December 19, 2008

Hampton Roads Bridge-Tunnel

Expansion Feasibility Study

Final Report

With Tunnel and Bridge Information Provided by
PB Americas and Moffatt and Nichol

Prepared by:
JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future®

Hampton Roads Bridge-Tunnel Expansion Feasibility Study

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EXECUTIVE SUMMARY

The Virginia Department of Transportation (the Department) identified six potential alternatives for consideration in order to mitigate the recurring congestion at the Hampton Roads Bridge-Tunnel (HRBT). The Department contracted with a team of engineering consultants which included Johnson, Mirmiran and Thompson, PB Americas and Moffatt & Nichol. This team was assigned to study and assess each of the six alternatives relative to the capability of managing congestion at the HRBT and present the findings in a facility expansion feasibility study. The goal of this study was to review the six identified alternatives, develop concept-level drawings, construction cost estimates and estimates of right-of-way impacts for each alternative, develop estimates of congestion-reduction benefits of the alternatives through traffic analysis and provide policy-level guidance on the feasibility and long-term benefits of the alternatives.

The study area is generally described as the portion of I-64 stretching from I-64/I-664 Interchange in the City of Hampton on the Peninsula to the I-64/I-564 Interchange in the City of Norfolk on the Southside.

The six study alternatives are defined as follows:

Alternative 1: Add two additional lanes of bridge-tunnel capacity to provide a contiguous, six-lane facility; approximate corridor limits are from Settlers Landing Road Interchange to I-64/I-564 Interchange;

Alternative 2: Add two additional lanes of reversible bridge-tunnel capacity to provide greater peak period and evacuation capacity; approximate corridor limits are from I-64/I-664 Interchange to I-64/I-564 Interchange;

Alternative 3: Add four additional lanes of bridge-tunnel capacity; approximate corridor limits are from I-64/I-664 Interchange to I-64/I-564 Interchange;

Alternative 4: Add four additional lanes of bridge-tunnel capacity, including two multimodal lanes; approximate corridor limits are from I-64/I-664 Interchange to I-64/I-564 Interchange;

Alternative 5: Add two additional lanes of bridge capacity to provide a contiguous, six-lane facility; approximate corridor limits are from I-64/I-664 Interchange to I-64/I-564 Interchange;

Alternative 6: Add four additional lanes of bridge capacity; approximate corridor limits are from I-64/I-664 Interchange to I-64/I-564 Interchange.

The following table summarizes the results of this study:

Alt. No.	Traffic Analysis (LOS)								R/W Impacts		Constr. Cost
	w/o Third Crossing				w/ Third Crossing						
	2018		2030		2018		2030				
	EB	WB	EB	WB	EB	WB	EB	WB	Impacted Buildings (#)	Impacted Sound Wall (LF)	in Billions
No Build	F (F)	F (F)	F (F)	F (F)	D (E)	C (E)	D (E)	C (F)	0	0	$0.0
1	D/D (C/D)*	C/D (C/D)*	F/E (F/E)*	C/E (F/E)*	D/D (C/D)*	C/D (C/D)*	D/D (C/D)*	C/D (C/D)*	50-75	7,400	$2.13
2	B (F)	F (B)	C (F)	F (B)	B (F)	F (B)	B (F)	F (B)	70-105	7,400	$2.25
3	C (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	70-105	7,400	$3.24
4	C/A (C/A)**	B/A (C/A)**	C/A (C/A)**	C/A (C/A)**	C/A (B/A)**	B/A (C/A)**	C/A (C/A)**	C/A (C/A)**	70-105	7,400	$3.27
5	As noted in the report, Alternative 5 is dismissed due to adverse structural design characteristics										
6	C (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	70-105	7,400	$3.14

* Denotes two lanes one direction / two lanes two direction
** Denotes three General Purpose lanes / One HOV lane

- Denotes LOS over capacity for either AM or (PM) peak. Does not meet FHWA LOS requirement for Interstate facilities
- Denotes LOS at or near capacity for AM or (PM) peak. Does not meet FHWA LOS requirement for Interstate facilities
- Denotes AM and (PM) peak LOS meeting minimum FHWA LOS requirements for Interstate facilities.
- Denotes Alternatives recommended to be eliminated from further consideration.

Alternative 1 is recommended for elimination from further study due to the fact that safety concerns with the two-way traffic sections along the bridge-tunnel facility cannot be adequately mitigated. The no build alternative and Alternative 2 are recommended for elimination from further study due to the fact that their implementation would not meet the FHWA minimum LOS requirements for Interstate facilities.

Introduction

On June 27, 2008, Johnson, Mirmiran & Thompson (JMT) was engaged by the Virginia Department of Transportation (VDOT) through an "On-Call" Contract to perform an independent feasibility study of six (6) proposed alternatives to increase capacity at the I-64 Hampton Roads Bridge-Tunnel facility. PB Americas and Moffatt and Nichol assisted JMT with the study of the tunnel and bridge portions respectively. This study outlines our findings of the potential issues and benefits of each alternative. The study area is defined as Interstate 64 between the interchanges with Interstate 664 on the Peninsula and Interstate 564 on the Southside.

Each alternative was developed using aerial mapping provided by VDOT. Each plan shows the alternative as identified in the scope of work provided by VDOT. Each alternative was developed on the plans using current VDOT Road and Bridge Design Standards. Where design standards may not be met (such as horizontal curves), this report summarizes these areas for each alternative. Impacts to the existing right-of-way limits and existing sound walls were also analyzed. These impacts are quantified based on potential impacts to buildings and linear feet of sound walls.

It is to be noted that no vertical control was provided or developed for the conceptual layouts. Impacts to side slopes, retaining walls and other roadside features are assumed based on engineering experience and "worst case" scenarios.

Traffic analyses were conducted on the bridge-tunnel segment of the study area only for each alternative and do not represent regional modeling. During the course of the study, it was determined that the focus of the traffic analysis should center on the bridge-tunnel facility as it is the controlling factor of traffic flow in the study area. Existing traffic data and travel demand forecasts were provided by VDOT. Analyses were performed on this data including Short Term Year 2018 and Long Term Year 2030 conditions both with and without the proposed Hampton Roads 3rd crossing in place. Appendix A provides further documentation on the development of the traffic volumes used in the analyses. Each alternative shows the respective Level of Service (LOS) results for the AM (PM) peak hours for an average weekday.

Additional issues and observations associated with each alternative are identified and discussed. Finally, a general construction cost estimate and implementation schedule have been developed for each alternative. The construction cost estimates shown for the roadway are based on lane miles. The bridge estimates are based on the square foot of bridge and does not include cost for any special design or considerations that may be required by the Navy. The tunnel estimates are based on a combination of square foot of bridge for the trestle, rough quantities for the immersed tube tunnel, and cut and cover for the tunnel and islands. Also included is the cost for the ventilation buildings which is based on square foot of building. The construction estimates do not include the cost of design, right-of-way acquisition, environmental assessments, environmental mitigation measures or utility relocations or adjustments. The implementation schedule for each alternative is a general estimate of construction time after engineering design is complete.

