**1,900** | **(1%)**<br><br>**180**<br>**2,600** | **(2.5%)**<br><br>**280**<br>**4,100** | **3,500 SF**<br>Enclosed Building<br>**50,000 SF**<br>Outdoor Waiting Area | **3** | **4**<br>(+1) | **7**<br>(+4) |
| **Total Other Private** | **2,099** | **2,871**<br>(1%) | **4,529**<br>(2.5%) | | **4** | **5** | **8** |
| **Total NYC Ferry + Regional Ferry** | **6,805** | **7,900** | **19,600** | | **9** | **10** | **11** |
| **Total** | **8,904** | **10,771** | **24,129** | | **13** | **15** | **19** |

[9] Consistent with the other services, the project team applied a 1% growth factor for the low scenario, and 2.5% in the moderate.

[10] There are many other factors that may impact the number of slips/docks needed, including size of vessels, assumptions on capacity, provisions for docking both bow-loading and side-loading vessels, and operational changes.

In the low growth scenario, a total of 15 ferry slips would be needed, which would require 1,730 linear feet of shoreline to accommodate. With an additional 200 linear feet for other uses than ferries, a total of 1,930 linear feet would be needed for all maritime uses—74% of the entire shoreline south of Pier 15.

In the moderate growth scenario, a total of 19 ferry slips would be needed, which would require 2,150 linear feet of shoreline to accommodate. With an additional 400 linear feet for other uses than ferries, a total of 2,550 linear feet would be needed for all maritime uses—nearly the entire shoreline south of Pier 15.

In total, there are 3,775 linear feet of shoreline from Pier 15 to The Battery. This is the area where current ferry services are located, and the area best positioned for accommodating any additional growth.

While the master plan assumes the existing level of maritime activity along this waterfront, these projections provided the project team with a sense of scale for potential future maritime uses. They also demonstrated the need to design a waterfront esplanade that can be flexible to accommodate future changes.

# 3. Transportation

## 3.1 Overview

The project team's evaluation of non-maritime transportation infrastructure in the study area was rooted in the need to support critical regional transportation connections while evaluating how major transportation infrastructure may need to be adapted to make room for coastal defense infrastructure.

*What the project team studied:*

- How the FDR Drive viaduct could be reconfigured to make room for coastal defense
- How the Battery Park Underpass could be reconfigured to make room for coastal defense
- The traffic implications of these potential changes

*What the project heard from the community:*

- The replacement of the FDR Drive viaduct with an at-grade street should be explored, but there are also concerns about the impacts of potentially increasing vehicle traffic on surface streets, especially in the vicinity of the Alfred E. Smith Houses
- The replacement of the viaduct should be considered as part of a regional strategy to modify the sections of the FDR Drive north of the Brooklyn Bridge

*Key takeaways:*

- Replacing the FDR Drive viaduct with an at-grade 6-lane roadway is a viable approach but requires future study
- Integrating coastal defense into the Battery Park Underpass would require the loss of one or more lanes of traffic, which could have impacts on regional traffic flows and/or divert traffic to local streets
- Ultimately, reconfiguration is not required to achieve the goals of the master plan

## 3.2 Existing Roadway Configurations and Projected Traffic Volumes

The project team started by evaluating existing roadway configurations in the study area to develop a baseline understanding of how they figure into the design of coastal defense infrastructure, how they currently support existing traffic volumes and connectivity through and beyond the area, and ultimately to support the development of alternatives. The alternatives must accommodate space for coastal defense while ensuring transportation infrastructure in the area continues to provide critical local and regional connections well into the future.

*Existing Roadway Configurations*

Existing roadway infrastructure in the study area is in large part defined by the FDR Drive viaduct, a regional highway under the jurisdiction of the New York State Department of Transportation (NYSDOT) that runs along the existing waterfront and travels from above-grade in the north of the study area to below-grade at the southernmost point of the study area, merging into the Battery Park Underpass (BPU). This highway provides critical connections to Route 9A and the Hugh L. Carey Tunnel via the BPU and to the Brooklyn Bridge at an interchange at the northernmost part of the study area. South Street runs below the elevated viaduct and is part of the neighborhood street grid in the area.

The project team determined that the FDR Drive viaduct is a major influence on the range of feasible strategies for alignment of coastal defense infrastructure. The FDR Drive viaduct currently has two travel lanes in each direction, though narrows to one lane southbound under the Brooklyn Bridge. These lanes support current peak hour traffic flows, as detailed below. Any alternatives for the FDR Drive viaduct would need to consider and account for regional connections at both the Battery Park Underpass (BPU) (including its connection to the Hugh L. Carey Tunnel) and the FDR Drive/Brooklyn Bridge interchange.

*Current Traffic Volumes*

The project team used traffic volume counts from October 2019[11] to estimate current-day traffic flows along the FDR Drive viaduct and at the Brooklyn Bridge interchange. Current traffic volumes, as well as representative past volumes, are also shown in **Error! Reference source not found.**.

[11] Provided by DOT

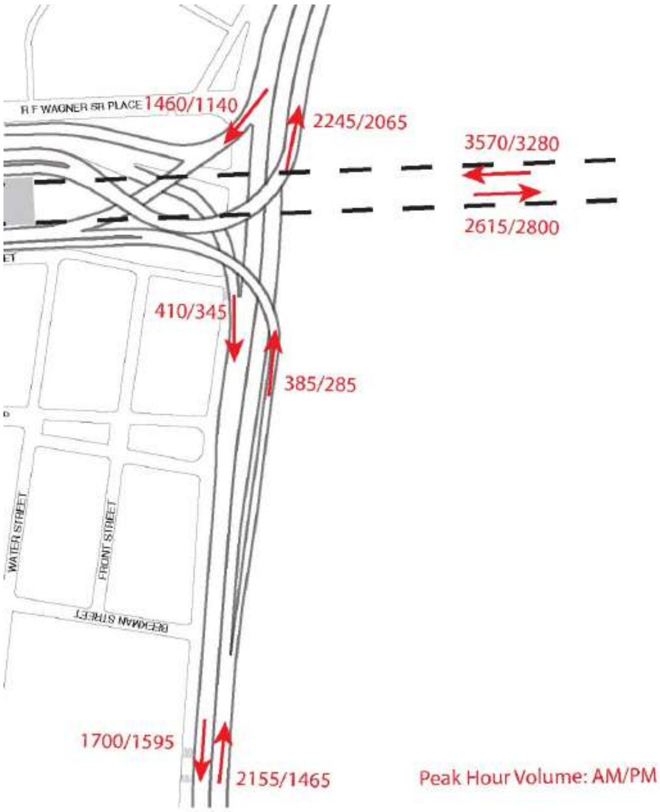


*Figure 9. 2019 Traffic Volumes (AM/PM)*

For point of comparison, the project team also looked at the 2002 Lower Manhattan FDR Drive At-Grade Study. The project team found that traffic volume counts from October 2019 for the FDR Drive viaduct northbound and southbound (south of the Brooklyn Bridge) are significantly lower than the assumed and projected future volumes in the 2002 study. As shown in **Error! Reference source not found.**, the 2002 study findings show traffic volumes 30-70% higher than current conditions.

*Table 3. Projected Peak Hour Traffic Volumes (in vph) from 2002 FDR At-Grade Study (AM Peak/PM Peak)*

| | From 2002 Study (1) | | DOT counts (2) |
|---|---|---|---|
| | **2002** | **Projected 2022** | **2019** |
| **FDR Drive SB (south of bridge)** | 2,400 / 2,050 | 2,640 / 2,255 | 1,700 / 1,595 |
| **FDR Drive NB (north of bridge)** | 2,570 / 2,300 | 2,827 / 2,530 | 2,155 / 1,465 |

(1) Lower Manhattan FDR Drive At-Grade Study, 2002 (2002 baseline and 2022 projected with 10% growth)

(2) NYCDOT Volume Counts October, 2019

*Future Traffic Volumes*

Owing to the long timeframe of the master plan and the general uncertainty regarding future conditions in 2050 and beyond given the expected implementation of congestion pricing as well as changes in travel patterns and emerging technologies, the project team developed three future traffic volume scenarios[12] to support the development of alternatives, as opposed to the traditional approach of a straight-line projection of current traffic volumes with one background growth rate. The project team began by looking at historic traffic volumes (1990 to today) into Manhattan's central business district via NYC DOT's Citywide Mobility Reports. These showed a relatively consistent downward trend in traffic volumes since 2000. The project team also looked at the City's own mode shift goals as part of its sustainability plans (notably OneNYC 2050[13]) and the implications for reduced automobile travel around the city.

Based on the historic traffic volumes into Manhattan, the OneNYC 2050 mode shift targets, and U.S. Census journey-to-work data into Lower Manhattan, the project team developed the three traffic volume scenarios:

1. 0% traffic reduction from current volumes (conservative)
2. 30% traffic reduction from current volumes (middle)
3. 60% traffic reduction from current volumes (optimistic)

These vehicle volumes are outlined in **Error! Reference source not found.**.

