TAPPAN ZEE BRIDGE/I-287
ENVIRONMENTAL REVIEW

New York State Department of Transportation
New York State Thruway Authority
Metropolitan Transportation Authority/Metro-North Railroad

Alternatives Analysis for Hudson River Highway Crossing

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ARUP

Tappan Zee Bridge/I-287 Corridor
Draft Environmental Impact Statement

July 2, 2007

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LIST OF ACRONYMS AND ABBREVIATIONS

AA	Alternatives Analysis
AGL	Above ground level
AREMA	American Railroad Engineering and Maintenance-of-Way Association
BPM	Best Practice Model
BRT	Bus Rapid Transit
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CRT	Commuter Rail Transit
CWA	Clean Water Act
dBA	Decibels on the A scale
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
EPB	Earth Pressure Balance
ESP	Electrostatic Precipitator
FHWA	Federal Highway Administration
HOT	High Occupancy Toll
LOS	Level of Service
LRT	Light Rail Transit
MTA	Metropolitan Transportation Authority
MW	Megawatt
NFPA	National Fire Prevention Association
NO_x	Nitrogen Oxides
NYSDEC	New York State Department of Environmental Conservation
NYSDOS	New York State Department of State
NYSDOT	New York State Department of Transportation
NYSTA	New York State Thruway Authority
PIARC	World Road Association
PM	Particulate Matter
RHA	Rivers and Harbors Act
ROW	Right-of-Way
RTA	Road Transport Authority
SMART	Stormwater Management and Road Tunnel
SO_X	Sulfur Oxides
sq ft	Square feet

TBM	Tunnel Boring Machine
TOFC	Trailer on Flat Car
TPSS	Traction Power Substation
USACOE	US Army Corps of Engineers
USEPA	US Environmental Protection Agency
VOCs	Volatile Organic Compounds
WHO	The World Health Organization
WRP	Waterfront Revitalization Program

1 Introduction

This paper is one of a series that documents the technical analyses that have been conducted as part of the Alternatives Analysis (AA) process for the Tappan Zee Bridge/I-287 Corridor Environmental Review. One of the objectives of both the Level 1 and Level 2 screening processes has been to reduce the number of individual project elements identified at the onset of the study (150) into a manageable number of alternatives to be carried forward into the Draft Environmental Impact Statement (DEIS). Over the course of the AA process, several decisions have been made regarding such factors as highway alignments, transit modes, and transit alignments. Studies have also been done to determine the type of river crossing (bridge vs. tunnel) for both highway and commuter rail transit (CRT) that should be studied further in the DEIS.

1.1 Background

\The process of determining the type of river crossing for highway and rail has been conducted in two steps. This report addresses the analysis of a highway bridge vs. a highway tunnel for inclusion in DEIS build alternatives. A separate study (*Alternatives Analysis for Commuter Rail Hudson River Crossing*, draft August 2005) addresses the type of Hudson River crossing for those build alternatives that include commuter rail transit (CRT) (Alternatives 4A, 4B, and 4C). Two options were studied using the Level 2 Screening Criteria (engineering, transportation, environmental, and cost):

- **Highway Bridge Option** – a new single-level highway bridge with two bus rapid transit/high occupancy toll (BRT/HOT) lanes and eight general purpose lanes.
- **Highway Tunnel Option** – a new highway tunnel, consisting of five tubes (one for BRT/HOT lanes), each with two traffic lanes.

The overall study area for the AA process has been the entire I-287 corridor from Suffern to Port Chester. However, the scope of this task encompasses the more limited area between Interchange 12 in Rockland and Interchange 8 in Tarrytown, where the significant differences between the two options occur.

Any option for a river crossing must meet the New York State Thruway Authority's (NYSTA) and Metro-North Railroad's operating and maintenance requirements. These requirements are fully described in Chapter 2 along with the facility design concepts. Chapters 3, 4, 5, and 6 present the evaluation of the design concepts with respect to the engineering, transportation, environmental, and cost criteria that were used in selecting the recommended option, which is described in Chapter 7.

1.2 Purpose and Need

Studies have shown that several transportation improvements including mobility, transit options, and safety are needed in order to meet the growing travel demands of the corridor. The corridor experiences significant delays due to congestion and is often operating at or near capacity particularly in the vicinity of the Tappan Zee Bridge. Rockland County is one of the fastest growing communities in the Metropolitan Region and Westchester is experiencing employment growth in areas around White Plains and the Platinum Mile. The Tappan Zee Bridge and the corridor provide an important link between these communities and to the overall regional transportation network. In addition to the capacity constraints of the corridor, the Tappan Zee Bridge is aging and in need of a regular and extensive maintenance program. As the region grows, travel demand will increase on an already strained roadway network. The following needs have been identified for the corridor:

- Preserve the existing river crossing as a vital link in the regional and national transportation network.

- Provide a river crossing that has structural integrity, meets current design criteria and standards, and accommodates transit.

- Improve highway safety, mobility, and capacity throughout the corridor.

- Improve transit mobility and capacity throughout the corridor and travel connections to the existing north-south and east-west transit network.

The Bridge and Tunnel Options are also considered in the context of the project Purpose and Need.

2 Engineering Elements

The following characteristics define the Bridge and Tunnel Options for the highway crossing of the Hudson River:

- **Highway Bridge Option**: A new highway bridge including four general purpose lanes, matching the existing lanes on both approaches, and one BRT/HOT lane in each direction. From previous analyses, the preferred alignment for this option was determined to be just north of the existing Tappan Zee Bridge.

- **Highway Tunnel Option**: This would consist of five highway tubes based on the limitations of current technology. Four tubes with two highway lanes in each would be located just to the north of the existing bridge, and would provide four general purpose lanes in each direction. A tube with two lanes for BRT is located in between the four highway tubes.

Figures 2-1 and 2-2 show the alignments and the profiles of the Bridge and the Tunnel Options respectively. These alignments are broken out by segments to facilitate the analysis in this paper.

2.1 Operating Requirements

One of the first steps in developing the engineering elements for both the Bridge and Tunnel Options was to define the operating requirements for the transportation systems. The specific requirements for the highway crossings were provided by NYSTA:

- Provide independent and dedicated access (southbound and northbound) from Thruway maintenance and administrative facilities (including State Police) to the mainline at all times.

- Maintain or improve existing levels of service.

- For safety reasons, locate access roads/ramps to and from the Thruway on the right side.

- Locate facilities such that State Police and Thruway maintenance vehicles are in close proximity to the crossing. Provide one-minute access time to the northbound and southbound lanes of the crossing.

- Design the crossing such that the probability of loss of crossing is less than 1 percent in 100 years for any natural hazard.

- Include staging areas on both ends of the crossing for quick and safe stopping of commercial traffic for inspection before entering the crossing.

- Provide access roads at both ends of the crossing for turn-around of Thruway maintenance and State Police vehicles carrying out emergency response and maintenance activities.

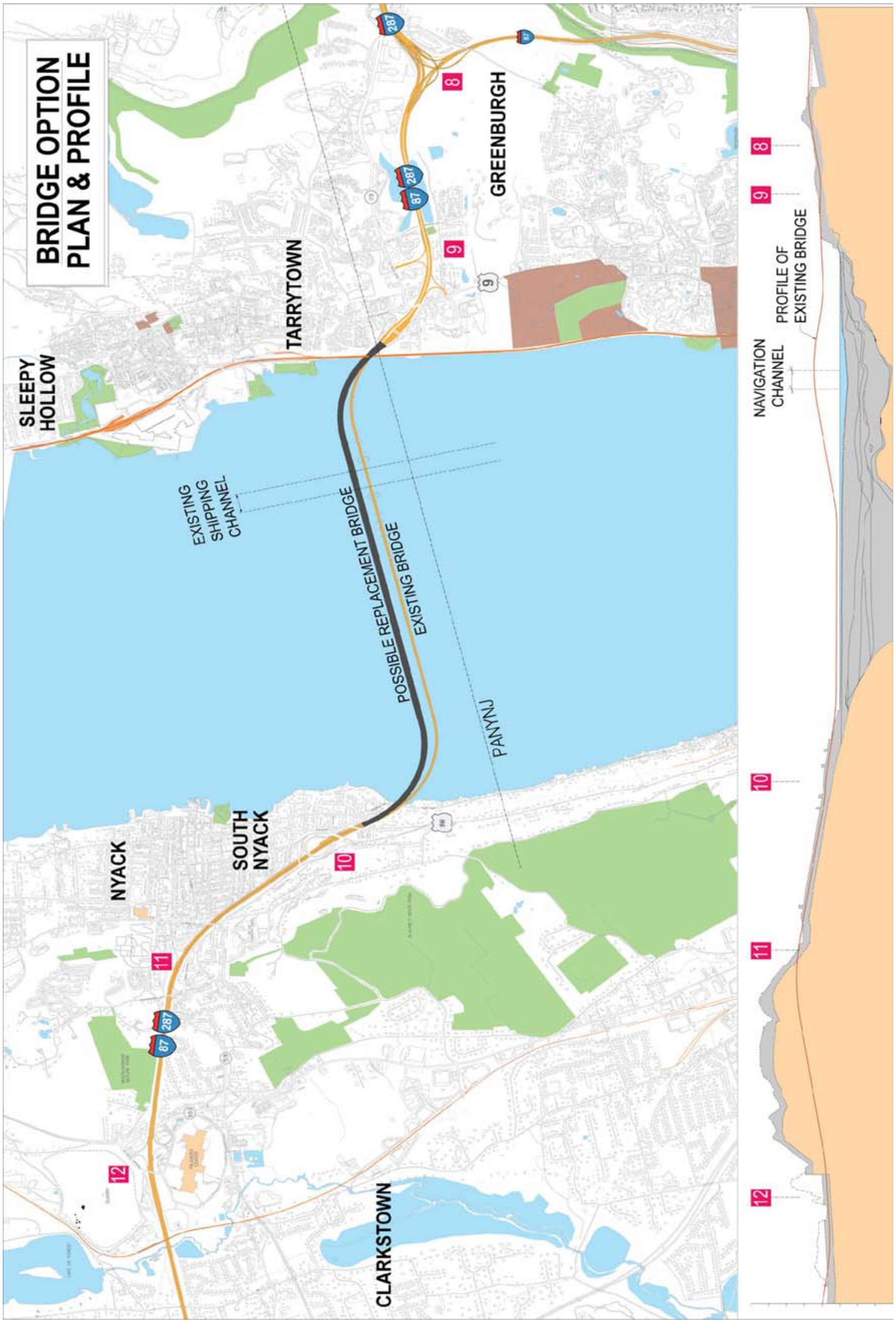

Figure 2-1 Bridge Option Plan and Profile

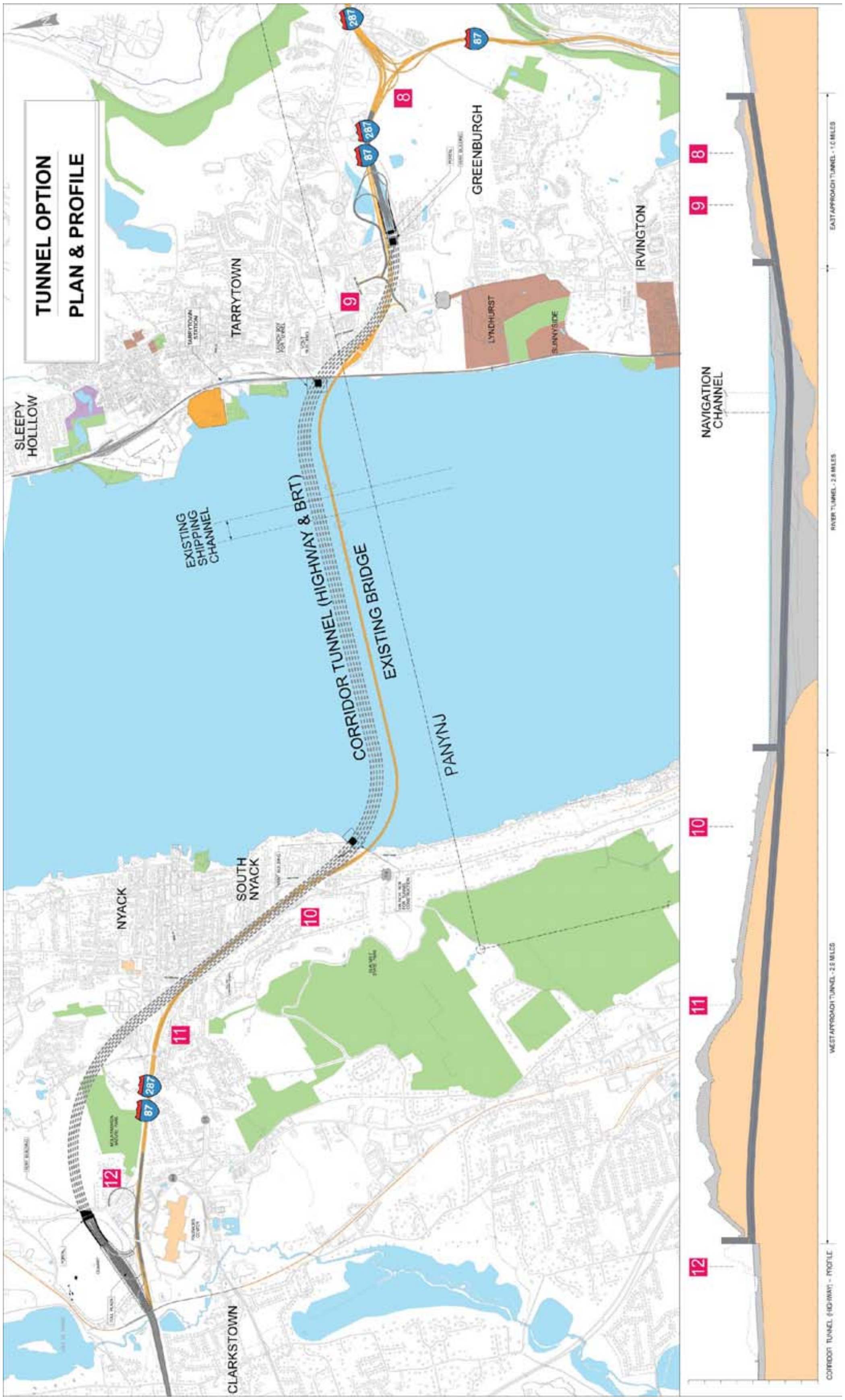

Figure 2-2 Tunnel Option Plan and Profile

- Replace in function, any NYSTA building or facility eliminated or significantly impacted.
- Locate all highway (vehicular) lanes on the bridge on one level to optimize lane utilization.
- Provide four U-turns on the bridge (with electronic gates) to accommodate emergency response and maintenance vehicles. Provide one U-turn on each end of bridge and two in between.
- Provide unrestricted access at all times to the bridge structure, including the area over commuter rail tracks.
- Design the bridge structure to accommodate pedestrians, cyclists, and alternative transportation modes.
- Provide effective separation between pedestrians and vehicular traffic on the bridge.
- Provide a full width shoulder in the tunnel bores to allow for emergency response and minimize delays due to breakdowns.
- Allow for truck traffic in all lanes of the tunnel bores to provide maximum operational flexibility.
- Comply with NFPA requirements for tunnel safety.