VDOT conducted Citizen Information Meetings on December 3, 2008 in Hampton and on December 10, 2008 in Norfolk, where the findings of the draft version of this study were presented. This final report incorporates the applicable comments received from those meetings.

ALTERNATIVE 1

General Alternative Information:

This alternative would provide two additional lanes of bridge-tunnel capacity to provide a contiguous, six-lane facility connecting the Peninsula and Southside. It was assumed that no additional through lanes will be added to the existing six-lane sections in the study area, which includes the segment between I-664 and Settler's Landing Road (MP 255).

The existing eastbound tunnel would be converted to accommodate two-way traffic. The bridge sections before and after the existing eastbound tunnel would need to be widened approximately 8' in order to provide full 12' shoulders. However, the existing eastbound tunnel would remain unchanged since it is not feasible to widen existing tunnels. The existing westbound bridge-tunnel facility would remain unchanged. A new facility would be constructed for eastbound traffic.

The existing Willoughby Bay bridge will be widened to the outside on each side. This bridge widening will have impacts to both the landside of the bay and the Willoughby Spit Marina areas.

The conceptual layout and roadway typical section for Alternative 1 is shown on Plan Sheet Nos. 1(1) thru 1(7). Typical sections for the tunnels are shown on Plan Sheet No. 1(8).

Structural:

Tunnels

The proposed location for the addition of a new tunnel crossing has been set at 250 feet from the existing eastbound tunnel. This approximately matches the distance used between the existing eastbound and westbound tunnels. This allows the excavation for and the placement of the proposed tunnel to proceed without impacting the existing tunnels. This also provides flexibility in the future should the existing tubes be replaced with wider sections similar to the ones proposed in this study. Further reduction of the distance between the new and the existing eastbound tunnels would require complex numerical analyses for estimating the magnitude and distribution of ground deformations, due to the dredging and excavation, as well as detailed structural analysis for evaluating the impacts of the ground deformations to the existing structures. This is particularly important in the south island area as soft and compressible soils are present and large ground deformations are prone to occur during and after construction.

While it may be possible to place a two-lane tunnel between the existing tunnels, it is likely that this would disturb the existing tunnels. Even if this could be done, it does not allow for future replacement of the existing tunnels without complications. Utilizing a tunnel boring machine to add a tunnel is not likely a practical solution as the soils in this region are not conducive to boring due to the looseness of the upper layers. If tunnel boring were utilized the tunnel would need to be lower than the existing tunnels to provide adequate cover over the new tunnel. This increased depth would result in a significantly longer tunnel. Given those considerations it is recommended that the new tunnel be placed as shown in the proposed alignments.

The proposed bridge-tunnel segment consists of the following:

- Existing islands will be expanded to accommodate the addition of the proposed tunnel.
- Expansion of south island will require ground treatment using surcharge and wick drains to avoid excessive settlement.
- Tunnel length will match the existing at approximately 7500 feet portal to portal.
- Rectangular concrete immersed tubes will be utilized.
- It is assumed that the top elevation of the new tunnel matches that of the existing eastbound tunnel.
- Backfill and stone blanket over tunnel will be 5 feet thick to match existing tunnel.
- Cast-in-place concrete boat sections will tie the tunnel to the trestle.
- Each traffic cell in the tunnel consists of 2 traffic lanes, each 12 feet in width.
- Shy distance (offset from travel lane) to the barriers is 2 feet each side.
- Roadway vertical clearance is 16.5 feet, with a 1.5 foot allowance for roadway signage.
- Tide gates will be required.
- Base slab, walls and roof to be waterproofed.
- Ancillary facilities consisting of a ventilation building and stormwater pump station at both ends of the tunnel that house mechanical and electrical systems.
- Mechanical Systems will include tunnel drainage, portal drainage, semi-transverse tunnel ventilation and fire suppression.
- Electrical Systems will include tunnel power, tunnel lighting and tunnel control and communication.
- Approach trestles similar to the existing bridges consist of precast beams on pile bents and are approximately 3300 feet in length on the north end and 6000 feet in length on the south end.
- Emergency egress is provided by a separate corridor separated from the traffic lanes by a firewall and fire-rated doors.

See Appendix B for additional general construction information with regards to tunnel alternatives.

Bridges

The bridges west of Settler's Landing Road on the Peninsula are already wide enough for this alternative. Starting at Settler's Landing Road and going south, all of the structures will need to be widened by one lane on each side of the median. Most of the standard grade separation structures (bridge over roads) can be widened to the inside. The structures over water will have to be widened to the outside. The necessity for outside widening is due to the size and amount of equipment that is required to drive large diameter piles into water. The construction will go much more efficiently if there is no inside widening on the structures over water. Also, piles driven next to the bridges over water may have to be battered in a direction that is parallel to the bridge in order to miss the existing piles that are battered transversely to the bridge. These new piles will have to be installed in opposing pairs with a pile cap that straddles the existing piles.

The inside to outside bridge widening will impact areas where there is existing concrete pavement. The existing pavement markers and markings are established along the longitudinal concrete joints. If the existing pavement is maintained through the widening operations, the new lane transitions will create areas where the pavement markings will deviate from the concrete joints, increasing the risk of "lane drifting" by motorists following the joints instead of the lane markings, thus increasing the risk of side-swipe incidents. This should be addressed in the later design stages if this alternative is further considered.

In order to widen the existing Willoughby Bay bridge, construction barges will have to be brought into the Bay from the water side and the equipment brought in from the land side. The amount of construction activity on the land side will adversely affect the property owners around the bay. In addition, due to the widening of the bridge and the construction, several private piers will have to be removed; some temporarily and some permanently.

Most of the grade separated structures affected in the study area can be widened to accommodate the improvements to I-64. However, the bridge that carries S. Mallory St. over I-64 will have to be replaced since the widening of I-64 will conflict with the pier locations and the bridge will have to be lengthened.

Traffic Analysis:

Travel demand forecasts were developed for the Hampton Roads Bridge-Tunnel and traffic analysis was performed for the 2018 and 2030 conditions. For Alternative 1, the analysis showed the following Level of Service (LOS) results for the AM (PM) peak hours for an average weekday:

	2018		2030	
	EB	WB	EB	WB
No Build	**F(F)**	**F(F)**	**F(F)**	**F(F)**
No Build with 3rd Crossing	D(E)	C(E)	D(E)	C(**F**)
Alternative 1 (3-3)	D/D(C/D)*	C/D(C/D)*	**F**/E(**F**/E)*	C/E(**F**/E)*
Alternative 1 (3-3) w/3rd Crossing*	D/D(C/D)*	C/D(C/D)*	D/D(C/D)*	C/D(C/D)*

* 2 lanes one direction/ 1-lane two direction level of service

Right-of-Way Impact:

The existing right-of-way limits for the study area were provided by the Department and are shown on each alternative display. Since the information provided is limited to only right-of way limits and does not include property or parcel information, the best assessment of impacts can only be quantified based on potential impacts to existing buildings and existing sound walls based on assumptions of side slope designs and roadside treatments. While not an optimal assessment, it does provide an order of magnitude of the potential impacts that may be expected by the implementation of this alternative. Thus, based on the available information, Alternative 1 will potentially impact 50 to 75 buildings and about 7,400 LF of sound barrier.