*Table 4. Future FDR Drive Traffic Volumes*

| | | | | 2050 | | | 2100 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2002(4) | 2019(5) | Conservative | Mid | Optimistic | Conservative | Mid | Optimistic |
| Southbound | Exit 2 (exits) | | 1,460 | 1,460 | 949 | 438 | 1,460 | 913 | 365 |
| | Pearl St On-Ramp | | 410 | 410 | 267 | 123 | 410 | 256 | 103 |
| | Elevated (south of bridge) | 2,400 | 1,700 | 1,700 | 1,105 | 510 | 1,700 | 1,063 | 425 |
| | Exit 1 (exits) | 1,002 | | 1,002 | 651 | 301 | 1,002 | 626 | 251 |
| | Exit 1 (entries) | - | | - | - | - | - | - | - |
| | Batt. Underpass | 1,398 | | 1,398 | 909 | 419 | 1,398 | 874 | 350 |
| Northbound | Exit 2 (exits) | | 385 | 385 | 250 | 116 | 385 | 241 | 96 |
| | Pearl St On-Ramp + BK Bridge | | 2,245 | 2,245 | 1,459 | 674 | 2,245 | 1,403 | 561 |
| | Elevated (south of bridge) | 2,500 | 2,155 | 2,155 | 1,401 | 647 | 2,155 | 1,347 | 539 |
| | Exit 1 (exits) | 350 | | 350 | 228 | 105 | 350 | 219 | 88 |
| | Exit 1 (entries) | 100 | | 100 | 65 | 30 | 100 | 63 | 25 |
| | Batt. Underpass | 2,750 | | 2,750 | 1,788 | 825 | 2,750 | 1,719 | 688 |

(4) Lower Manhattan FDR Drive At-Grade Study, 2002
(5) NYCDOT Volume Counts October, 2019

None of these scenarios predict an increase in vehicle traffic due to the 20-year downward trend and the City's policy goals that seek to further reduce automobile traffic. Although congestion pricing may slightly increase traffic volumes on the FDR Drive viaduct because these trips would not be subject to a toll under State legislation, overall traffic into and around Manhattan is still expected to decrease.

The project team developed all alternatives using the conservative scenario as a baseline starting place for analysis. To maintain the current volumes on the FDR Drive viaduct, one lane in either direction is sufficient if it is

[12] Traffic data was obtained from NYC DOT's available sources: TIMS database, CBD Tolling EIS, and Streetlight data for origin/destination patterns

[13] NYC's long-term strategic plan to achieve growth, equity, sustainability, and resilience goals

limited access. Two lanes in either direction are needed if signalized intersections are introduced, with a potential fifth center turn lane where left turns are permitted.

## 3.3 Potential Alternatives to the FDR Drive Viaduct

The project team examined several alternative FDR Drive viaduct configurations that had the potential to create additional space available on-land to site flood protection. Structural feasibility and traffic implications were also analyzed.

From discussions with NYCEDC, the Mayor's Office of Climate Resiliency (MOCR), and New York City Department of Transportation (NYCDOT), and NYSDOT, the team established that the FDR Drive viaduct is a critical regional connection between the Battery Park Underpass and the Brooklyn Bridge and the master plan must maintain this connection in some form. Traffic volumes in Manhattan and on this section of the FDR Drive viaduct have reduced in the last several decades, consistent with the City's OneNYC 2050 sustainability goals. Feedback from NYCDOT and NYSDOT indicated an openness to "right-size" the section of the FDR Drive viaduct south of the Brooklyn Bridge to an at-grade, non-limited-access road, supported by community feedback indicating general interest in removing the current FDR Drive viaduct.

The project team explored and evaluated the technical feasibility of the following alternatives to the FDR Drive viaduct remaining as-is, driven in part by projections of future traffic volumes:

a. FDR Drive viaduct replaced with a smaller viaduct
b. Tunnel or trough
c. At-grade roadway

### 3.3.1 Alternative A: Reduced Viaduct

This alternative would involve reconstructing the elevated FDR Drive viaduct at a narrower width (see Figure 10).


*Figure 10. Alternative A. Reduced FDR Drive Viaduct*

Given the significant reconstruction or adaptation of the FDR Drive viaduct required to implement this alternative, significant expected impacts to traffic, and the minimal benefits it would provide from a transportation or urban design perspective, the project team ultimately did not recommend moving forward with Alternative A.

### 3.3.2 Alternative B: Tunnel or Trough

The project team explored two variations for replacing the FDR Drive viaduct as limited-access highway below-grade with one lane in either direction:

- **Trough**, where the roadway would be below grade and constructed through cut and cover
- **Tunnel**, where the roadway would be below grade in a bored tunnel

The trough option could be either mostly on-land, taking up space where the elevated FDR Drive viaduct is today, or located outboard. The tunnel would most likely need to be located outboard, as it would face conflicts with existing underground utilities both on-land and nearshore. While a trough option could maintain the traffic connections between the Brooklyn Bridge and FDR Drive viaduct, the tunnel option would likely have to bypass the Brooklyn Bridge interchange. Both options could provide additional space to site the coastal defense on-land but were deemed infeasible due to considerations described below.

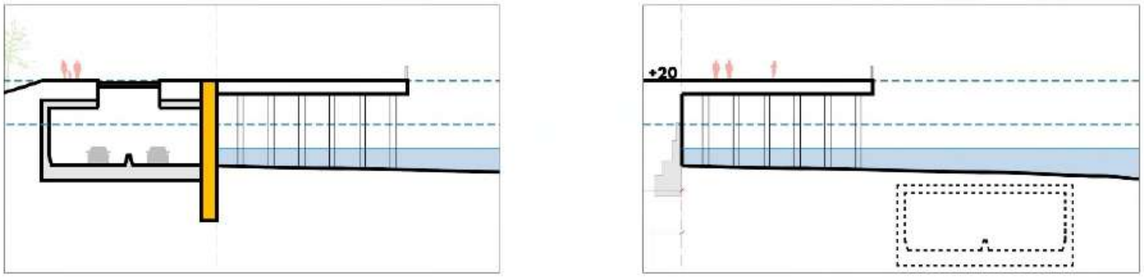


*Figure 11. Alternative B: Trough (left) or Tunnel (right)*

As shown in Figure 11, the on-land trough option would not eliminate the need to go into the water as it would need to be elevated enough to avoid sub-grade conflicts, be able to connect to the existing elevations of the Battery Park Underpass and the Brooklyn Bridge, and provide sufficient headroom for ventilation. While the tunnel option would provide additional space on-land to construct the coastal defense, it would not eliminate the need to go into the water to site coastal defense while maintaining access to maritime functions (and the tunnel would be constructed in-water, outboard of the existing bulkhead). Both options also present additional engineering challenges:

- **Existing subway tunnels**: Regardless of whether the project is on-land or in-water, subway tunnels (such as the 2/3 tunnel) will need to be crossed with bridging structures. The tunnel and trough options would increase the complexity of crossing the subway tunnels.
  - A tunnel would need to pass under the existing subway tunnels. This would be dependent on an acceptable roadway slope being achieved to go under the 2/3 tunnel and connect to the Battery Park Underpass (BPU) above the 4/5 tunnel.
  - A trough would need to go over the top of the 2/3 tunnel, placing the top of the trough at roughly 13ft NAVD88, which is 7 feet above the existing grade. This would still require significant grading to create an up and over and maintain waterfront access.
- **Cost**: Scaling the projected cost for the Gateway Tunnel project ($11.6B) by length, the tunnel option would cost $3.5B alone, not factoring in the cost of coastal defense.
- **Need to avoid the Battery Maritime Building (BMB)**: Assuming the tunnel would be offshore, it would need to tie back into land north of the BMB, before the FDR Drive transitions from at-grade to subsurface. Realigning with the BPU would require avoiding disturbances to the BMB, resulting in some complex alignment issues. The tunnel cannot be under the maritime uses and therefore must go around them. Additionally, as mentioned above, the road grade needed to tie back into the BPU at an acceptable roadway angle is not within the acceptable range; it is not possible to realign an outboard tunnel or trough with the BPU while avoiding conflict with the BMB, which is a historic structure.
- **Underground infrastructure conflicts:** An onshore trough would require siting and constructing new oil-o-static and interceptor lines outside of the trough alignment and removing the existing lines prior to construction. A tunnel would also require siting and constructing new oil-o-static and interceptor lines outside of the tunnel alignment and removing the existing lines prior to construction (for some distance) at the northern tie-in location.

Figure 12 illustrates the on-land trough option. The subsurface infrastructure, particularly the subway tunnel crossings, located where the through would go renders this option impractical. Additionally, the tunnel entrance would likely block off Peck Slip and the feasibility of the interchange with Brooklyn Bridge would need to be studied.