2.2 Physical Constraints

In addition to the operating requirements, a number of physical constraints influenced the engineering requirements within the crossing area:

- **River/Shoreline Topography**: The advance and retreat of Pleistocene era glaciers through raised rock formations at the bridge site created a local river valley. On the west side, both bedrock and the overlying topography slope rapidly upward away from the river. On the east side there is a cliff formation with overlying topology that continues to rise away from the river. The high elevations of the existing ground on both shores relative to the river require long approach tunnels for the Tunnel Option.
- **River Geology**: Historical and recent data from borings in the river adjacent to the existing Tappan Zee Bridge indicate that soil conditions in the river are poor. Bedrock beneath the river varies from a depth of 200 feet on the eastern half to 750 feet and more on the western half. The rock is overlain by layers of progressively softer soils deposited by glacial action, by downstream river flow, and carried upstream by tidal action, respectively. Bridge foundations can reach the competent rock on the eastern half, but piers would have to be founded in the poor soils in the western half, making settlement and seismic forces of significant concern.
- **Upland Geology:** Review of historical geological data received from NYSTA, Metro-North, and NYSDOT confirms the general knowledge of the corridor’s geology away from the river, with competent rock at generally shallow depth beneath the corridor in Westchester and Rockland counties. Therefore, the bulk of the approach tunnels must be bored, mined or cut through rock.

- **Shoreline Geology**: Limited historical geological data is available for the Westchester or Rockland shore areas. This is a key area for tunnel construction, as the elevation of the rock to soil interface would impact the location of launch and recovery boxes for tunnel boring machines (TBMs).

- **Seismic Issues:** There is a history of moderate seismicity in the New York City region, with earthquakes estimated at a magnitude of 5.2 having occurred in 1737 and 1884, along with numerous lesser ones. The deep soft soils overlaying the bedrock will tend to amplify the ground shaking in a seismic event. A site-specific design 500-year earthquake is likely to occur within the service lifetime of the bridge.

- **River Depth and Tidal Range**: Both depth and tidal range do not present major constraints. .

- **Navigable Channel:** Existing navigation channel width (600 feet) and depth (32 feet) must be maintained as well as the height above mean high water (139 feet).

- **Right-of-Way (ROW):** Abutting sensitive land uses constrain bridge shore landings and tunnel portals.

2.3 Bridge Option

2.3.1 Highway Improvements

Within the limits of this study, the Rockland highway improvements would include three general purpose lanes, a climbing lane, and a BRT/HOT lane in each direction. It would also include reconstruction of Interchanges 10, 11, and 12.

In Westchester, roadway improvements would continue through Interchange 9 and would include toll plaza reconstruction and ramps/bridges related to the BRT/HOT lane connection to Route 119.

2.3.2 Bridge Option Configuration

For the purposes of this assessment, an economical highway bridge might have the configuration shown in Figure 2-3. The bridge would be configured to carry four general purpose lanes and one BRT/HOT lane in each direction, matching the lane arrangement on both approaches. The bridge configuration used for this assessment is assumed to be a minimum weight steel truss solution, which would reduce the demands on the poor founding soils. The use of trusses facilitates spans of up to 300 to 400 feet, resulting in 40 to 60 foundations across the river, each supporting two piers. The total area occupied by pilecaps in the river is 5 acres. The main span lengths would be 1,200 to 1,500 feet, compared to 1,212 feet for the existing bridge. The total bridge width would be 250 feet, comprised of two truss structures each up to 105 feet in width separated by up to 40 feet to allow space for a tower in the main spans over the channel (Figure 2-3). This separation would not be required other than at the main towers.

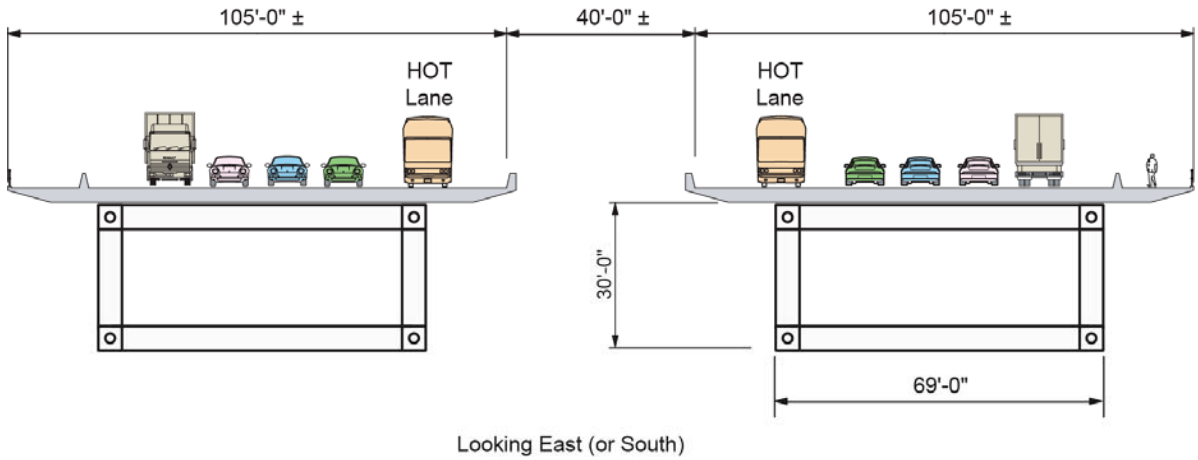

Figure 2-3 Highway-Only Bridge Cross-Section

2.3.3 Bridge Plan and Profile

A replacement bridge over the Hudson River would be approximately 16,000 feet in length. Based on discussions with the Coast Guard, clearance over the channel may need to be increased from the current 139 feet to 155 feet. This results in 1.2 and 2.0 percent grades, respectively, on the Rockland and Westchester structures approaching the shipping channel. The arrangements of the bridge at the main spans will be studied in the DEIS.

2.3.4 Bridge Option Landings

The required width at the Rockland shore approaching the highway bridge is 260 feet (Figure 2-4), which includes highway and BRT/HOT lanes, shoulders, two ramps for Interchange 10, and an 8-foot allowance for sound walls/median and maintenance access ramps. The minimum existing ROW is 250 feet. Reconfiguration of Interchange 10 and replacement of the associated bridges, including the Route 9W bridge would also be required. Further evaluation of the access ramps to the Thruway maintenance facility may reduce the cross-section required.

The construction of a highway bridge with the associated access roads and ramps, while maintaining Thruway operations, involves the following:

- Additional easements would be required on both sides of the ROW for tie-backs and retaining wall construction.

- The final elevation on the Thruway would be + 45 feet for the highway bridges, compared to an existing elevation of +35 feet at the shoreline. The raised elevation is a consequence of a potentially deeper bridge structure.

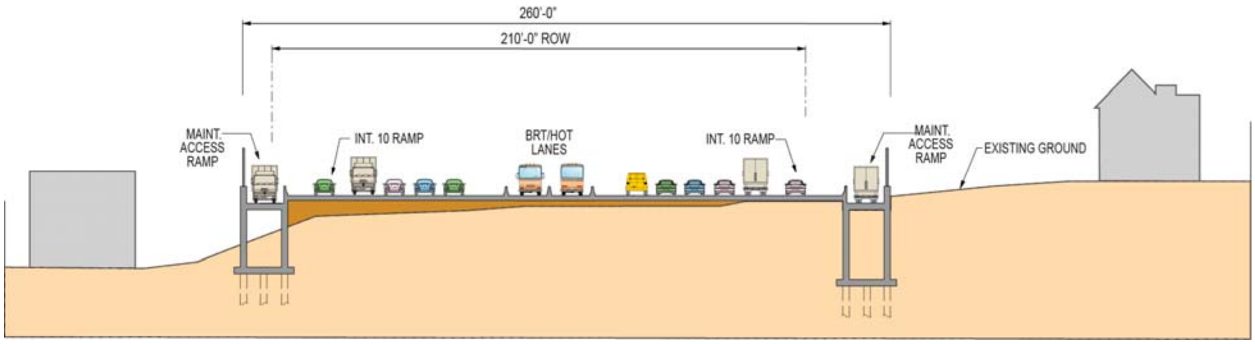

Figure 2-4 Section at Rockland Shore Landing

2.3.5 Construction Staging

Construction of the Bridge Option in the Rockland shore area would most likely occur in three stages:

- **Construction Stage 1:** reconfigure Interchange 10.
- **Construction Stage 2**: relocate the Thruway to the south for approximately 4,000 feet. This allows construction of the northern half of the new highway bridge and highway at grade. This temporary realignment would be anticipated for 2 to 3 years and would involve temporary access ramps at Interchange 10.
- **Construction Stage 3:** relocate Thruway traffic from the existing bridge to the newly constructed northern half of the replacement highway bridge with four restricted lanes in each direction in this temporary condition. The existing bridge would be demolished to make space for construction of the remaining half of the new highway bridge.

Construction in the river would include foundation work for the approach spans, carried out from mobile barges, and in-river platforms for the main span pier construction. Construction of up to 2 acres of temporary platforms on each side of the river would be required for construction staging, storage, and transshipment of equipment and construction material as well as foundation work. Shore facilities would be required to provide a staging area and a location for deliveries of materials. Until construction of the road deck was commenced, river transport on boats and barges, including floating cranes, would be required to transfer materials, labor and equipment to the bridge piers.

Construction in Westchester would generally be limited to the toll plaza and Interchange 9. Additional bridges may be required to allow BRT/HOT lane access to Interchange 9. The construction impact would involve temporary diversions on the Thruway for several years.

2.4 Tunnel Option

2.4.1 Tunnel Configuration

Due to the terrain, with steep embankments on the Westchester side of the Hudson River, the eastern tunnel portal would have to be located some distance from the shore. A portal east of Exit 9 is envisaged. On the Rockland shore, the existing 3 percent grade of the Thruway could be extended to the shoreline; however, a sizable portal structure would be required to make the transition between the contiguous lanes of the highway and the multiple tubes of the tunnel. Much of this structure would be in the Hudson River, and might extend up to 2,000 feet from shore. An increase in the Thruway grade to 4 percent might significantly reduce the quantity of portal constructed in the river; however, it will require constructing the portal in the same location as the existing Thruway lanes but at significantly greater depth.

Because of the complexities involved in developing a western shoreline portal, both in terms of river impacts and construction staging, an alternative configuration that extends the tunnel bores through the Palisades to the existing quarry near Exit 12 has been adopted for the purposes of this comparison. The result is a crossing from approximately Exit 12 in Rockland to just beyond Exit 9 in Westchester. The resulting tunnel crossing would be approximately 36,000 feet long. The varied rock and soil conditions experienced over this almost 7-mile distance means significant tunneling would have to be carried out in two distinctly different types of ground conditions: in soft ground materials in the Hudson River bed, and in rock in the tunnels on either side of the river.

2.4.1.1 Hudson River Highway Crossing

Issues specific to the choice of tunneling method for the crossing include the ground conditions, the water depth, the significant depth of soils overlying rock in the river, and the transitions from these soils to rock near each bank. For the Hudson River highway crossing, consideration of these factors leads to two main possible tunnel construction methods: immersed tube tunnels and bored tunnels. It was concluded in the Level 1 screening process that an immersed tube tunnel is not a preferred solution for the river crossing due to a number of negative impacts, in particular since a 600- to 700-foot wide trench would be required, which would cause a large impact on the river environment and management of this would be a major undertaking and perhaps prohibitive (initial information indicated that there may only be a seasonal window in which particular aquatic species would not be disturbed excessively). As a result, if a tunnel option is chosen, the preferred tunnel construction method for the Hudson River highway crossing is bored tunnels.

In soft ground, bored tunnels are constructed using a TBM. Factors affecting the construction of a bored tunnel under the Hudson River include:

- Tunnel construction wholly within the soft organic clays that underlie the entire width of the river is impractical, because of increased risks of tunnel movements and instability of the tunnel excavation face.

- None of the competent soil layers is sufficiently thick to allow tunnel construction entirely within one soil horizon and therefore the design of appropriate tunneling methods needs to address a range of ground conditions, including the possibility of encountering boulders in the glacial deposits.

- Lenses and layers of more permeable sands within the varved clay and silt glacial deposits may present zones of high groundwater inflow, which should be addressed in the tunnel construction methodology.

- At the shoreline, the transition from soft ground to rock results in mixed face conditions, with a long transition likely on the eastern side in particular. These present complexities for the TBM, resulting in longer construction periods and greater construction risk.

Given the combination of relatively soft ground conditions and the presence of water, a TBM would be required that provides support to the ground and stops water inflow. Based on the available geological information, the types of TBM that would deal with the expected ground conditions are an Earth Pressure Balance (EPB) TBM or a Slurry TBM. A Slurry TBM would be better able to cope with varying ground conditions caused by the layering of the clay, sand, and organic clays and should be able to deal with boulders in the glacial till up to approximately one quarter of the TBM diameter if a crusher machine is included in the face. Given that a Slurry TBM would also be capable of providing a larger tunnel diameter, it is likely that a Slurry machine would be preferred.

Temporary access shafts are required on both sides of the river to allow for launching and retrieval of the TBM, provide access for supplies to the TBM, provide a means for extraction of spoil, and to deal with the mixed face conditions at the soft ground to rock interface. Ideally, these shafts would lie across the interface between soft ground and rock, thus ensuring that the TBM would not encounter rock or mixed face conditions, which would increase the complexity of construction. While construction of the tunnels in one continuous drive is theoretically possible, this approach would require an extremely sophisticated TBM which has never been manufactured at the required diameter. In addition, this would carry a significant construction risk and would imply a noticeably longer construction period. As a result, construction of the tunnel would likely be in three segments – one in the river and one at either approach.

