7 Level 2 Screening Results - River Crossing Scenarios

This chapter presents the results of the river crossing studies conducted as part of the Level 2 screening process. The 15 crossing scenarios were grouped into four common crossing options:

- Preservation Option.
- Rehabilitation Option.
- Replacement Bridge Option.
- New Highway and/or CRT Tunnel Option.

Of these four crossing options, only the Preservation Option was assumed at the outset to be progressed into the DEIS stage, as it would be an integral part of the No Build Alternative required under NEPA and SEQRA. Study of the Preservation Option, therefore, included baseline conditions for comparison to the other options. Assessment of the Rehabilitation Option built on the results of the preservation study to determine the retrofit requirements and cost to bring the bridge up to current design standards. Assessment of the new crossing options, Replacement Bridge or New Tunnel, was comparative to determine a preference.

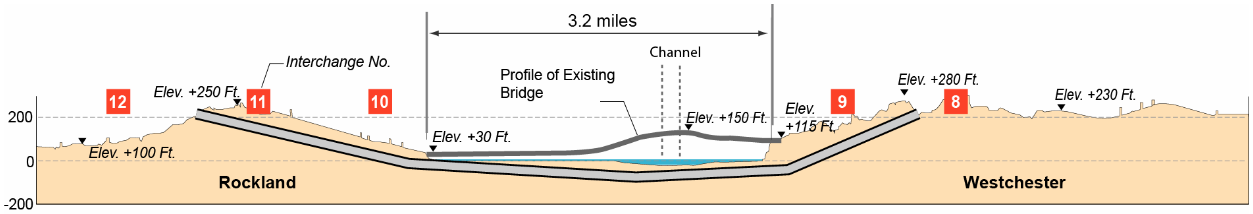
7.1 Crossing Constraints

Level 1 Screening concluded that, due largely to the presence of the existing I-287 Corridor and the surrounding development, any new crossing of the river should be in the proximity of the existing crossing. Following is a summary of physical and other constraints that affect the location and design of the crossing:

- The crossing site is a glacial river valley. On the west (Rockland) side, both bedrock and the overlying topography slope rapidly upward away from the river. On the east (Westchester) side there is a cliff formation with overlying topology that continues to rise away from the river. The high elevations and sustained grades on both sides of the river imply long approaches to tunnel options (Figure 7-1).

- 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 and downstream river flow and carried upstream by tidal action. Bridge foundations can reach the competent rock on the eastern half if necessary, but piers will have to be founded in the poor soils in the western half, making settlement and seismic forces a significant concern.

- Review of historical geological data received from NYSTA, Metro-North, and NYSDOT confirms the general knowledge of the corridor’s geology in the approaches to the river, with competent rock at generally shallow depth.



Topography Along Existing Corridor

Figure 7-1

- 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 in the river will tend to amplify the ground shaking in a seismic event. A site-specific 500-year design earthquake is considered likely to occur within the service lifetime of the bridge.

- Tidal range is not significant, but the existing Hudson Line and Tarrytown Station area elevations are below the 50-year flood level.

- The main spans of the existing bridge are located over the natural channel for the river. Initial discussions with the Coast Guard indicate potential demand for an increase in the required clearance over the channel. For the purpose of Level 2 screening, the clearance has been increased from 134 feet to 150 feet over a 600-foot-wide channel. Further assessment of the clearance and channel width is required during the DEIS.

- Limited historical geological data is available for the Westchester and Rockland shore areas. These are key areas 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).

- A tributary of the Hudson River formerly occupied the area of the present Tarrytown Station and the proposed Ferry Landing development site on the Westchester shore. Geotechnical information indicates soft soils extend 120 feet below existing ground, with potential implications for construction methodology.

- Records indicate that fill placed in the area along the Hudson Line included uncontrolled spoil from the construction of Grand Central Terminal and could consist of large boulders. This condition would impact the design of a tunnel.

- The line of jurisdiction of the Port Authority of New York and New Jersey (PANYNJ) is just to the south of the existing bridge crossing, approximately perpendicular to the river.

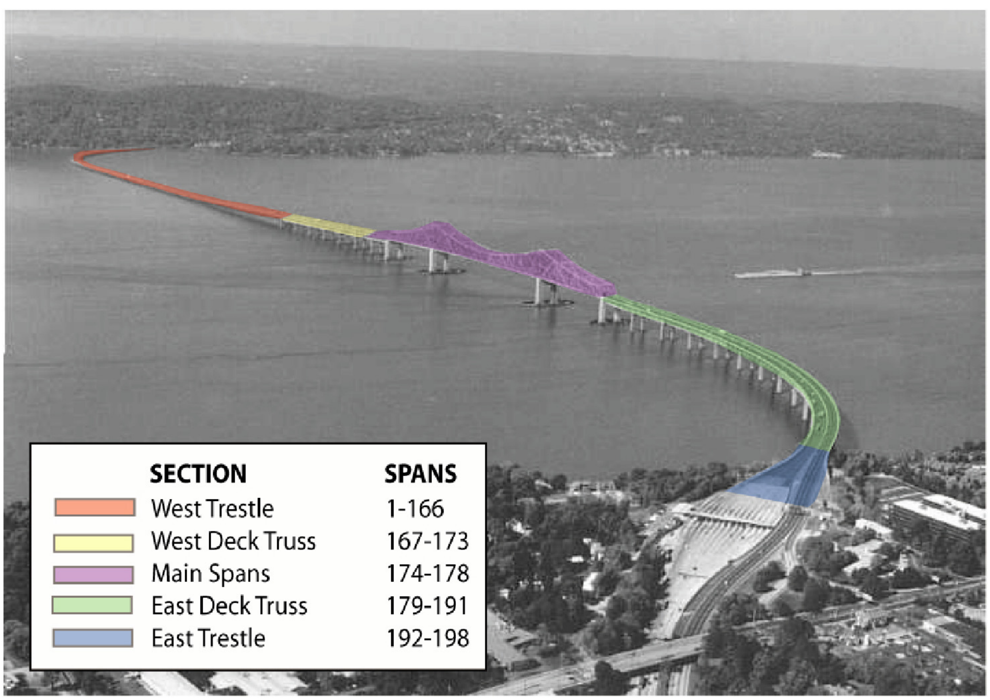
7.2 Preservation of the Existing Tappan Zee Bridge

Preservation of the existing bridge is included in Scenario H1; for this study, preservation was considered to be continuation of the ongoing maintenance measures to keep the bridge in a safe condition without changing its functional and capacity limitations. The preservation study was intended as a baseline comparison for the other crossing options, and included physical inspection to determine existing condition of the structure, review of historic documentation and deterioration, and analysis of structural and traffic capacity.

The applicable screening criteria used included structural integrity, vulnerability, and traffic operations. Overall the bridge was found to be safe for general traffic loading, but it has major vulnerabilities, mounting maintenance requirements, and undesirable traffic conditions.

7.2.1 Structural Integrity

This criterion is a measure of how much a scenario brings the river crossing into compliance with current structural standards. However, as preservation is intended as a no-change option, the evaluation reported here involves primarily the existing levels of non-compliance and the condition of the existing bridge. The 16,600-foot-long bridge is comprised of 198 spans that are divided into five distinct structural segments (Figure 7-2).



Existing Tappan Zee Bridge

Figure 7-2

7.2.1.1 Tappan Zee Bridge Condition

As part of the alternatives analysis, a standard biennial inspection of the bridge was conducted in 2002 and 2004. To supplement the standard inspection, a 100 percent "hands-on" in-depth inspection was conducted in 2002. The in-depth inspection also included an extensive testing program on key concrete and steel components and a full radar survey of the entire concrete deck. Inspectors recorded and sketched all deterioration/defects present on all structural and non-structural components, or members, of the bridge and allocated individual ratings.

The overall bridge condition rating resulting from these inspections was 4 on a NYSDOT scale of 1-9, indicating that the bridge was safe for traffic but that repairs were required (Table 7-1). Typically, a rating of at least 5 would be expected for a bridge in good condition, and a rating of 3 or below would indicate that deterioration was affecting the structural functioning of the bridge and would be unacceptable. The 4 rating matched the lowest inspection rating for the bridge since the formalized inspection program commenced in 1979, and was a reduction from a rating of 5 in the 2000 inspection. Compared to the historical condition ratings of other long-span bridges in the New York area, however, a rating of 4 ranks among the highest.

Table 7-1

NYSDOT Condition Inspection Rating

1	Totally deteriorated or in a failed condition
2	Used as a shade between ratings 1 and 3.
3	Serious deterioration or not functioning as originally designed.
4	Used as a shade between ratings 3 and 5.
5	Minor deterioration but functioning as originally designed.
6	Used as a shade between ratings 5 and 7.
7	New condition. No deterioration
8	Not applicable.
9	Condition and/or existence unknown

Historically, the condition rating for the Tappan Zee Bridge dropped from 5 to 4 only once (in the late 1980s), resulting in increased expenditure by the NYSTA in a series of repair contracts through the 1990s. Repairs included a series of steelwork and substructure concrete refurbishment contracts, a series of planned and emergency contracts to install a new deck on the east deck truss, and removal and replacement of the asphalt overlay and waterproofing for the remainder of the bridge deck. The result was a return to a 5 rating in the mid 1990s. Further expenditure in the late 1990s maintained the bridge at a 5 rating. Since the 1980s, the expenditure to maintain the bridge at a 5 rating has continually increased.

The reduction in the inspection rating to 4, as part of the 2002 inspection conducted for this study, signals the commencement of another series of repair contracts to regain the 5 rating. Cost for repairing members found to warrant immediate action was estimated at up to $40 million at 2003 prices.

7.2.1.2 Structural Capacity (Traffic Loads)

As stated on the original drawings, the Tappan Zee Bridge was designed in accordance with the AASHTO *Standard Specifications for Highway Bridges* (AASHTO, 1949) for loads and stress limits, and in accordance with the requirements of New York State Public Works Specification, 1951 edition, for materials. These specifications have since been updated to incorporate changes in the loads to be resisted (traffic, wind, seismic, etc.), material capacities, design methodologies, and new durability and integrity requirements. Analysis for this study shows that not all components of the bridge have the structural capacity required to carry the current AASHTO design loads with the corresponding safety factors used in the updated specifications.

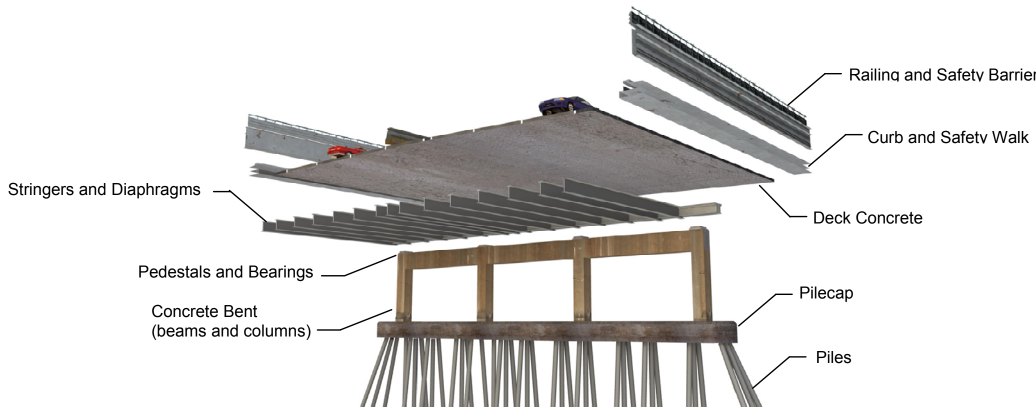
Nonetheless, the bridge is considered to be safe under the new larger design live loading because reduced factors of safety are permitted under the provisions of the AASHTO *Manual for Assessment of Existing Structures*. The adoption of these reduced safety factors to operating levels is common for older bridges. Adopting lower safety factors provides a rational basis for keeping bridges in service that were designed under older code provisions. Doing so assumes regular inspection and acknowledges the likelihood of a reduced lifespan for the affected components. Approximately 1,600 of the 38,000 members on the Tappan Zee Bridge were found to warrant a lower factor of safety. These were predominantly near the deck surface and their low capacity is a result of the local effect of the heavier design wheel loads. Components with reduced factors of safety include the concrete deck, supporting stringers, and some of the steel members in the floorbeams and trusses of the east and west deck truss spans.

The original design live load for the bridge was the HS20 loading, which is a 36-ton, three-axle semi-trailer. New York State now requires new bridges and the superstructures of rehabilitated bridges to be designed for the HS25 loading, a 45-ton vehicle with the same configuration. Therefore, all structural analysis and evaluation for this study used the HS25 loading. Typically, on major truck routes of this nature, a significant proportion of trucks would be expected to weigh more than the legal limit. Therefore, a high rate of deterioration of the concrete deck on the bridge is to be expected.

Analysis also indicated that only 8 of the approximate 38,000 members on the bridge had safety factors below acceptable levels when considering HS25 loading. This was a result of local deterioration since the previous bridge inspection. These members were subsequently repaired by NYSTA Thruway maintenance staff.

7.2.1.3 Component Lifespan

Though the present condition of the bridge is adequate for continued use, the rate of deterioration and continual increase in expenditure point toward the end of the useful service life for the bridge as originally constructed. The implications for components of the bridge (Figure 7-3) are described below:



Bridge Components

Figure 7-3

- **Concrete Deck** – Investigation and inspection of the concrete deck indicated widespread severe deterioration and overall poor condition caused by chlorides in the marine environment and road salts, aggravated by the high volume of truck traffic. The current rate of deterioration of the deck is in places undesirably high, with the extent of deterioration increasing significantly between biennial inspections (as shown for 1984-2002). This deterioration has resulted in more than 45 recent punch-through failures (potholes) of the deck in the last few years. Approximately 1,000 areas of potential future failure were identified during the course of this study.

  Forty-four of 45 deck failures have occurred in the outer two traffic lanes (in either direction) and are directly attributable to truck loading. As the deck continues to deteriorate, trucks will continue to cause punch through failures at an ever-increasing rate. The original deck has reached the end of its useful life. It is estimated that approximately 60 percent of the deck area needs to be replaced soon (13 percent of the deck area has already been replaced), prompting the NYSTA to develop a plan for replacing the remaining sections of the original deck over the next few years.

- **Safety Walks** – The safety walk is an area on the edge of the bridge in each direction that contains the safety fence, traffic barriers, fascia beams, drainage outlets, and a narrow 1.5-foot-wide safety area. Though the structure and components in this area do not directly support the traffic lanes, they are vital to the safe functioning of the bridge since they provide containment for errant drivers. Because of the accumulation of road salts, the condition of the structure in these areas was rated less than 4 throughout much of the length of the bridge, indicating that the safety walk was no longer functioning as designed.

  Though the bridge maintenance staff regularly cleans these areas of the deck, they were considered beyond their useful lifespan, with replacement and reconfiguration required soon. Full replacement of the safety walks on the causeway spans was considered a high priority. Analysis of the source of deterioration for the 2,600 locations on the bridge recorded as “conditions requiring attention” shows the majority (83 percent) were attributable to leakage through the open drains in the safety walk areas.

- **Deck Joints** – The original design of the Tappan Zee Bridge incorporated 198 spans with a transverse deck joint across the full width of the bridge at each support pier. Due to the volume of truck traffic and deterioration of the adjacent decks, these joints have been repaired or replaced a number of times, particularly on the west trestle spans. A major rehabilitation of the west trestle joints completed in recent years reduced the number of joints in those spans by half. Continued repair of the deck joints will be necessary, since a joint lifespan as low as ten years is evident from past repair records.