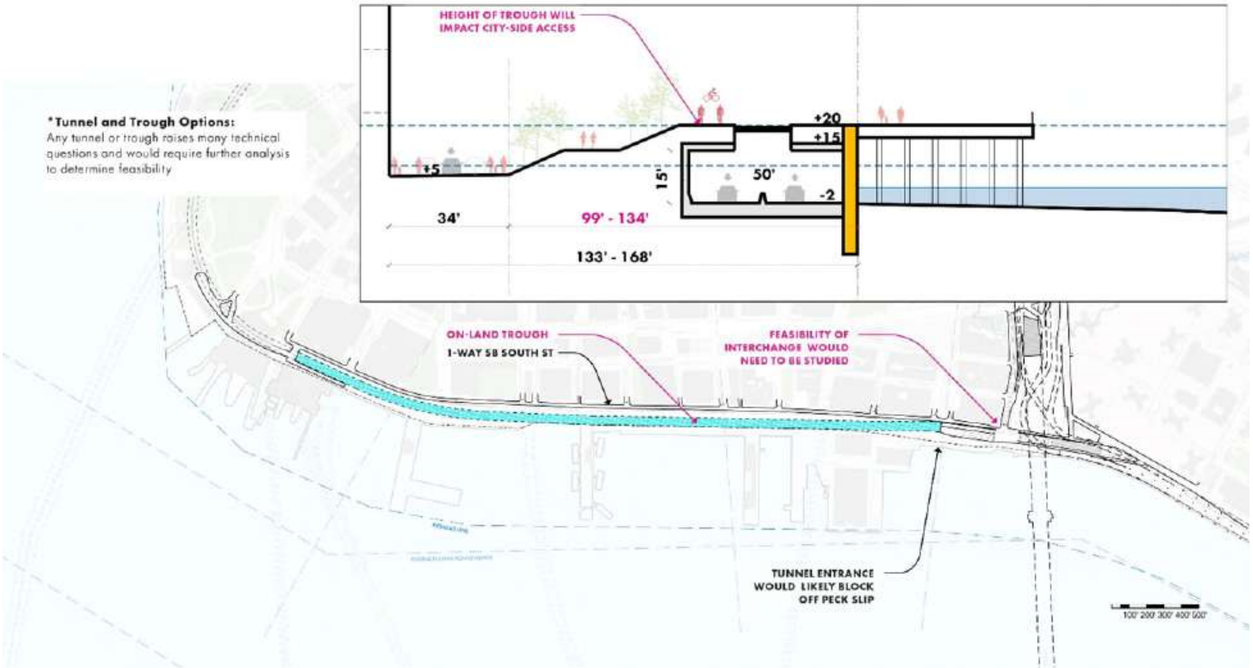


*Figure 12. On-Land Trough Option*

Figure 13 illustrates the in-water trough option. This option does not reduce the amount of in-water space needed to complete the project; rather, it likely increases it. Additionally, the feasibility of the interchange with Brooklyn Bridge would need to be studied.

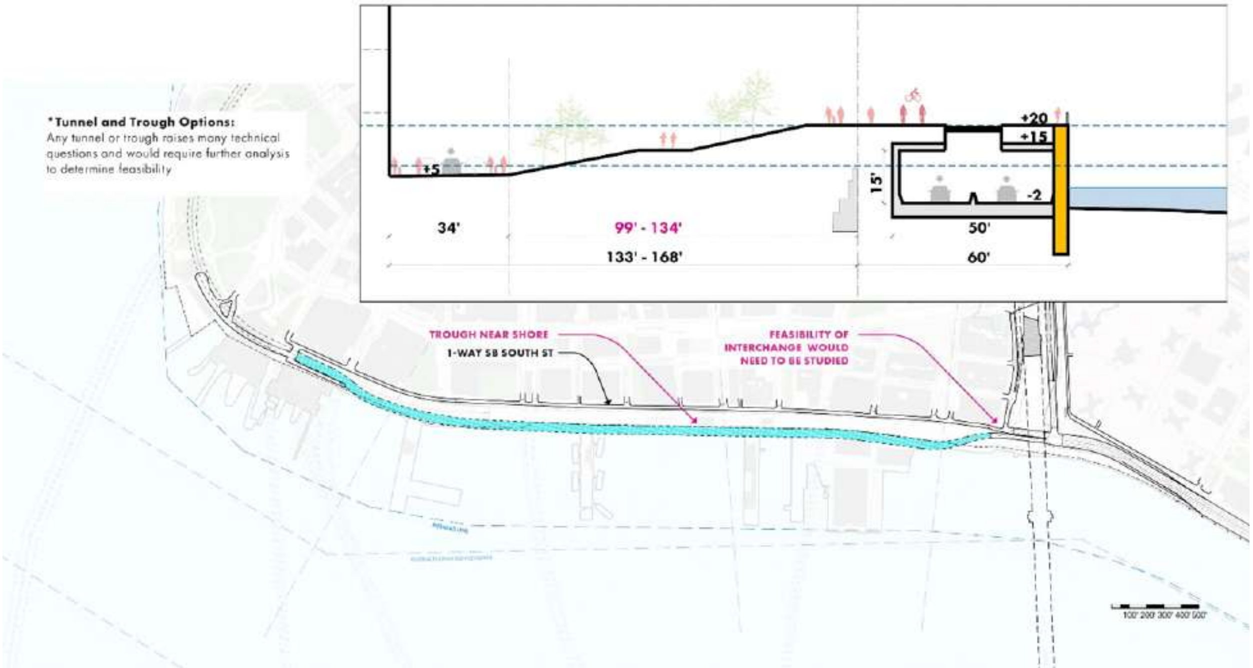


*Figure 13. In-Water Trough Option*

Figure 14 illustrates the outboard tunnel option. These tunnels would conflict with subway tunnels. Furthermore, it is unclear how they would work with the Brooklyn Bridge.

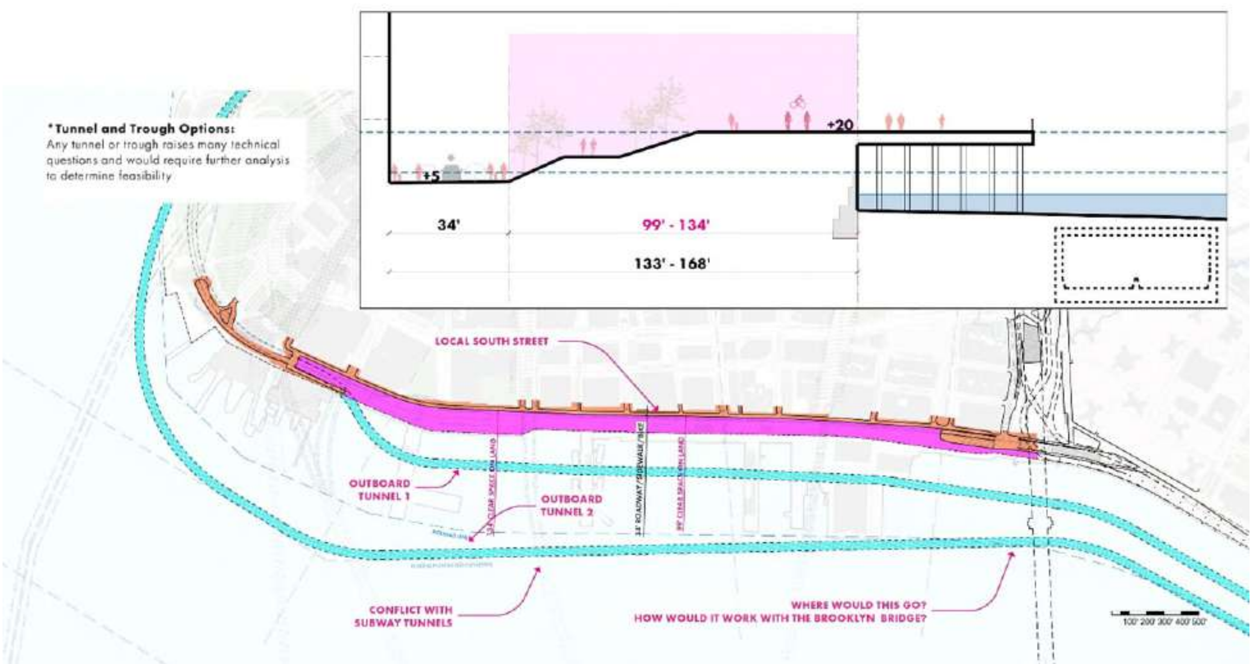


*Figure 14. Outboard Tunnel Option*

### 3.3.3 Alternative C: At-Grade Roadway

The team also explored several options for how the FDR Drive viaduct elevated structure could be replaced with an at-grade roadway, where the FDR Drive would be combined with South Street into a single roadway (see Figure 15).

- **At-grade avenue/boulevard**
  - o This option would provide two travel lanes in either direction with left-turn lanes at key intersections (for a total width of approximately 61 to 63 feet) and could accommodate current traffic volumes.
- **At-grade street**
  - o This option would provide one travel lane in each direction.
- **Reduced one-way**
  - o This option would divert northbound traffic to other routes (primarily Water Street).


*Figure 15. At-Grade Roadway Configurations*

In determining the feasibility of these at-grade roadway configurations in place of the existing FDR Drive viaduct, the project team performed an analysis to:

- Develop future demand traffic projections and test implications of changes to major traffic movements within, through, and to/from the study area
- Test potential ramp reconfigurations for access to the Brooklyn Bridge and connections to the FDR Drive viaduct north of the study area

*At-Grade Avenue/Boulevard*

The project team determined that only the at-grade avenue/boulevard option could feasibly accommodate present-day traffic volumes.

An at-grade avenue/boulevard would involve two lanes in each direction, if signalized with a fifth northbound center turn lane where left turns are permitted, plus potential parking/loading lane(s) (see Figure 16). Signalized pedestrian crossings would be maintained throughout the corridor. Limited northbound left turns would be permitted at select intersections to provide local access.


*Figure 16. At-Grade Avenue/Boulevard Signals and Turn Lanes*

Figure 17 illustrates the at-grade boulevard option. This option makes on-land space available and can accommodate current traffic volumes.