Mainline, Ramp and Shoulder Deficiencies:

The existing westbound bridge approaching the tunnel (Station 475+00 to 490+00) has substandard curvature as it departs the Willoughby Bay area. Also, the existing westbound tunnel has a substandard height restriction. This concept assumes that these will be retained through design exceptions due to the cost of modifying the structures to meet current standards.

The existing interchange ramps were analyzed based on AASHTO and VDOT requirements. The design criteria investigated for each ramp consisted of:

1. Taper length
2. Deceleration/Acceleration lane lengths
3. Ramp radii

Alternative 1 has 4 ramps with deficient radii and 10 ramps with inadequate acceleration or deceleration lengths. The majority of the taper lengths on the corridor are 200 feet in length which meets the AASTHO requirement of 180 feet but not the VDOT length of 300 feet.

Further Study Considerations:

The operation of the eastbound inspection area will need to be further addressed if the design of this area is progressed beyond this stage.

The most critical issue affecting this alternative is the implementation of two-way traffic in the existing eastbound bridge-tunnel facility. A design exception would need to be granted for this to be permitted on an interstate facility. Such an exception would likely be difficult to obtain from the governing agencies which would have an enormous impact on the funding for the project. Due to the lack of shoulders in the tunnels and the lack of additional space, the use of reinforced barriers separating the traffic would not be possible. Separation would be by means that could not guarantee the minimization of head-on collisions in the tunnel. The bridge sections of the facility have similar limitations. This results in a 4 mile section of undesirable two-way traffic.

It is doubtful, due to safety concerns, that a 55 MPH speed limit within the two-way traffic section can be implemented. Consequently, a lower speed limit required for safety will take away most of the capacity improvement this alternative will offer. Couple this with motorists likely avoiding the option of using the lane due to the lower speed limit and the trepidation of oncoming traffic; this alternative will not provide the relief that is desired.

Incident management and hurricane evacuation operations would be severely impacted due to the separation of traffic in the middle tunnel. The implementation of this alternative would need to give additional consideration to these operational elements.

Estimated Construction Cost and Implementation Schedule:

The following is a general construction cost estimate for Alternative 1:

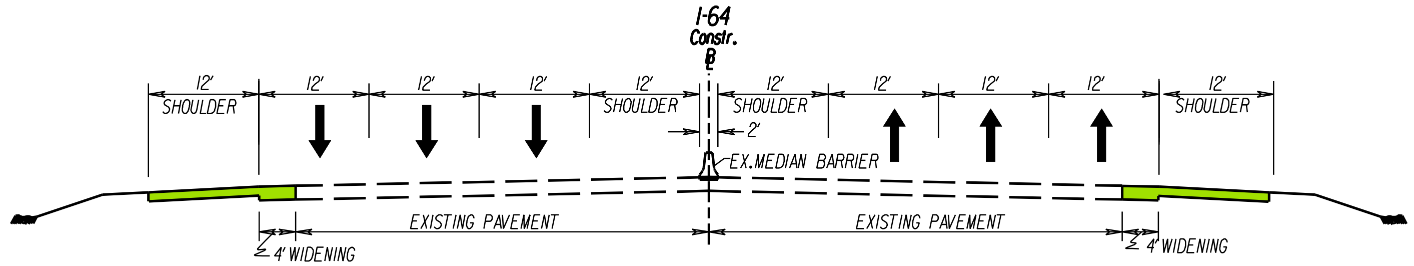
Roadway: $44 million

Bridges: $82 Million

Tunnel: $2.0 Billion

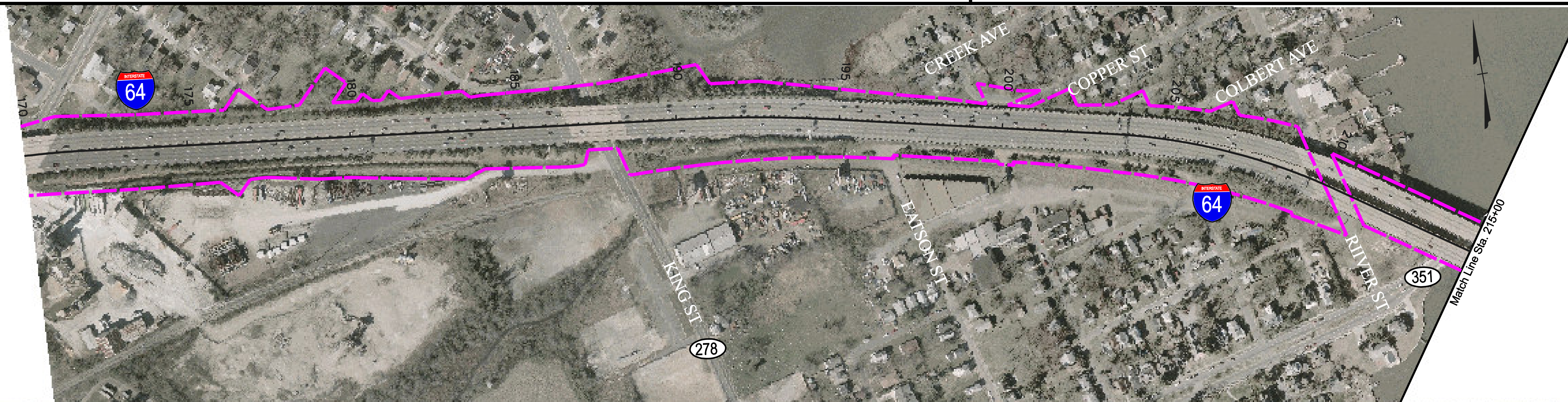
Total: $2.13 Billion

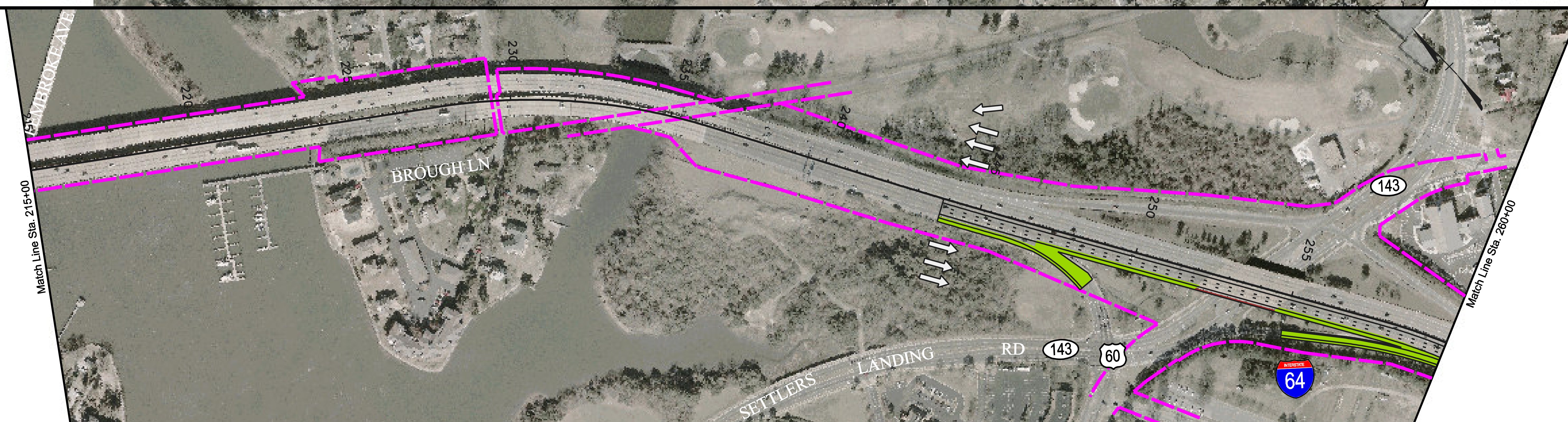
The construction schedule for Alternative 1 is estimated to be 6 years.



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



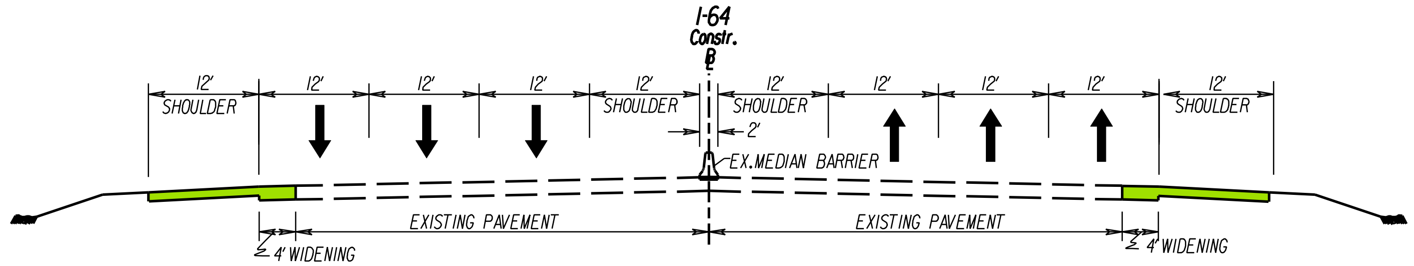


Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

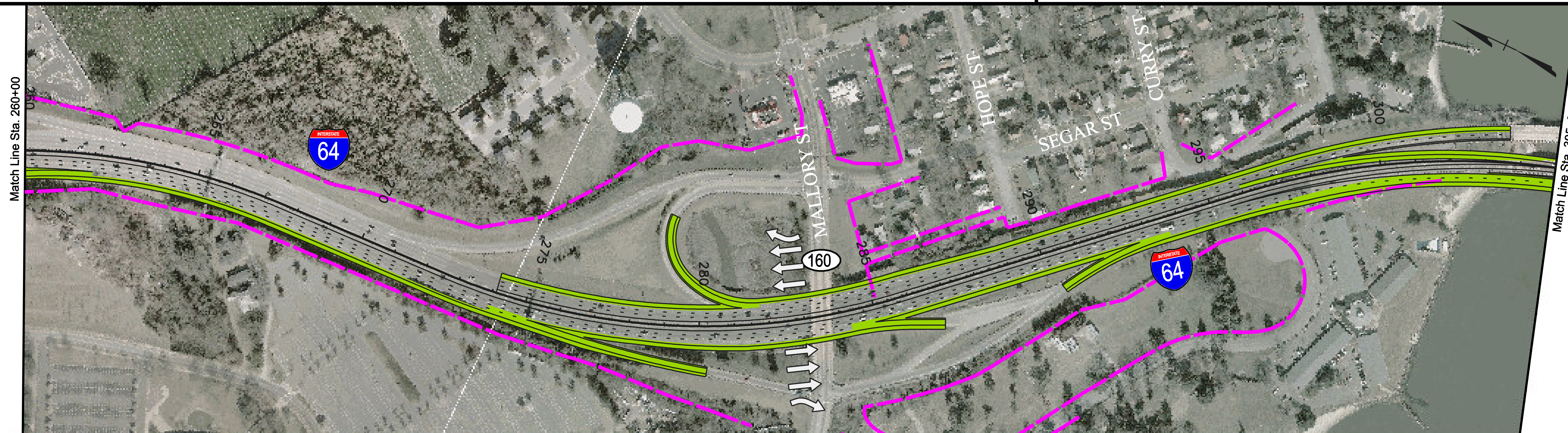
SCALE
0 300' 600'