- **Stringers** – Stringers are the steel beams that directly support the concrete deck along the entire bridge length. In general, stringers were in good condition but with notable exceptions near current or eliminated deck joints and along both edges of the bridge under and adjacent to the safety walkways. In these regions, leakage of water and road salts, particularly in non-accessible areas, has resulted in severe corrosion of the steel. The open drainage from the deck provides unrestricted outfall on to the steel below the deck, resulting in high rates of corrosion. This open drainage feature would not conform to current bridge design standards and is considered a liability to preservation of the bridge.

- **Superstructure Steelwork** – This is the main steelwork that supports the deck stringers and transfer load to the piers in the deck truss and main span segments of the bridge. Overall, the superstructure steelwork was found to be in good condition, particularly the steel in the main spans above the roadway. Nevertheless, extensive steel section loss was recorded on many members, with some previous repairs and replacement evident. Section loss varied up to 30 percent of the member cross sectional areas; however, repair was recommended in only a few locations where the loss of section was severe enough to have reduced the factor of safety to below acceptable values.

- **Substructure** –The substructure is that part of the bridge below the top of the bearings. Since 1995, major repairs have been made to the concrete and steel piers supporting the various bridge segments. These repairs were completed by the time of the 2002 inspection. Overall, condition ratings were good, but renewed deterioration was found to be extensive, with 190 outer columns in the causeway spans found to have major cracking. The presence and rapid appearance of these cracks since the repairs were completed was a concern. Additional testing determined that the source of the cracking was chloride contamination, most likely from road salt already present in the concrete. Though the previous repairs had replaced the spalled or non-sound concrete in patches, the source of contamination remained and was exacerbated by the continual leakage through deck joints and edge drainage. Renewed repair of the concrete piers in the causeway was anticipated in the near future. Similar but less extensive cracking was found in the concrete columns supporting the deck trusses.

- **Foundations** – Inspection of the foundations found no major deterioration beyond minor spalling of pilecaps. Underwater inspection found no evidence of deterioration of the visible timber piles supporting the causeway. Tests on representative pilecap concrete did not indicate the presence of chlorides and consequently no major condition repair of the foundations was anticipated. Ongoing monitoring confirmed the absence of marine borers in the timber piles.

7.2.2 Vulnerability

7.2.2.1 Vulnerability Assessment

Vulnerability assessments were conducted for various bridge segments in accordance with the NYSDOT and Thruway Authority vulnerability manuals. These manuals represent a compendium of bridge experience and were designed to allow comparison of a large number of bridges to result in a prioritization of risks. The manuals did not consider mitigation but only the presence of particular physical or design features that are prone to failure.

Table 7-2

NYSDOT Vulnerability Rating

Rating	Description
1	Safety Priority
2	Safety Program
3	Capital Program
4	Inspection Program
5	No Action
6	Not Applicable

Results were determined on the 1 to 6 rating scale shown in Table 7-2, with the lower values indicating the greater vulnerability. A vulnerability rating of 4 would be considered normal for the Tappan Zee Bridge. Seven specific vulnerabilities were considered: vessel and vehicle collision; overload; seismic; concrete details; steel details; and hydraulics.

Results of the assessment implied that the bridge has significant vulnerabilities. With the exception of hydraulics, all vulnerabilities were rated 3 or less for some segment, implying that the bridge was vulnerable to local or major collapse from a number of different causes. The vulnerability scores were:

- Overload and steel details – rated 1.
- Vessel collision, vehicle collision, and seismic – rated 2.
- Concrete details – rated 3.
- Hydraulics – rated 4.

Key results with an initial indication of the scale of potential retrofits were:

- There was high overload vulnerability as a result of the low structural capacity of some stringers. Mitigation would require greater control of traffic weight or replacement of some stringers.

- There was high concrete and steel details vulnerability due to lack of redundancy in many individual bridge members, metal fatigue (particularly at flange plate details in the west trestle stringers), and historical severe deterioration on steel and concrete members, particularly from open drains and joints.

- There was high vulnerability from vessel impact because of the low capacity of the pier protection around some piers and the presence of low superstructure elements. Mitigation would require enhanced pier protection around some piers.

- The presence of steel elements close to traffic above the highway resulted in a high vulnerability to traffic accidents for the main spans. Mitigation would require enhanced protection measures.

- There was high seismic vulnerability. The vulnerability rating recognized that performance of the bridge did not match the requirements for a lifeline structure in accordance with current design specifications. Mitigation would require major structural retrofit.

- The presence of marine borers was not recorded during the diving inspection of the timber piles supporting the causeway spans. However, marine borers on similar timbers elsewhere on the Hudson River have caused structural degradation and the need for replacement. Future impacts to the causeway structure are anticipated and a monitoring program is in place.

In summary, the bridge had many components that had been shown historically to be vulnerable and warranted further study to determine the degree of mitigation required. Seismic vulnerability and an overall lack of redundancy would involve the greatest mitigation cost.

The vulnerability assessment only considered natural and accidental events. Events associated with malicious intent were also studied and were a major concern. However, for security reasons those results cannot be discussed in this report.

7.2.2.2 Seismic Assessment

Based on the results of the vulnerability assessment, further seismic analysis of the bridge was conducted in accordance with the requirements of the 1998 NYC hazard assessment issued by NYSDOT. The Tappan Zee Bridge is categorized as a critical bridge that should be capable of achieving the following performance level for two different seismic events:

- **Lower level seismic event (500-year return period) –** The lower event represents a 1:500 chance of occurring in any year. (i.e., a 20 percent chance of occurring in an assumed 100-year lifespan). Given this high probability, the seismic criteria stipulate that the bridge should be fully functioning following this type of event. No damage to primary structural elements would be allowed and the bridge must be capable of being opened almost immediately for general use. Some damage to secondary components would be accepted. Major loss of life would not be expected.

- **Upper level seismic event (2,500-year return period) –** The upper event represents a 1:2500 chance of occurring in any year. This corresponds to a 4 percent chance of occurring over the assumed 100-year lifespan of a typical bridge. Performance of a critical bridge at this level does not require perfection and significant damage to primary members would be an accepted consequence. However, the bridge must be capable of reopening within 48 hours for emergency and defense vehicles and within a few months for general use. Major loss of life would not be expected.

Flexibility of a bridge and the soil conditions are of particular importance in the estimation of the horizontal seismic force. Those bridges that are transversely flexible and are founded on solid rock, for example, suspension bridges with long spans like the George Washington Bridge, do not tend to generate large horizontal forces under seismic events. Those that are less flexible and are founded on soft ground (e.g., the Tappan Zee Bridge) can experience much greater forces.

The behavior of the Tappan Zee Bridge in a seismic event is primarily determined by calculating the magnitude of the horizontal forces from an earthquake and the bridge's ability to either resist with no consequent damage or damage that is predictable, controllable, and repairable. For damage to be controllable, predicable, and repairable, it is imperative that those elements that are overstressed behave in a ductile manner. This simply means that members or connections must remain functional under major reversible deformation, even though their capacity has been exceeded. Ductility is dependent upon the type of material, configuration, and confinement. To ensure safety, those members or connections that are not ductile cannot be overstressed in the design seismic event.

Assessment of the soil conditions at the Tappan Zee Bridge, particularly under the causeway, indicated that soil conditions would amplify the magnitude of a seismic event by factors ranging from 4 to 6, with resulting horizontal forces of up to 50 percent of gravity. These forces are significantly above the standard horizontal forces that are typical for non-seismic bridges. These compare to lateral forces of 10 to 15 percent for which the existing bridge was initially designed. The resulting structural damage from a 2,500-year seismic event would include:

- **Causeway** – For the causeway, the analysis indicated that the capacity of the existing horizontal load resisting system would be substantially exceeded and that the raked end piles at each pier would be significantly damaged. This would not imply failure of the whole structure, as alternative horizontal load capacity would exist in the multitude of vertical piles present in the foundations. Analysis that assumed continued functioning of these vertical piles indicated possible adequate capacity to resist the seismic forces, though with substantial displacements and damage to connections and details. Despite the alternative horizontal capacity, the causeway would be out of position and unusable by general traffic following an upper level seismic event. Further, the potential for collapse cannot be discounted, as the connections and details are non-ductile.

- **Deck Truss** – The simplified analysis for the deck truss segments indicated major overstress of bearings, some steel members, and the supporting piers. The magnitude of the overstresses and the inability of these members to behave in a ductile manner in a 2,500-year seismic event would have major structural consequence leading to potential collapse.

- **Main Spans** – Simplified analysis for the main spans indicated extensive overstress, with the greatest overstresses at the bearings, pier anchor bolts, steel piers, main trusses, and foundations. The configuration of the tower legs, connections and piles do not indicate adequate ductile behavior, implying major damage from the governing upper limit event, leading to potential collapse.

Should the decision be to retain the existing bridge, major retrofit would be necessary. The exact extent of the seismic retrofit would need to be determined from more sophisticated analyses than was done for the AA process. Also, further site specific seismic studies to determine local characteristics would need to be done using the recently updated NYSDOT seismic guidelines. For the alternatives analysis costing purposes, an indicative retrofit program was developed (Figure 7-4).

Seismic Vulnerability – Retrofit Locations

Figure 7-4

Overall, initial seismic assessment of the bridge indicated that this critical structure would not be operable after a 2500-year seismic event, and that there would be potential for major collapse. For the 500-year event, analysis indicted borderline performance but with potential for major displacements that may render the bridge inoperable for a significant period after the event. The performance of the bridge did not comply with the 1998 NYSDOT seismic design requirements.

7.2.3 Traffic Operation and Conditions

This criterion is a measure of how much a scenario improves the roadway geometrics of the river crossing. However, as preservation is intended as a no build option, the evaluation reported here is focused on existing conditions (geometry, capacity and demand, congestion and delay, and accidents) to facilitate later comparison with other crossing options.

7.2.3.1 Existing Geometric Features

Horizontal alignment of the crossing is typically west-to-east with curves of radius 2,850 feet subtending approximate angles of 60 and 45 degrees at the west and east approaches respectively. Traveling west to east, grades vary from 2 percent at the western approach to level along the trestle spans, rising and declining at 3 percent to get over the shipping channel. There is an incline of 0.66 percent along an elevated east approach and a final change to a decline of 0.8 percent in the region of the toll plaza. In cross section, the bridge is typically 91 feet wide with seven lanes of traffic.

The bridge roadway is currently not in accordance with design standards, which include the *Thruway Structures Design Manual* (NYSTA, 2002) and *Policy on Design Standards for the Interstate System* (AASHTO, 1991). As summarized in Table 7-3, the roadway on the bridge has substandard lanes, shoulders, and median.

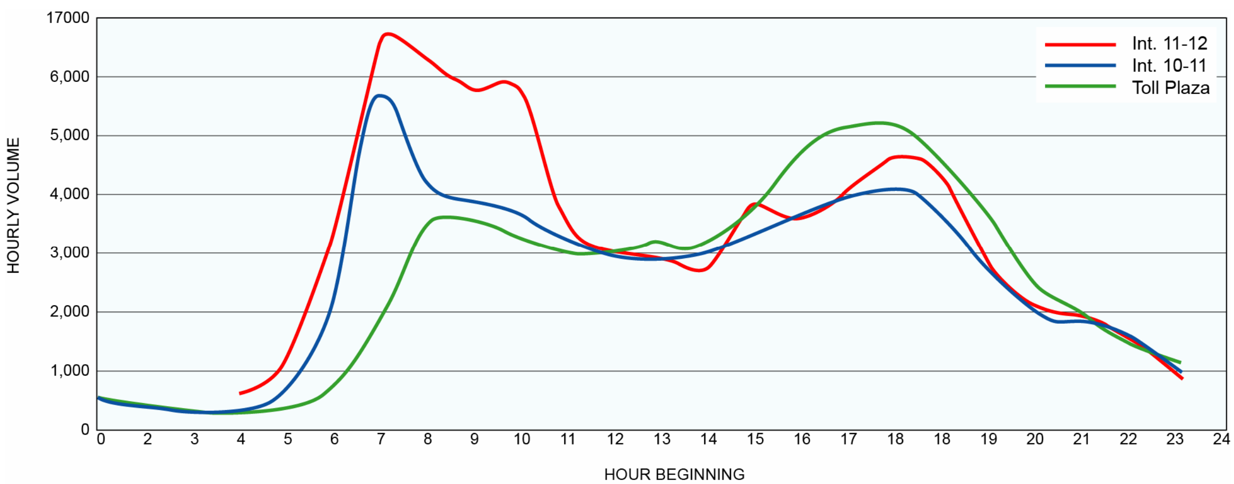
Table 7-3

Roadway Features on Tappan Zee Bridge

Roadway Features	Existing	Recommended
Minimum width of traffic lanes	11 feet 5 inches	12 feet
Minimum width of shoulders	none	10 feet right 3.5 feet left
Minimum median width (two 3.5-foot shoulders and one 2-foot barrier)	2 feet	9 feet

7.2.3.2 Traffic Capacity and Demand

Discussion of the traffic capacity and demand for the full corridor is included in Chapter 4 but is summarized here to establish the general traffic conditions on the bridge. The current configuration on the bridge is seven lanes separated by direction into three and four lanes by use of a median barrier that can be moved to accommodate the morning and evening peak periods. The theoretical bridge traffic capacity, determined in accordance with the *Highway Capacity Manual* (Transportation Research Board, 2000), in the weekday AM peak and PM peak hours was calculated at approximately 8,200 vehicles. This, when compared to a maximum throughput at the toll plaza of approximately 7,500 vehicles on the example date of Wednesday November 9, 2001, indicates that the toll plaza, and possibly the configuration of Interchange 8, limited the capacity of the bridge prior to the recently completed improvements.(Figure 7-5).



Hourly Traffic Volume November 7, 2001 (Wednesday)

Figure 7-5

The recent introduction of high speed E-ZPass lanes at the toll plaza and the reconfiguration of Interchange 8 has increased throughput and resulted in an overall increase in traffic capacity. Exact data on the increased capacity will be addressed in the DEIS.

Again, from the example day of Wednesday, November 7, 2001, the total eastbound traffic on the bridge was approximately 70,000 over the 24-hour period, with 25,000 passing through the toll plaza in the peak hours from 6 to 10 AM. This volume represented full capacity of the crossing at that time. Extended peak hours were also evident, during which time approximately 31,000 vehicles passed through the toll plaza.

7.2.3.3 Traffic Conditions

Given the "at capacity" functioning of the bridge, congestion and delay are the primary conditions experienced by bridge users, with stop and go traffic in the morning and evening peak periods, often exacerbated by accidents, sun glare, or emergency maintenance operations. While congestion and delay do not generally start on the bridge, the 3 percent grade to climb over the channel is a major contributor. The key sources of congestion in the eastbound direction are:

- **High Merging Volumes** – In the morning peak hours, congestion between Interchange 11 in Rockland and Interchange 8 in Westchester is first observed in Rockland near Interchanges 11 and 10, principally due to high merging volumes from the on-ramps. Despite the provision of the added fourth lane, the additional traffic expands to occupy more roadway space as speeds increase, and creates turbulence in the adjacent travel lanes.

- **Grades** – The 3 percent grade in the west approach to the main span, possibly aggravated by the glare presented by the early morning sun rising directly ahead, is another factor contributing to congestion. Because of the combination of the turbulence due to Interchange 10 and the curve at the start of the causeway, traffic volumes are effectively metered through this segment. As some vehicles slow by failing to compensate for the grade, differentials in speed occur, resulting in turbulence. The slower speeds of some vehicles cause following vehicles to initiate lane changing, which in turn induces other vehicles to slow and increase headways.