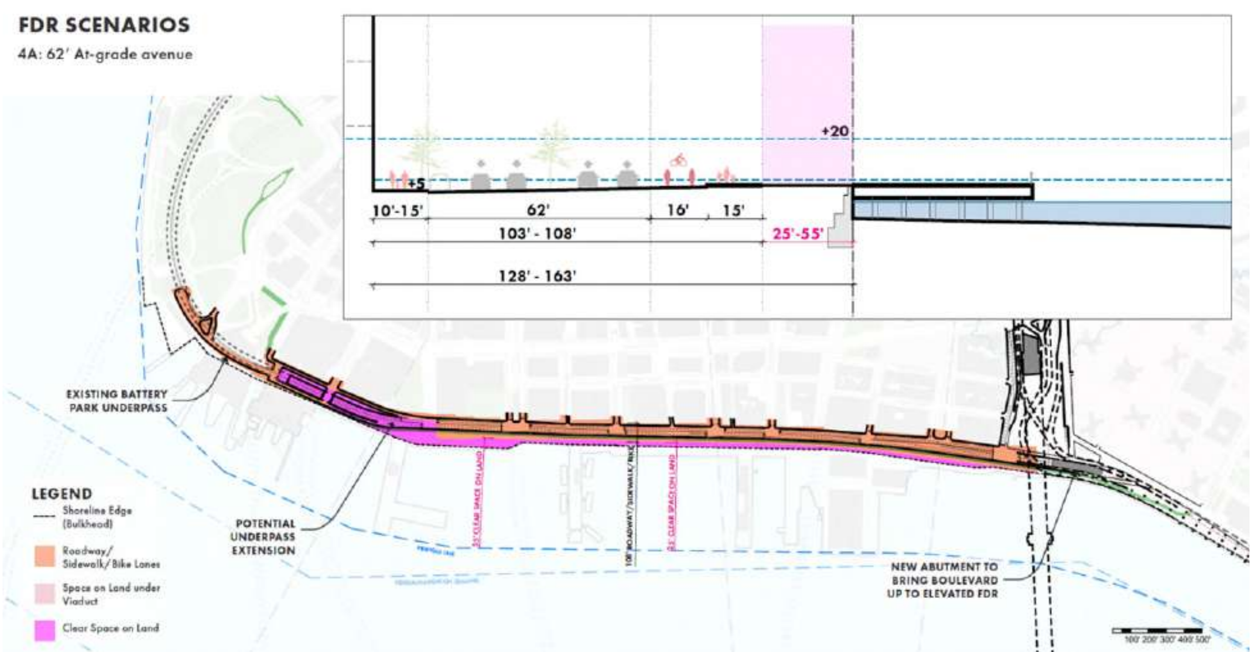


*Figure 17. At-Grade Avenue/Boulevard Option*

It is important to note that while replacing the elevated FDR Drive viaduct with an at-grade boulevard within the study area (a length of about half of a mile), would afford some additional space on-land to site coastal defense, it would be insufficient to site the entire coastal defense system entirely on existing land while maintaining access to key maritime & waterfront uses. Rather, taking down the FDR Drive viaduct provides only an additional ±35 feet of space on-land to construct the proposed project, which is insufficient to site the coastal defense entirely on land.

Transforming the FDR viaduct to an at-grade boulevard (two travel lanes each direction) creates an additional 25 to 55 feet of clear space for flood protection (see Figure 17); however, this would still be insufficient to site coastal defense while maintaining access to the waterfront.

*At-Grade Street and Reduced One-Way*

The project team determined that the at-grade street (one lane in each direction) and reduced one-way options cannot accommodate current traffic volumes but are expected to operate at marginally acceptable levels of service under the Medium Scenario (35% reduction) and at acceptable levels of service under the Optimistic Scenario (75% reduction). Note that these projections are based on assumed traffic volumes and lane capacities and not on detailed evaluations using traffic analysis software.

The at-grade street (one travel lane each direction) provides additional space to site coastal defense (50-85 feet) but as noted above, would create significant vehicle level-of-service impacts with existing traffic volumes and therefore was not recommended by the project team.

Figure 18 illustrates the at-grade street option with the BPU repurposed. While this option would make on-land space available, it could not accommodate current traffic volumes, and was therefore deemed non-viable.

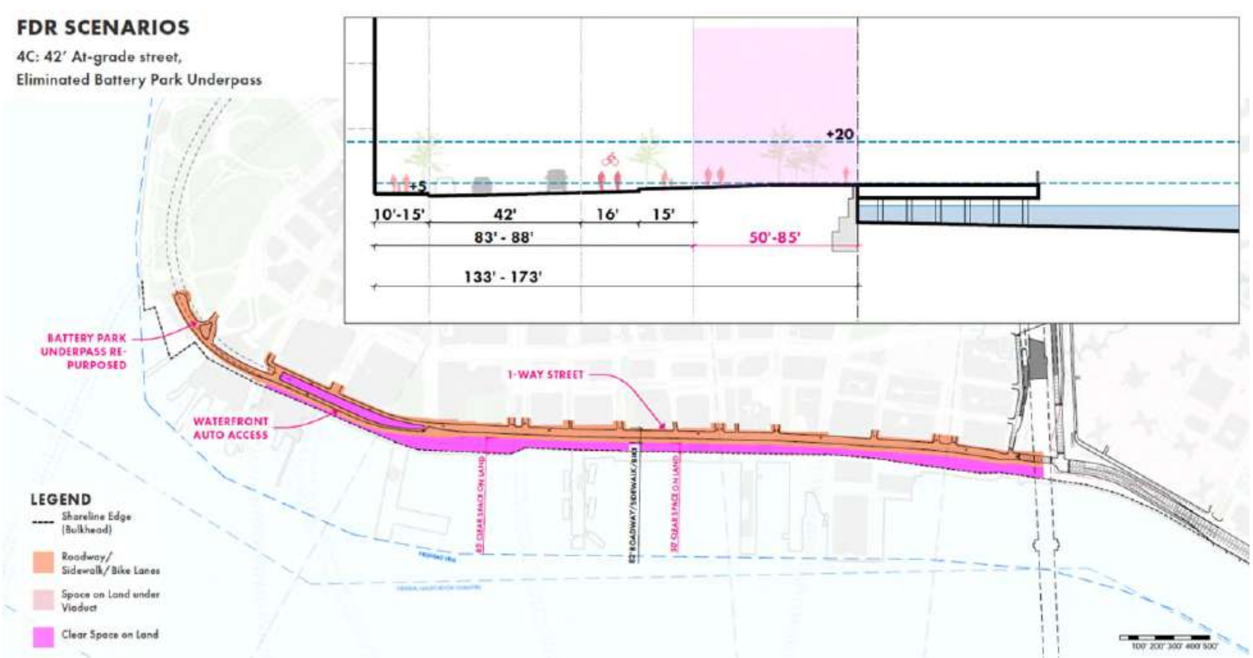


*Figure 18. At-Grade Street Option*

*Brooklyn Bridge Interchange*

Additionally, the project team determined that significant changes to the Brooklyn Bridge ramps would be required to convert the FDR Drive viaduct to at-grade at the Brooklyn Bridge interchange, requiring one to two new signalized intersections (at Dover Street and/or Robert F Wagner Place). It would be easier to signalize the Brooklyn Bridge ramps with the FDR Drive viaduct to/from the south at Dover Street since those ramps are significantly lower volume than the ramp connections to/from the FDR Drive viaduct north of the Bridge. The project team therefore evaluated two at-grade alternatives at the Brooklyn Bridge interchange (as shown in Figure 19):

1. The first alternative involves a partial at-grade interchange with the ramps to and from the FDR Drive viaduct south of the Brooklyn Bridge, which are the lower-volume ramps. A signalized intersection would be created along the FDR Drive at Dover Street.
2. The second alternative involves a full at-grade intersection that would create a second signalized intersection along the FDR Drive viaduct north of the Brooklyn Bridge at Robert F Wagner Place. This would require bringing the FDR Drive viaduct north of the bridge, potentially affecting views and waterfront access to the adjacent residential buildings including parts of the NYCHA Smith Houses.

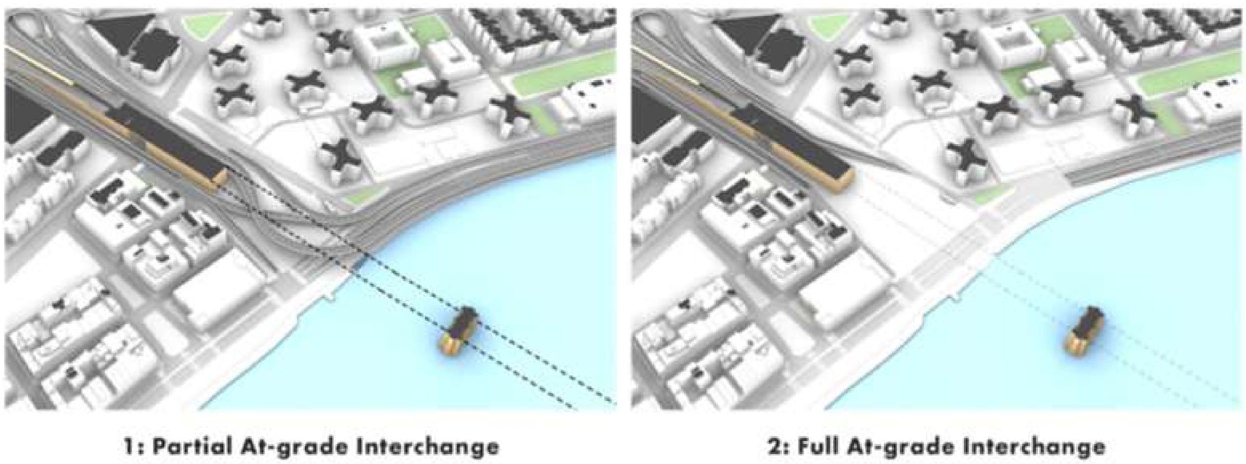


*Figure 19. At-Grade Alternatives for Brooklyn Bridge Interchange*

*Partial At-Grade Interchange*

Key features of a partial at-grade interchange option (see Figure 20) include:

- An at-grade signalized intersection at Dover Street, plus new westbound travel direction on Dover Street between the FDR Drive viaduct and Pearl Street
- South Street merged with the FDR Drive viaduct south of the Brooklyn Bridge
- No right from FDR Drive viaduct southbound onto Dover Street; traffic would exit onto Robert F Wagner Place and use Pearl Street to travel south
- Direct ramp connections from local streets to the FDR Drive viaduct northbound eliminated and instead handled at signalized intersections