PLAN SHEET NO. 1(1)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



VDOT
Virginia Department of Transportation

JMT
JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

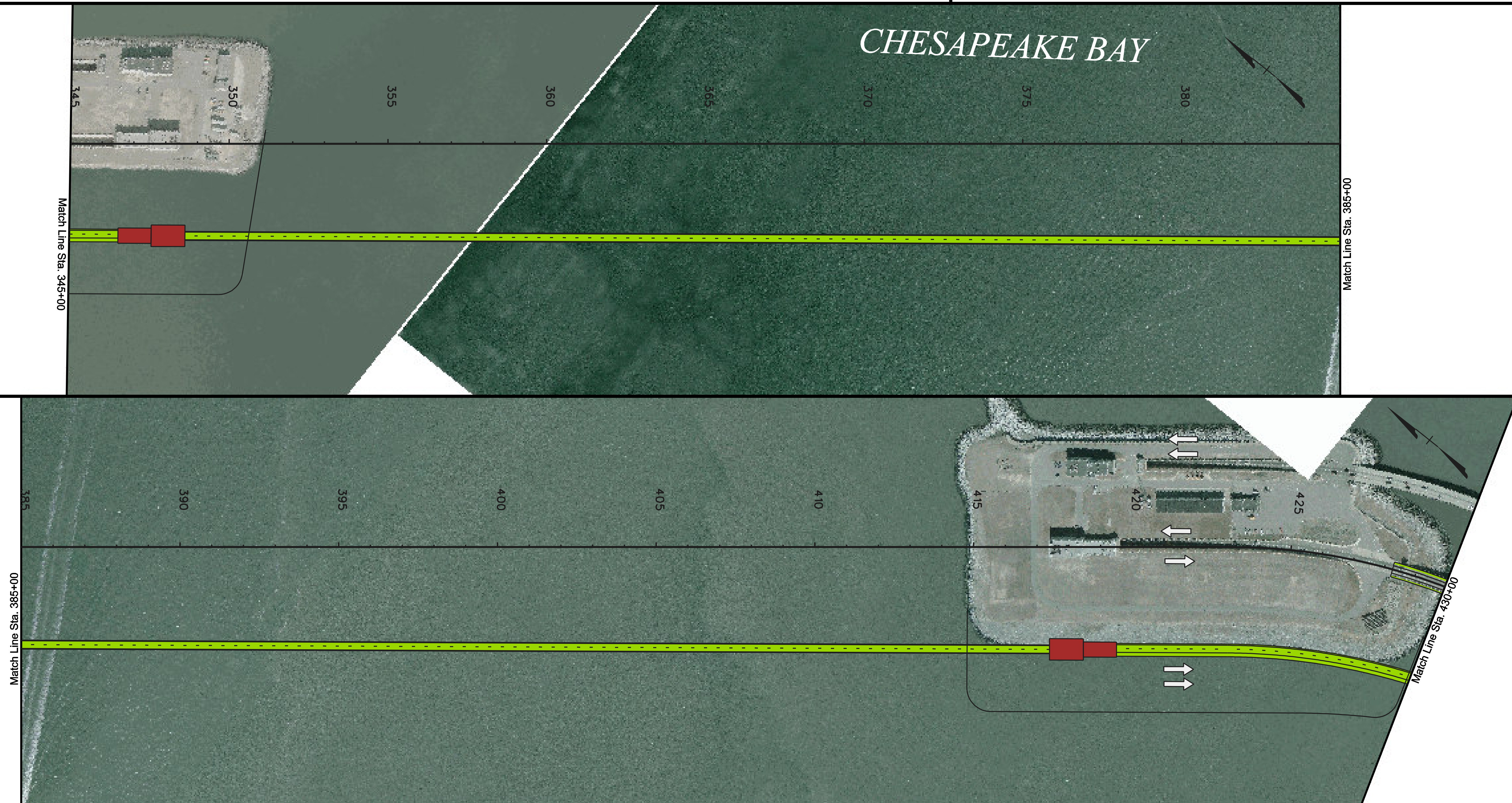
ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

SCALE
0 300' 600'

PLAN SHEET NO.
1(2)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

SCALE
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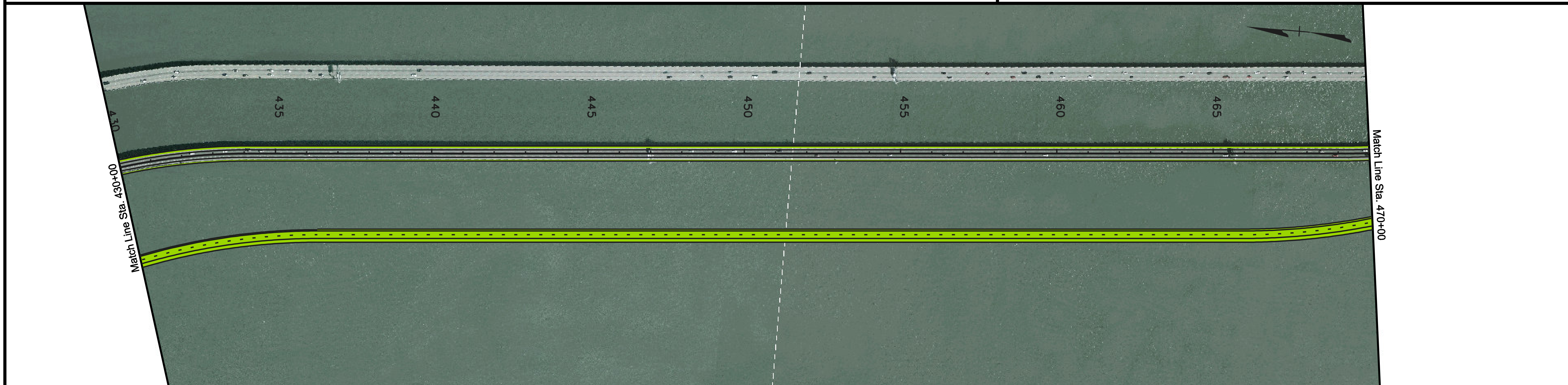
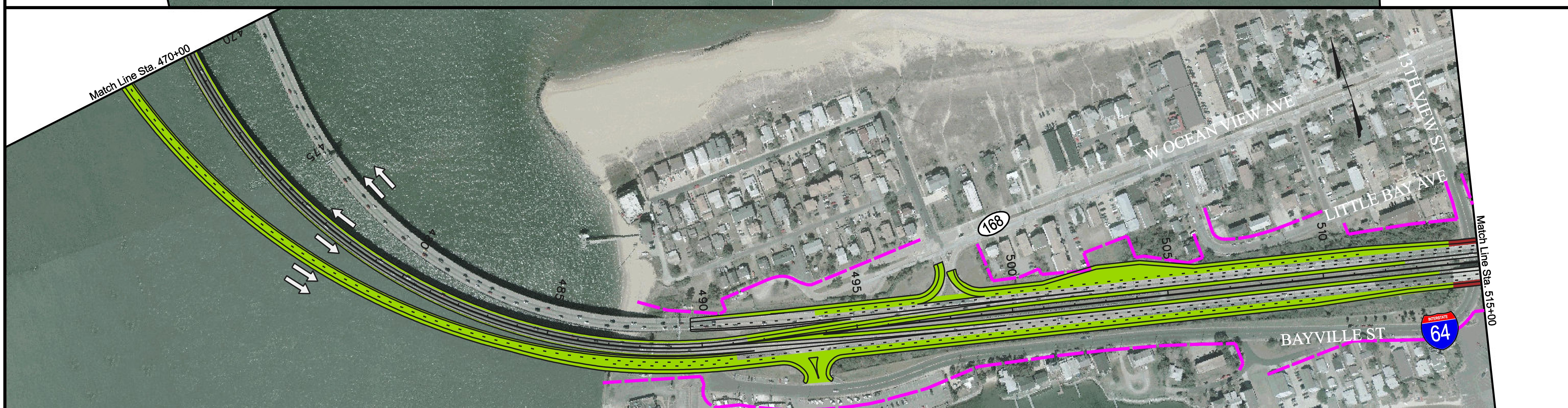
PLAN SHEET NO. 1(3)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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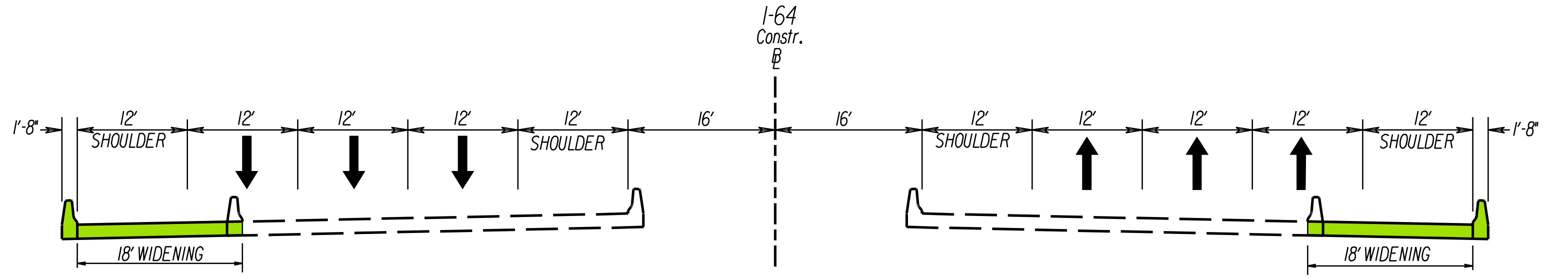
- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