- **Bridge Toll Plaza** – Delays at the bridge toll plaza have been particularly severe during Sunday afternoon and evening as vacationers to upstate New York return to the city. During the weekday morning peak period, congestion levels are modest, mainly due to the high percentage of E-ZPass usage (~85 percent) and the commuters' inherent familiarity with the toll plaza operations. On weekends, the reduction in E-ZPass usage results in major congestion.

The westbound traffic typically experiences congestion due to the high grades at the east approach to the main spans and the grades in the section approaching Interchange 10 in Rockland, as previously described.

7.2.3.4 Traffic Collisions

Given that the Tappan Zee Bridge has substandard safety features (i.e., lane widths, shoulders, and medians), operates at or near full capacity, has long periods of stop and go traffic, and areas of notable traffic turbulence, a high accident rate on the crossing was not unexpected.

In the three-year period from October 1999 to September 2002, the latest for which sufficient data were available for this study, 1,424 traffic collisions occurred in the 3.7 mile distance between Interchange 9 (Tarrytown) and Interchange 10 (Nyack), which includes the bridge, both approaches, and the toll plaza.

This corresponded to an average collision rate of 1.3 collisions per day, and was four times greater than the average rate (per million vehicle miles traveled) when compared to the whole of the Thruway system. As reported in the collision reports recorded by New York State Police Troop T, 926 collisions (65 percent) occurred on the bridge itself. Human error was recorded as the cause of the majority of these (83 percent), while mechanical error/failure and obstruction/debris accounted for 8 percent and 12 percent, respectively. The most common human errors included following too close, unsafe lane changing, and unsafe speed.

The high rate of human error recorded by Troop T is a reflection of the undesirable traffic conditions along the bridge that require drivers to pay close attention to changing conditions, with little space for error due to the absence of shoulders (both left and right) and narrow lanes. The full compendium of factors that combine to influence drivers includes heavy traffic volumes with a high truck volume, narrow lanes widths, lack of shoulders, sun glare, steep grades, poor drainage, frequent lane closures, moveable barriers, and the toll plaza.

Notable trends in the collision data included:

- Close correlation with periods of high traffic volumes (peak hours, peak days, and peak periods during the year), implying a link between collisions and traffic congestion.
- Significant differential in the traffic directions, as 58 percent of collisions occurred in the eastbound direction.
- No correlation to environmental conditions, as 77 percent of the collisions occurred in the day time, 71 percent on clear days, and 88 percent on a dry road surface. Notably, sun glare was noted as an issue in less than 1 percent of the accidents.
- Geographic distribution indicated a concentration of collisions in a number of specific locations. These areas were associated with the locations of changes in grade on the bridge and in the approach to the toll plaza.

7.2.4 Preservation Summary

Overall the Tappan Zee Bridge was found to be safe for general traffic loading but with major maintenance requirements, significant vulnerabilities, and undesirable traffic conditions:

- **Capacity** – The bridge was found to be safe for current traffic loading. Though the bridge could adequately support the originally intended design load, which was equivalent to the modern HS20 truck, the ability to support HS25 loading is required in accordance with current design codes for new bridges. As a major transportation link, particularly for truck traffic, the bridge capacity should be upgraded in accordance with current design codes. About 1,600 of the 38,000 bridge members were found to warrant a lower factor of safety under HS25 live loading. These members were predominantly near the deck surface and were a result of the local effect of wheel loads. The adoption of these reduced safety factors requires regular inspection and implies a reduced lifespan for the affected members.

- **Condition** – The general condition rating for the bridge was evaluated at 4 in 2002 and 2004, a reduction from the 5 rating determined in the previous inspection in 2000. The reduction in condition rating was due to the extent of the defects found in tertiary members, previously unrecorded defect types found on floorbeams and causeway diaphragms, and the widespread reappearance of defects repaired recently in concrete columns. The rate of deterioration of the bridge was unusually high and the deck is near the end of its useful lifespan. It was estimated that 59 percent of the deck area would need to be replaced in the near future.

  Since the 1980s the expenditure to maintain the bridge in good condition has continually increased. This trend is expected to continue based on the results of this assessment. The cost to repair immediate defects and replace a substantial portion of the deck concrete in the near future is estimated at approximately $500 million.

- **Vulnerability** – Results of the assessment implied that the bridge has significant vulnerabilities. With the exception of hydraulics, all vulnerabilities were rated 3 or less for some segment, implying that the bridge is vulnerable to local or major collapse from a number of different causes. This low rating indicates a need for further study of the bridge and potential additional retrofits. The vulnerability assessment only considered natural and accidental events. Events associated with malicious intent were also studied and were a major concern. Results cannot be published.

  Seismic assessment of the bridge indicated that this critical crossing would not be operable after a 2,500-year seismic event, with potential for major collapse. For the 500-year event, analysis again indicted inadequate performance and potential for major span displacements that may render the bridge inoperable for a significant period. The performance of the bridge did not comply with the 1998 NYSDOT seismic design requirements.

- **Traffic Safety and Operations** – Traffic conditions on the bridge are not in accordance with current design standards. Substandard features included reduced lane widths and median and an absence of shoulders. Given the recent introduction of high speed E-ZPass lanes at the toll plaza and the reconfiguration of Interchange 8, it is considered that the 3 percent grade on the Tappan Zee Bridge currently dictates the traffic capacity in the crossing.

  The rate of vehicle accidents on the bridge and in the approaches was approximately four times the average of the whole of the Thruway system. Factors present on the bridge that influence driver error resulting in accidents include heavy traffic volumes, narrow lanes, lack of shoulders, sun glare, poor drainage, truck volumes, driver frustration, frequent lane closures, and the presence of the toll plaza.

7.3 Rehabilitation

Under the Preservation Option, the primary goal was to establish that the bridge was safe for traffic loads, determine its condition, and identify vulnerabilities. Major modifications were not anticipated, as the definition of that option was a continuation of the ongoing maintenance measures. However, the scale of deterioration of the concrete deck caused by environmental deterioration and the actions of trucks led to a recommendation to replace major portions of the bridge deck in the near future, for which an expenditure of $500 million has been estimated. Beyond this partial deck replacement it was considered that the bridge would be maintained as it has been over the past 20 years, the period when major maintenance has continually been required.

However, it is apparent from the deterioration rate that major maintenance expenditures will continue to be necessary. Thus, preservation is not a viable strategy for the Thruway Authority, and it is clear that as major repairs are planned and executed, upgrades and improvements will be incorporated and the bridge will eventually be completely rehabilitated. This may take 20 to 30 years or more, given that major repair contracts are reactive to biennial inspections.

The danger in this strategy is that the time taken to rehabilitate the bridge would be comparable to the deterioration cycle, and that continual rehabilitation would be necessary. Given the extending congestion periods on the bridge, the impact of continual repair would be manifested as continual disruption and delay to bridge users. The ultimate risk is a functionally obsolete crossing in which the volume of traffic and magnitude of repairs are incompatible.

The intention of the Rehabilitation Option for the bridge is to allow all upgrades, improvements, and maintenance-reducing measures to be completed as soon as possible as part of a single reconstruction period. Though this would result in substantial construction impacts to bridge users, it would be limited in duration.

A major part of the modifications included in this option would be the strategic replacement of bridge components that represent a substantial future maintenance risk. These components would include steel sections prone to fatigue and/or timber piles prone to marine borers. Rehabilitation of the bridge would not eliminate all vulnerabilities or undesirable traffic conditions, as these are inherent in the limitations of the existing bridge form (e.g., floating caissons, lack of redundancy in truss members, etc.). The lifespan for a fully rehabilitated bridge would be greater than the 50 years that has been achieved since initial construction, and the bridge would be expected to survive well into the 22nd century with continued maintenance.

Based on the four Level 2 screening scenarios that included rehabilitation of the existing bridge (H2, CRT2, M4, and M6), three specific rehabilitation configurations were studied:

- Rehabilitation maintaining the current seven-lane arrangement.
- Rehabilitation plus LRT.
- Rehabilitation as a linear park.

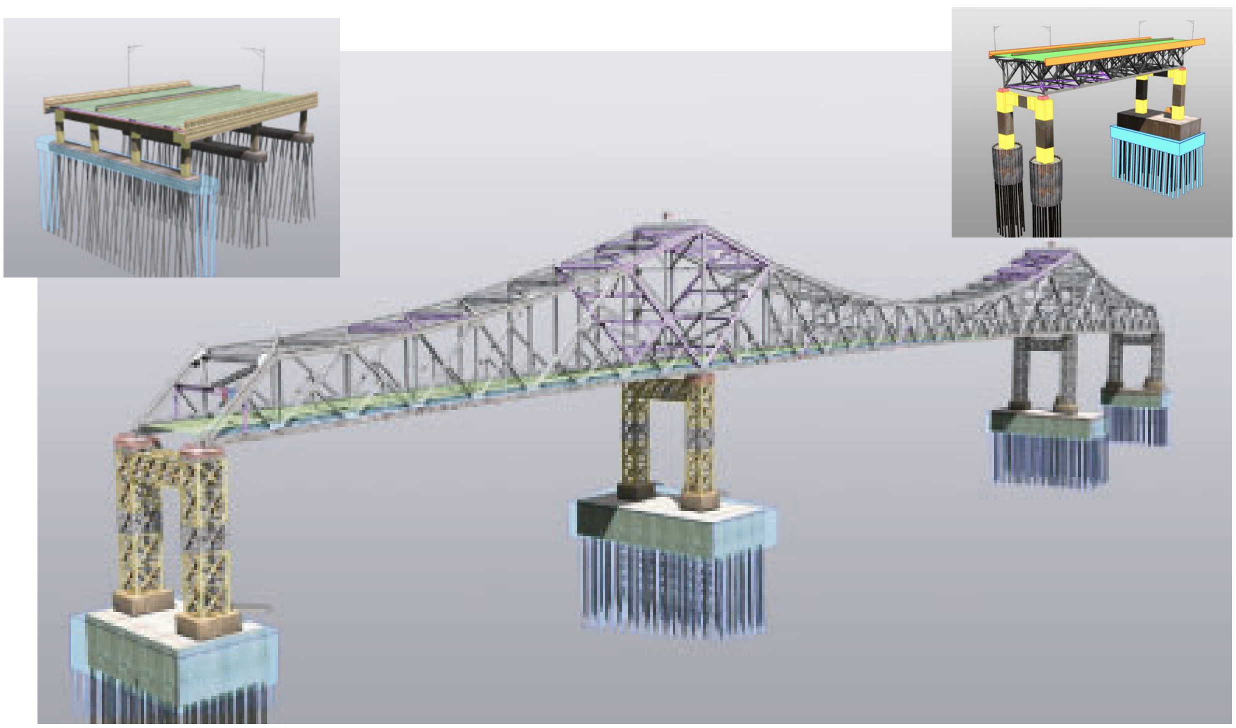
7.3.1 Rehabilitation of the Existing Bridge

Overall, modifications to the existing bridge would be extensive; many of the physical modifications described below would be interdependent. For the causeway spans the cumulative changes would warrant consideration of a full replacement structure. For the east and west truss segments, modification would be less substantial but with significant challenges associated with the floating foundations. Similarly for the main spans, the floating foundations and the required interactions with the steel substructure would represent significant challenges warranting detailed analysis and testing to justify a final arrangement. However, to facilitate cost estimates, initial retrofits have been assumed or allowances included.

These modifications would not eliminate all vulnerabilities, nor would they significantly affect traffic accident rates as changes to lane arrangements are restricted by the available width at the main spans. Remaining vulnerabilities would be associated with the truss form of the bridge, for which every truss member is a critical member and the loss of one would result in major distortion or collapse.

To make a notable traffic safety improvement a major increase in the overall width would be required that would include shoulders on each side of the four lanes of traffic in each direction, as required in the current design codes. This could be accommodated by widening the overall bridge and using the existing bridge for one direction of traffic only. However, this would result in twinning of the existing structure, an option that was eliminated from consideration at the start of the study as part of Level 1 Screening.

Figure 7-6 presents a visual summary of the primary physical modifications that would be incorporated into the various segments of the Tappan Zee Bridge. The following material outlines specific rehabilitation objectives and associated physical modifications.



Modifications to Tappan Zee Bridge

Figure 7-6

7.3.1.1 Structural and Seismic Integrity

There are a variety of potential concepts that could be implemented to improve the structural and seismic integrity of the Tappan Zee Bridge:

- Retrofit to reestablish original capacity and condition, such as retrofitting the main span floorbeam top flanges and main truss connections (unquantified risk due to limited access during inspections).

- Upgrade to HS25 traffic loading, such as replacing extensive portions of the deck on causeway, deck truss, and main truss segments.

- Retrofit to accommodate seismic events, such as strengthening or modifying approximately 24,500 members, enlarging foundations extensively.

- Upgrade traffic containment, such as strengthening traffic containment measures including outer barriers and safety walk.

- Alleviate reactive maintenance and arrest the rate of deterioration, such as replacing the complete drainage system and introducing containment systems for all runoff.

- Upgrade support systems, such as the flood warning system in the caissons, and replace and expand the electrical and communications systems.

7.3.1.2 Vulnerabilities

There are a number of physical improvements that could reduce vulnerabilities to natural or accidental events:

- Reconstruct ship impact protection for anchor spans (continuing risk due to low spans).
- Reinstate pier protection at causeway and truss spans.
- Introduce redundancy for key members.
- Enhance impact protection for main span members adjacent to roadway.
- Supplement timber piles supporting causeway spans (continuing risk from marine borers).

For security reasons, modifications to reduce vulnerabilities to malicious events are not reported here.

7.3.1.3 Traffic Operation and Safety

A variety of approaches is available to maximize traffic safety and reduce the accident rate:

- Widening of the causeway and truss spans to incorporate shoulders, standard lane widths and median. These changes would not be possible at the main spans due to the location of the trusses. The resulting loss of shoulders and reduction in lane widths at the main spans would be a safety concern. Widening would require strengthening and extension of the superstructure members.

- Correction of the deck camber on causeway spans to improve drainage.

- Introduction of additional traffic measures to control and inform traffic, such as enhanced signage, and disallowance of lane changes at key locations.

Traffic capacity could also be improved by:

- Introduction of 8-foot shoulders (results in an approximate 2 to 3 percent increase in capacity).

- Introduction of 12-foot-wide standard lanes (results in an approximate 2 to 3 percent increase in capacity).

7.3.1.4 Other Modifications

Other modifications, such as incorporation of pedestrian and cycle ways over the full length of the bridge, are possible.

7.3.1.5 Impacts

The duration of construction for the works above would extend to ten years or more, given that the bridge would need to remain open to traffic, with major works primarily occurring at night and between rush hour periods. For the duration of construction, delays and congestion would be an ongoing characteristic of the crossing and it is probable that a number of longer duration closures would be necessary.

Retrofit for seismic events, reconstruction of the causeway spans, and enhancement of pier impact protection would require the construction of new and extended foundations that would permanently disturb 4 to 5 acres of river bed.

Based on the quantities determined from the inspections conducted and the outline analysis completed, the total cost for rehabilitation of the existing bridge would be $1.5 to $2.0 billion, including replacement of the causeway spans and widening of the whole crossing to incorporate a pedestrian and cycle way, but excluding the addition of shoulders. It should be noted that all costs are in 2004 dollars, are preliminary in nature based on conceptual layouts, do not include all cost elements, and are presented only to allow comparisons among various alternatives.