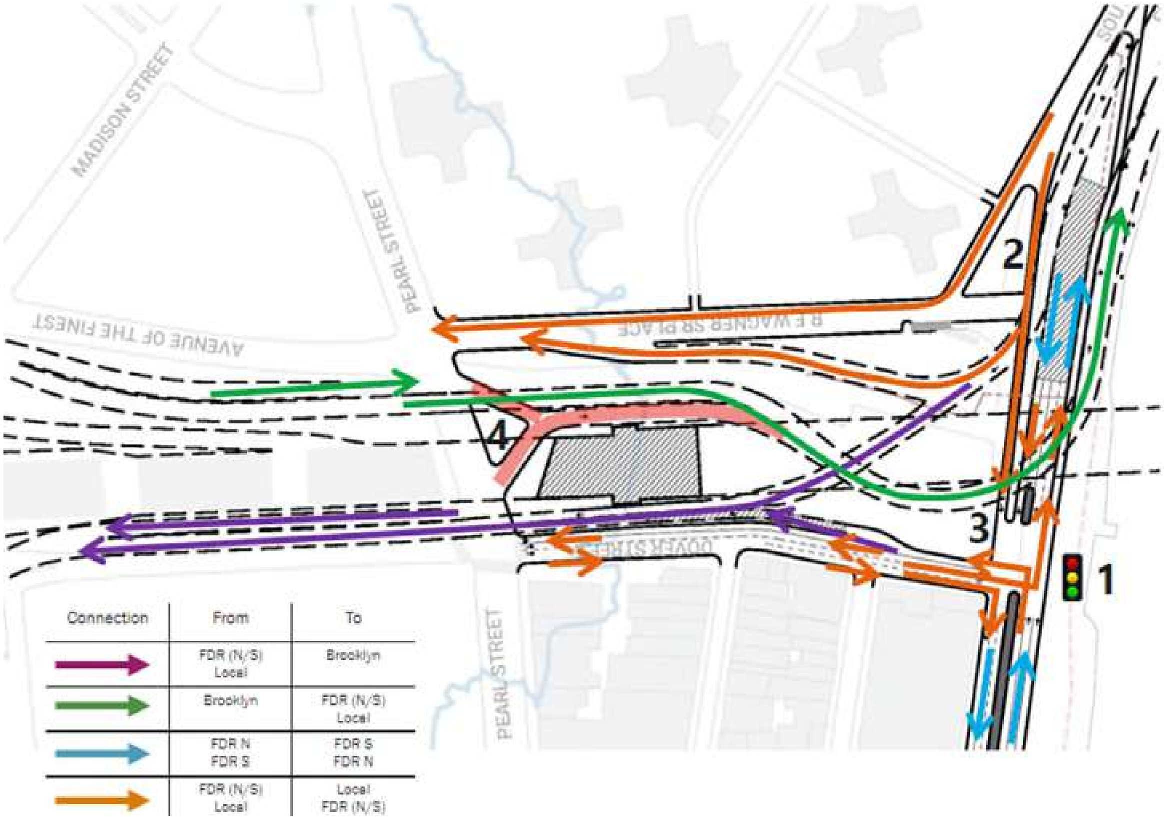

*Figure 20. Partial At-Grade Interchange*

With this option, the new at-grade intersection at Dover Street (south of Brooklyn Bridge) (see Figure 21) would:

- Include a three-phase signal with a double left turn from Dover Street onto the FDR Drive viaduct northbound to accommodate the high turn volume
- Be projected to operate at acceptable levels of service

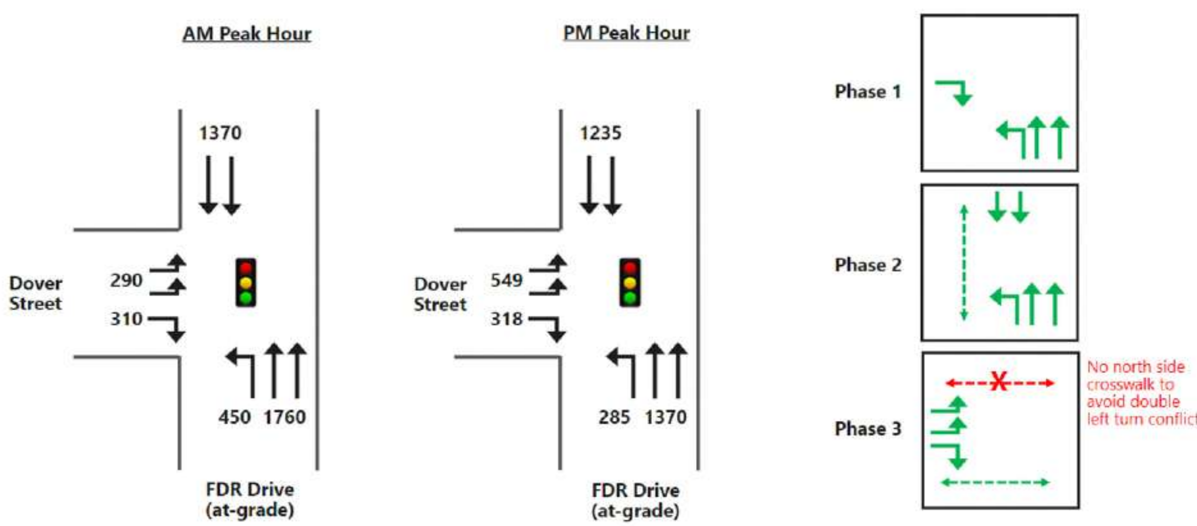

*Figure 21. At-Grade Intersection at Dover Street (Partial At-Grade Alternative)*

*Full At-Grade Interchange*

Key features of a full at-grade interchange option (see Figure 22) include:

- Robert F Wagner Place converted to one-way eastbound and shifted southwards to better align with the Brooklyn Bridge local off-ramp, with a new signalized intersection at the FDR Drive viaduct
- Signalized merge point where the Brooklyn Bridge off-ramp joins Robert F Wagner Place eastbound to control the weave area approaching the FDR Drive viaduct
- Traffic heading southbound on South Street north of the bridge would be forced to exit towards Pearl Street via a one-way westbound street. This would be a low-volume movement that could potentially be aligned closer towards Smith Houses and designed as low speed with on-street parking
- Dover Street becomes one-way westbound with a new signalized intersection at the FDR Drive viaduct
- Simplifies vehicular movements at Pearl Street intersections with Wagner Place and Dover Street with fewer conflict points

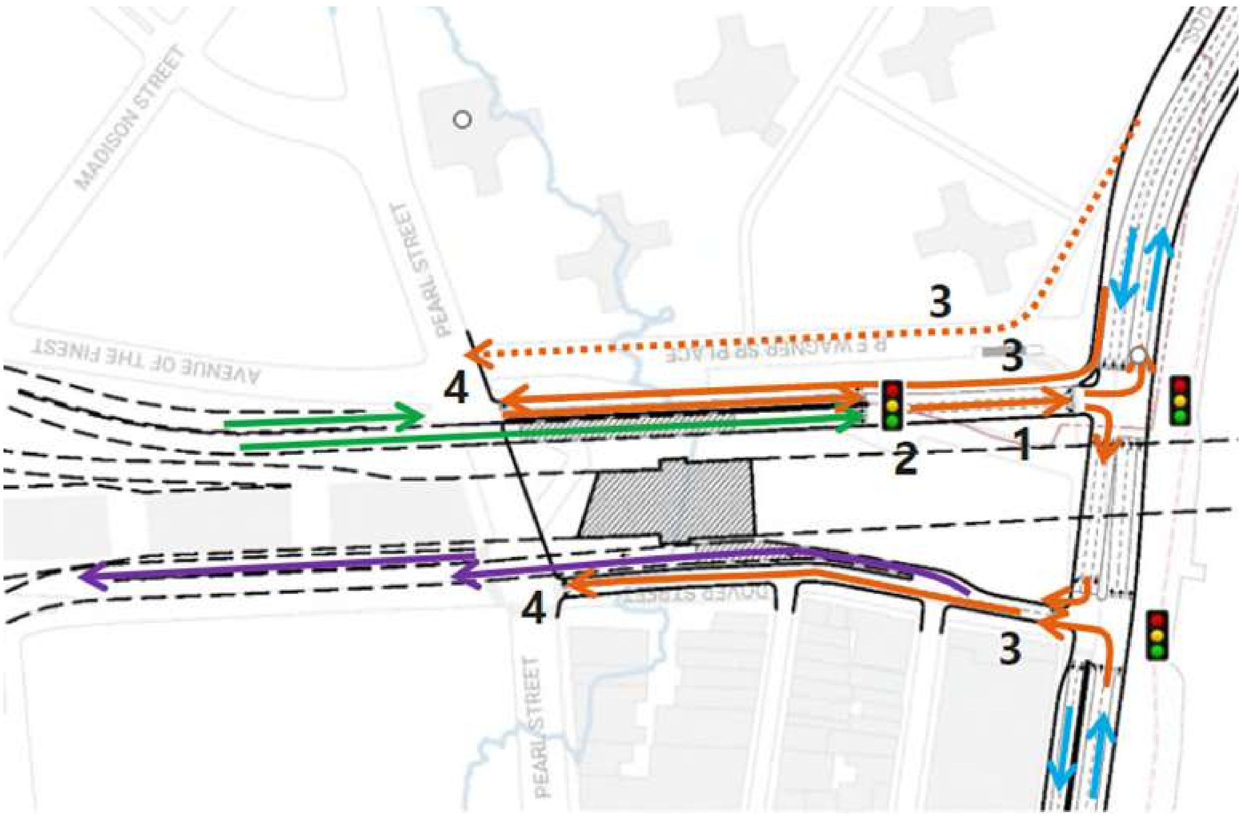


*Figure 22. Full At-Grade Interchange*

With this option, the new at-grade intersection at Robert F Wagner Place (north of Brooklyn Bridge) (see Figure 23) would:

- Include signalizing at the merge point, which would control the movements to avoid weaving conflicts. It would also allow for signalized pedestrian crossings without any vehicular conflicts, thereby facilitating pedestrian and bicycle access to and from the waterfront.
    - However, the new signalized intersection would carry heavy volumes, including an eastbound left turn onto the FDR Drive viaduct northbound that would exceed 2,000 vehicles per hour. This

intersection would not operate well under existing traffic volumes but would likely operate at acceptable levels of service under the more optimistic future volume scenarios (-35% or -70%).