2.4.1.2 Approaches to the Hudson River

The Rockland shore approach involves long lengths of tunnel, ranging from approximately 9,500 to 15,000 feet. The ground conditions are well suited to tunneling, with the top of rock relatively close to the ground surface. The Westchester approach is generally similar but with more competent rock, and a shorter tunnel length (ranging from 5,000 to 7,000 feet). However, the connections to existing infrastructure are more complex in Westchester.

The main tunneling options for the approaches are bored tunnels constructed with a TBM (either a hard rock TBM or a modified slurry TBM) or a mined tunnel constructed by drill-and-blast. On the Rockland approach tunnels, mining could also be carried out with a roadheader, which would be able to excavate the softer sandstones, arkose sandstones and mudstones that make up the Brunswick formation, which is the predominant rock type in the area. Mining of the Westchester approach tunnels is unlikely to be possible by roadheader, because the rock is part of the Manhattan prong, which is formed of stronger rocks including gneiss, schist, and marble. Short lengths of cut-and-cover tunnel would be required at the portals.

2.4.1.3 Tunnel Cross-Section

A number of tunnel cross-sections that provide sufficient space to address the design criteria and meet international norms for ambient air quality were investigated. For the bored tunnel, an outside tunnel diameter of 53 feet was identified, with a spacing of one tunnel diameter between adjacent tunnels in the soft soil, and half a diameter in rock. This tunnel diameter is dictated by the ventilation requirements and is based on a fully transverse ventilation system, incorporating an emergency passage below the deck. The design of the highway lanes within each tunnel are based on the recommendations contained in AASHTO's *A Design Policy on Geometric Design of Highways and Streets* (2001) and the NYSDOT *Highway Design Manual*.

The roadway width comprises 12-foot travel lanes with an AASHTO recommended 12-foot right side shoulder and a 4–foot left side shoulder for general traffic. While, not obligatory, the presence of shoulders and their resulting widths have been adopted to allow a direct comparison with bridge alternatives. The design vehicle is the WB-67 (Interstate semi-trailer) and design speed is 70 miles per hour (mph). A minimum vertical clearance of 16 feet 6 inches has been adopted for use within the tunnels, which is consistent with the proposed vertical clearance for the balance of the corridor. Figure 2-5 shows the typical cross section of the highway tunnels.

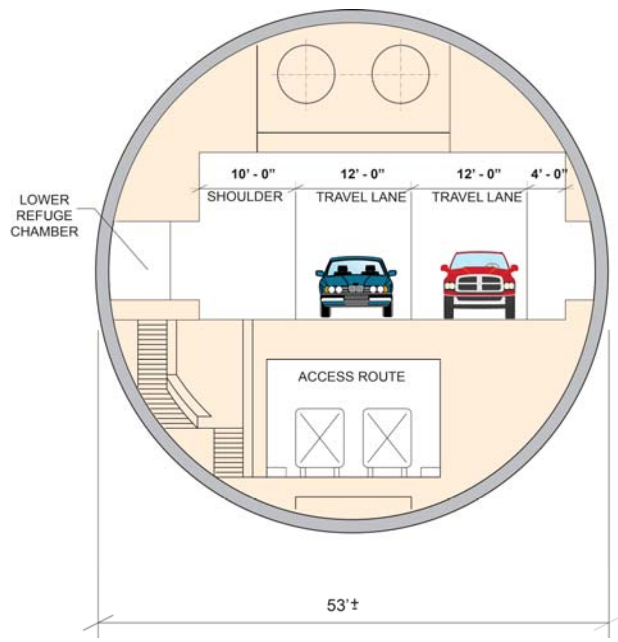

Figure 2-5 Cross-Section of Highway Tunnel

An alternative approach in developing a tunnel cross section is to use a reduced shoulder or eliminate it altogether. This approach has been used on other highway projects, although generally for shorter tunnel lengths. The 12-foot side shoulder used in developing the cross section would allow vehicles experiencing mechanical difficulty to stop safety without interrupting the flow of traffic. Using only minimal shoulders would result in traffic delays and potentially unsafe conditions during vehicle breakdowns. Disabled vehicles would have to be extracted by specialized towing equipment that would have to travel against the prevailing traffic to reach the vehicle in question. Using 3-foot shoulders would allow the diameter for a two lane tube to be reduced from the 53 feet described above to around 43 feet.

For the reduced shoulder option, the overall tunnel configuration would remain the same as that described for the 53-foot diameter tubes and the related impacts would be the same for both. The construction cost would be reduced by about 15 percent and the volume of spoil generated by around 35 percent for the reduced shoulder option. While the reduced shoulder option does offer some significant benefits, these have to be weighed against safety performance and higher incidence of traffic delays. For the purpose of this report, the standard shoulder option has been used for comparison with the bridge.

2.4.1.4 Tunnel Ventilation

Ventilation systems are required to control air quality, air temperature, and the migration of smoke in the event of a tunnel fire. The capacity and configuration of the ventilation system is determined by the volume of air to be handled, which is a result of the distance between vent buildings, the nature of contaminants (carbon monoxide [CO], nitrogen oxides [NO_x], and smoke from diesel engines), heat release, and the fire load.

The ventilation system for the Tunnel Option would require mechanical ventilation to satisfy the normal and emergency operational scenarios and would have to meet the following prime objectives:

- Control of pollutant levels within the tunnel to acceptable levels during all possible modes of normal and congested operation.

- Control of pollution levels near the tunnel portals and or ventilation stacks to acceptable levels during normal modes of operation.

- Control the flow of smoke in the event of a fire to allow the safe escape of people within the tunnel and access for fire fighters.

During normal operation, vehicles using road tunnels produce pollutants. The amount of emissions produced by each vehicle depends on many factors including the type and age of the vehicle, the gradient of the road, and the speed of the vehicle. Without sufficient ventilation, the concentration of these pollutants can increase to dangerous levels. Of particular concern are concentrations of CO and particulate matter (PM). Exposure to high levels of CO, even for short periods, can be harmful. Particulate matter or turbidity is produced mainly by diesel engines. High concentrations can have long-term health effects, but even small concentrations can reduce visibility within a tunnel and potentially cause accidents. Other pollutants such as NO_x and sulfur oxides (SO_x) are also produced by combustion engines, but are generally not a critical factor in the design of the ventilation system.

The World Health Organization (WHO) defines maximum in-tunnel pollution levels. Typical limits are:

- CO: 100 mg/m^3 (WHO 15-minute exposure limit).
- Visibility: 0.001 m–1 (World Road Association - PIARC), linked to PM10.
- NO_2: 9000 $\mu g/m^3$ (OSHA 15-minute exposure limit).

Analysis has demonstrated that for tunnels of the length proposed, transverse ventilation systems are more efficient and economical. A transverse system has both an air supply and an air exhaust that are independent of the roadway. Fresh air typically is supplied to the roadway from an air supply duct below the roadbed. Exhaust gases are drawn from the driving area via openings in the ceiling to an exhaust duct above. In event of an emergency, the lower fresh air duct can serve as an emergency refuge and egress.
In the event of a fire, the tunnel ventilation system must be capable of controlling smoke and heated gasses to allow the safe escape of passengers. Specific requirements are defined in *NFPA 502: Standard for Road Tunnels, Bridges, and Other Limited Access Highways*. General fire design criteria for a road tunnel similar to those proposed are:

- Fire load for a tunnel open to gasoline tankers is 100 megawatts (MW).
- Ventilation equipment fire rated to 482 °F.
- Air velocities within a tunnel should be limited to 2,200 feet per minute.
- Tunnel noise levels should not exceed 115 dBA (decibels on the A scale) for a few seconds and a maximum of 92 dBA during the rest of the emergency.

Recent full-scale fire tests (Memorial Tunnel Fire Ventilation Program) have shown that under certain conditions transverse ventilation systems do not control smoke spread in fire events larger than 20 MW. Therefore, the ventilation system adopted for the river crossing is a hybrid system that includes both longitudinal and transverse system characteristics. This system works as fully transverse for the purging of car fumes and as multi-zone longitudinal point extraction during a fire scenario. Because air is continually supplied and exhausted along the tunnel at regular intervals, large longitudinal air velocities are not induced.

Initial analysis indicates that a transverse system with at least three separate ventilation shafts and plants are needed to ventilate the highway tunnels, depending on the spacing that can be achieved. This is largely determined by the overall length of the tunnel and the limited amount of ducting space available within the proposed cross-sectional area. Although it is technically possible to have fewer shafts and plant, the duct area required becomes larger than that available. If this is the case an additional tunnel would be required to serve as a ventilation duct.

Although such a tunnel could additionally be used for escape and or maintenance purposes it would be considerably more expensive. The proposed distance between ventilation buildings is approximately 14,000 feet, assuming vent buildings located on both the Rockland and Westchester shores. As an adequate ventilation system could be developed with shore buildings, other alternatives utilizing vent buildings in the river were discounted to avoid the associated visual and access implications.

Each highway tunnel ventilation plant requires a minimum of two supply and two exhaust air fan plants (one of each near both ends) as well as a supply and exhaust air duct running the length of the tunnel. The major elements associated with each road tunnel ventilation plant (either supply or extract) are:

- Equipment:
  - Four large centrifugal fans (approximately 8 feet in diameter).
  - Splitter sound attenuators at the tunnel and atmosphere side of each fan plant.
  - Fire rated isolation dampers at the inlet to each fan.

- Approximately 4,000 square feet of plant space at 16-feet high per bore (for primary ventilation plant only).

- A single supply/exhaust shaft approximately 23 feet in diameter to ambient with a louvered inlet/outlet per bore.

- An air supply duct of approximately 270 square feet cross sectional area running the length of the tunnel with outlet grilles approximately 100 feet, per bore.
- An exhaust air duct of approximately 270 square feet cross sectional area running the length of the tunnel with inlet grilles approximately every 300 feet, per bore (each grill to be fitted with a fire rated, motorized, volume control damper).

There are a number of constraints on shaft locations including a limited number of sites large enough to accommodate ventilation buildings, the need to build shafts high enough to ensure that the pollutants in the exhaust gases are sufficiently diluted by ambient air before they return to ground level, and the need to minimize aesthetic impacts on the surrounding area. Typical examples of highway ventilation buildings are shown in Figure 2-6. Overall, the size of the ventilation buildings will depend on the balance between plan area and height, and the space available for machine rooms underground, but a typical ventilation building would have an area of 30,000 square feet (300 feet by 100 feet) and a height of 30 feet. The ventilation shafts could extend above the roof of the building up to a height of 100 feet.

Figure 2-6 Typical Ventilation Buildings
(Left: Boston Harbor Tunnel; Right: Route 3 Tunnel, Hong Kong)

For the road tunnels, the ventilation shafts would be continually releasing tunnel air containing vehicle emissions. Atmospheric dispersion modeling will be required to determine the required stack height and outlet air velocity needed to achieve the air quality criteria in the surrounding areas. Measures such as the use of filtration, electrostatic precipitators, and chemical or biological scrubbers can be considered.

Emission treatment technologies in road tunnels for PM, CO, NO_x, and volatile organic compounds (VOCs) are at various stages of maturity and acceptance around the world. Scrubbers and electrostatic precipitators (ESPs) have been around for several decades to remove PM, and are widely used in Japan and Norway. Despite high costs of capital investment and/or maintenance schedule, they are being installed into new tunnels in Japan, Norway, Vietnam, South Korea, and Australia.

Removing NO_2 (denitrification) is much more difficult, as it is a chemical (catalytic) process and it has not been practical until recently. Japan approved denitrification plants in 2004 for installation in their road tunnels. This still involves a relatively large plant layout for a given air quantity. The technology has proven viable, but its cost effectiveness is questionable.

The technology for removing CO has not matured, and no practical successful applications are known. The last pilot plant for removal of CO, NO_2, and VOC in Austria reported partial success in Austria in 1993, but the large volumes of air requiring treatment did not make it practical.

Tunnels are gradually shifting towards the use of these technologies in road tunnels, although various countries have different views about how practical and useful they are. The latest tunnel filtration report commissioned by the Road Transport Authority (RTA) of Australia for the M5 East Freeway (September 2004) is an authoritative text on the technology, the equipment, and the manufacturers identifying the trade-offs involved. It is premature at this stage to make any form of recommendation regarding these emerging technologies.

2.4.1.5 Fire

Accidents in the tunnel resulting in a fire can have serious safety implications. This has been illustrated in a number of major incidents in Alpine tunnels. However, modern tunnels with appropriate safety provisions can manage the effects of fires to contain the impacts of an accident. This was illustrated in a recent incident in the Burnley Highway tunnel in Melbourne, Australia, where deluge systems and public messaging systems were effectively used to prevent the spread of a fire after an incident. A recent Federal Highway Administration (FHWA) publication, "*Underground Transportation Systems in Europe - Safety, Operations, and Emergency Response*" describes modern tunnel safety systems used in Europe and provides recommendations for future developments in US standards and procedures.

If required, travelers evacuating a tunnel in a fire condition would leave the area of the roadway and enter a separated, enclosed, emergency walkway along the entire length of the tunnel. To enter the emergency walkway passengers would pass through a fire-rated concrete wall via fire doors spaced 200 to 300 feet apart. From this place of safety, which would be supplied with fresh air, passengers could either wait for emergency assistance or make their way to the surface by walking to the vent buildings at either end of the river tunnel. Egress from the tunnel would be through pressurized and fire-rated stairways located at each ventilation building.

2.4.2 Tunnel Plan and Profile

Two possible alignments were considered for the Tunnel Option: North 1 and North 2 (Figure 2-7). The North 1 Alignment for the Tunnel Option generally follows the same alignment as the existing Thruway. North 2 would be a shorter alignment, passing underneath Nyack, and crossing the river about one mile north of the existing bridge. The tunnel portals for both options are in the same locations, west of Interchange 12 in Rockland and east of Interchange 9 in Westchester.