7.3.2 Rehabilitation Plus LRT

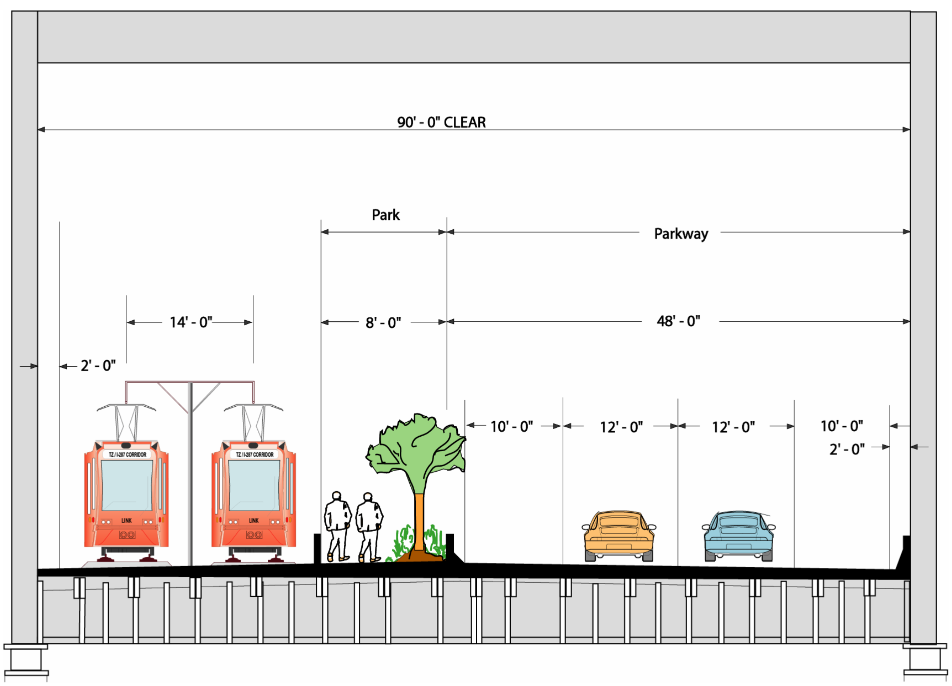
The introduction of LRT in addition to the existing seven lanes was included in Scenario M6. Based on the available capacity of the crossing segments and the desire to keep the two LRT tracks together for operational reasons, the LRT was assumed to be located along one side of the existing bridge (Figure 7-7). This arrangement would require widening and strengthening the existing bridge to accommodate the LRT, with works extending from foundations to the top of the main span trusses. However, as outlined in Chapter 6, full-corridor LRT was not recommended for inclusion in the DEIS, and consequently was not considered further.

7.3.3 Rehabilitated Bridge as a Linear Park

Scenario M4 involved retention of the existing bridge as a parkway with two travel lanes and pedestrian and bicycle ways within a linear park with LRT; however, cross-corridor LRT was subsequently eliminated from consideration. The cross section shown in Figure 7-8 indicates a two-lane parkway with shoulders and a linear park, and pedestrian and cycle ways within the overall available width of 91 feet. The linear park concept accompanied a new highway tunnel, and retention of the existing structure was intended to serve local traffic and to provide for pedestrian and cyclist access across the river.

Rehabilitation Plus LRT

Figure 7-7



Outline Cross Section at Main Span for Linear Park

Figure 7-8

While the linear park could be accommodated within a retained bridge, it was not recommended for inclusion in the DEIS for the following reasons:

- As outlined in Subchapter 7.4 following, a highway tunnel is not recommended. The retention of the existing bridge as a linear park would therefore be accompanied by a replacement highway bridge.
- Pedestrian and cycle ways could be incorporated on the replacement highway bridge. A separate crossing would not be required.
- The concept would incur high initial rehabilitation costs and long-term maintenance costs associated with the 50 year-old structure. The initial investment to rehabilitate the bridge to current seismic standards would exceed $1 billion, and would exceed $0.5 billion even if the seismic retrofit was omitted. Operating costs were estimated at $1 to $2 million per year assuming some security and maintenance activities.
- Future cost risks are associated with marine borers, security requirements, and pedestrian/cyclist safety.
- Traffic access requirements for both a new and retained bridge crossing would complicate approach ramps and require some additional right-of-way to provide the necessary connections on both the Rockland and Westchester shores.
- As traffic conditions, even on a replacement bridge, would be characterized by congestion during the peak hours, the lanes on the retained bridge would be attractive to many users and would increase the overall crossing capacity. The consequence would be tolling and likely increased traffic on local routes.
- Security would be a concern as casual access is enhanced.
- Settlement of the causeway spans would become a concern if uneven additional weight is required for landscaping
- In the opinion of the US Coast Guard, the existing bridge adjacent to a new bridge would pose an unnecessary obstruction to navigation.

Given that the concept of a parkway does not significantly improve mobility in the corridor, the high costs did not justify carrying the concept forward into the DEIS.

7.3.4 Rehabilitation Summary

Overall, rehabilitation of the existing Tappan Zee Bridge was found to be feasible, but because of the structural form, modifications could not eliminate all vulnerabilities or result in a significant improvement to traffic safety and operations. Key conclusions were as follows:

- Rehabilitation of the bridge was considered to be feasible but with notable challenges, particularly for seismic retrofits.

- Based on the rate of deterioration and scale of expenditure, a rehabilitation strategy that repairs the bridge as needed would eventually lead to full rehabilitation over the course of 20 to 30 years or more, given that major repair contracts are reactive to biennial inspections. This strategy was not considered a preferable strategy given the potential for renewed deterioration cycles and incompatibility with traffic volumes.

- The Rehabilitation Option for the bridge offered an early and single period of repair and upgrades, avoiding overlapping of deterioration cycles while reasonable time was available for construction between peak traffic periods and at night.

- The cost to rehabilitate the bridge was estimated at $1.5 to 2.0 billion.

- Duration of construction was estimated in excess of ten years, with congestion and delay common, though most construction would be during off-peak periods.

- The use of a rehabilitated bridge as a linear park and parkway was not recommended for inclusion in the DEIS because pedestrians and cyclists could be accommodated on a replacement bridge, the concept would not significantly improve mobility, and the associated costs would be high.

7.4 New Highway Crossing

Replacement bridge and tunnel options were developed and considered for the highway crossing and were evaluated in accordance with the Level 2 Screening criteria.

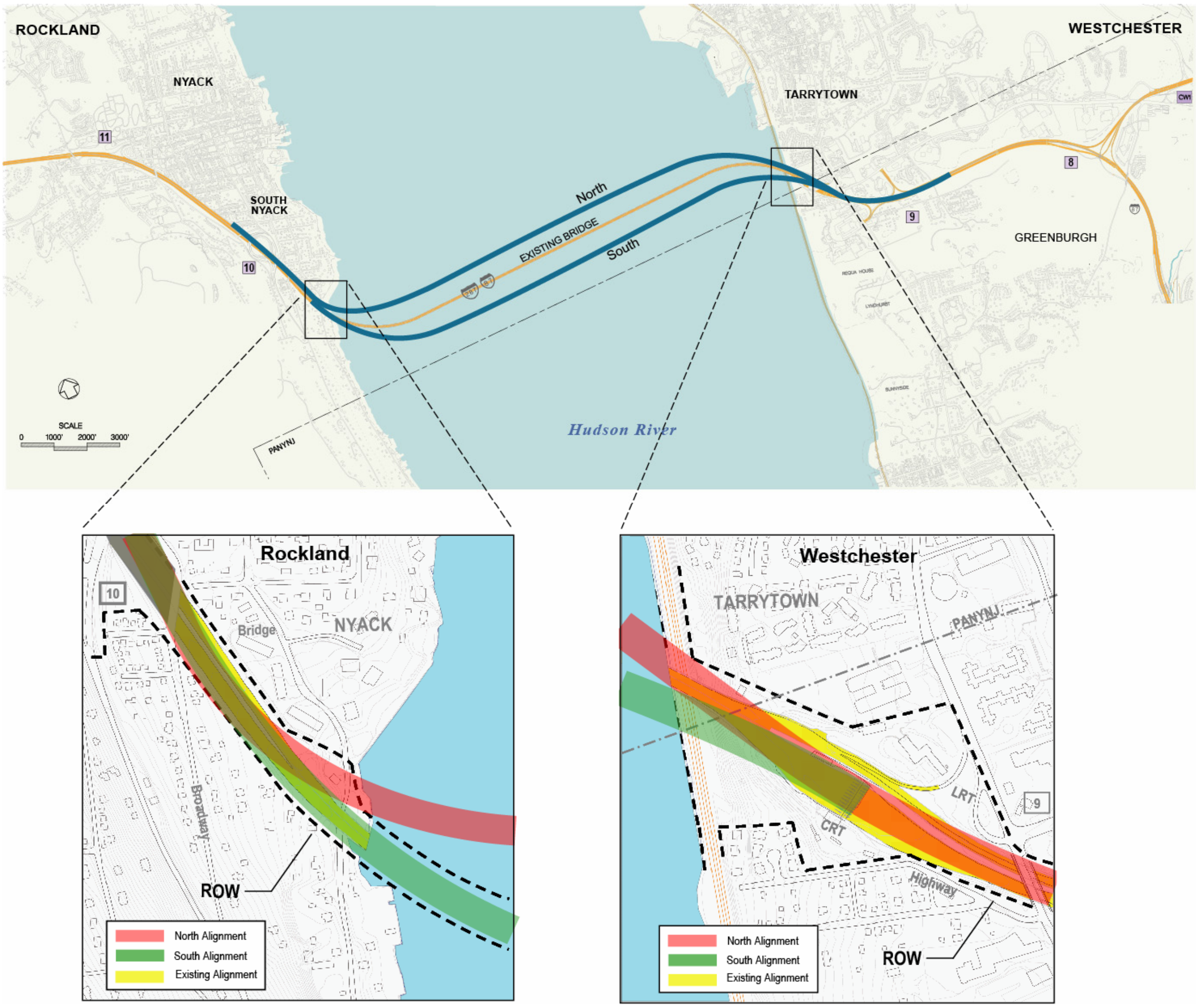
7.4.1 Bridge Option

A replacement bridge would match the existing Thruway approaches, carrying eight general-purpose lanes plus two HOT/BRT lanes, and would meet the operating requirements established by the NYSTA. The NYSTA operating criteria require that all lanes be on one level to provide maximum operational flexibility.

7.4.1.1 Alignment

The Level 1 screening process eliminated possible new Hudson River crossings at a remote north or south location, primarily to minimize the impacts (particularly property takings) that would be associated with the construction of new corridors to a relocated bridge in both Rockland and Westchester. All of the bridge crossing locations that remain for Level 2 screening, therefore, would be located immediately adjacent to the existing Tappan Zee Bridge (Figure 7-9).

The existing bridge, located in one of the widest sections of the Hudson River, is approximately 3 miles long and follows an S curve in plan to accommodate the approach highways. The approach elevations differ, with the Westchester abutment at an elevation approximately 80 feet higher than the Rockland abutment. The original alignment was tailored to minimize the costs of tall piers by using a steep grade immediately to the west (Rockland side) of the main spans down to the west trestle structure, which has a low clearance of approximately 20 feet.



Bridge Alignments Studied

Figure 7-9

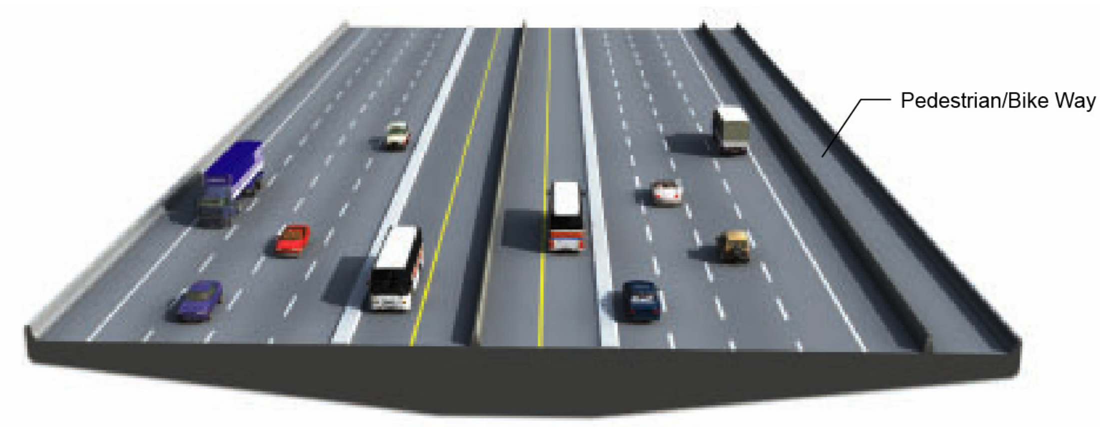
The multitude of alignments considered for a new bridge crossing can be combined into the following groups by location relative to the existing structure: north, south, and crossover alignments.

As the alignments are all adjacent to the existing bridge, the geometry of a replacement bridge would be controlled by the same factors that influenced the original Tappan Zee Bridge. The bridge alignment must tie into the existing approach highway on each side of the river both horizontally and vertically, and provide adequate horizontal and vertical clearance at the shipping channel. The preferred alignment was controlled by the ease of making the connections to the existing approach highway at each end of the bridge.

The space available within the existing Thruway right-of-way favors an alignment north of the existing bridge on the Rockland side and south of the existing bridge on the Westchester side. Such a crossover alignment would optimize the use of the existing right-of-way, but would likely infringe on the PANYNJ jurisdiction near the Westchester shore, making it undesirable in that regard. To avoid the PANYNJ jurisdiction, a north alignment would be required. Such an alignment would suit the Rockland approach well, and is feasible on the Westchester side, although it would complicate construction staging somewhat. A south alignment would similarly complicate construction staging at the Rockland shore, requiring a temporary west trestle structure to avoid significant right-of-way takings, and would also likely infringe on the PANYNJ jurisdiction on the Westchester side. Thus, a north alignment for the bridge was selected.

7.4.1.2 Cross Section

The highway bridge would be configured with four general-purpose lanes that match the existing lanes on both approaches, one buffer-separated BRT/HOT lane, shoulders, and a pedestrian/bicycle path in each direction (Figure 7-10). The total width of the bridge would be 250 feet, comprising two deep steel truss structures, each up to 105 feet in width, separated by up to 40 feet to allow space for a tower at the main spans over the channel. This separation would not be required other than at the main towers. The deep trusses would permit spans of 300 to 400 feet between piers. The main span lengths would be 1,200 to 1,500 feet.