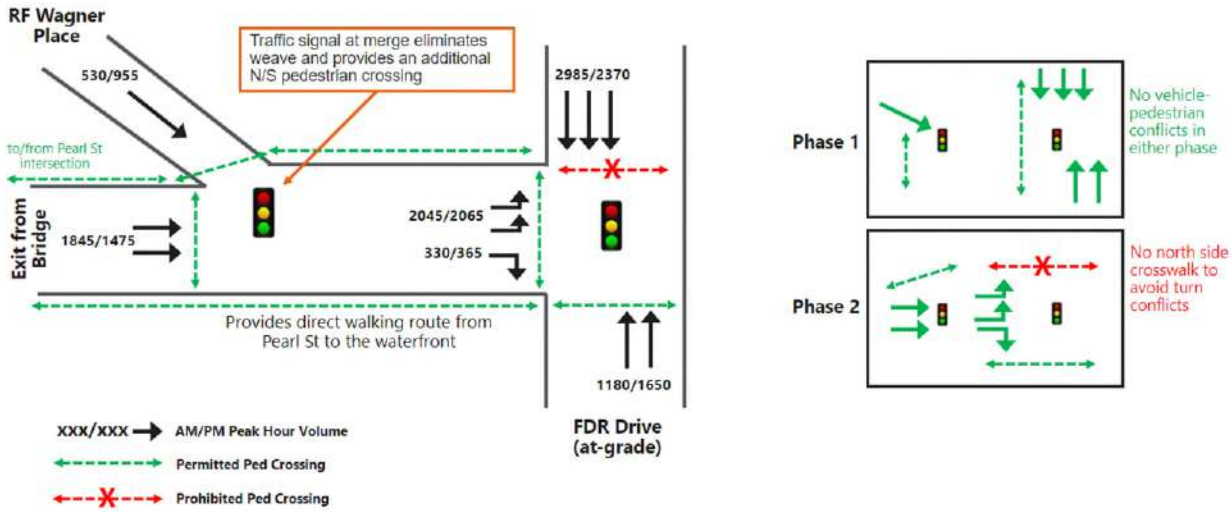


*Figure 23. At-Grade Intersection at Robert F Wagner Place (Full At-Grade Alternative)*

## 3.4 Global Precedents for Highway Removal

The project team researched national and global precedents for highway removal, highway-to-boulevard, and other urban highway mitigation approaches to understand the possibilities as well as potential benefits and drawbacks of transforming the elevated FDR Drive viaduct within the study area. These findings are presented in Table 5 below.

*Table 5. Global Precedents for Highway Removal*

| Global Precedents for Highway to Boulevard | Cost/Timeline | Access / Connectivity for the Community | Economic Development | Safety | Environmental Justice / Equity | What worked well? | What did not work well? | Lessons learned |
|---|---|---|---|---|---|---|---|---|
| Sheridan Expressway[14] | $97M, with additional funding for ramp replacements on adjacent highway; (2017-2019) | Expanded community's access to riverfront; crosswalks added where there had been none before, but could be more bike/pedestrian friendly | Created direct truck access to a vital regional food distribution center | New pedestrian signalized crossings & refuge; increased truck conflict with bikes/pedestrians | About getting trucks off local streets so that BIPOC community does not bear brunt of traffic and pollution | Boulevard conversion with crosswalks; better access to open space; economic hub (distribution center) connectivity continued | Did not reduce number of lanes; more truck traffic next to parks; community not pleased with outcome-political expediency drove process away from their vision | Transportation is linked to land use; new residential development catalyzed pedestrian safety features (but this could be an example of improvements only due to gentrification); it is important to have buy-in from major government officials, although this could risk a shift from the community's vision; centering a BIPOC community vision can drive enthusiasm to achieve future outcomes |
| Route 9A (West Side Highway)[15] | $380M, much less than the cost of earlier proposals; (1973- 2001) | Highway had cut neighborhoods & residents off from waterfront; boulevard gave access to waterfront & open space | After boulevard, new infill buildings lining corridor | Gradual increase of safety with speed limit reduction, leading pedestrian intervals, etc.; usage of pedestrian bridges in some locations | Plans to replace the elevated highway with another freeway or tunnel were prevented largely due to environmental concerns | Hudson River Park, pedestrian promenade & bike path are well-used public amenities | The boulevard is still pedestrian-unfriendly with difficulty and an unpleasant environment to cross | 53% of traffic disappeared after removal, demonstrating induced demand and that removing freeways reduces traffic; it is important not to rebuild infrastructure that contributes to inequities |
| Inner Loop East (Rochester)[16] | $22M, including $16M TIGER Grant with state & local matches; (2012- 2017) | Encircled Rochester's CBD, a major physical barrier from nearby, densely populated neighborhoods | $22 million in public funds generated $229 million in economic development; 9 acres freed for infill, which may improve economically distressed area | Complete Street design of freeway removal includes safety focus, Protected Bike Lane, etc. | Infill development includes 20 units for supportive housing programs that aid formerly homeless residents | Walking increased 50%, cycling 60% in area; momentum carried over for Inner Loop North project | Limitations of infill development architecture (could have been more distinctive for placemaking purposes); perception of catering to wealthier, whiter neighborhoods first | Persistence with acquiring Federal grant funding (in this case TIGER) is essential; however, social equity must be at the forefront in order to achieve public buy-in (for example, the Inner Loop East is along wealthier, whiter neighborhood, compared to the Inner Loop North which is deferred as part of "phase 2") |
| Embarcadero (San Francisco)[17] | $50M; much cheaper than reconstructing earthquake-proof structure; (1989- 2002) | 100 waterfront acres once dominated by elevated freeway replaced with new public plaza & waterfront promenade | Dense commercial development lined the boulevard; area housing increased by 51%; jobs increased by 23% | Current project iteration supports Vision Zero & will implement targeted safety improvements; cycle track to become a PBL; enhanced ped crossings/islands; high visibility crosswalks | Long activism against the Embarcadero led to 1st time in history a gov't body voted to stop freeways, and support to replace with a boulevard (before earthquake) | Public transit ridership increased 15%; boulevard design accommodates significant auto traffic but also gives options other than private vehicles | Conversion did not address how Embarcadero needs to be raised due to sea level rise | An existing network of streets may be able to absorb traffic if they have previously underused capacity; escalating cost projections for freeway reconstruction could change public debate in favor of boulevard; freeway removal activism can bear fruit with persistence |
| Cheonggyecheon (Seoul)[18] | $400M, including funds pulled from the highway renovation option; (2003- 2005) | City continues developing waterfront plans; mixed-use development downtown/waters' edge; dramatic increases in property value | Cheonggyecheon area was known as a shabby industrial area before freeway removal | Existing at-grade crossings below freeway were along congested 4 lanes of traffic in each direction | Surrounding area recorded highest noise/congestion levels in Seoul | Quick implementation; 9 km green corridor through city center helped the attract affluent & educated | Displacement and gentrification of lower income residents & small businesses/craftsmen; | Freeway removal can have transformative impacts on the economy (including through boosting tourism) |

[14] Sheridan Expressway sources: https://www.dropbox.com/s/sxur6fh28rp819v/ZM%20Future%20of%20Highways%20Session%20Video.mp4?dl=0; https://www.cnu.org/new-york-city-sheridan-expressway; https://www1.nyc.gov/site/planning/plans/sheridan-hunts-point/sheridan-hunts-point.page; https://nyc.streetsblog.org/2016/04/05/sheridan-expressway-removal-gets-97-million-boost-in-state-budget/; https://www.cnu.org/sites/default/files/FreewaysWithoutFutures_2021.pdf
[15] Route 9A sources: https://opencommons.uconn.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1103&context=gs_theses; http://www.preservenet.com/freeways/FreewaysWestSide.html; https://www.amny.com/news/speed-limit-reduction-among-safety-changes-coming-to-the-west-side-highway/
[16] Inner Loop East sources: https://www.cnu.org/highways-boulevards/model-cities/Rochester; https://www.cityofrochester.gov/InnerLoopEast/; https://reconnectrochester.org/2013/08/latest-inner-loop-plan-a-winner-in-our-book/; https://usa.streetsblog.org/2018/03/01/a-new-neighborhood-will-replace-a-sunken-rochester-highway/; https://www.cnu.org/sites/default/files/FreewaysWithoutFutures_2019.pdf
[17] Embarcadero sources: https://www.cnu.org/what-we-do/build-great-places/embarcadero-freeway; https://www.berkeleysquares.co.uk/2018/10/misogyny-racism-and-the-san-francisco-freeway/; http://www.preservenet.com/freeways/FreewaysEmbarcadero.html; https://opencommons.uconn.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1103&context=gs_theses
[18] Cheonggyecheon sources: https://www.cnu.org/highways-boulevards/model-cities/seoul; https://www.thechicagocouncil.org/commentary-and-analysis/blogs/dispatch-seoul-city-transportation-extremes; https://www.theguardian.com/world/2014/mar/13/seoul-south-korea-expressway-demolished; http://www.preservenet.com/freeways/FreewaysCheonggye.html; https://core.ac.uk/download/pdf/231129165.pdf; https://opencommons.uconn.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1103&context=gs_theses