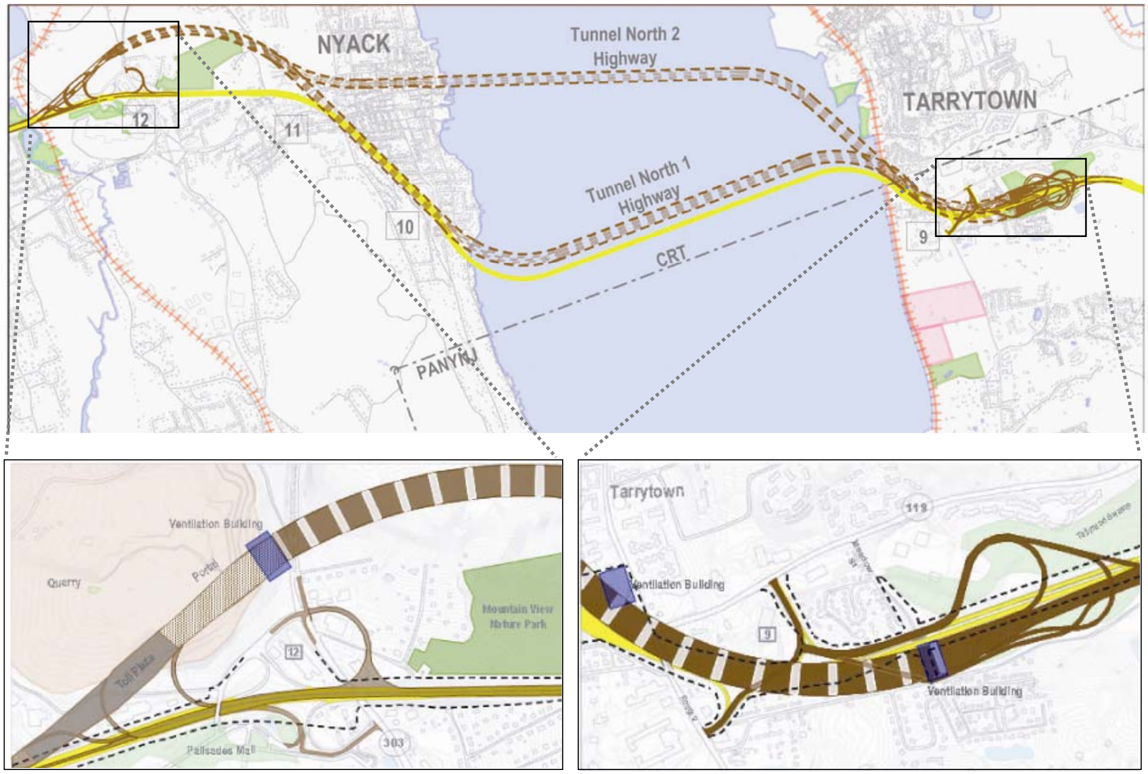

Figure 2-7 Corridor Tunnel Alignments

While the curves on the Tunnel North 2 alignment would be gentler than those on the Tunnel North 1 alignment, making it more favorable for the use of TBMs, and the route is more direct, the risks, environmental impacts, and larger number of subgrade easements associated with tunneling below Nyack are undesirable, making the Tunnel North 1 alignment preferable.

2.4.2.1 Rockland Approach (Segment 1)

Due to the depth of the alignment, long grades at 3.5 to 4 percent are required for the highway tunnel to drop down under the level of the river. The new highway would bypass Interchanges 10 and 11, requiring a major reconfiguration of Interchange 12 and longer journeys for traffic heading for Interchanges 10 and 11 from Westchester. This would alter local traffic patterns, and the existing highway between Interchange 12 and the river would be altered, rather than removed, to maintain access for local traffic.

A plan of the west portal area is shown in Figure 2-8. This alignment shows the thruway diverging to the north from the existing corridor, and entering into a tunnel within the existing quarry that is adjacent to Interchange 12. Due to space constraints on the Westchester approach, the toll plaza would have to be relocated to Rockland, and the space required for construction staging and for the development of the toll plaza prevents it from being located within or to the south of the existing ROW.

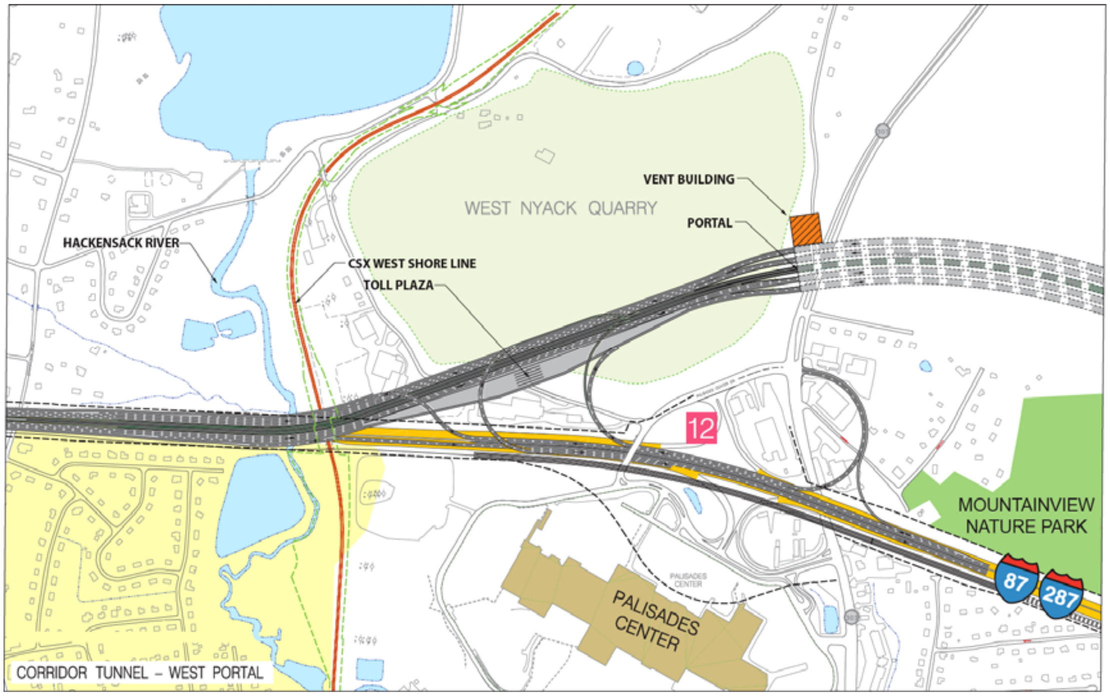

Figure 2-8 Rockland Portal Area

It should also be noted that a portal in this area would require tunneling under Mountainview Park. This portal arrangement would require extensive new highway construction north of the Thruway from Hackensack River through Interchange 12. This includes construction of the mainline, toll plaza, ramps, bridges, the approach roads over the 300-foot wide approach, the tunnel portal, and the tunnel ventilation building. The four highway tubes and the BRT/HOT lane tube would run parallel to each other. The tunnel corridor would be at least 370-feet wide due to the size of the tubes and the spacing between them.

2.4.2.2 River Crossing (Segment 2)

Under the river, the tubes would be located at least one diameter below the river bed to counter buoyancy and provide stability of the ground above the tunnel during construction. The tubes would run parallel to each other, just north of the existing bridge. The highway tunnel corridor would be at least 480-feet wide due to the additional spacing required between tubes in soft ground. A typical arrangement is shown in Figure 2-9

2.4.2.3 Westchester Approach (Segment 3)

The highway would require steep grades from under the river to the elevation of the existing highway. With a gradient of 3 percent (maximum desirable grade), the highway and BRT/HOT lane tubes would portal between Interchanges 9 and 8 to the south of the existing Thruway in the Talleyrand Swamp. This would require additional ROW, relocation of the existing toll facilities, and a complex interchange to allow traffic to connect to Route 9 at Interchange 9. The portal would be located just east of Meadow Street at approximately 50 feet below the level of the Thruway.

The Tunnel Option would require extensive signing in Rockland to direct traffic to different tubes depending on their destination in Westchester. The interchange arrangement is shown in Figure 2-10.

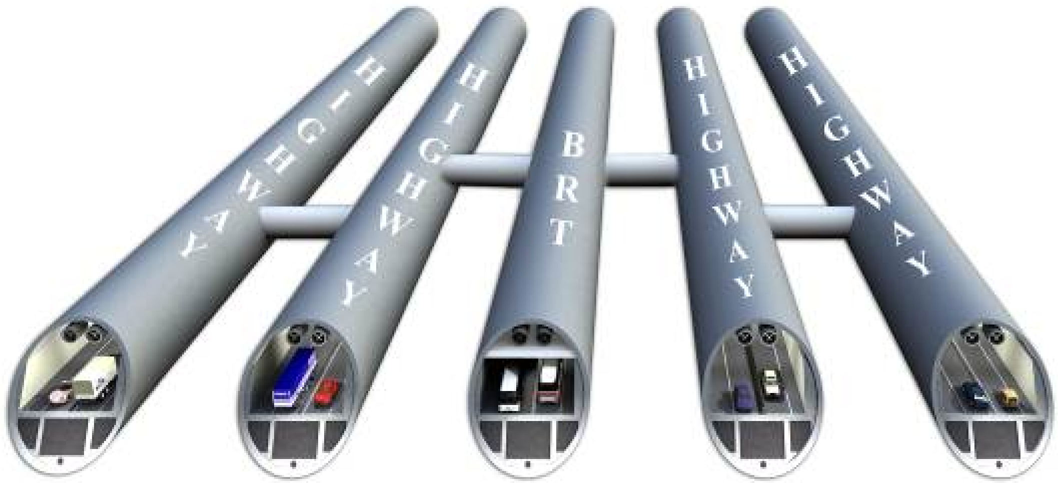

Figure 2-9 Cross Section of Highway Tunnel Option

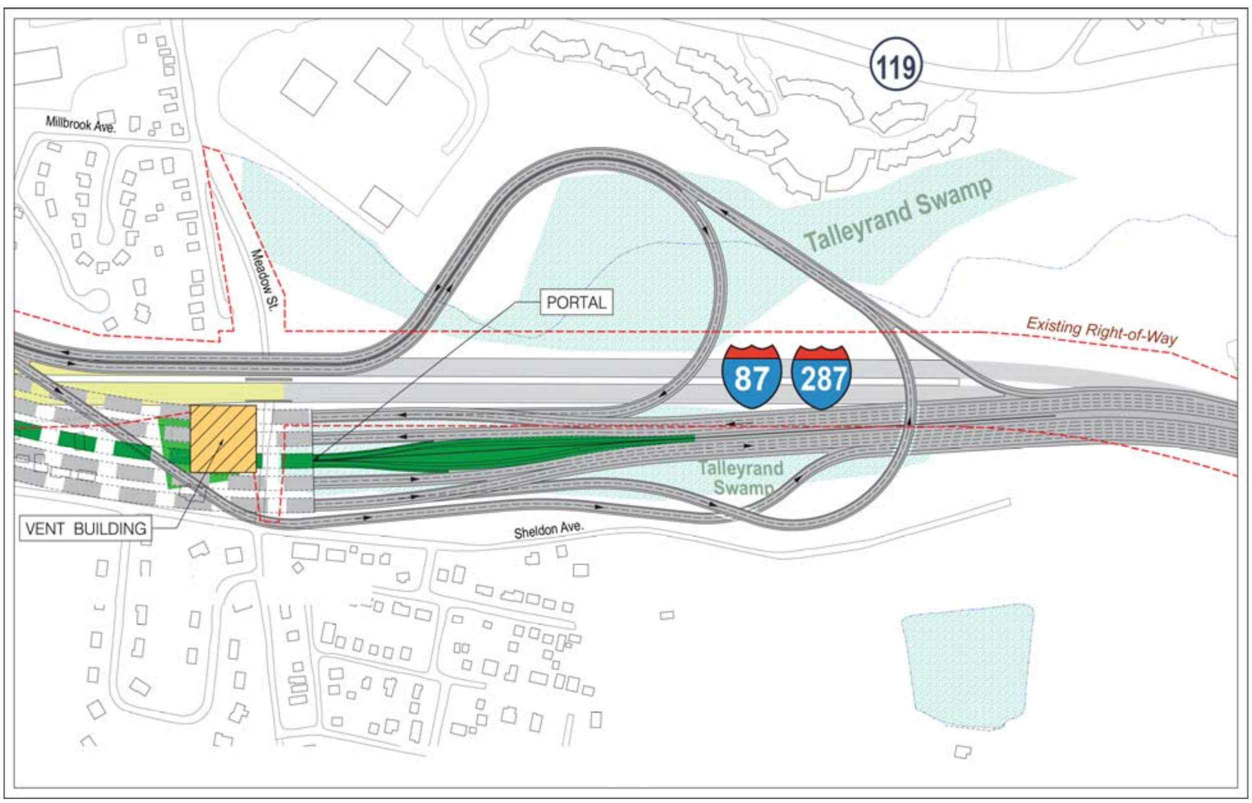

Figure 2-10 Westchester Portal Area

2.4.3 Support Facilities

Ventilation facilities would be required in three or four locations along the alignment of the highway tunnels. As previously described, these facilities are large, requiring a building footprint of 30,000 square feet (approximately 100 feet by 300 feet). Ventilation buildings would be required at each portal. Additionally, three arrangements for the location of intermediate ventilation buildings were investigated (Figure 2-11):

- **Mid-river:** Only one intermediate ventilation facility, located mid-river on an artificial island, would be required. The island platform would be above the flood elevation of the river to support the ventilation building with vent stacks extending up to 100 feet high. The total footprint of the island would be up to 2 acres. Construction would cause addition disturbance of the river bed, and access for routine maintenance would be difficult.

- **Close to the shore:** Provision of the ventilation buildings close to the shore would allow the construction shafts in the same location to be used for the permanent facilities, reducing the cumulative impact of construction. Access for maintenance would be possible via a permanent jetty from the shore.

- **On shore:** Although it is possible to locate vent buildings on-shore no viable locations have been identified. .

For the purposes of this study, intermediate ventilation buildings close to the shore are assumed.

Figure 2-11 Options for Ventilation Building Locations

2.4.4 Construction Staging

As previously described, tunnel construction for the crossing would be split into segments, with each segment matched to the ground conditions. For the Rockland approach, the tunnel segment would run between the portal and the shafts in the river at the soil/rock interface near the shore and the portal. The major construction area would be at the portal, and a significant area of ROW would be required for the permanent toll plaza and approach roads. The tubes on the Rockland approach would all be in hard rock and could be constructed by drill-and-blast, roadheader, or hard rock TBM.

For the river crossing, construction of the tunnels requires a launch or recovery box on either side of the river, with adjacent construction staging and storage areas. The boxes would be directly adjacent to the shore on either side of the river with access and egress for construction personnel, material, and equipment from the river or Thruway on the Rockland side. On the Westchester side, access would be predominantly from the river but temporary vehicular access would be required along the west side of the tracks to the existing Metro-North Railroad station. Up to 7.5 acres would be required on each side of the river, including a river location for the launch box (300 feet by 150 feet) that would incorporate the area of the assumed soil/rock interface. All spoil (approximately 6 million cubic yards from the river) would be removed through the launch box and would be disposed by barges.