Cross Section of Highway Bridge

Figure 7-10

7.4.2 Tunnel Option

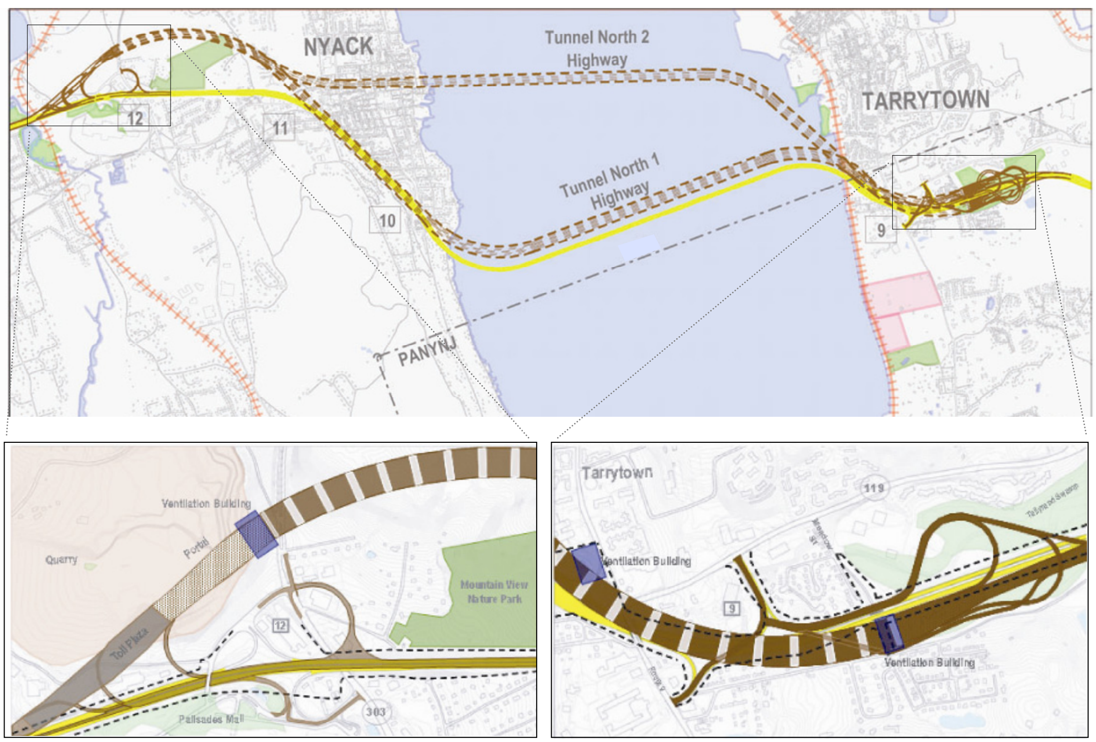
The Highway Tunnel Option was developed to provide the same configuration of eight general-purpose lanes and two BRT/HOT lanes as the Highway Bridge Option.

7.4.2.1 Alignment

Two alignments were considered for the Highway Tunnel Option:

- **Tunnel North 1 Alignment** – This alignment (Figure 7-11) would be similar to the north alignment for the highway bridge, located adjacent to the existing bridge to the north. Because of the depth of the tunnel under the river, the fact that the land rises quickly on both sides of the river, and limitations on the steepness of highway grades, the highway would not emerge from the tunnel until some distance into both Westchester and Rockland, resulting in a total length of roughly 6 miles with 3.5 to 4 percent tunnel grades. From the shoreline in Westchester, the tunnel would remain below the Thruway right-of-way, emerging at a point east of Interchange 9, where new ramps and connector roads would be required to link with the by-passed Interchange 9 and local roads. The existing toll plaza would be entirely bypassed.

  Due to space constraints in Westchester, the toll plaza would be relocated across the river. From the Rockland shoreline, the tunnel would also remain under the Thruway right-of-way until the vicinity of Interchange 11, where the Thruway curves to the west. Here the tunnel would diverge, continuing north before curving west and emerging at a point north of Interchange 12. The new toll plaza would be located in this area, and the Thruway would converge with its existing alignment to the west of Palisades Center Mall.



Corridor Tunnel Alignments

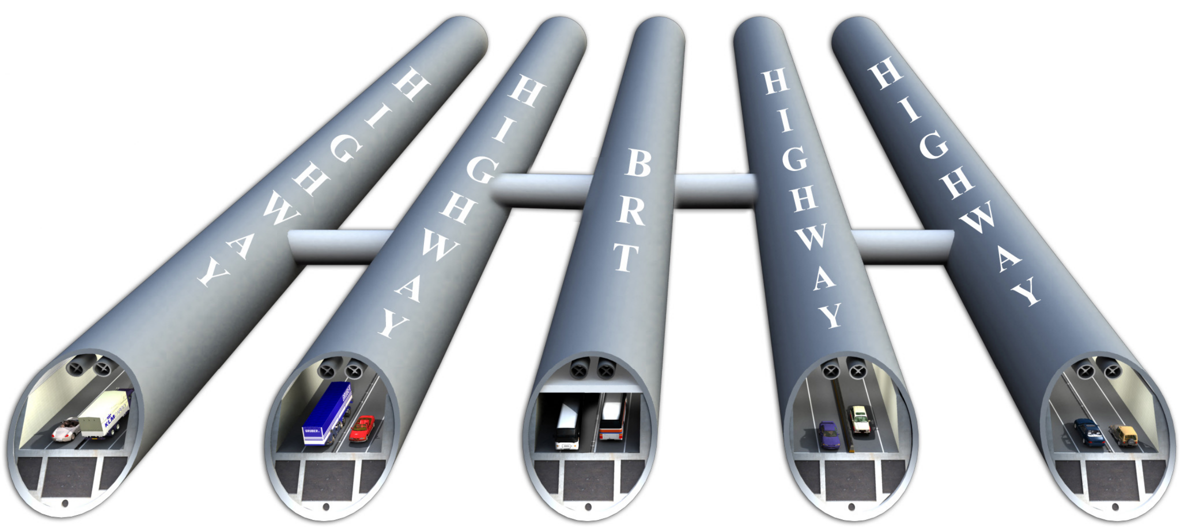
Figure 7-11

- **Tunnel North 2 Alignment** – Similar in length to Tunnel North 1, this alignment would be identical in Westchester until the shoreline, where the Tunnel North 1 alignment would curve west to cross perpendicular to the river. Here the Tunnel North 2 alignment would diverge, continuing northwest and crossing below the river at a skew, reaching the Rockland shoreline beneath Nyack. The tunnel would continue west, converging with the Tunnel North 1 alignment to the north of Interchange 11. From there, the alignment would be identical to the Tunnel North 1 alignment. The Thruway toll plaza would be relocated to Rockland north of Interchange 12, as above.

While the curves on the north tunnel alignment would be gentler than those on the corridor tunnel alignment, making it more favorable for use of tunnel boring machines (TBMs), and the route is more direct, the risks, impacts, and large number of subgrade easements associated with tunneling below Nyack are undesirable, making the Tunnel North 1 alignment preferable.

7.4.2.2 Cross Section

The highway tunnel cross section developed during Level 2 screening would comprise five 45-foot diameter tunnels with two lanes each, bored 50 feet below the riverbed, as shown in Figure 7-12. The total width required would be 425 feet, 175 feet wider than the existing Thruway right-of-way. An additional tunnel (dual tubes) would be provided if CRT were to be included in the crossing as discussed in Subchapter 7.5.

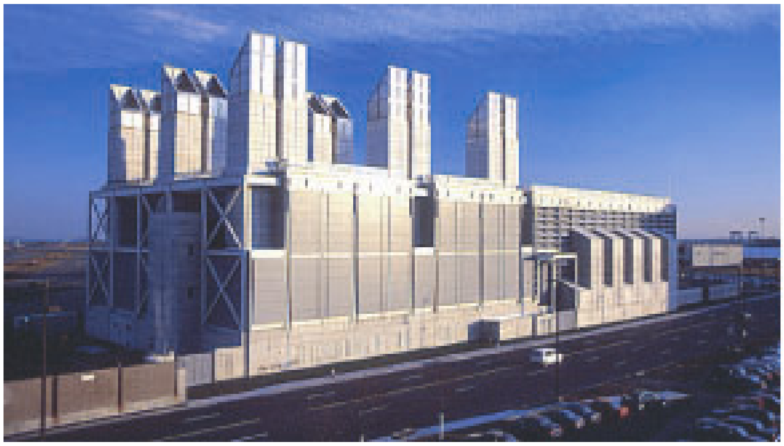


Cross Section of Highway Tunnel

Figure 7-12

7.4.2.3 Support Facilities

Ventilation facilities would be sited near both the Rockland and Westchester shorelines. The length of the tunnels would necessitate large fan arrays to circulate the required volume of air, housed in very large buildings. Up to five ventilation buildings would be required, with the maximum facility size approximately 500 feet by 300 feet and up to 100 to 150 feet high, assuming an above-ground location and allowing for adequate exhaust dispersal. For an example of a highway vent building, see Figure 7-13.



Boston Harbor Tunnel Highway Vent Building

Figure 7-13

7.4.3 Comparison of a Highway Bridge to a Highway Tunnel

The results of the Level 2 screening process confirmed that development of a highway tunnel across the Hudson River would be inconsistent with the project's goals and objectives. The main factors in this conclusion are as follows:

7.4.3.1 Transportation Performance

- **Missed Interchanges** – Interchanges 9, 10, 11, and 12 would all be bypassed by the tunnel, requiring all to be reconfigured and forcing highway users to backtrack to the interchanges. These changes would significantly affect local traffic patterns in Rockland and Westchester, and particularly in Nyack and Tarrytown.

- **Steep Highway Grades** – A highway tunnel in this location would require longer and steeper grades (3.5 to 4 percent) than are recommended for interstate highway operations.

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

7.4.3.2 Property Impacts

- **Tunnel Portals** – Given their size and the limited area available along the existing Thruway right-of-way, the tunnel's portals and ramps and connecting roads leading to them would extend outside the right-of-way, requiring significant property takings.

- **Toll Plaza** – Relocation of the toll plaza to Rockland would require property acquisition.

- **Ventilation Buildings** – These large structures would likely require property takings on both sides of the river.

- **Realignment of Adjacent Highway** – Sections of the existing highway beyond the tunnel would have to be realigned to meet the highway tunnel portals, requiring property takings.

- **Underground Easements for Tunnel** – The total width of the four highway tunnels, including required space between them, would be approximately 425 feet, extending well beyond the Thruway right-of-way and requiring underground easements and property takings. The highway tunnels would also pass under private property in Nyack and Tarrytown.

7.4.3.3 Construction Period Impacts

- **TBM Launch/Recovery Boxes** – Large boxes would be excavated in the water at or near both shorelines, at the rock-to-soil interface to launch and recover the TBMs.

- **Spoils** – Roughly 8 million cubic yards of excavated material would be extracted, dewatered, and hauled from the site.

- **In-River Decks** – The in-water construction activities would require very large (2- to 4-acre) in-river decks for stockpiles, support systems, plants, and barge loading facilities.

- **Longer Construction Period** – Construction of multiple highway tunnels, even with the use of several TBMs, would take two to three years longer than construction of a bridge.

7.4.3.4 Environmental Impacts

- **Increased River Bottom Disturbance** – The permanent disturbance for the bridge and tunnel would be about the same (4 acres). However, if ventilation shafts need to be constructed in the river along both shorelines, this area would increase significantly. Temporary bottom disturbance would be greater with a highway tunnel (22 vs 4 acres) and would also increase dramatically if ventilation shafts are constructed in the river along both shorelines.

- **Wetland Impacts** – In Westchester, the tunnel alignment would affect approximately 25 acres of the Talleyrand Swamp.

- **Environmental Permit Complications** – The US Army Corps of Engineers (USACE) and NYS Department of Environmental Conservation (NYSDEC) permitting processes for a highway tunnel would be complicated by the fact that a viable option (a highway bridge) exists that would result in significantly fewer environmental impacts.

- **Visual Impacts** – The tunnel ventilation buildings would be large structures, resulting in visual impacts.

- **Historic and Recreational Properties** – Several properties (e.g., Laguna Field/Pennybridge School in Westchester and Mountain View Park in Rockland) would be directly impacted.

7.4.3.5 Construction Vulnerability and Risks

- **Greater Complexity** – Construction of a lengthy eight-lane highway tunnel under complex geological conditions and near or beneath built-up areas would pose substantially greater construction risk and vulnerability than a shorter, more straightforward highway bridge.

- **Impacts of Construction Costs and Duration** – Vulnerability could affect ultimate construction costs, duration and local environmental impacts, both in the river and on both shorelines.

7.4.3.6 Construction and O&M Costs

- **Higher Capital Costs** – A highway tunnel crossing would cost up to two times the cost of a new bridge crossing ($4 to $6 billion more).

- **O&M Costs** – Long-term operation and maintenance (O&M) costs of a bridge are normally higher than for a tunnel, but total long-term O&M costs would likely be roughly the same for the highway and a tunnel because the tunnel would be twice as long.

7.4.4 Summary

Overall, based on its greater adverse impacts on transportation operations, extensive long-term construction and construction period environmental impacts, greater construction complexity, and considerably higher capital costs, the highway tunnel is not a viable option to replace the existing Tappan Zee Bridge. Therefore, only the Highway Bridge Option will be advanced to the DEIS.

7.5 New CRT Crossing

Bridge and tunnel options for the CRT river crossing were evaluated in accordance with the Level 2 screening criteria to determine the preferred option (see *Alternatives Analysis for Commuter Rail Hudson River Crossing* [NYSTA/Metro-North, September 26, 2005]). As outlined in this report the primary objectives of the CRT Bridge and Tunnel Option were to:

- Maximize the use of the existing NYSTA and Metro-North right-of-ways in both the cross-corridor and Hudson Line routes.

- Minimize construction impacts.
- Provide connectivity to the Hudson Line and Cross-Westchester CRT, LRT, or BRT.
- Accommodate the rapid rise in grades in Rockland and Westchester.
- Accommodate existing dual-mode Metro-North rolling stock and to allow for failure of the electric mode (third rail) without disruption of normal services. (There would be third rail from Suffern to the Hudson Line with dual modes coming from north of Suffern.)
- Accommodate intermodal freight.
- Allow for maintenance operations.

7.5.1 Bridge Option

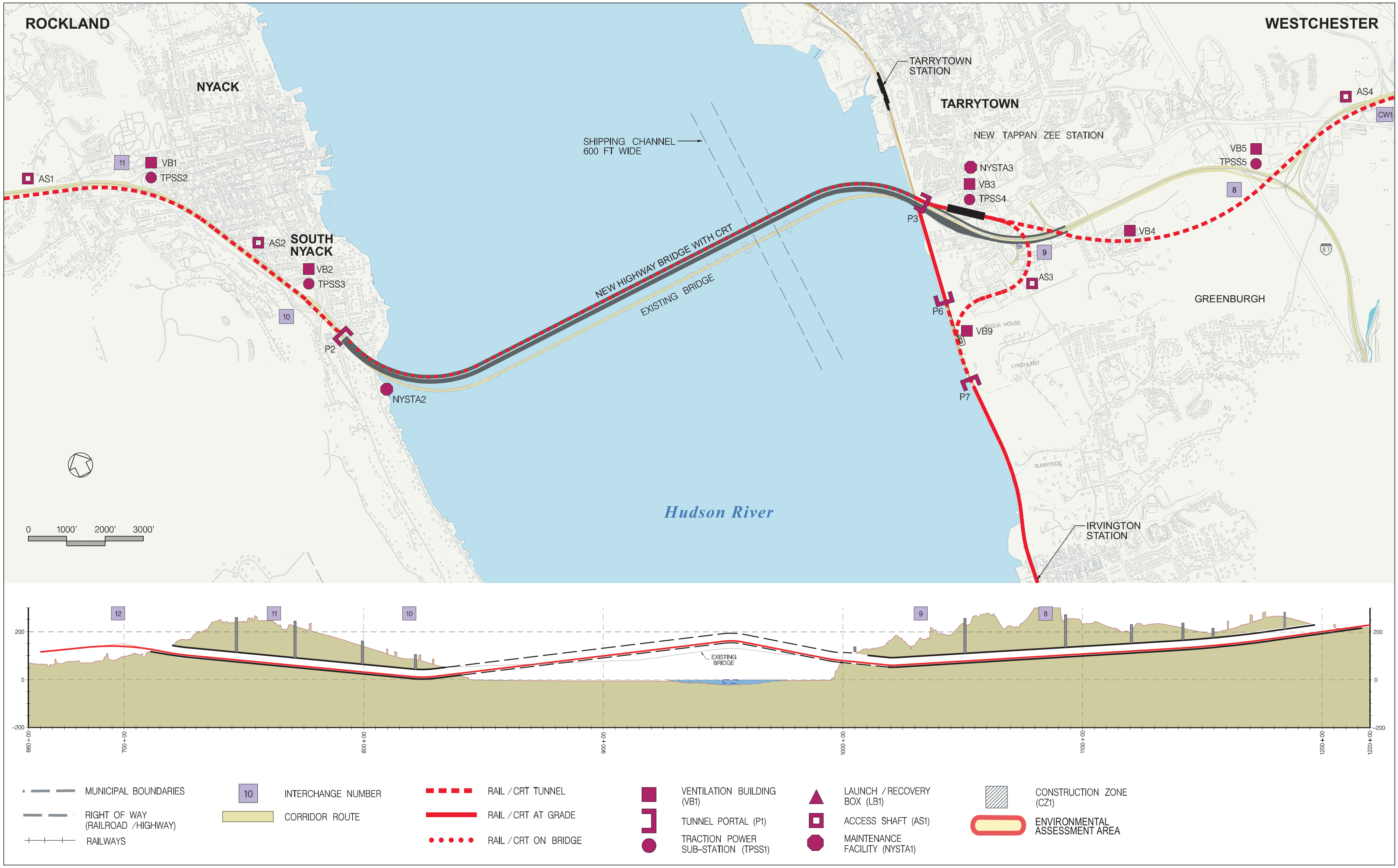
As indicated in Subchapter 7.4, an alignment just north of the existing Tappan Zee Bridge was selected for a replacement highway bridge. After considering a variety of ways to incorporate CRT onto this bridge crossing, and ways to connect the CRT alignment to the bridge from Rockland and Westchester, the optimum CRT Bridge Option alignment was selected. On both sides of the river, the CRT alignment would leave the bridge and enter a shoulder tunnel to accommodate the rapid rise in grades, and at the Westchester shoreline would permit direct connections to the following: a new Tappan Zee Station in the vicinity of the existing Thruway Toll Plaza, the Hudson Line, and a cross-Westchester Line. This alignment (and corresponding profile) is presented in Figure 7-14 and described below.