| Global Precedents for Highway to Boulevard | Cost/Timeline | Access / Connectivity for the Community | Economic Development | Safety | Environmental Justice / Equity | What worked well? | What did not work well? | Lessons learned |
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| | | resulted from replacement of freeway with at-grade boulevard | | | | workers/residents who appreciate a natural environment in an urban setting | construction unfairly benefited certain contractors | |
| Octavia Boulevard (San Francisco)[19] | $45M; (1989- 2002) | Freeway replaced with a median, 4 through-lanes, and boulevard-style parking lanes | Pre-removal, neighborhood homes were 66% of city average prices, post-removal, prices grew to 91% of city average. | Current enhancement program: capital projects to make boulevard & surrounding streets safer, more ped-friendly, and better at serving multiple users | Had blighted swaths of its surrounding neighborhood | Well-regarded urban design: landscaping, side lanes for local traffic/parking, and special considerations for views from side streets; ped amenities: special light fixtures and brick color | N/A | Freeway removal can enable significant neighborhood revitalization |
| Harbor Drive (Portland)[20] | $20M: 5+ phases; (1974- 1988) | The planned park would open up the waterfront to pedestrians, creating a major downtown amenity | City continues developing waterfront plans; mixed-use development downtown/waters' edge; dramatic increases in property value resulted from replacement of freeway with at-grade boulevard | Due to the success of the park (site of the freeway), sections of the adjacent boulevard are being made more pedestrian-friendly | Portland's air pollution was so bad when Harbor Drive existed that the EPA fined the City daily; a long linear park was at the centerpiece of this freeway removal | 1st major US highway to be intentionally removed; after removal there was minimal negative traffic impact (partially due to street patterns & traffic management) | Freeway removal catalyzed downtown development but lagged in retaining/adding affordable housing, adding perception that Downtown is an elite neighborhood | Freeway removal can enhance a city's reputation for bike, pedestrian, and transit-friendly planning as well as for prioritization of preservation and livability |
| Riverfront Parkway (Chattanooga)[21] | $60M; (2004- 2016) | Parkway conversion included 4 new pedestrian access points via evenly distributed at-grade intersections | The conversion brought millions of dollars in investments, new development concentrated around the boulevard, making the riverfront a premiere address within the city. The parkway became a key component in Chattanooga's riverfront revitalization plan: The 21st Century Riverfront Plan. | The reduction of the roadway from 4 lanes to 2 and addition of 4 at-grade intersections with marked pedestrian crossings increase visibility, accessibility, and safety | The industrial truck traffic freeway contributed to air pollution and divided downtown Chattanooga from the Tennessee River. The City of Chattanooga launched Vision 2000 to make a plan to reduce pollution and enhance quality of life. | The city initially only converted a portion of the freeway into the parkway, from Lookout Street to downtown, but continued to use goals of the project to conduct future studies to assess further implementation. In 2005 the rest of the reconstruction was implemented, and studies initiated to better connect/extend the downtown grid. In 2016 this led to the 3rd and 4th Street Improvements Masterplan, developed in conjunction with a broader economic development study, which evaluated three concepts to achieve goals around economic development and enhanced connectivity. | N/A | A collaborative approach using incremental master/comprehensive planning to execute a vision in stages for a similar project can enable successful outcomes |

[19] Octavia Boulevard sources: https://www.cnu.org/highways-boulevards/model-cities/octaviaboulevard; https://opencommons.uconn.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1103&context=gs_theses; https://www.sfmta.com/projects/octavia-boulevard-enhancement-program; https://www.pps.org/article/octavia-boulevard-creating-a-vibrant-neighborhood-from-a-former-freeway

[20] Harbor Drive sources: https://opencommons.uconn.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1103&context=gs_theses; https://www.cnu.org/highways-boulevards/model-cities/portland; https://www.oregonlive.com/multimedia/2014/05/portlands_old_harbor_drive_was.html; http://www.preservenet.com/freeways/FreewaysHarbor.html; https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.963.3855&rep=rep1&type=pdf; https://www.researchgate.net/publication/277657946_Harbor_Drive_teardown_in_Portland_Oregon-_The_new_post_industrial_city_in_the_making

[21] Riverfront Parkway sources: https://www.cnu.org/highways-boulevards/model-cities/chattanooga; https://connect.chattanooga.gov/3rd-and-4th-street/about-copy/project-history/; https://www.smartcitymemphis.com/2007/04/chattanooga-shows-how-a-riverfront-can-transform-a-city/

| Global Precedents for Highway to Boulevard | Cost/Timeline | Access / Connectivity for the Community | Economic Development | Safety | Environmental Justice / Equity | What worked well? | What did not work well? | Lessons learned |
|---|---|---|---|---|---|---|---|---|
| Central Artery (Boston)[22] | $24B; (1982- 2007) | The Central Artery highway displaced 20,000 residents and divided Boston's North End and waterfront from its downtown. The six lane highway was replaced with an underground expressway and in its place an open space urban infill development was initiated. | The project catalyzed real estate development in the surrounding area, and restored the city's waterfront as a major amenity. It was projected that the project has attracted $7b in private investment, including 7,700 housing units, 10 million sq ft of commercial space, 2,600 hotel rooms, and 43,000 new jobs in Boston. | The accident rate on the Central Artery before the project was four times the national average. | A 12 percent reduction in carbon monoxide levels citywide was achieved. Clay and dirt from the project was used to fill and cap landfills throughout New England. | The Rose Kennedy Greenway that replaced the Central Artery highway now connects neighborhoods that were previously separated by the highway. | The project temporarily eased traffic congestion, but largely just transferred it to different points north and south. The state promised parallel investments in public transit that never happened. | It is possible to maintain traffic capacity and access for residents and businesses while undertaking such a monumental effort, but the project budget must account for the significant cost of such mitigation efforts in order to be successful |
| Park East Freeway/McKinley Boulevard (Milwaukee)[23] | $45M; (2002- 2006) | The Park East Freeway/spur was never completed due to community opposition. The land east of the spur remained undeveloped until it's zoning designation was changed, at which point it was developed into the East Pointe neighborhood. The success of this convinced the city to remove the spur all together. | Average assessed land values per acre in the Park East Freeway footprint grew by more than 180 percent. Average assessed land values in the Park East Tax Increment District grew by 45 percent between 2001 and 2006 (higher than the citywide growth rate of 25 percent). | N/A | While the new development brought in new upper and middle class professionals, it did little for the city's poorer residents. Eventually some major development projects did employ a large number of minority-owned businesses and unemployed/underemployed low income workers. | The freeway spur was converted into a six lane boulevard, which connected to the existing and new street grid. These blocks opened up 24 acres of retail, entertainment, and light industrial uses for development. Since removal, the Park East Corridor has seen over $1b in private investment. | This investment spurred by this development largely benefited higher income residents/businesses (i.e. a new basketball arena). | N/A |
| Manzanares River Banks (Madrid)[24] | $5B (all but $500m spent to move the highway underground); (2007- 2015) | The M30 highway, constructed in the 1970s, causing neighborhoods on both sides to decline. The highway was moved underground and the area converted into a linear park. The result is renewed connectivity between these surrounding neighborhoods and to the city's center. | This project also included significant investment in the city's transit: dozens of new metro and light-rail stations were constructed that more directly connect the previously disconnected lower income neighborhoods on the outskirts of Madrid's downtown. The project also included 32 foot bridges. | N/A | Residents of neighboring areas previously subject to the pollution of the highway now have a more environmentally welcoming and aesthetically pleasing surrounding area. | The combination of the highway to linear park with the addition of new transit lines and stations | Madrid's mayor has initiated over 70 major construction projects since the beginning of his tenure, including the River Banks. Due to this overextension, this project was delayed and ended up costing twice what was planned. The project contributed to the city's debt, which is the largest in Spain. | Urban renewal can be undertaken to create instant transformations of space rather than incremental development, but such an approach could have serious financial repercussions |
| Bonaventure Expressway (Montreal)[25] | $141.7M; (2011- 2017) | The multi-modal urban boulevards brought green spaces, parks (totaling more than 200,000 square meters), and public art as well as access to the city's waterfront. | East-west cycling lanes, pedestrian walkways, and dedicated bus lanes included were included in the development. | The expressway was reapportioned to better allocate space between modes- 65 percent dedicated to active transportation; 10 percent to public transit; 25 percent (previously 70 percent) to motor vehicles. | 95 percent of the concrete from the torn down expressway was reused; landscaping manages stormwater on-site as well as reduces urban heat island effect with 300 trees. Overall the project received a SITES sustainable landscape | Montreal was able to leverage the redevelopment project to achieve sustainability goals. | The project has been criticized for lacking north-south cycling lanes, but it was determined that they would have caused safety issues for the dedicated bus lanes. | Freeway removal can create a more user-friendly urban space, serve to connect previously separated neighborhoods, and support urban development |