The Westchester approach segment is similar to that in Rockland. Construction would occur from the portal area and the tunnels would be constructed using drill-and-blast or hard rock TBM.

Large amounts of excavated spoil would be generated at the various tunneling sites (a total of 10 million cubic yards). Typical disposal sites are abandoned gravel pits or other infrastructure projects that require embankments or a general increase in ground elevation. Specific spoil disposal sites have not yet been identified. Depending upon the location of the access shafts, material would be removed by truck, barge, or both. At approximately 10 cubic yards per dump truck, the quantity of trucks will be significant. If half the excavated material is trucked from the portal, and the balanced is barged from the access shafts, approximately 500,000 truck trips and 6,000 barge trips would be required. The shallow depths of the Hudson River on the Rockland shore may make spoil removal by barge difficult from a Rockland access shaft. Dredging may be required to facilitate barge access. Excavation of material from a particular access shaft would be continuous for 2 to 3 years.

2.4.5 Similar Tunnels

The scale of the Tunnel Option is unprecedented in its overall scope. Although longer tunnels have been successfully implemented elsewhere, the combined length, diameter, and number of bores required in the Tunnel Option would impose a monumental challenge in this tunnel construction. This section presents an overview of other tunnel projects around the world that are under construction or have been recently completed to facilitate comparison with the scale and implications of the Tunnel Option. Table 2-1 summarizes the key data for these projects.

Table 2-1

Examples of Large Diameter Worldwide TBM Highway Tunnels

	Configuration	Tunnel Diameter (Internal/Excavated) (feet)	Ground Conditions	Notes
M30, Madrid Spain	Two parallel tunnels, each with three lanes, 11.5-foot wide, and two 1.6-foot wide shoulders.	44.1/ 49.6	Soft ground	Electrostatic precipitators used to remove particulate matter from the air.
Elbe Tunnel, Essen, Germany	Two traffic lanes 12.3-feet wide, one emergency lane 6.6-feet wide, and two 1.6-foot wide shoulders	40.5 / 46.6	Soft ground	
A86 West Tunnel, Paris, France	Two traffic levels each with two 9.2-foot wide traffic lanes and a shoulder	34.1 / 36.9	Rock and soft ground	Car traffic only (max height 6.6 feet, 8.4-foot headroom)
Port of Miami Tunnel, Florida	Two 12-foot wide traffic lanes and two 1.5-foot wide shoulders	36 / 41	Rock and soft ground	

2.4.5.1 M30, Madrid, Spain

The construction of Madrid M30 motorway inner ring road started in September 2004 and was scheduled to be completed in mid-2007 (currently behind schedule). This project is divided into 15 projects in four regions: north, south, east and west. This project includes 61.5 miles of new road and 34.8 miles of tunnel, with a cost of approximately $5.8 billion for the entire project. Each tunnel has a three-lane highway, each having a width of 11.5 feet and a 1.6-foot wide shoulder on the left and right sides (Figure 2-12).

Up to seven EPB TBMs are used in the project, with the largest having a diameter of 50 feet (Figure 2-13). Most of the tunnel is constructed in soft ground with a small portion in hard rock. The TBM segment erectors are configured to line tunnels with 27.5-inch-thick concrete segments, although some sections may be double lined with a second segmental ring to act as a safeguard against fire.

The tunnel has an air cleaning system of electrostatic precipitators has a processing capacity of 1,670 cubic meters per second, through nine stations. Electrostatic precipitators are particulate collection devices that remove particles from the air by ionizing the particles when air is passed through polar plated with high voltage. Over 90 percent of the particles can be removed, making it suitable for improving internal and external environment of underground tunnels.

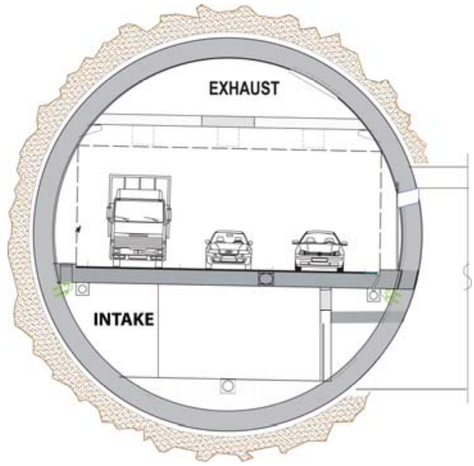

Figure 2-12 Typical Cross Section of M30 Tunnel

Figure 2-13 Earth Pressure Balance TBM (50ft Diameter)

2.4.5.2 Elbe Tunnel, Essen, Germany

The new 4th Elbe Tunnel Tube, completed in 2003, is a 1.6-mile long fourth tube in the roadway system to increase the number of traffic lanes from six to eight at a cost of approximately $678 million. The new tube actually contains two lanes: two 12.3-foot wide lanes and one 6.6-foot wide emergency lane, together with a 1.6-foot wide shoulder on either side. The alignment runs underneath the Elbe River, in soft ground, with a minimum cover of only 23 feet.

The outer diameter of the TBM was 46.6 feet. The tunnel inner diameter is 40.5 feet to accommodate two traffic lanes and an emergency lane. The outer diameter of the tunnel is 45.1 feet, with concrete segmental liner that is 27.5-inches thick. The TBM is one of the largest shield machines ever built, and it had to deal with difficult ground conditions of glacial deposits consisting of clay and sand with boulders of all sizes and high water pressure of 5.6 bar (81 psi). Using the Sonic Soft Ground Probing System, the construction crew was able to investigate the ground conditions up to 164 feet in front of the cutting wheel.

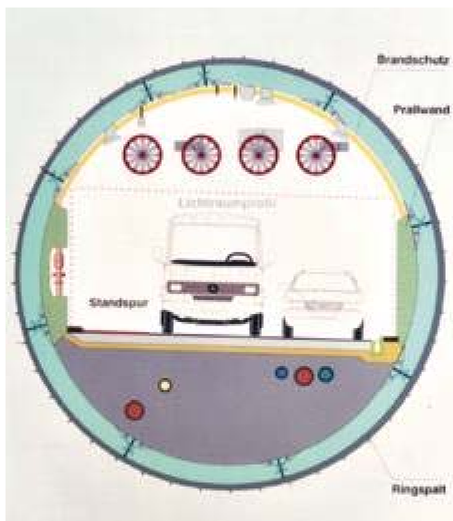

Figure 2-14 Typical Cross Section of 4th Elbe Tunnel Tube

2.4.5.3 A86 West Tunnel, Paris, France

The new A86 West Tunnel (Figure 2-14) will complete the A86 ring road around Paris. A86 West consists of a 6.2-mile long, double deck tunnel for light vehicles (no trucks) with a maximum height of 6.6 feet (tunnel clearance is just under 8.4 feet). Each traffic level has two 9.2-foot wide traffic lanes and an emergency lane. The project budget is approximately $2.98 billion.

The east tunnel has an internal and external diameter of 34.1 feet and 36.9 feet, respectively, bored using a TBM with an external diameter of 38.8 feet. The TBM was design to function using both EPB and slurry modes to enable tunneling through hard rock (limestone) as well as soft ground (clays and sand).

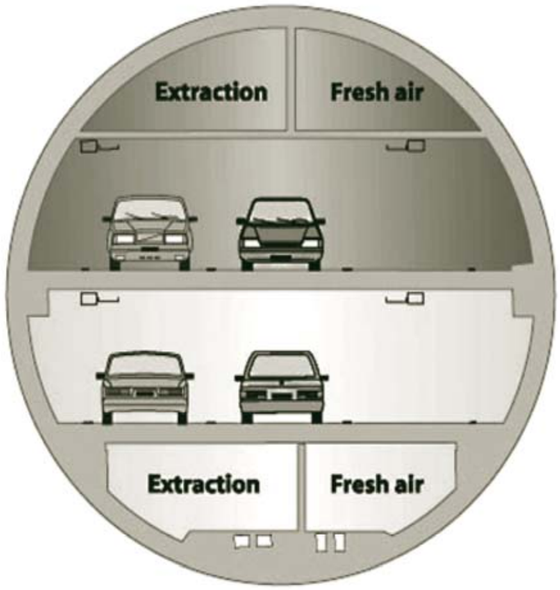

Figure 2-15 Typical Cross Section of A86 East Tunnel

2.4.5.4 Port of Miami Tunnel, Florida

The Port of Miami Tunnel is planned to allow traffic from the port to access the freeway system and Miami International airport without traveling through downtown Miami. After procurement as a Design-Build, Finance and Operate (DBFO) project, construction is due to start in late 2007. Excavation duration is estimated at one year. The tunnel consists of two tubes, just over a mile long, with each containing two 12- foot wide traffic lanes and two 1.5-foot wide shoulders. The internal diameter of the tube is 36 feet and the TBM diameter will be around 41 feet. This will be the largest highway tunnel constructed by a soft ground TBM in the United States. The tunnel cross-section is shown in Figure 2-16.

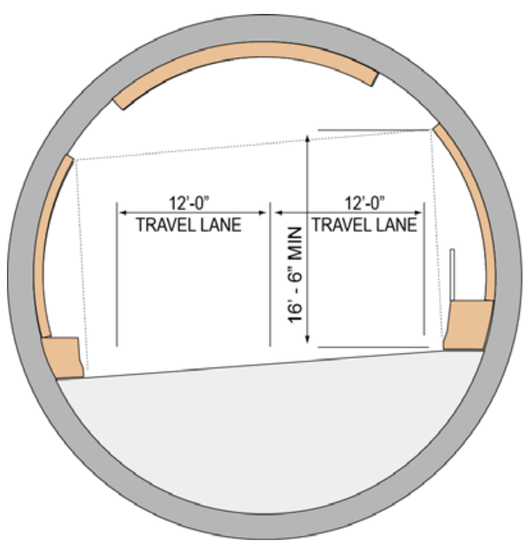

Figure 2-16 Cross Section of Port of Miami Tunnel in Florida

3 Engineering Criteria

This section reviews four engineering criteria: fire/life safety, emergency response, redundancy, and construction impacts. The first three consider operation of the crossing in emergency conditions as determined from provisions included in the engineering concept design. The fourth criterion concerns potential impacts on local residents and businesses during the construction process.

3.1 Fire/Life Safety

As part of the operations assessment of the Bridge and Tunnel Options, an outline review of emergency operations was conducted to determine potential hazards (both natural and manmade) and included fire, explosion, flood, ship collision, earthquakes, and loss of power. From this study, emergency procedures were considered for fire/life safety, emergency response, and redundancy.

3.1.1 Bridge Option

The maximum fire size on the bridge would be up to 250 MW (NFPA 502) but would depend on the fire source, the material available for combustion, and the type of vehicle. This maximum fire would correspond to flammable liquids from a liquid bulk carrier and assumes a high leakage rate and an unconstrained spill area, with the resulting flames estimated at up to 75-feet high.

For a fire event on the bridge, flames would likely engulf the surrounding structure and traffic would come to a stop. To limit consequences, structural elements would be increased in size to provide redundant capacity and additional protection and control measures would be introduced. For this event, potential mitigation measures would include drainage to allow for removal of the flammable liquid (channeling) to control the maximum liquid pool size. Standpipes and other related firefighting equipment would be included to facilitate firefighting. After the fire event, some damage to the primary and secondary structural members would be anticipated, requiring closure of part of the bridge to traffic while inspection and structural repairs were conducted.

Life safety in this event scenario would require evacuation from the fire area to a place of safety along the bridge at some distance from the incident. Smoke would not be the major life safety concern as this would be blown off the bridge by the prevailing wind.

3.1.2 Tunnel Option

Similar to the Bridge Option, the maximum fire size would be associated with flammable liquids in a scenario involving a stopped liquid bulk carrier with a high leakage rate and an unconstrained spill area. The maximum fire size would be smaller than that of the bridge because of the limited supply of air from the ventilation system and could be up to 100 MW (NFPA 502). A fire in one of the highway tubes would have no effect on traffic in the other highway tubes other than traffic disruption generated by responding emergency equipment on the Thruway ROW.

In the tunnel, flames would reach the walls resulting in spalling concrete and reduced structural capacity. Structural elements would be increased in size to provide redundant capacity and similar protection and control measures would be introduced as in the Bridge Option. To control smoke and temperature, the Tunnel Option would require a full ventilation system as described in Chapter 2, including the necessary detection and communication systems to provide warning.

It is expected that traffic movement would stop shortly after a large tunnel fire starts. Vehicles ahead of the fire would be able to drive safely out of the tunnel. Those behind the fire would not be able to pass the fire or turn around and reverse out of the tunnel as traffic is likely to back up behind them. It is therefore imperative that tenable pedestrian egress routes are available to vehicle drivers and passengers. A transverse ventilation system should provide tenable conditions at all locations throughout the tunnel except immediately adjacent to the fire. Experience in previous road tunnel fires shows that people are most likely to walk out of a tunnel the way they entered, by the road, ignoring emergency exits even if they are well signposted. It is however usually necessary to provide alternate routes of escape should conditions in the incident tunnel become untenable. Section 7.16 of NFPA 502 outlines the emergency egress requirements for road tunnels. These are summarized below:

1. Signage in accordance with NFPA 101, Section 7.10 is required at all emergency exits and cross passageways.

2. Slip resistant walkways are required.

3. Portions of the tunnel that are not involved in an emergency, as well as in emergency exits and cross passageways, must remain tenable.

4. Doors must open in the direction of exit travel for emergency exits; in cross passageways, doors are permitted to open in either direction. The doors must be listed and rated for 1-hour of fire-resistance. The maximum door opening force cannot exceed 50 pounds.

5. Travel distance to an emergency exit is required to be less than or equal to 1,000 feet.

6. Emergency exits must be enclosed in a 2-hour fire-resistive enclosure with not less than Class A interior finish, designed to conform with NFPA 101, Chapter 7.

7. Cross passageways can be used in lieu of emergency exits, provided that the cross passageways are no more than 656 feet apart, the openings at cross passageways are protected by a 1-hour self-closing fire door and that the minimum clear width of 3 feet 6 inches on each side of the cross passageway is provided. The tunnels must be divided by a minimum 2-hour rated separation.

8. If the portal to the tunnel is below grade, surface grade must be accessible by way of a stair, vehicle ramp, or pedestrian ramp (i.e., no walking on the roadway).