The rail line would enter a 2.3-mile shoulder tunnel east of Palisades Center Mall in Rockland and run east below the Thruway right-of-way, ending at the new bridge abutment near the Hudson River. The varying geological and alignment constraints along the route would require four different cross section types – cut and cover, retained cut, single bore and double bore, primarily depending on ground conditions and depth.

Two Hudson River bridge crossing types were considered: a dual-level bridge and a single-level bridge:

- **Dual-level Bridge Option** (Figure 7-15) – Each upper deck would carry four vehicular lanes with inside and outside shoulders. In addition, a pedestrian walkway would be provided on the outside of the right shoulder in each direction. To maximize off-site fabrication and facilitate erection, the structure would be separated into two similar halves corresponding to traffic direction. The total width would be up to 215 feet. The depth of the deck would facilitate long spans of 400 to 500 feet with 35 to 45 foundations across the river, each with two vertical piers with main span lengths of 1,200 to 1,500 feet.

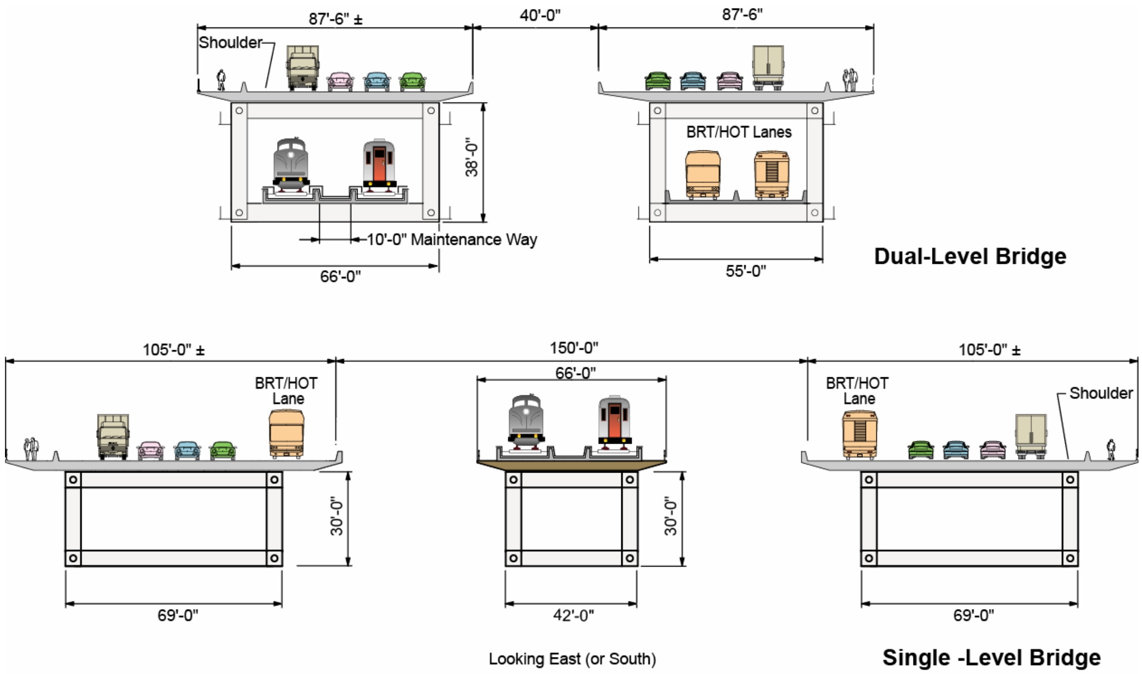
  Two CRT tracks separated by a 10-foot-wide maintenance way would be carried on the lower level of the north superstructure. Two BRT/HOT lanes, one in each direction separated by a median barrier with shoulders, would be carried on the lower level of the south superstructure. One issue is, however, that a dual-level bridge with BRT/HOT lanes on the lower level would not meet the NYSTA operating requirement for having all traffic on one level. This consideration will be addressed further in the DEIS stage.



Bridge Option - Plan and Profile

Figure 7 - 14

- **Single-Level Bridge Option** (Figure 7-15) – This option would comprise three sections, with the outer two carrying highway and BRT/HOT lanes and the center section carrying two CRT tracks and a vehicular maintenance way. Other arrangements would be possible, such as rail on the north side of the bridge, but their study is deferred to the DEIS stage. The total width would be up to 360 feet.



Typical Bridge Cross Sections

Figure 7-15

For either option, a new Tarrytown area station (Tappan Zee Station) would be located in the vicinity of the existing Thruway toll plaza near the Westchester abutment of the bridge, serving Manhattan-bound and cross-Westchester CRT, or cross-Westchester BRT or LRT via transfer. The station platforms would be below Route 9, with approximately half the platform located underground within the NYSTA right-of-way and the other half located underground east of Route 9 in an area currently occupied by banking and retail properties.

The station complex would include parking for up to 500 vehicles, a small Metro-North maintenance facility, an upgraded NYSTA maintenance facility, and facilities for the state police. Multi-level structures would be required to accommodate these space requirements. Initial layouts were prepared to facilitate preliminary traffic studies but the specific configuration and location of the surface facilities were deferred to further study in the DEIS Stage.

The alignment for the Hudson Line connection tunnel would leave the Tappan Zee Station and sweep south and west towards the Westchester shore, passing under the Thruway in the region of Interchange 9 and under a number of residential and commercial properties. This alignment is governed by the minimum length needed to bring the rail line from the Tappan Zee Station (on the high plateau above) down to the Hudson Line below (low along the shore). The connection to the Hudson Line would begin under the Kraft-owned Requa House property (a New York State-inventoried archaeological site) and continue south, with the new tracks rising to merge with the Hudson Line and providing a new interlocking just north of Irvington Station.

From the area of Interchange 9, the cross-Westchester CRT Line would split from the Hudson Line connection tunnel and proceed east under the Thruway alignment (deviating briefly to avoid the Talleyrand Swamp) for 4 miles, to the vicinity of Knollwood Road in Elmsford, where it would surface at a new Greenburgh Station. The remainder of the line would continue in tunnel through White Plains, surface along the I-287 Corridor, and continue to its connection to the New Haven Line. Cross-Westchester LRT or BRT would rise rapidly from the Tappan Zee Station platforms and follow surface routes east across Westchester.

Permanent support facilities (e.g., traction power substations (TPSSs), vent buildings, access shafts, maintenance facilities) would be required at 17 locations for the Bridge Option in the crossing area. The total surface area of all facilities in the crossing area would be approximately 200,000 sq ft, including nine ventilation buildings, seven TPSSs, and six access shafts. Some facilities would be combined, and some would be within underground CRT stations. Notable facilities that are required in the Bridge Option but not the Tunnel Option include one 20,000 sq ft underground vent facility located on either Requa House or Kraft property adjacent to the Hudson Line. Preliminary assessment indicates that this facility would incorporate vent stacks rising 50 to 100 feet above ground.

Temporary support facilities during construction would include temporary platforms in the Hudson River at three locations with a total area of 8.5 acres. These platforms would be used for staging, storage and transshipment of material and for personnel facilities.

7.5.2 Tunnel Option

Under the Bridge Option, both highway and CRT would be on the same facility – a single-level or dual-level bridge. Under the Tunnel Option, the highway would be on a bridge while the CRT would be in a separate tunnel. The first step in developing the Tunnel Option was to decide on a preferred alignment for the tunnel.

7.5.2.1 CRT Tunnel Alignments Studied

The steep shorelines on both sides and the depth beneath the riverbed required for bored tunnels (a least one tunnel diameter) effectively force all CRT tunnel options to follow approximately the same vertical profile. All would begin in Rockland just east of Palisades Mall near Route 303 (the same as the shoulder tunnel for the Bridge Option), drop toward the Rockland shoreline, and pass beneath the riverbed. From there, the alignment would rise in Westchester to connect to tunnels leading to a Hudson Line connection, and continue east across Westchester, surfacing east of the Saw Mill River.

Five possible alignments were considered for the CRT Tunnel Option (Figure 7-16). They would vary in their placement in the corridor, in horizontal alignment, and in the degree of transportation connectivity and integration they would provide.

CRT Tunnel Options Considered

Figure 7-16

- **CRT Tunnel Option 1: South Tunnel.** This alignment would follow the Thruway right-of-way as closely as possible in Rockland, and then swing south of the existing Tappan Zee Bridge in the river (into the area under PANYNJ) and back under the Thruway right-of-way in Westchester. The connection to the Hudson Line would swing southward from a track split below the river near the Westchester shoreline. The Hudson Line connection portion of the alignment would not provide a practical location for a new station. An underground station below the Thruway toll plaza for local access to and transfer between the Hudson Line and cross-Westchester service would be possible, but its poor accessibility and deep elevation (170 feet below the surface) would make this station undesirable.

- **CRT Tunnel Option 1A: North Tunnel.** This alignment would follow the Thruway right-of-way in Rockland, swing to the north of the existing Tappan Zee Bridge in the river, and then curve south to parallel the alignment of the new bridge as it reaches the Westchester shore just to the north of the bridge. The split between the Cross-Westchester and Hudson Lines would be located underground in Tarrytown. The segment heading east into Westchester would swing under the Hudson Line and continue into Westchester under the Thruway. A new station on the Hudson Line would be impractical, due to a lack of space, poor access, and close proximity to the existing Tarrytown Station. An underground station would be possible near the existing Thruway toll plaza to provide local access to east-west CRT service and transfer between the Hudson Line and east-west service, although its depth below grade (150+ feet) would make this station undesirable.

- **CRT Tunnel Option 2: North Tunnel with Underground Transfer at Existing Tarrytown Station.** This alignment would follow the Thruway right-of-way in Rockland, swing north of the existing Tappan Zee Bridge, and continue northeast across the river to reach the Westchester shore farther north in the vicinity of Horan's Landing Park and the proposed Ferry Landing development, just south of the former GM site. It would then curve southward and pass beneath and adjacent to the existing Tarrytown Station, where a new underground station would be constructed 60 feet below the surface to allow local Tarrytown boarding and transfers between lines. The new tracks would continue south below the Hudson Line, rising to merge with it between the new bridge and Irvington Station. The Cross-Westchester line would split off and curve eastward near the new bridge and continue east across Westchester under the Thruway right-of-way. This alignment would provide transfer capability to the north.

- **CRT Tunnel Option 2A: North Tunnel under Nyack with Underground Transfer at Tarrytown Station.** In Rockland, this alignment would depart from the Thruway right-of-way to pass farther north under Nyack, and then continue across the river to reach the Westchester shore at the same location as Option 2. The alignment is the same as Option 2 from that point on. An underground station could be constructed in Nyack. However, its depth (140 feet below street level), access limitations, and close proximity to the Palisades Mall Station would make a Nyack Station undesirable.

- **CRT Tunnel Option 3: North Tunnel Under Nyack with At-grade Transfer at Tarrytown Station.** This alignment would be the same as Option 2A in Rockland, but would take a more northerly route across the river, curving northward and then southward around the former GM site. After reaching the Westchester shore, the alignment would leave the tunnel just south of the Philip's Manor Station and follow the Hudson Line right-of-way through Tarrytown to near the Tappan Zee Bridge. It would rise to the same elevation as the existing Hudson Line tracks at the Tarrytown Station, allowing passengers to transfer there. The tracks would merge into the Hudson Line to the south of the existing station along a reconfigured interlocking. A connector tunnel would cross under the existing tracks south of the Tarrytown Station to Cross-Westchester service, which would continue east following the same alignment as Options 2 and 2A.