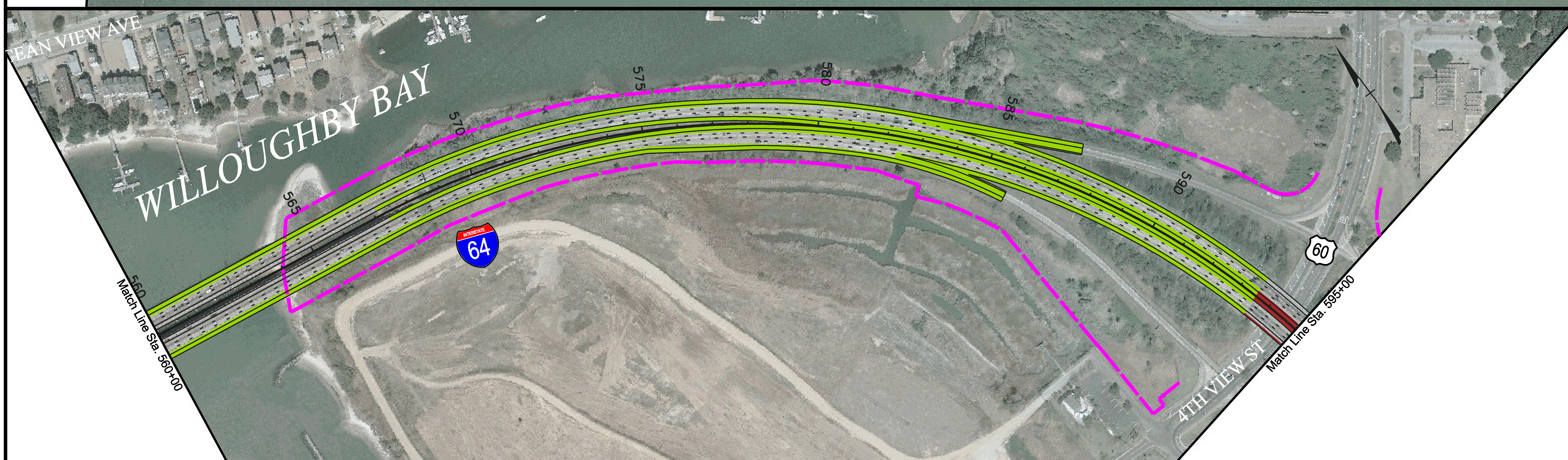
ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

SCALE
0 300' 600'

PLAN SHEET NO. 1(4)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY





VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

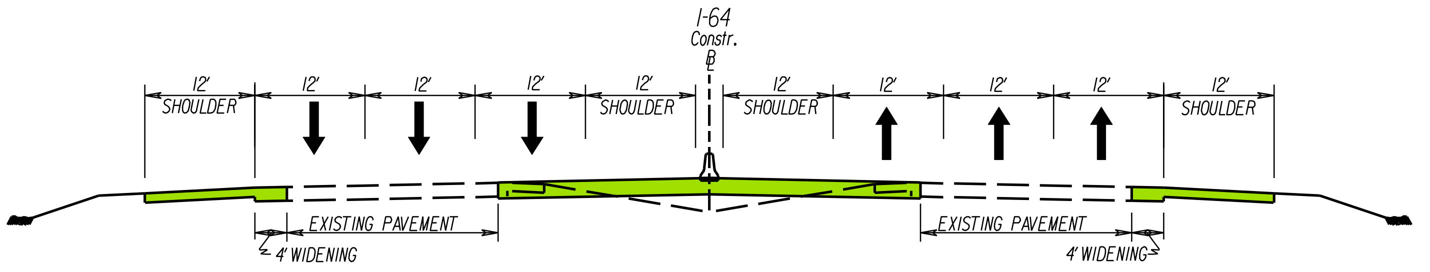
Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

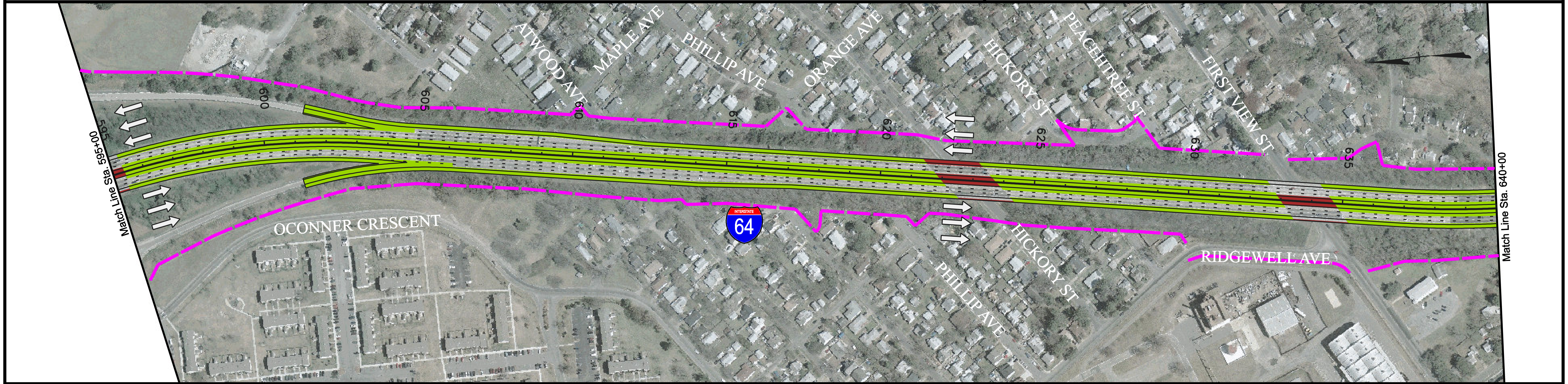
ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