The following may be provided to ensure a safe emergency escape route:

- Refuge galleries at intervals of approximately 800 feet with pressurized staircases and refuge isolated from tunnel by fire doors.

- Cross passage access to the adjacent tunnel at approximate intervals of 800 feet.

Due to the complex ground conditions under the river, which would make construction of cross passages difficult, it is likely that a combined emergency and maintenance way, an enclosed concrete chamber located under the roadway slab, would be provided along the full length of each highway tunnel bore. Egress to this place of safety would be through the emergency stairs on one side of the roadway, which passengers would access through fire doors at 200- to 300-foot intervals. Positive pressurization of the emergency and maintenance way would be used to ensure that smoke does not enter. Lobbies at the top of the stairs would also be pressurized to provide a safe place of refuge for the disabled or elderly who could not use the stairs.

3.1.3 Comparison of Options

The Bridge and Tunnel Options provide for the evacuation of highway passengers to a place of safety, and access to shore areas. The Bridge Option has the advantage of more space for egress and emergency access (four lanes plus shoulder compared with two lanes plus shoulder).

In the Tunnel Option, a smoke condition in a confined area would dictate more extensive provisions not required in the Bridge Option. These would include: a ventilation system; management and operating staff; system monitoring and controls to inform operations; continuous specialist staff training and; an extensive maintenance program. The Tunnel Option would represent a greater fire/life safety risk to passengers because of the longer time required to reach a place of safety; potential evacuation through a smoke zone; potential failure of power or detection systems or vent systems and possible controller error; and the long time (60 to 90 minutes) to access the surface.

3.2 Emergency Response

Provision for emergency response would be included in both the Bridge and Tunnel Options. Detailed emergency response plans would be developed in the course of final design and coordinated with the appropriate authorities based upon best practices in the industry. This criterion focuses on the ability of emergency services to access emergency events.

3.2.1 Bridge Option

In the Bridge Option, first responders to minor incidents on the bridge would be maintenance personnel who are permanently stationed at both ends of the bridge. They would be supported by state police and would form a first level of response, able to reach an incident from staging areas that would be permanently located on or adjacent to the bridge with dedicated access ramps. The expected response time would be within the first few minutes of the incident.

Incident sites would be accessed using one of the four shoulders. As the bridge would likely be configured as parallel twin structures, cross-over ramps would also be incorporated at regular intervals on the upper level to provide access between the two traffic directions.

For more significant incidents, second responders that include medical and fire services would access the bridge on the same route as first responders, with response times expected to be in the range of 5 to 10 minutes after notification. For a major incident a second wave of responders would be expected to include the necessary specialist emergency personnel. In this event scenario, traffic on the incident side of the bridge would likely be stopped and diverted to the opposite side of the bridge, which could be converted to two-way traffic flow to maintain reduced Thruway capacity. The incident side of the bridge would be available for all emergency personnel and could also be used for helicopter evacuation from close to the incident site.

3.2.2 Tunnel Option

For minor incidents in the tunnel, first responders would be maintenance personnel. First responders for a fire emergency would include trained medical and fire service personnel. Depending on the severity of the fire and the traffic level in the tunnel, they would typically access the tunnel by entering in the opposite direction to the flow of traffic (assuming the traffic flow was blocked and the traffic in front of the incident had cleared the tunnel). Time for first responders, once notified, would be 10 to 15 minutes. Although special vehicles would be available to access the maintenance way to evacuate injured passengers, the majority of drivers and passengers would have to walk out of the tunnel. The first responders would be local to the area of the tunnel, possibly supplemented by specially trained NYSTA personnel.

The Tunnel Option would likely require supplemental assistance as well. These would be personnel from regional emergency services specially trained to access tunnels in the case of emergency. Their task would be both rescue of passengers and specialized fire fighting techniques. They would be familiar with the tunnel and its systems and would be an addition to existing regional emergency services capabilities. Response times for the supplemental responders would be 30 to 60 minutes, once notified. This increases the complexity of the emergency response. When considering the release of toxic gases, the need for specialized training for supplemental responders becomes a distinction from the emergency response requirements in the Bridge Option.

3.2.3 Comparison of Options

Both the Bridge and Tunnel Options would be designed for adequate emergency response. The Bridge Option would have quicker response times because there are multiple vehicular access routes including highway travel lanes and shoulders. In the tunnel, access in emergencies would take longer as a result of the greater length of the tunnel. Specialized training for all responders would be required for the Tunnel Option.

3.3 Redundancy

Redundancy is a measure of the capacity of the crossing (people and goods) after a major emergency and the time taken to re-establish full capacity. Table 3-1 presents a summary comparison between the Bridge and Tunnel Options for various single events.

Table 3-1

Emergency Event Scenarios

Scenario (Single Event)	Highway Bridge Option	Highway Tunnel Option
Explosion	Potential loss of 50% of highway capacity for up to 1 year	Potential loss of 20% of highway capacity for up to 3 years
Ship collision main spans	No loss of service – impact protection included	Not Applicable
Seismic*	Loss of service for up to 2 months	Loss of service for up to 2 months
Note: *This bridge is most likely to be designated a “critical bridge” which according to AASHTO means it must remain open to all traffic after the design earthquake (500-year return period) and open to all traffic emergency vehicles after a large earthquake (2500- year return period).		

The advantage of the Tunnel Option derives from the fact that there are five tubes compared with two bridge decks, so tunnels not involved in the incident would be available to provide capacity once the emergency situation had been resolved, with the exception of a river flood. The disadvantage of the Tunnel Option, from a redundancy perspective, is that events affecting the tunnel are more difficult to repair and may disrupt capacity for longer periods of time. For the Bridge Option, the loss of capacity in one direction in an emergency can be partially compensated for by converting the other direction into a two-way facility (by using HOT lanes and shoulders). For the Tunnel Option, a similar reconfiguration to make use of available shoulders (with acknowledged reduction in air quality to historical standards), could provide consistent capacity until repairs are effected.

The inherently greater redundancy of the Tunnel Option is balanced by the potentially longer duration of disruption.

3.4 Construction Impacts

This discussion compares the type, scale, and duration of construction activities which are associated with impacts such as restricted access, noise and vibration, traffic disruption, air quality, and construction equipment and personnel.

3.4.1 Bridge Option

In Rockland the existing Thruway between Interchanges 10 and 12 would be widened as part of the bridge option with construction and traffic impacts for 3 to 4 years while Interchanges 10 and 11 are reconfigured. Narrow traffic lanes would be used and the highway configuration altered several times to allow a phased construction of the widened Thruway. Construction impacts would occur along this length of the Thruway during this time. At the Rockland shore, access for construction vehicles and materials would be required for the bridge piers and deck from River Road over a period of 5 to 6 years.

Construction in the river, including foundation construction for the side spans and main piers, would take place over 5 to 6 years.

In Westchester, the existing toll plaza would require some reconfiguration to accommodate the new bridge alignment. Access will be required from the shore area to support bridge foundation work, in a similar fashion to the Rockland shore.

3.4.2 Tunnel Option

In Rockland, the new toll plaza in Rockland for the tunnel option will serve as one of the tunneling sites, and construction, including 24-hour working, will be required there for 7 to 8 years. Once the tunnel is open, work would take place over a time period of about one year to reconfigure the existing Thruway between Interchanges 10 and 12 to a local road. Access would be required at the Rockland Shore from River road to support the work in the river.

In the river, the construction boxes used for construction of the tunnel tubes would also be used as ventilation shafts during operation of the tunnel. One construction box would be close to each shore and would be accessed by a temporary bridge from the shore. Barges could be used to remove the excavated spoil. The river boxes will be used for construction for about 7 to 8 years.

The new portal area in Westchester at Talleyrand swamp will also be used to support tunneling operations and with around the clock construction will take approximately 7 to 8 years to complete. There will also be construction of bridges and roads to link to the existing road network. Between the new portal area and Interchange 9, the existing Thruway will be converted to a local access road once the tunnel is open, taking approximately one more year. Access will also be required at the shore area, most likely via Green Street, to provide a connection the construction shaft in the river.

For the tunnel option, a large volume of spoil would be excavated and would require disposal. While some can be removed from the construction boxes in the river and taken away by barge, approximately half will be removed from the two portal sites and will require to be removed by truck.

3.4.3 Comparison of Options

The Bridge Option would be constructed in a shorter period than the Tunnel Option, 5 to 6 years compared to 7 to 8 years. Construction of the Tunnel Option would be off-line to the Thruway with little effect on traffic, while for the Bridge Option considerable traffic staging and surface reconstruction would be required which would disrupt travelers.

Both the Bridge and Tunnel Option would have typical impacts associated with major construction sites, including noise, air quality impacts, traffic, and general disturbance associated with worksite activities, the arrival, departure and presence of a sizable workforce, and materials deliveries and removals. For the Bridge Option the major construction sites would be the corridor from Interchange 12 to the Hudson River, two construction sites in the river and reconstruction of the toll plaza in Westchester. For the Tunnel Option, major construction sites would be at the Tilcon Quarry/Interchange 12, along each shore line and at Talleyrand Swamp/Interchange 9.

Under the Tunnel Option, the significant volume of material removed (upwards of 500,000 truck trips and 6,000 barge trips) may be exceptionally disruptive to communities experiencing this added truck traffic.

3-8 Engineering Criteria

4 Transportation Criteria

The alternatives analysis process includes several transportation criteria that must be evaluated in comparing the Bridge and Tunnel Options. The relevant criteria for this analysis are as follows:

- Transportation system integration.
- Highway operations.

4.1 Transportation System Integration

The improvements proposed in the Bridge and Tunnel Options would be to an existing network of transportation facilities and services in the region. These improvements are intended to enhance major movements, but would fit into a network that serves a variety of smaller movements as well.

4.1.1 Bridge Option

The Bridge Option builds upon the existing roadway, with some interchange modifications proposed, and all connections maintained. Adding BRT/HOT lanes in the center of the roadway between Interchange 9 and Interchange 14B would require access to the lanes from those interchanges, and access from Interchange 10 does not appear feasible. All other interchanges would have access to the BRT/HOT lanes.

4.1.2 Tunnel Option

Due to the shoreline topography on both sides of the river, the tunnel portals would be east of Interchange 9 and west of Interchange 12. The Tunnel Option would result in a modification to the Interstate system (see Figure 2-2):

- Interchanges 10 and 11 would be eliminated as would 3 miles of the Thruway, which would likely be reclassified as a local arterial.

- Interchanges 9 and 12 would be relocated and reconfigured to accommodate movements around the portals.

The result is a complex arrangement of backtracking ramps at each portal to connect interstate traffic with the shore communities including Nyack, South Nyack, Grandview-on-Hudson, Piermont, and Tarrytown. This would result in an increase in vehicle miles traveled (as vehicles backtracked to the portal then reversed direction to continue to the river crossing) and would have an adverse impact on air quality.

The eastern portal is located close enough to Interchange 8 that there is concern that weaving distances would be inadequate for drivers continuing south on I-87 or east on I-287 after emerging from the portal. This would necessitate signing for Interchange 8 shortly after Interchange 13 to move all drivers for that interchange into the appropriate tube in the tunnel. Similarly, drivers exiting the tunnel that wish to use either Interchange 9 or 12 would need advance signage prior to entering the portal to direct them to the appropriate tube.

BRT/HOT lane access to any of the above interchanges would also be difficult to accommodate. No provision is made for access to or egress from the BRT/HOT lanes from Interchanges 12 to 9. The utility of the HOT lanes for buses, carpoolers and other HOT lane users to and from Nyack and Tarrytown would be diminished. Access to the Tarrytown Station for buses from Rockland and Orange Counties is an essential element in the network. Providing those ramps at the eastern portal would require further widening and additional flyover structure in an environmentally sensitive location.

4.1.3 Comparison of Options

In the Bridge Option all interchanges can be rebuilt in their current locations, BRT/HOT lane access can be provided for Interchanges 9 and 11, access to Interchange 8 can be provided from all lanes and buses can be provided with direct access to Tarrytown Station. In the Tunnel Option, two interchanges would be eliminated and BRT/HOT lane capability is diminished in Tarrytown and Nyack.

4.2 Highway Operations

4.2.1 Bridge Option

NYS Thruway operations would be improved by the Bridge Option as a result of the fourth travel lane in both directions (eliminating the moveable barrier), the introduction of shoulders, and the reduced maintenance requirements.

4.2.2 Tunnel Option

Implementation of the Tunnel Option would have significant effects on Thruway operations:

- **Steep Grades –** A highway tunnel in this location would require longer and steeper grades (3 percent), which could result in lower overall traffic speeds and safety conflicts between passenger vehicles and slower-moving trucks.

- **Reduced Flexibility in Highway Operations –** The tunnel’s design would split the highway lanes into five tubes, forcing additional traffic maneuvers and reducing operating flexibility (e.g., the ability to shift traffic among lanes).

- **Toll Plaza Operations** – The toll plaza would have to be relocated to the western shore in Rockland, with the complexity of separating high speed EZ-Pass traffic from other tunnel traffic beyond the portal, coupled with the complexity of separating Interchange 8 traffic from I-287 traffic at the same location.

4.2.3 Comparison of Options

With respect to Thruway operations, the Bridge Option contains none of the complexity of the Tunnel Option due to toll plaza relocation and traffic separation.

5 Environmental Criteria

Environmental criteria considered for the Bridge or Tunnel Options include potential impacts with respect to the following:

- Land use, property acquisitions and displacements and parklands.
- Visual resources.
- Cultural resources.
- Ecology.
- Air quality and noise.
- Spoils management.

5.1 Land Use, Acquisitions and Parklands

5.1.1 Bridge Option

Rockland

The Rockland bridge approach and the associated reconstruction of Interchanges 10 and 11 would require the acquisition of park property on the south side of the Thruway at Elizabeth Place Park and a small sitting area in a triangle at Broadway opposite Elizabeth Place. However, the reconstruction of Interchange 10 may subsequently allow this park to be expanded and enhanced. The reconstructed interchange would require no other acquisitions or displacements.

Another potential acquisition may be required in the vicinity of Broadway and Ferris Lane, which would occur as a result of the bridge's bike/pedway landing. This would be a sliver of residential property and require no displacements.

The Westchester bridge approach would utilize the existing Thruway ROW and no acquisitions would be required.