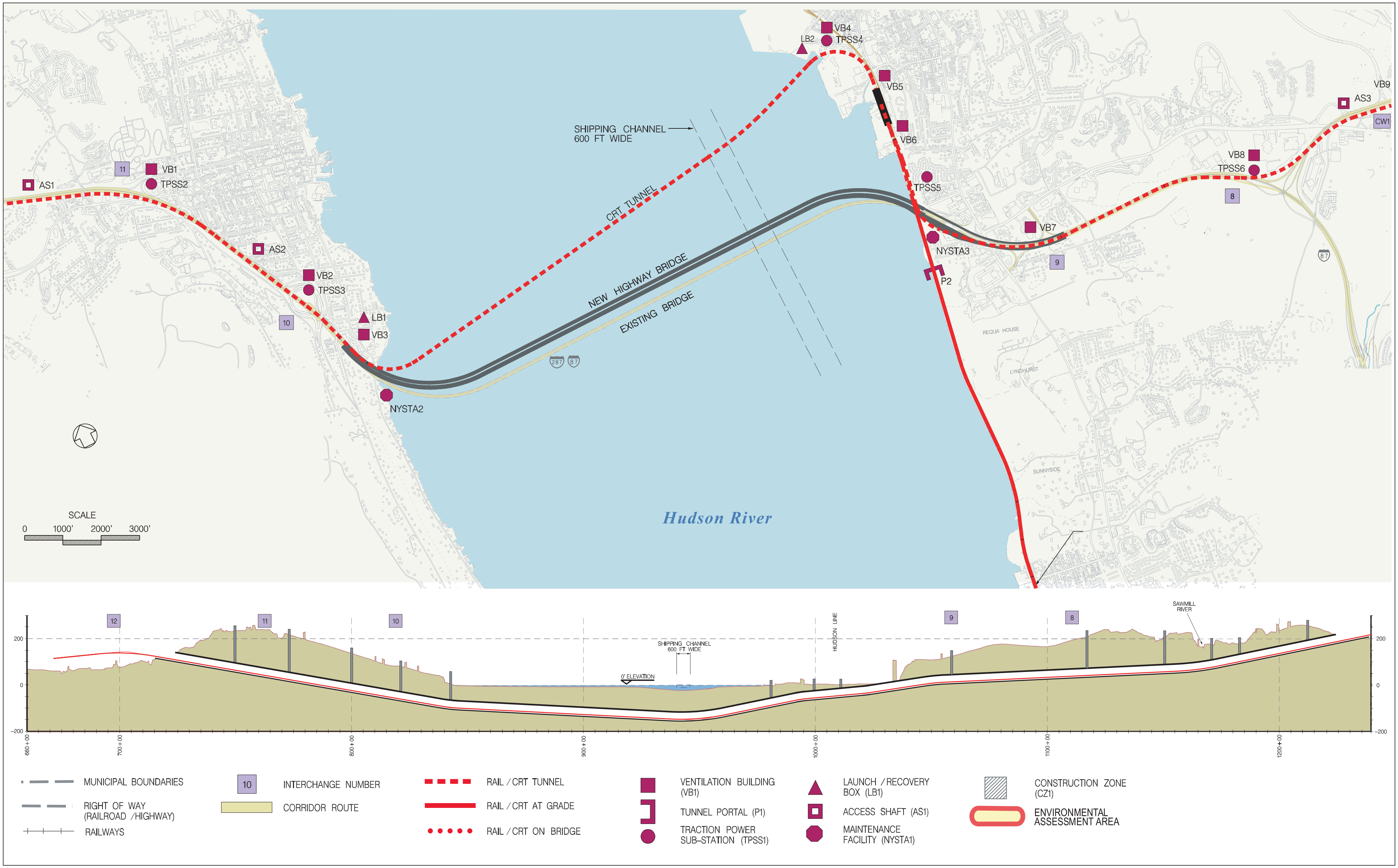
7.5.2.2 Preferred CRT Tunnel Alignment

Alignment options 2, 2A, and 3 would provide a more integrated CRT system and better connections to other transit modes than Alignments 1 or 1A. Both Alignments 2A and 3 would require tunneling under Nyack outside the Thruway right-of-way, which would entail easements and greater construction impacts and risk. A station in Nyack would not be warranted due to the proximity of the Palisades Mall Station, and would be at an undesirable depth. Overall, Alignment 2 provides equal system integration with less risk and impact, making it the preferred alignment.

Figure 7-17 presents the Tunnel Option Alignment and corresponding profile. The alignment of the Rockland shoulder tunnel and its basic cross sections would be the same as previously described for the Bridge Option, with the exception that the tunnel would arrive at the Rockland shoreline at a much lower elevation.

The tunnel alignment would reach the Westchester shore north of the existing Tarrytown Station in the area of Horan's Landing Park and the proposed Ferry Landing development, and curve southward to reach a new lower station level adjacent to the existing Tarrytown Station. The new platform would be constructed 60 feet underground to the west of the existing platforms. For access and station facilities, a new mezzanine level would be introduced between the surface and underground platforms.

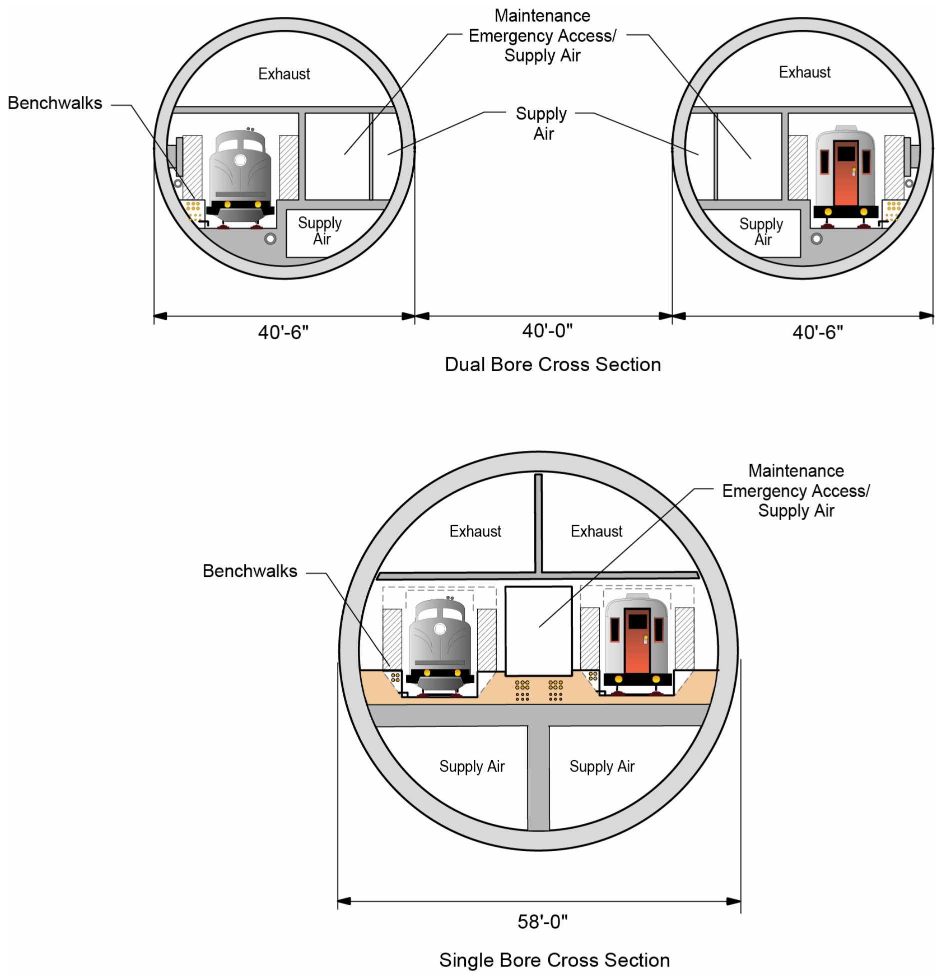
From the lower level of the expanded Tarrytown Station, the new tracks would continue south below the Hudson Line, rising to merge with it between the new bridge and Irvington Station. The cross-Westchester



Tunnel Option - Plan and Profile

Figure 7 - 17

line would split off and curve eastward near the new bridge and continue east across Westchester under the Thruway right-of-way.



River Tunnel – Single and Twin-Bore Cross-Sections

Figure 7-18

7.5.2.3 Tunnel Cross Section

A number of tunnel cross sections that provide sufficient space to meet all requirements were evaluated against the design criteria. Two cross sections were developed in detail: a twin-bore solution with tunnels of 40 feet 6 inches outer diameter and a single-bore cross section with an outer diameter of 58 feet (Figure 7-18). Though 40-foot diameter bores have not been constructed in the New York area, they are relatively common internationally and costs can be accurately estimated. The single-bore solution is not recommended at this stage, as the largest bore constructed internationally is 46 feet. While recent orders have been placed with TBM manufacturers for diameters up to 54 feet for projects in China; this is not proven technology, however, and is less than the 58 feet required for a single-bore tunnel. Spatial requirements for the river tunnel included:

- **Track Clearance Envelope.** The trainway was sized and clearances provided to allow for a basic envelope 18 feet wide and 17 feet 9 inches high, which included separate emergency and maintenance benchwalks and dynamic clearances.

- **Combined Emergency/Maintenance Way.** A 10-foot-wide vehicular road was provided for a maintenance way that also functions as an emergency way for passengers.

- **Support and Safety Systems.** Space was allocated to power, communications, signal, drainage, and other systems within the overall circular section.

- **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 (located on each shore), heat release and fire load, and the nature of contaminants (carbon monoxide, nitrogen oxides, and exhaust from diesel locomotives).

Given the large size of the tunnel sections, additional study was conducted to review ways in which the section size might be reduced. This primarily focused on reducing the space necessary for ventilation as the space for track clearance, support and safety systems and the emergency/maintenance way were less flexible. Study included potential reduction in diesel emissions, increase in headways and the feasibility of electrification of the west of Hudson Lines. The results of these studies are summarized in the following subsections but collectively indicate that only the dual-bore tunnel cross-section shown in Figure 7-18 could be marginally reduced in size.

Diesel Emissions

In the tunnel cross-section (Figure 7-18), ventilation flow rates and duct sizes reflect existing Metro-North stock and US Environmental Protection Agency (USEPA) Tier 0 emissions, with specific allowable pollutant emission rates for nitrogen oxides (NO_x), particulate matter, and other toxic gases. With the introduction of ever stricter USEPA air quality standards, all newly manufactured locomotives are required to comply with Tier 2 emissions by 2005, and Tier 4 by 2014. Current Metro-North diesel engines meet the Tier 0 standards.

If USEPA Tier 2 emission standards were adopted, the required ventilation flow rate and tunnel duct sizes would be reduced by approximately 50 percent below the requirements for Tier 0 emissions. This would result in a reduced tunnel cross-section for the twin bore tunnel option – with bores of 36-feet diameter compared to the 40-feet proposed. The diameter of a single-bore alternative would be unchanged as the cross-section is dictated by lateral spacing of the tracks and the maintenance/emergency way and not by the ventilation requirements. The adoption of Tier 2 emission standards would have implications for Metro-North rolling stock.

If USEPA Tier 4 emission standards were adopted, the spatial requirements for the ventilation system in the tunnel would fall below those of the design fire. The resulting tunnel cross-section would be slightly smaller than that of the Tier 2 emission requirements.

In summary, lower diesel emissions standards (Tier 2 or Tier 4) would not significantly change the river crossing tunnel size requirements. The twin bore arrangement would still be the preferred section but with slightly smaller diameter and cost.

Crossing Headways

To avoid delay to trains in the tunnel, the ventilation ducts in the above cross-sections are designed to allow full venting of the tunnel in a maximum of 4.5 minutes, or about the average headway between trains (3 to 6 minutes), as required in the operational criteria. (See *Alternatives Analysis for Commuter Rail Hudson River Crossing* [NYTA/Metro-North, September 26, 2005]) for details of operational criteria.

If this period were increased, by delaying entry into the tunnels for those trains following a train operating in diesel mode, a reduction in the ducting requirements within the tunnel section would result. For the single bore, this reduction would not change the overall diameter of the tunnel cross-section as this is dictated by the width required for the tracks and the maintenance/emergency way and not by the ventilation requirements. For the twin-bore Tunnel Option, this would result in a reduced tunnel cross-section, similar to that for the above mentioned diesel emission, but the reduction would be limited by the ventilation requirements for the design fire events associated with diesel commuter and freight trains - two bores of 36-feet diameter compared to the 40-feet proposed would be required.

In summary, an increase in the time allowed for tunnel ventilation would not significantly change the river crossing tunnel size requirements. The twin-bore arrangement would still be the preferred section but with slightly smaller diameter and cost.

Electrification of West of Hudson Lines

A possible alternative to alleviate diesel ventilation requirements would be electrification of any Metro-North lines that would use the tunnel. While analyses (as presented above) showed the diesel ventilation requirements were not the only driving force in determining tunnel size, it is useful to review the implications of the electrification of west of Hudson Lines.

Electrification would include the Port Jervis Line west of Suffern (electrification east of Suffern was assumed in this paper), the Pascack Valley Line (if a direct connection were to be made), and potentially New Jersey Transit lines that could run north in the future and connect with the cross-Rockland Line leading to the tunnel. An electrification program would include installation of third rail or catenary, construction of substations, breaker houses, and power distribution elements. These modifications are not included in any long-term capital program or any long-range planning horizon and have not been studied by Metro-North.

The primary considerations that preclude electrification on the west of Hudson Lines are:

- An undetermined number of property partial takings and displacements that would result in extensive capital expenditures and community impacts.

- The Operating Agreement with Norfolk Southern Railroad, the owner of the ROW, requires that lateral clearance from center of track to high level platform edge be at least 7 feet 6 inches whereas the Metro-North standard for high level platform clearance is 5 feet 7 inches, resulting in an unacceptable 23-inch gap between platform edge and door thresholds. (The Americans with Disabilities Act requires a gap of 3 inches or less.) Construction of low level platforms with third rail raises safety issues in terms of proximity to passenger access and presents unacceptable operating, equipment, and staffing impacts associated with using high platform rolling stock on low platform stations. The construction of an additional freight-only track at all stations to mitigate the above problem would require property displacements, be extremely costly, and greatly add to the complexity of train operations on the lines.

- Electrification of yards would be required and the Port Jervis Yard is in a floodplain with the associated dangers of flooding in an electrified yard.

- The alternative of catenary lines instead of third rail would involve major construction of catenary support structures as well as several large substations resulting in greater visual impacts in a suburban/exurban environment. The Norfolk Southern Railroad Operating Agreement requires a minimum height of 23 feet above top of rail whereas Metro-North would require a catenary power line no higher than 18 to 19 feet over top of rail, violating the Norfolk Southern operating requirement on the Port Jervis ROW.

Similar to the results for modifications to diesel emissions and headway, electrification of the lines west of Hudson would only marginally reduce the size of the tunnels in the dual-bore tunnel section, but would incur partial takings and conflict with Operation Agreements and flood plain or freight clearance requirements.

7.5.2.4 Support Facilities

Permanent support facilities are required at 19 locations for the Tunnel Option in the crossing area. Each facility has a number of functional requirements including TPSSs, vent buildings, etc. The total surface area of all facilities in the crossing area would be approximately 260,000 sq ft, including 11 ventilation buildings, eight TPSSs, and five access shafts. Some facilities would be combined, and some would be within underground CRT stations. Notable facilities that are required in the Tunnel Option but not the Bridge Option include two 40,000 sq ft ventilation buildings located at the shores to serve the under-river tunnels. These would likely be located as close as possible to each shoreline. Preliminary assessment indicates that these buildings would incorporate vent stacks rising up to 100 feet above ground.

Temporary support facilities during construction would include temporary platforms in the Hudson River at 3-4 locations with a total area of 13.5 acres. Two of these temporary locations would be located adjacent to each shore and would include launch boxes for the installation of the tunnel boring machines (TBM) plus staging, storage and transshipment facilities for the removal of the tunnel waste material (spoil).

7.5.3 Comparison of CRT Bridge and Tunnel Options

This subchapter presents an outline of the transportation benefits to be gained by both the Bridge and dual-bore Tunnel Options, followed by the key environmental, engineering, security, and cost implications of each.

7.5.3.1 Transportation Performance

The introduction of CRT across the Hudson River would improve mobility for the markets served by the corridor. This overall transportation benefit would be realized equally by the Bridge and Tunnel Options. While both options would provide the necessary direct (one-seat) connections for the major markets across the corridor and to New York City, and would accommodate transfers to and from minor markets, they differ in how they would accomplish this.

The key difference would be the development of a new Tappan Zee Station in the Bridge Option vs. the expansion of the existing Tarrytown Station in the Tunnel Option. Both options would significantly reduce the number of Rockland commuters driving across the river to use the Tarrytown Station or to continue across the corridor or to New York City, and the total ridership using the stations would be roughly equal. However, the patterns of usage and resulting benefits would be different. The Tappan Zee Station would supplement the existing Tarrytown Station and provide an additional access point to rail service across the corridor and south via the Hudson Line, while also diverting some traffic from the existing station reducing the associated congestion. On the other hand, the expanded Tarrytown Station would serve all trips at a single station.

Full Corridor CRT

The key transportation benefits from a new Tappan Zee Station in the Bridge Option would be as follows:

- The new Tappan Zee Station would attract more Tarrytown area riders than the expanded Tarrytown Station (425 more area riders in the AM peak period) because of its location on Broadway, the provision of additional parking, and express service to Grand Central Terminal.