[22] Central Artery sources: https://www.cnu.org/highways-boulevards/model-cities/boston; https://www.mass.gov/info-details/the-big-dig-project-background#central-artery/tunnel-project-milestones-
[23] Park East Freeway/McKinley Boulevard sources: https://www.cnu.org/highways-boulevards/model-cities/milwaukee; https://city.milwaukee.gov/DCD/Projects/ParkEastredevelopment; https://themetropole.blog/2021/04/12/harnessing-the-memory-of-freeway-displacement-in-the-cream-city/
[24] Manzanares River Banks sources: https://www.nytimes.com/2011/12/27/arts/design/in-madrid-even-maybe-the-bronx-parks-replace-freeways.html?pagewanted=all&_r=2&; https://www.smartcitiesdive.com/ex/sustainablecitiescollective/madrids-pharaoh/24172/; https://use.metropolis.org/case-studies/the-madrid-rio-project
[25] Bonaventure Expressway sources: https://www.cnu.org/highways-boulevards/model-cities/montreal-bonaventure-expressway https://montrealgazette.com/news/local-news/montreal-unveils-new-plans-for-bonaventure-expressway; https://www.bloomberg.com/news/articles/2018-11-06/how-montreal-redesigned-the-bonaventure-expressway

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|---|---|---|---|---|---|---|---|---|
| | | | | | certification and Award of Excellence in Urbanism 2018 from the Canadian Institute of Planners. | | | |
| Mandela Parkway (Oakland)[26] | $13M; (1997- 2005) | The Cypress Street Viaduct cut through West Oakland, displacing over 600 families and destroying over 5,000 residences. The relocation of the freeway and addition of the four lane Mandela Parkway boulevard created renewed pedestrian connections for this neighborhood. | Three dozen new businesses have opened along the parkway. | N/A | Mandela Gateway affordable housing provides 168 affordable units for neighborhood residents. Annual nitrogen oxide levels in proximity decreased by 38 percent, annual black carbon levels decreased by 25 percent, and the project links to the Bay Trail - a planned 500 mile walking and biking trail. | The city used a natural disaster that destroyed some of the Cypress Street Viaduct to spur the viaduct relocation and construction of the parkway. | N/A | Collaboration between the project team and residents—especially involving residents in planning and design—is indispensable to carrying such a project to successful implementation |
| Pompidou Expressway (Paris)[27] | $50M (2012- 2014) | The plan converted the Pompidou Expressway into a boulevard that served pedestrians and cars. Further development brought a pedestrian promenade to the Right Bank, public space to the Left Bank, as well as an 1,800 square meter floating garden. | The project attracts millions of visitors each year and has increased economic development along the waterfront. | N/A | This renewed access to the Seine, a UNESCO World Heritage site, provides Parisians who may not be able to travel outside of the city with access to outdoor beach space. | Mayor Delanoe initially instituted a temporary closure of the expressway between 6am and 11pm for a month to help Parisians imagine the benefit of a permanent closure. He continued this month long closure each summer for 8 years, at which point he revealed the plan for the permanent closure of the Pompidou Expressway. | Differences in political leadership delayed the project for two years. | Temporary seasonal closure of an expressway can demonstrate to political leadership and residents that there is mass support for permanent conversion |

[26] Mandela Parkway sources: https://www.cnu.org/oakland-mandela-parkway; https://www.eastbaytimes.com/2005/07/13/mandela-parkway-unveiled/; https://highways.dot.gov/public-roads/marchapril-1998/replacing-oaklands-cypress-freeway
[27] Pompidou Expressway sources: https://www.cnu.org/highways-boulevards/model-cities/paris; https://www.npr.org/sections/parallels/2013/08/19/212384535/sun-sand-and-the-seine-the-beach-comes-to-paris; https://www.theguardian.com/world/2012/aug/02/paris-seine-riverside-expressway-pedestrian

## 3.5 Implications of Altering the Battery Park Underpass

The project team analyzed the traffic implications of aligning the flood protection alignment through the Battery Park Underpass (BPU), which would avoid impacts to the Battery Maritime Building and the Whitehall Ferry Terminal but would require the loss of at least one lane. The BPU provides a critical direct link between the west (e.g., West Street and Hugh Carey Tunnel) and east sides of Lower Manhattan. Most of the traffic using the BPU is "through traffic" heading to/from the FDR Drive viaduct north of the Brooklyn Bridge.

- BPU to FDR Drive viaduct northbound (see Figure 24): highest during AM peak hour, with 1,915 vehicles per hour (vph). 60-65% of that volume continues on the FDR Drive viaduct north of the Brooklyn Bridge and approximately 8% of vehicles take the Brooklyn Bridge out of Manhattan. The remainder have local destinations.
- FDR Drive viaduct southbound to BPU (see Figure 25): highest during PM peak hour, with 1,250 vph. Over 80% of that volume is coming from the FDR Drive viaduct southbound from points north of the Brooklyn Bridge, while approximately 6% is coming from the Brooklyn Bridge.

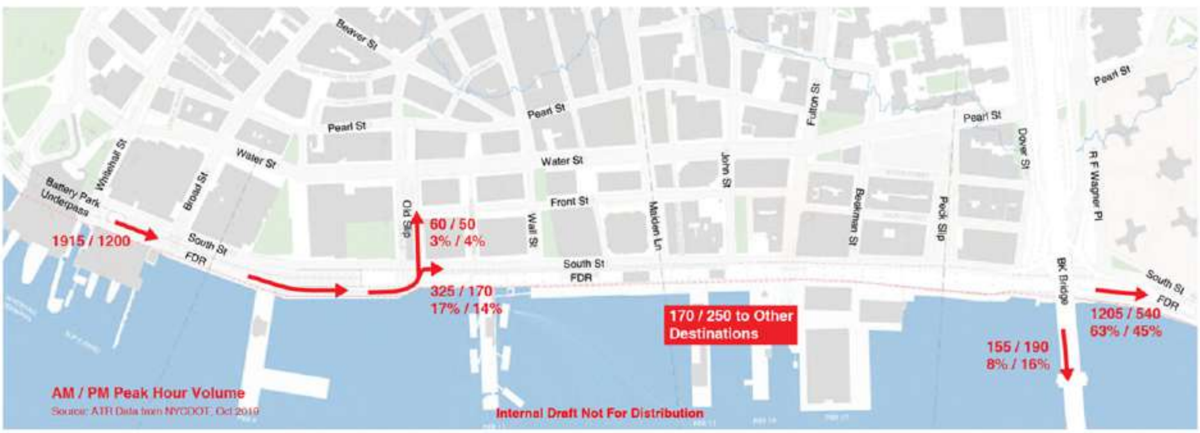


*Figure 24. Existing Battery Park Underpass Northbound Peak Hour Volumes*


*Figure 25. Existing Battery Park Underpass Southbound Peak Hour Volumes*

If the capacity of BPU were to be reduced in one or both directions, traffic would need to filter through the Lower Manhattan grid to move crosstown. Few viable routes exist due to the lack of a consistent grid in Lower Manhattan (see Figure 26 and Figure 27).

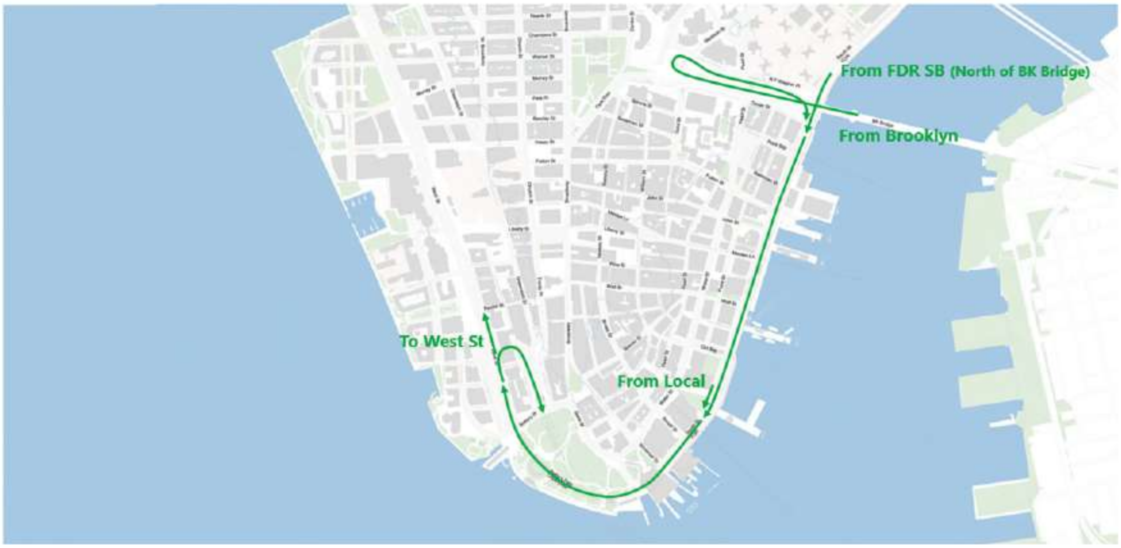


*Figure 26. Existing Battery Park Underpass Southbound Routes*


*Figure 27. Alternative Southbound Route without the Battery Park Underpass*

Eliminating the BPU could send over 1,000 to 2,000 peak hour vehicles to filter through a Lower Manhattan grid that is not designed for such high volumes. It would also work against the City's goals for maximizing the pedestrianization of Lower Manhattan. Significant traffic volume reductions (e.g., the optimistic -70% volume scenario) would be required. Reducing the number of lanes in the BPU would create less traffic issues than the complete elimination of the BPU. Ultimately the coastal protection alignment along the BPU was deemed less desirable than other options due to conflicts with existing infrastructure in the area, so the traffic impacts were not studied further.