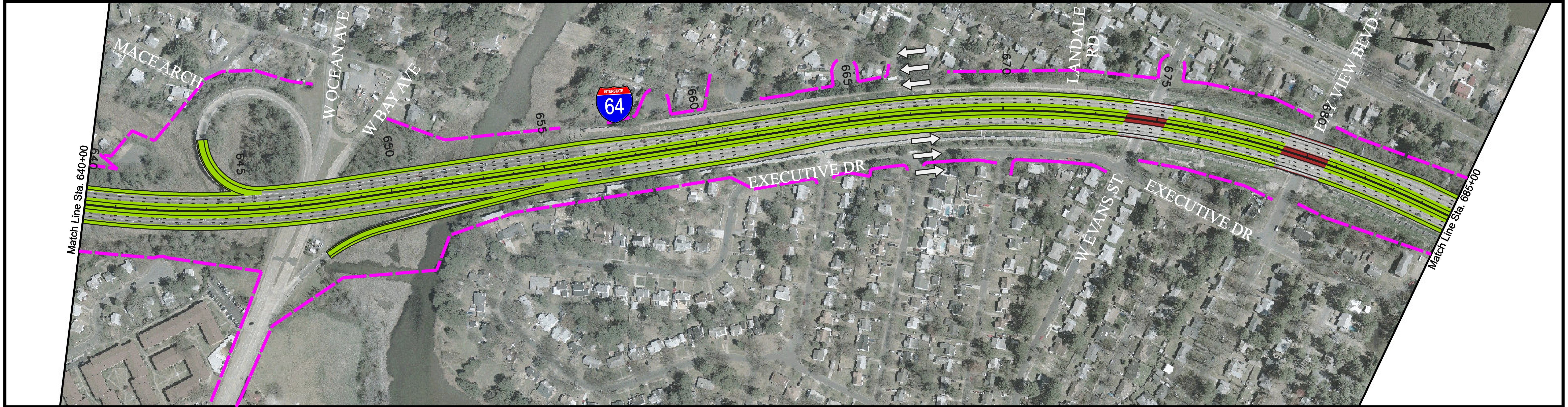
SCALE
0 300' 600'

PLAN SHEET NO. 1(5)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







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JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

SCALE
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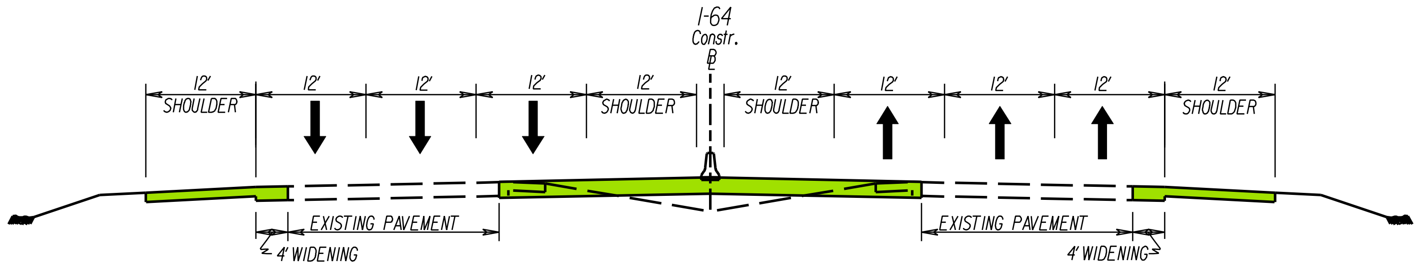
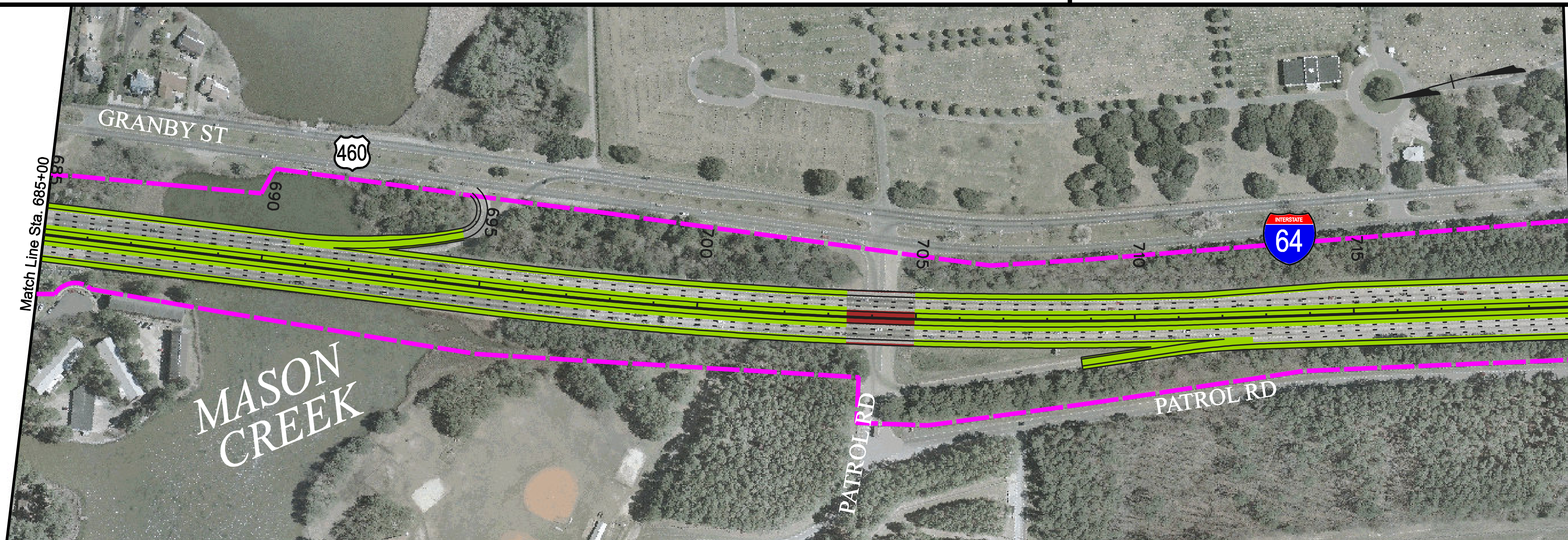
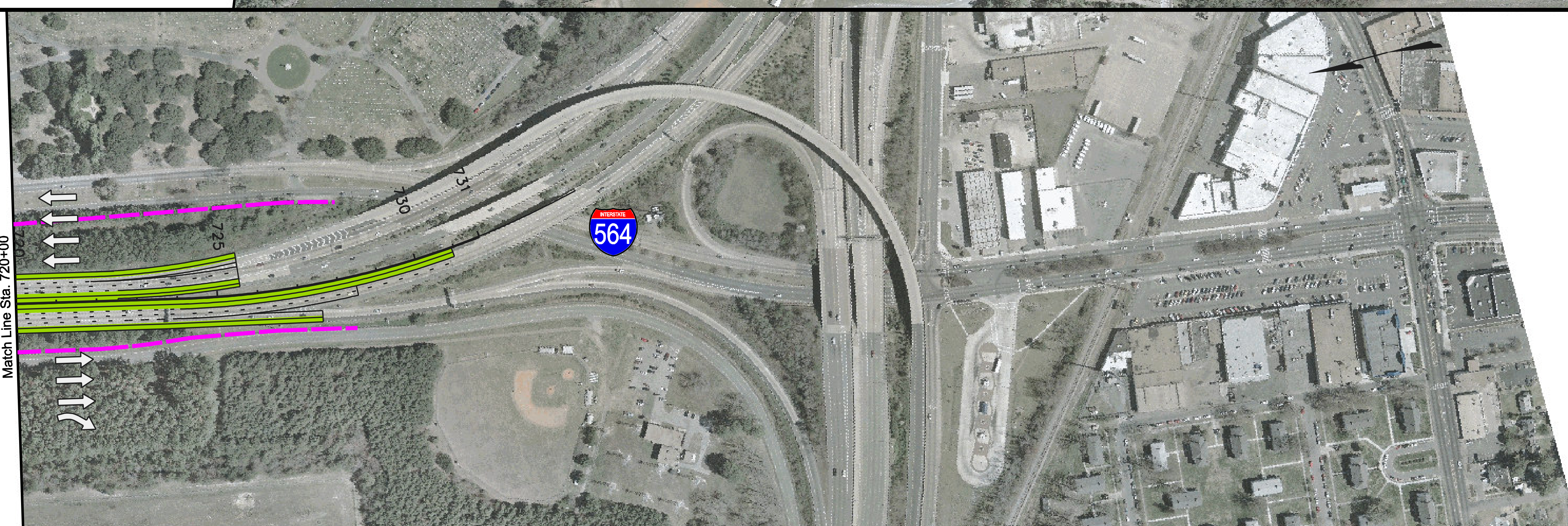
PLAN SHEET NO. 1(6)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 1 : Two Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Six- Lane Facility Connecting the Peninsula and Southside.