- The new Tappan Zee Station would provide an alternative station for riders from the south and east, diverting approximately 400 riders from the Tarrytown Station in peak periods. As parking at the existing Tarrytown Station is currently saturated, this would free up parking for Westchester commuters and reduce the number of kiss and ride trips. The reduction in extra vehicle trips, the diversion of traffic away from the area of the existing Tarrytown Station, and the improved circulation patterns in downtown Tarrytown associated with a new Tappan Zee Station would reduce traffic congestion in Tarrytown overall.

The key transportation benefit of the expanded Tarrytown Station in the Tunnel Option is that it would provide a direct transfer between the Upper Hudson Line and the Cross-Corridor (east-west) CRT Line, generating up to 400 more transfers compared to the Tappan Zee Station in the Bridge Option. In the Bridge Option this transfer would rely on bus services between the existing Tarrytown Station and the new Tappan Zee Station.

Overall, the Bridge Option provides significant transportation benefits to the Tarrytown area, whereas the Tunnel Option provides a lesser degree of benefit to riders in small markets along the Upper Hudson Line with a more direct connection. Considering the constrained local traffic network and parking capacity around the existing Tarrytown Station and downtown traffic concerns, the diversion of riders to the Tappan Zee Station would provide greater benefit than would the more convenient small market transfers, making the Bridge Option preferable if a full-corridor CRT alternative is selected.

Cross-Westchester LRT or BRT

Both the Bridge and Tunnel Options would accommodate Rockland CRT to Cross-Westchester LRT or BRT transfers, but the transfer configurations would be notably different. LRT and BRT would serve both the Tarrytown Station and the Tappan Zee Station in the Bridge Option. The Tappan Zee Station would provide a very convenient cross-platform transfer between Rockland CRT and Cross-Westchester LRT or BRT, taking less than 1 minute. The equivalent transfers at the expanded Tarrytown Station in the Tunnel Option would be much less convenient. Rockland riders would have to transfer from the new lower level of the expanded Tarrytown Station to Cross-Westchester LRT or BRT at street level to the east of the Hudson Line, taking up to 5 minutes. Because of the more convenient configuration at the Tappan Zee Station, the Bridge Option would attract more such transfers than the Tunnel Option (380 more transfers in the AM peak period with LRT) and greater ridership overall (420 more riders in the AM peak period with LRT).

The greater ridership and larger number of transfers would again make the Bridge Option preferable if a Cross-Westchester LRT or BRT alternative is selected.

7.5.3.2 Environmental Impacts

Both the Bridge and Tunnel Options would have environmental impacts, with those associated with the Tunnel Option being somewhat greater. The more notable environmental impacts of both options would include property impacts, impacts on visual resources, aquatic habitat impacts, and construction impacts.

Property Impacts

The Bridge and Tunnel Options have different, but significant, potential property impacts. Under the Tunnel Option, potential property impacts would include:

- Residential displacements within Ferry Landing (4 acres, including 15 to 20 units).
- Displacement of the Castle Oil terminal, asphalt plant, and other commercial properties in Westchester.
- An easement under Horan's Landing Park.
- Relocation of the currently unused Lyndhurst pedestrian bridge over the Hudson Line tracks.
- Fewer than five residential displacements and fewer than five residential partial takings near the Rockland shore.

Under the Bridge Option, the dual-level and single-level bridge options would have the same potential impacts (as each other) in Westchester, but different impacts near the Rockland Shore. Potential property impacts would include:

- Potential temporary or permanent partial takings or relocation of the shopping center in Tarrytown at the intersection of Broadway and Route 119, depending on the configuration of the Tappan Zee Station.
- Partial takings at the Requa House property adjacent to the river.
- Relocation of the currently unused Lyndhurst pedestrian bridge over the Hudson Line tracks.
- Fewer than five partial residential takings and one commercial taking in Westchester beyond those associated with the shopping center.

- For Rockland, the single level bridge results in fewer than 15 residential displacements and fewer than 15 partial residential takings. The dual level bridge is the same as the tunnel except for a piece of Elizabeth Park.

For the dual-level Bridge Option there would be fewer residential property displacements and more partial takings than for the Tunnel Option. For the single-level bridge, there would be an increase versus the tunnel in the number of partial takings and displacements. The potential displacements within the Ferry Landing development in the Tunnel Option would likely be the most significant and disruptive property impact. Overall, the property impacts of the Tunnel Option are more significant and disruptive than those of the dual-level Bridge Option, and are similar in magnitude and disruption to those of the single-level Bridge Option.

Visual Impacts

Visual impacts would include:

- For distant viewers, the appearance of a new bridge would be substantially the same in all options. The most notable features would be the new, modern-appearing bridge towers and sleeker deck structure of the main spans compared with the deep and busy truss work of the existing main spans. Because there would be fewer piers in the river, there would be a more open appearance to the approach structures.

- Rail commuters on the bridge would have views of the river. Commuters in the Tunnel Option would not experience river views and instead would be in tunnel for up to 10 miles.

- Visual impacts of a new highway-only bridge crossing would be most significant in the near-field view from Rockland shoreline areas, due to the wider, deeper, and somewhat higher structure.

- Addition of CRT to the bridge in a single-level configuration would increase the Rockland side near-field visual change incrementally by increasing the width of the bridge over that of a highway-only bridge.

- Addition of CRT in a dual-level bridge would further increase the Rockland side visual change by increasing both the depth of the structure and the height of the bridge over that of a highway-only bridge.

- The Tappan Zee Station would alter the visual setting in the vicinity of the toll plaza.

- The ventilation building and stack on the Rockland shore and the ventilation stacks on the Westchester shore would be new and intrusive features in the Tunnel Option, affecting residences in South Nyack, Ferry Landing, and Ichabod's Landing as well as users of Horan's Landing Park.

Overall, the single-level bridge has fewer visual impacts than the dual-level bridge or the Tunnel Option. For distant viewers, the appearance of a new bridge in any option would likely be more attractive than the existing bridge, which would be a positive impact. The dual-level bridge has greater near-field visual impacts on the Rockland side than either the single-level bridge or the Tunnel Option, but the Tunnel Option has greater overall near-view visual impact due to the vent stacks on both shores.

Aquatic Habitat Impacts

Ecosystem and water resource impacts are categorized as temporary or permanent. Temporary impacts are disturbances of the river bottom or shoreline that would be restored by natural means or active on-site restoration measures. Permanent impacts are irreversible disturbances to river bottom or shoreline that must be offset by implementation of either near-site or off-site mitigation measures.

Permanent impacts to the river bottom in both the Bridge and Tunnel Options are measured by the area of bridge foundation pile caps and the area of riprap along the Westchester shoreline extended into the river to accommodate the Hudson Line CRT connection. For the Tunnel Option, additional permanent impacts are measured by the area of the TBM launch and recovery boxes that would be constructed near the Rockland and Westchester shorelines, which would permanently house ventilation plants. Temporary ecosystem impacts would also occur during construction of both the Bridge and Tunnel Options, caused by temporary platforms that would be constructed along both shorelines to handle incoming equipment and material and outgoing spoils. These platforms would be located along the shoreline at either end of the new bridge.

In the Hudson River, the Bridge and Tunnel Options would have comparable permanent impacts to aquatic habitat. The Tunnel Option would have greater temporary impacts to aquatic habitat due to longer duration of construction from temporary river platforms.

Construction Impacts

Construction impacts are much more significant for the Tunnel Option than the Bridge Option as follows:

- All construction impacts for the tunnel are in addition to those associated with construction of a highway-only bridge (i.e., the Tunnel Option incorporates a highway bridge and a CRT tunnel).
- Removal and processing of 1.5 million cubic yards of spoil materials, transport of the spoils off site by truck and barge, and need for a continuously available disposal site(s).
- Severe impact of duration and scale of construction in and around the Ferry Landing development.
- Construction of launch boxes for the tunnel boring machines.
- Construction of ventilation facilities on each shore.
- Duration of work on temporary platforms along the shoreline of up to 6 years for tunnel construction as opposed to up 4 years for Bridge Construction.

While there are potential location and volume of traffic impacts in the vicinity of the Tappan Zee Station in the Bridge Option, the construction impacts of the Tunnel Option are much more significant overall.

7.5.3.3 Engineering and Security

In considering engineering criteria, the objective was to assess the implications to the crossing structure and its users under key accidental but natural event (major storm or earthquake) scenarios. In considering security criteria, the objective was to assess the implications to the crossing structure and its users under malicious event scenarios. Three engineering criteria were evaluated for each option: fire/life safety, emergency response, and redundancy. Operation of the crossing in emergency conditions was evaluated, as determined from provisions included in the engineering concept design.

Though both the Bridge and Tunnel Options would be designed to meet all code requirements and to provide sufficiently strong and safe crossings, analysis of the engineering and security criteria for both highway and transit resulted in a clear preference for the Bridge Option, particularly the single-level bridge. The bridge scored well in these criteria because of its inherent characteristics:

- Limitation of event consequences, such that any event would only affect a small part of the overall crossing (both single-level and dual-level bridges). This would be a major differentiator compared to the Tunnel Option where some event scenarios could result in damage to the complete crossing (e.g., flooding).

- Multiple access points for emergency responders (both single-level and dual-level bridges). Emergency responders would use the highway lanes to access emergency CRT events rapidly with standard emergency vehicles. In the Tunnel Option, access would be on foot for first responders and it would take considerably longer to reach incident locations.

- Multiple egress paths (both single-level and dual-level bridges). The bridge section incorporates sufficient space on both sides of both CRT tracks to allow passengers to egress a train in an emergency event through all doors with egress to a place of safety possible for most passengers in 10 to 20 minutes. For the Tunnel Option, egress to a place of safety would only be possible through one side of the train with subsequent funneling of passengers along benchwalks, resulting in longer egress times than the Bridge Option. Egress time for most passengers to a place of safety would be 30 to 45 minutes or 60 to 90 minutes to the surface.

- Open framework. The open nature of the Bridge Option (both single-level and dual-level bridges) would allow for natural dissipation of smoke without the need for a ventilation system on the crossing. A major ventilation system with supporting monitoring, management, and maintenance systems would be required for the Tunnel Option. Extensive training and specialist personnel would also be required to operate these systems to ensure optimum performance in event scenarios.

- All incidents on the bridge would be essentially visible. One of the keys to emergency response is the correct identification of an incident location and magnitude. This would be inherent in the Bridge Option (both single-level and dual-level bridges) but would depend on cameras and other detection equipment in the Tunnel Option that would be subject to malfunction and misinterpretation.

- A single river crossing (both single-level and dual-level bridges). It would be easier and more efficient to provide security for a single facility than for the multiple facilities including key vent buildings required in the Tunnel Option.

- Separation between the superstructure elements supporting the highway and CRT on the single-level bridge. Consequently, should any emergency event occur in any one mode, the other would only be minimally affected. This separation would also be available in the Tunnel Option.

7.5.3.4 Cost

As the bulk of the shoulder tunnels in both Rockland and Westchester Counties are essentially the same in both the Bridge and Tunnel Options, the scope of the cost estimates was limited to the river crossing and those associated landside segments of the project that are different in the two options. These segments include:

- Interchange 10 to the waterfront in Rockland.
- In Westchester, the waterfront to Interchange 9.
- The Hudson Line connection tunnel.
- The expanded Tarrytown Station in the Tunnel Option and the new Tappan Zee Station in the Bridge Option.

The dual-level CRT bridge was estimated for the Bridge Option. While preliminary engineering for the single-level CRT bridge was not advanced sufficiently for a detailed cost work-up, it is estimated to be on the order of 10 percent more costly than a dual-level CRT bridge. The total estimated cost of each option, including soft costs and contingency, is shown in Table 7-4.

Table 7-4

CRT Crossing Capital Cost Summary

Component	Bridge Option	Tunnel Option	Cost Differential
Highway-Only Bridge	$3.0 billion	$3.0 billion	-
Incremental Cost of Adding CRT to Highway Bridge or Constructing a CRT Tunnel	$4.0 billion	$5.3 billion	$1.3 billion
Total Cost of Option	$7.0 billion	$8.3 billion	$1.3 billion
Note: All costs are in 2004 dollars. Bridge Option cost is for a dual-level bridge. The incremental cost of a single-level bridge would be 10 percent higher than a dual level bridge.			

The preliminary cost estimates for the dual level Bridge and Tunnel Options are $7.0 billion and $8.3 billion respectively, including contingency and soft costs. The Tunnel Option is $1.3 billion (20 percent) more expensive than the dual level Bridge Option and would be considered the greater risk because of the extensive works through the soft ground beneath the Hudson River and along the Westchester shore.

7.5.4 CRT Crossing Summary

The Bridge Option has identifiable advantages over the Tunnel Option in the areas of:

- Local traffic improvements in Tarrytown.
- Lower cost.
- Lower construction risks.
- Fewer environmental impacts, including property displacements.
- Lesser construction impacts.
- Better security.

The only notable benefit of the Tunnel Option would be the greater ease of transfers at the expanded Tarrytown Station to/from minor markets such as the Upper Hudson to the Cross-Corridor (east-west) Line in a full-corridor CRT alternative. Transfers from these markets to LRT or BRT are equal or better in the Bridge Option.

For these reasons, the Tunnel Option was eliminated from further consideration in the DEIS stage and a combined transit/highway bridge will be advanced to the DEIS. A preference for either the single-level or dual-level bridge will be addressed in the DEIS stage.

7.6 Conclusions

Study of the river crossings considered four options: preservation, rehabilitation, new highway crossing, and new CRT crossing. A new crossing that included BRT was discussed in Chapter 5 as part of the highway scenarios, while a new LRT crossing was omitted as recommended in Chapter 6. Comparative study of the rehabilitation and new crossing options was not included but deferred to the DEIS stage. The following were the key conclusions and recommendations:

- The Tappan Zee Bridge was found to be safe for general traffic loading but with major maintenance requirements, significant vulnerabilities, and undesirable traffic conditions. The cost to repair immediate defects and replace a substantial portion of the deck concrete in the near future was estimated at approximately $500 million.

- Based on the rate of deterioration and scale of expenditure, preservation of the bridge would eventually lead to full rehabilitation over the course of 20 to 30 years or more given that major repair contracts were reactive to biennial inspections. This strategy was not considered a preferable strategy given the potential for renewed deterioration cycles and incompatibility with traffic volumes.

- Rehabilitation of the Tappan Zee Bridge was considered to be feasible but with notable challenges particular for seismic retrofits. The rehabilitation option for the Tappan Zee Bridge offered an early and single period of repair and upgrades, avoided overlapping of deterioration cycles, and could be implemented while reasonable time was available for construction between peak traffic periods and at night. The cost to rehabilitate the bridge was estimated at $1.5 to 2.0 billion.

- The use of a rehabilitated bridge as a linear park and parkway was not recommended for inclusion in the DEIS because pedestrians and cyclists could be accommodated on a replacement bridge, the concept did not significantly improve mobility, and there were associated high costs.

- A replacement bridge option was recommended for any new highway crossing. Based on greater adverse impacts on transportation operations, extensive long-term construction and construction period environmental impacts, greater construction complexity, and considerably higher capital costs, the highway tunnel was not a viable option to replace the existing Tappan Zee Bridge. Therefore, only the Highway Bridge Option will be advanced to the DEIS.

- A replacement bridge was also recommended for any new CRT crossing. This option had identifiable advantages over the tunnel option in the areas of local traffic improvements in Tarrytown, lower cost, lower construction risks, fewer environmental impacts, including property displacements, lesser construction impacts, fewer and less intrusive support facilities, and better security.

- Preference for a single- or dual-level bridge was not determined but was deferred to the DEIS stage.