5.1.2 Tunnel Option

The Tunnel Option in Rockland requires its portal to be located in the quarry north of Interchange 12, requiring extensive acquisitions of private property for a new toll plaza, realignment of the Thruway, and provision of a ventilation structure. It would also cut through Snake Hill Road to the quarry, requiring its closure or relocation. It would result in the displacement of one or two businesses on Snake Hill Road and may substantially limit operations at the quarry.

The Tunnel Option would also require extensive underground easements from property owners on both sides of the river. The tunnel tube configuration would be approximately 500-feet wide, and would require an easement extending beyond the Thruway's ROW (typically 250 feet).

In Westchester, the tunnel's portal would be located in the Talleyrand Swamp, requiring extensive acquisition of undeveloped (wetlands) private property (see Figure 2-10). This would transform a natural wetlands dominated area into one containing a major highway interchange with subsequent impacts to the adjoining residential neighborhoods. However, the existing bridge toll plaza and approach would be replaced offering opportunities to redevelop these areas between the river and Broadway.

The tunnel portal at the Tilcon quarry in Rockland would preclude the use of Interchanges 10 and 11 for the river crossing, necessitating detours to Interchange 12 (see Figure 2-8). Traffic consequences to South Nyack and Nyack could adversely affect neighborhood character and business operations. On the other hand, the Thruway from Interchange 10 to the river would become redundant and could be reused for a public amenity. A similar issue of detours would occur at Interchange 9 with the tunnel portal east of the existing interchange, necessitating travelers from Tarrytown to first go east in order to go west under the river, altering local traffic patterns.

Construction platforms would be required at the river, north of the existing bridge, on both shores. In Rockland these would most likely be located near the Salisbury apartments, and in Westchester near the Quay and Tarry Landing residential communities, and close to Losee Park and marina. These would also be the likely locations of the large ventilation structures that the river tunnel would require.

5.1.3 Comparison of Options

The Tunnel Option involves large numbers of subsurface property easements and some notable acquisitions in both Rockland and Westchester Counties. In both counties, extensive property acquisitions would be associated with the portal areas, and new interchanges (40 acres in the Talleyrand Swamp and 60 acres in the Tilcon Quarry and surrounding areas including three commercial properties.). In Rockland, the portal and interchange would displace two businesses and limit quarry operations. In Westchester, the portal and interchange would disturb an important wetlands area and would negatively impact adjacent residential communities.

The Bridge Option would involve none of the subsurface easements and much less acquisition. A small sliver of parkland would be required at Elizabeth Place Park, as well from a nearby residential property.

The Tunnel Option requires detours to the new portals for users of existing Interchanges 11, 10 and 9. Such detours have the potential to aggravate conditions on local road networks, particularly in Nyack and South Nyack. On the other hand, the redundant segments of the Thruway, east of Interchange 10 and west of Interchange 9, could be reused for new community amenities.

Construction of the Tunnel Option would involve extensive work from platforms in the river adjacent to each shore, including the removal of spoils. On both shores these activities would be adjacent to residential communities and likely to adversely affect their quality of life during the extended period of construction. The same locations would likely accommodate the permanent ventilation facilities that the tunnel requires (although these may be alternatively located on shore but require additional acquisitions and likely impacts to other residential communities). The construction of the Bridge Option, while also requiring extensive construction in the river, would not be as concentrated at these two shoreline locations.

5.2 Visual Resources

5.2.1 Bridge Option

A replacement bridge immediately north of the existing bridge would be wider than the existing bridge, although this feature would be unlikely to be noticed by most viewers because of the scale of the river here (3-miles wide) and the plane from which they would view the bridge. The deck profile of the bridge would be slightly higher than the existing because of the potential increase in the channel clearance

Viewers north of the existing bridge landings would have the new bridge somewhat closer to their viewpoints. On the Rockland shore this would affect the residents of the Salisbury and Bradford Mews apartments, and on the Westchester shore the Quays and Tarry Landing communities. On the other hand, viewers south of the existing bridge landings in Grand View in Rockland and near Van Wart Avenue in Tarrytown would have the bridge a little further away from them. In Westchester, it would also bring the bridge structure closer to Losee Park and marina; however, the bridge would be almost 0.25 miles away and generate only modest changes of visual scale from the existing structure.

The replacement bridge may have a different design appearance than the existing bridge but such changes will not be finalized until much later in the design process. For example, a new bridge may have cable stays from tall columns, as compared to the existing arched truss form. The primary approach would be to have form follow function. Consequently, little can said of the final bridge form other than it is likely to be the subject of significant design interest and could be a “signature” bridge with the potential to improve its visual quality.

5.2.2 Tunnel Option

The Tunnel Option would involve significant visual changes at the location of the tunnel portals and where the tunnel ventilation structures would be located. Ventilation structures would most likely be at the same locations as the launch box shafts at both shorelines, and additionally near the tunnel portals farther inland.

The Rockland portal would require relocating the Thruway and building a new toll plaza ahead of the portal located in the quarry north of Interchange 12. While this context is non-residential and less visually sensitive, it would involve construction of a major new feature. A required ventilation structure near the portal would likely be visible to nearby residential areas to the east of Route 303. The ventilation structure at the river edge would likely be quite massive and tall (see Figure 2-6), adding a prominent visual feature at the South Nyack shore and likely to be visible from extended distances.

The Westchester portal would be located in the Talleyrand Swamp and its associated roadways and ramps would substantially alter the natural environment of this wetland area. Moreover, a ventilation shaft near the portal would be highly visible to the adjacent residential communities on Sheldon Avenue and Meadow Street. The riverside ventilation tower would be located adjacent to the Tarry Landing and Quay residential communities and introduce a prominent visual feature likely to be visible from extended distances in Tarrytown.

The removal of the bridge would also have major visual impacts, with different impacts for different viewers:

- Loss of a prominent and defining visual landmark, symbolic of connectivity.

- Restoration of a natural appearance to a scenic reach of the river.

- Significant improvement of river views for residents in close proximity to existing bridge landings (however, tunnel's ventilation structures could offset this, depending on its specific location).

- Loss of views to bridge travelers, with over 110,000 trips a day, the bridge permits millions of viewers a year to achieve views of this unique scenic resource.

- Redundant sections of the Thruway east of Interchange 10 and west of Interchange 9 could be reused to enhance the visual quality of adjacent communities.

5.2.3 Comparison of Options

The new tunnel portals would introduce major features, including ventilation structures, interchange ramps and, in Rockland, a new toll plaza. While the context in Rockland at the quarry may not be highly sensitive, the natural wetlands of the Talleyrand Swamp in Westchester are, and these would be drastically altered. Moreover, in both cases the portal ventilation structure would likely be visible to nearby residential communities.

At the shorelines, the Tunnel Option would add major ventilation structures, so that a new intrusive visual feature would replace the bridge for viewers near the existing bridge landings. The scale of these structures would also make them visible for extended distances.

The Bridge Option would bring the structure marginally closer to viewers north of the existing bridge and marginally farther from viewers south of the bridge. Changes of scale of the bridge structure (i.e., wider deck, taller profile of the causeway), would be likely to generate only minor changes to viewers' perception of the bridge structure, while major potential changes to the design form are likely to occur, however they are not available to assess at this time.

Removal of the bridge in favor of a tunnel would eliminate the visual experience of the river crossing and its excellent landscape quality for millions of travelers each year. On the other hand, removal of the bridge would substantially restore the natural views of the Tappan Zee, with the exception of the new ventilation towers that would mark the path of the tunnel at each shoreline. Removal of the bridge would also potentially free the Thruway segments east of Interchange 10 and west of Interchange 9 for more visually pleasing reuse.

5.3 Cultural Resources

The analysis presented here is focused on direct impacts of the Bridge and Tunnel Options to historic architectural resources. Direct impacts are those that entail taking property or those that result in other direct effects such as vibration. With regard to potential archaeological resources, the analysis addresses direct impacts to known sites; however, other potentially eligible sites may be impacted but these will need to be identified as part of a Phase 1B program to investigate archaeologically sensitive areas. Archaeological sites are identified herein by site number: four digit designations refer to New York State Museum sites; alphanumeric designations refer to State Historic Preservation Office sites.

5.3.1 Bridge Option

5.3.1.1 Rockland County

The Bridge Option may directly impact the following recommended National Register-eligible architectural resources (Figure 5-1):

- Tappan Zee Bridge.
- 321 S. Broadway (South Nyack).
- River Road Historic District (Grand View-on-Hudson).

The Bridge Option landing at the Hudson River shore in Rockland County may directly impact three previously identified, but unevaluated archaeological sites:

- NYSM 6402.
- NYSM 4643.
- NYSHPO A08745000003

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5.3.1.2 Westchester County

The Bridge Option would directly impact the National Register-eligible Tappan Zee Bridge. In addition, the Bridge Option landing at the Hudson River shore in Westchester County may directly impact four previously identified, but unevaluated archaeological sites (Figure 5-2):

- NYSM 5234.
- NYSM 6870.
- NYSM 4639.
- NYSM 5186.

5.3.2 Tunnel Option

5.3.2.1 Rockland County

The Tunnel Option would directly impact the Tappan Zee Bridge and may directly impact historic architectural resources in Rockland County (Figure 5-1):

- 118 North Greenbush Road (Clarkstown).
- 108 North Greenbush Road (Clarkstown).

It should be noted that to date, no survey has been conducted at the Tilcon Quarry in the vicinity of the proposed tunnel portal and ventilation structure. If undertaken, such a survey may result in the identification of other recommended National Register-eligible resources.

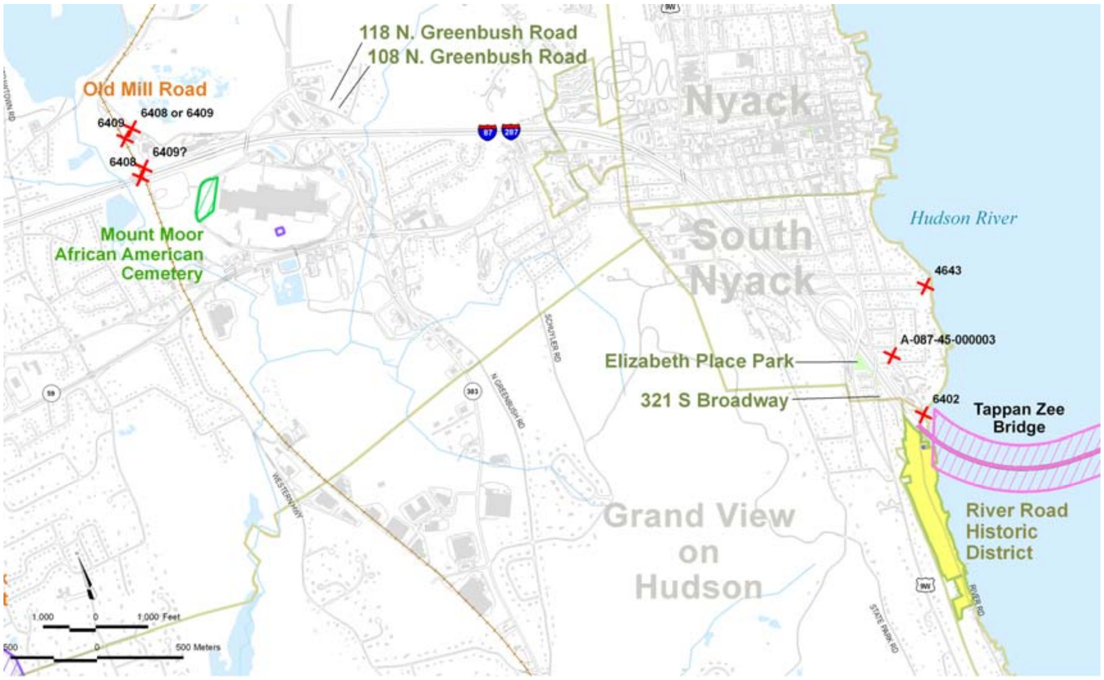

Figure 5-1 Cultural Resources – Rockland

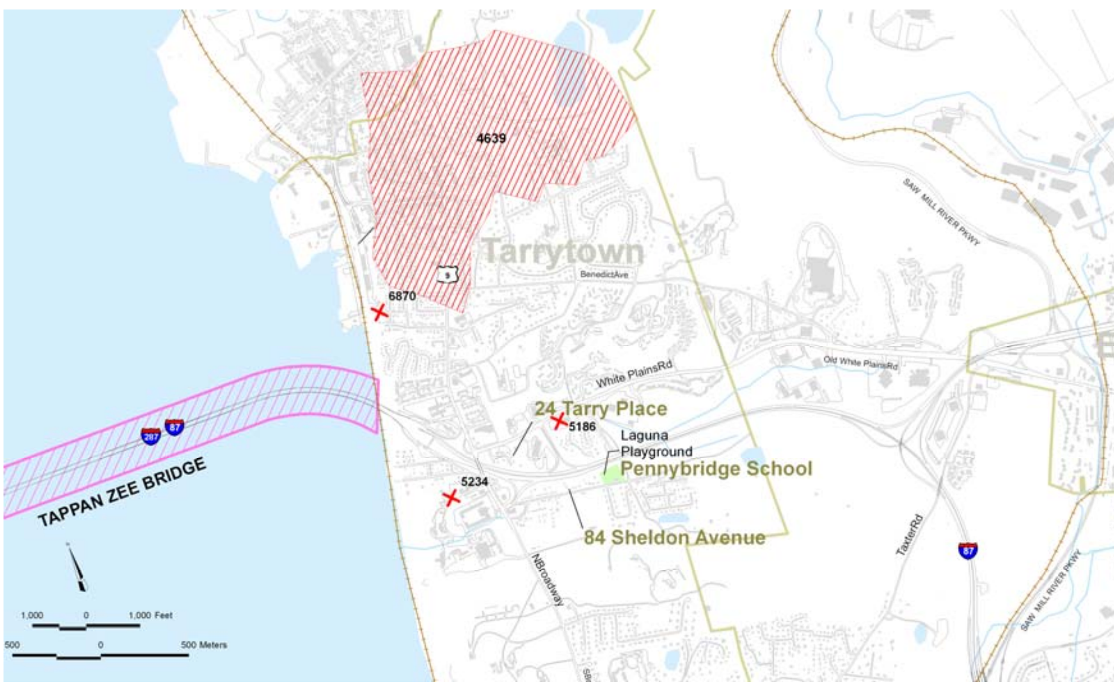

Figure 5-2 Cultural Resources – Westchester

The Tunnel Option may impact multiple archaeological resources in Rockland County. Direct impacts to previously identified sites and potential sites may occur as a result of construction activities and/or construction staging area activities associated with the option. The proposed tunnel portal, ventilation structures, relocated toll plaza and relocation of the I-287 main line may directly impact the following previously identified, but unevaluated archaeological sites:

- NYSM 6408 (two locations).
- NYSM 6409 (two locations).

In addition, the Tunnel Option proposed ventilation structures on the Hudson River shore in Rockland County may directly impact the following previously identified, but unevaluated archaeological sites:

- NYSM 6402.
- NYSM 4643.
- NYSHPO A08745000003.

5.3.2.2 Westchester County

The Tunnel Option may directly impact historic architectural resources in Westchester County (Figure 5-2):

- Pennybridge School.
- 84 Sheldon Avenue.
- Tappan Zee Bridge.
- 27 Tarry Place.

Direct impacts to previously identified and potential archaeological sites may occur as a result of construction activities and/or construction staging activities associated with the Tunnel Option. The activities include construction of the tunnel portal, ventilation structures, and ramp system necessary to connect with the existing I-287 main line. There are no previously identified archaeological sites in the Talleyrand Swamp area, where the proposed tunnel portal and ventilation structures would be located.

The tunnel option ventilation structures on the Hudson River shore in Westchester County may directly impact the following previously identified, but unevaluated archaeological sites:

- NYSM 5234.
- NYSM 6870.
- NYSM 4639.
- NYSM 5186.

5.3.3 Comparison of Options

The Bridge and Tunnel options would both have impacts to cultural resources. The National Register-eligible Tappan Zee Bridge may be directly impacted by the Bridge Option, and will be directly impacted by the Tunnel Option. In addition, while the Tunnel Option would impact six architectural resources, the Bridge Option would impact three architectural resources. In neither case would it be necessary to displace the structures. Both options may have impacts to archaeological resources but the magnitude of these impacts would have to be established by future surveys.

5.4 Ecology

5.4.1 Bridge Option

Construction of a bridge would involve considerable activity in the Hudson River. The principal phase of the work that would impact the river's ecological resources is construction of new bridge foundations. Depending on the nature of the bridge footings (piles, caissons, etc.) it can be expected that construction activity would resuspend river sediments causing local impairment to river water quality. It is also likely that some dredging would be needed to enable access to sections of the bridge structure situated in shallow water. Finally, approximately 4 acres of temporary work platforms would be erected in the river to support construction work.

In its completed condition the bridge piers would encompass about 5 acres of river bottom. The piers or footings would be distributed across the entire width of the river including shallow and deep areas. Once the new bridge opens it is likely that the existing structure would be demolished. However, demolition would occur under both the Bridge and Tunnel Options.

5.4.2 Tunnel Option

Several features of the Tunnel Option may impact ecological resources in the project vicinity. These include construction work in the Hudson River, construction work in wetlands, and ventilation structures placed along the river shoreline.

With regard to construction work in the river, a TBM launch box would be temporarily located along the Rockland County shoreline. Associated with the launch box would be several work platforms and supporting facilities for spoil handling and equipment and material storage. It is estimated that about 7.5 acres of river bottom would be covered by the temporary work platforms. Since the work area along the Rockland shore is in shallow water, it is likely that some dredging would be needed to provide access to the construction site from the river. On the Westchester side of the river, the temporary work area would also encompass approximately 7.5 acres of river bottom. The TBM would be recovered on this side of the River at the conclusion of tunnel boring operations. The shallow shoreline zones of the river are considered important juvenile fish habitat because fish typically seek such areas for protection and for food resources.

The principal wetland that would be impacted by construction of a vehicular tunnel is the 55-acre Talleyrand Swamp (Figure 2-10). Talleyrand Swamp has been determined by the New York State Department of Environmental Conservation (NYSDEC) to be one of the three largest marsh areas in Westchester, a circumstance that provides significant regulatory protection to the resource. The construction of the Westchester tunnel portal, and associated highway and highway ramps, would eliminate much of the marsh and fragment the remainder. It is not likely that approval for such extensive work in the wetland, from either the Army Corps of Engineers or the NYSDEC would be obtained.

Options for siting ventilation structures associated with the vehicular tunnel include locations along the Rockland and Westchester County shorelines. The footprint of each ventilation structure (one per tunnel) is estimated to be 20,000 square feet. Associated with each structure would be a jetty or pier that would provide access to the ventilation structure for maintenance and egress from the structure. The total footprint of the permanent structures associated with the ventilation facilities in the river would be approximately 1 to 2 acres of river bottom.

5.4.3 Comparison of Options

The Tunnel Option is estimated to permanently impact 42 acres of wetland and river habitat including most of Talleyrand Swamp as compared to 5 acres for the Bridge Option. For both the Bridge and Tunnel Options the loss of aquatic habitat would be offset by the removal of the approximate 4 acres of encompassed by existing bridge pier foundations. During construction the Tunnel Option would impact 15 acres of river habitat while the Bridge Option would impact 5 acres. Table 5-1 summarizes the impacts of the Bridge and Tunnel Options on ecological resources.

Table 5-1

Affected Wetlands/Waters

Source of Impact	Bridge Option (Acres)	Tunnel Option (Acres)	Comments
Bridge Piers, etc.	5	-	Permanent
Ventilation along River Shoreline	-	2	Permanent
Wetlands in Westchester	-	40	Permanent
Total Permanent	5	42	Permanent
Work Platforms	4	15	Temporary
Total Temporary	4	15	Temporary

5.5 Noise and Air Quality

5.5.1 Bridge Option

For the Bridge Option, highway operations and associated noise emissions would be similar to the current conditions. Initial baseline studies indicate residences adjacent to the highway experience noise levels that exceed noise abatement criteria. The estimated increase in community noise levels under the Bridge Option would depend on the projected traffic volumes, details of the new roadway geometry and the extent of mitigation, such as noise walls, installed to abate ambient noise levels.

The air quality impacts are related to the total vehicular emissions and concentration of air pollutants at specific locations. With regard to emissions, the bridge option will have emissions comparable to those of the future no-build alternative; however the precise change will depend on total vehicular traffic and on levels of service along the corridor. With regard to localized air quality impacts, estimates are not yet available, but it is expected that ambient air quality standards will not be exceeded.

5.5.2 Tunnel Option

For the Tunnel Option noise levels between Interchanges 9 and 12 would be significantly less due to the reduction in surface traffic moving between these interchanges. However there would be increase in noise levels at the tunnel portal interchanges and other locations where traffic would increase due to diversions. The impacts would be expected to be greater in Westchester because of the proximity of residences to the portal. Additionally some increase in noise levels would be expected at each ventilation site.

For the Tunnel Option air emissions would be expected to exceed those of the Bridge Options due to the increase in vehicle miles traveled by vehicles accessing Interchanges 9 to 12. Also emissions from the tunnel would be concentrated at the ventilation structures located at each portal and at the shorelines. Air emissions would also increase in those areas where traffic would be diverted. Finally, there would be air emission increases during the construction period related to the movement of excavated materials by 500,000 truck trips and 6,000 barge trips.

The ventilation structures, however, could be fitted with air pollution controls systems that would reduce emissions entering the ambient environment. Thus for those pollutants that could be captured by an air pollution control system, emissions would be reduced. For those pollutants that could not be captured by air pollution control systems, ventilation structures would be point sources of pollution requiring construction of tall stacks for pollution dispersion.

5.5.3 Comparison of Options

With regard to noise levels, under the Tunnel Option noise levels would be reduced compared to the Bridge Option between Interchanges 9 and 12. However noise levels at residences adjacent to the Westchester portal would increase due to the new complex interchange. For the Bridge Option it is anticipated that noise mitigation would be required such as noise walls.

For both the Bridge and Tunnel Options the resulting air emissions would not contravene federal and state ambient air quality standards. The Tunnel Option could reduce total pollutants with the inclusion of pollution control systems. However, air emissions would increase related to the removal of excavated materials through 500,000 truck trips and 6,000 barge trips.

5.6 Spoils Management

5.6.1 Bridge Option

Construction of the new bridge will require the removal of river sediment at those locations where bridge foundations will be placed. It is estimated that approximately 300,000 cubic yards of river sediment would need to transported and disposed at an approved site. Some fraction of this material will be moderately contaminated. In addition the existing bridge would be demolished and the demotion debris would recycled or be disposed in a licensed landfill

5.6.2 Tunnel Option

The Tunnel Option would require the removal and disposal of approximately 10,000,000 cubic yards of rock and uncontaminated river soils. Management of this quantity of material would entail a significant logistics operation involving barges, trucks and earth moving equipment.

5.6.3 Comparison of Options

The Tunnel Option would require handling and disposal of approximately 30 times more material than the Bridge Option resulting in a more extensive material management system.

6 Cost Criteria

The scope of the cost estimates extends between Interchange 8 in Westchester and Interchange 12 in Rockland, and includes the following segments:

- **Bridge Option**:
  - Alterations to Interchange 9 in Westchester, and highway widening in Rockland up to Interchange 12, to accommodate BRT/HOT lanes and the new bridge alignment close to the shore.
  - The bridge itself.
- **Tunnel Option**:
  - Construction of the tunnel portal between Interchanges 8 and 9 in Westchester, including ramps to allow backtracking to Interchange 9.
  - The tunnel bores.
  - Construction of the tunnel portal and new toll plaza near Interchange 12 in Rockland, and reconfiguration of the Thruway between Interchanges 10 and 12 to carry the lower traffic volumes.
  - The waterfront to Interchange 9 in Westchester.

6.1 Basis of Estimate

Construction cost estimates for the Bridge and Tunnel Options were based on unit costs for construction as shown on concept engineering drawings, soft costs, and contingencies, using available ROW, aerial mapping, and historical geotechnical investigation data. The estimates were built-up from approximately 200 individual cost items and were done in 2004 dollars. Unit costs were either calculated from analysis of material costs, crew costs and productivity, and equipment costs, or from bid prices or cost estimates available for similar projects in the region. These unit costs reflect the direct cost of the work plus:

- General contract conditions.
- Contractor overhead.
- Contractor profit.
- Contractor performance bond.
- Allowance for design changes, changes in scope, additional work orders, etc.

The estimates do not include allowance for:

- ROW acquisition.
- Insurance and financing.

- Third party mitigation.
- Hazardous material handling.
- Extraordinary utility relocation costs.
- Signature bridge main spans.
- Agency force accounts.
- System upgrades.

Soft costs have been set by project team consensus at 45 percent of the direct construction costs, and include:

- Program management cost.
- Design fees.
- Construction management cost.
- Direct agency costs.

Industry practice is to apply a contingency of 30 percent to conceptual cost estimates on bridge projects. This value has been adopted for all bridge-related work in both options. It has also been adopted for work items common to both options, including systems, ventilation and temporary works.

Recent tunneling projects in the region have used a 40 percent contingency. This reflects the common industry experience that tunneling projects entail greater risk than bridge projects. This value has been adopted for all direct tunneling-related work. As a significant number of engineering parameters would only become known during tunnel construction, there is risk that a longer construction period may be required.

6.2 Cost Estimate

The detailed cost estimates (in 2004 dollars) result in the highway tunnel crossing ($10 billion to $12.7 billion) costing up to two and a half times the cost of a new bridge crossing ($3.8 billion to 4.8 billion). Details of the cost estimates for the various components are shown in Table 6-1.

Table 6-1

Cost Estimates for Highway Bridge and Tunnel Options (Year 2004 dollars)

Project Segment	Highway Tunnel Option	Highway Bridge Option
Tunnel	$8.5 to 10.8 billion	
Bridge		$3.1 to 3.9 billion
Tunnel portal and connection to Interchange 8 and 9	$170 to 220 million	
Tarrytown toll plaza and Interchange 9		$50 to 70 million
Tunnel portal and Toll plaza Interchange 12	$340 to 430 million	
Reconfiguration of Rockland Interchange 11 and 10	$90 to 110 million	
Thruway reconstruction Interchange 12 to Interchange 10		$510 to 650 million
Construction shafts in river (two, 500 feet by 100 feet)	$370 to 470 million	
Operational Systems and Commissioning	$90 to 110 million	$20 to 25 million
Ventilation (four buildings, five tunnels each)	$340 to 430 million	
Bridge demolition	$120 to 150 million	$120 to 150 million
Total:	$10.0 to 12.7 billion	$3.8 to 4.8 billion

7 Conclusions

The Bridge Option could take 5 to 6 years to construct at a cost in the range $3.8 to 4.8 billion. During construction, the Bridge Option would result in traffic disruptions along the Rockland corridor between Interchanges 12 and the river and in Tarrytown at the toll plaza. The bridge would have minor property acquisitions, modest ecological impacts, and would be less costly to maintain and operate.

The Tunnel Option could take 7 to 8 years to construct at a cost in the range $10 to 12.7 billion. During off-line construction of the tunnel, traffic would be maintained on the Thruway. Significant construction impacts would occur at the Talleyrand Swamp and along each shore line where major ventilation structures would be sited. In the permanent condition, major acquisitions would be required at each portal, Interchanges 9, 10 and 11 would be removed from the I-287 interstate system, and transportation system connectivity would be impaired. The ventilation structures would be visually intrusive but could control some vehicle emissions.

Other notable differentiating factors include:

- Disposal of 10,000,000 cubic yards of spoil for the Tunnel Option compared to 300,000 cubic yards for the Bridge Option.
- Complex traffic movements at the portal interchanges for the Tunnel Option.
- The tunnel's design would split the highway lanes into five tubes, forcing additional traffic maneuvers and reducing operating flexibility (e.g., the ability to shift traffic among lanes).
- Long steep grades (3 miles at 3 percent) in the Tunnel Option could impact traffic operations, particularly for trucks.
- Quicker response times for emergencies for the Bridge Option.
- Longer evacuation times in a non-familiar environment in the Tunnel Option.
- Specialized training for all responders would be required for the Tunnel Option.
- Longer duration of disruption and greater cost of restoration of service after an incident in the Tunnel Option.
- Relocation of the toll plaza to Rockland in the Tunnel Option.
- No provision for pedestrian and bike access in the Tunnel Option.

On balance, given the factors presented above, the Bridge Option would provide the more cost-effective highway improvement that meets the study goals and objectives. The visual impacts of massive ventilation structures at the shoreline, the extensive property acquisition for tunnel portals including a major portion of Talleyrand Swamp, the degraded highway performance due to steep tunnel grades and loss of interchange connectivity, and the substantial construction costs lead to the conclusion that the Tunnel Option should not be carried forward into the DEIS.