SCALE
0 300' 600'

PLAN SHEET NO. 1(7)

DGN $REF001 $REF002 $REF003 $REF004 $REF005 $REF006
$DGNLEV $LEV001 $LEV002 $LEV003 $LEV004 $LEV005 $LEV006

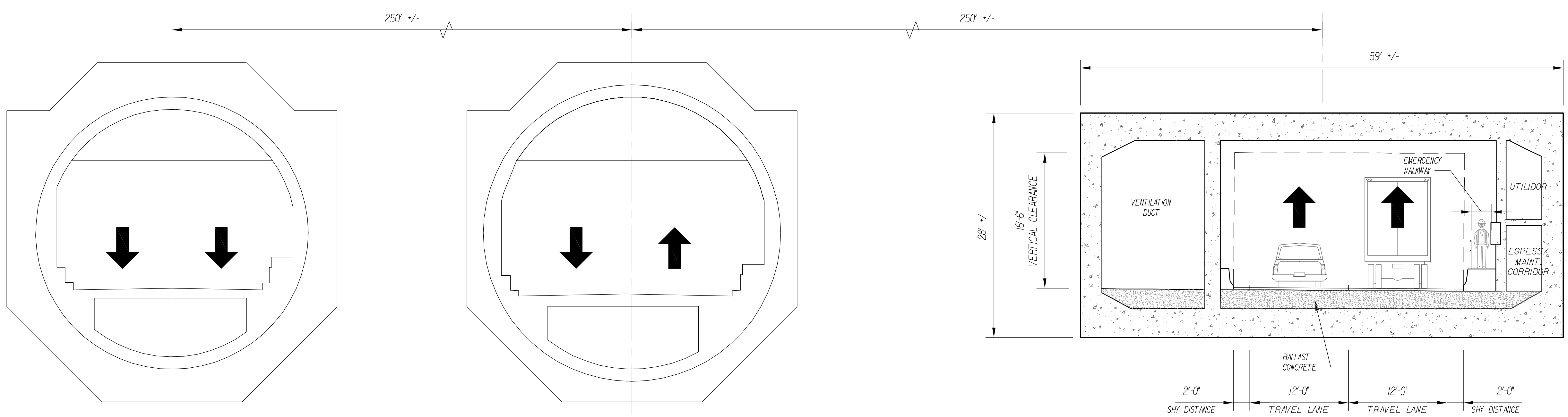
SURVEYED BY
SUPERVISED BY VDOT
DESIGNED BY PB Americas, INC.

DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	VA.				1(8)

PARSONS BRINCKERHOFF
PB 100 YEARS

TYPICAL SECTIONS
ALTERNATIVE 1



WEST BOUND LANES

EXISTING TUNNEL

WEST BOUND LANE   EAST BOUND LANE

EXISTING TUNNEL

EAST BOUND LANES

PROPOSED EAST BOUND TUNNEL

BRIDGE TUNNEL TO I-64/I-564

Virginia Department of Transportation
VDOT

$TIME$STAMP$

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
			1(8)

ALTERNATIVE 2

General Alternative Information:

This alternative would provide two additional lanes of reversible bridge-tunnel capacity to provide greater peak hour and evacuation capacity. The reversible facility would run between I-664 and I-564 and would have direct connections to each. It is assumed that there would not be any intermediate connections to the reversible roadways from the mainline roadway or cross streets. The reversible lanes would be barrier separated from the general lanes such that the reversible lanes would operate as “express” lanes. While not envisioned as an HOV facility, it could easily be converted to one at the end points of I-664 and I-564 and tie in to the existing HOV lanes on I-64.

The reversible lanes would utilize the existing eastbound bridge-tunnel facility as well as the existing eastbound bridge over Willoughby Bay. A new crossing would be constructed for the eastbound traffic.

The conceptual layout and roadway typical section for Alternative 2 is shown on Plan Sheet Nos. 2(1) thru 2(8). Plan Sheet No. 2(9) shows typical sections for the tunnels.

Structural:

Tunnels

The proposed location for the addition of a new tunnel crossing has been set at 250 feet from the existing eastbound tunnel. This approximately matches the distance used between the existing eastbound and westbound tunnels. This allows the excavation for and the placement of the proposed tunnel to proceed without impacting the existing tunnels. This also provides flexibility in the future should the existing tubes be replaced with wider sections similar to the ones proposed in this study. Further reduction of the distance between the new and the existing eastbound tunnels would require complex numerical analyses for estimating the magnitude and distribution of ground deformations, due to the dredging and excavation, as well as detailed structural analysis for evaluating the impacts of the ground deformations to the existing structures. This is particularly important in the south island area as soft and compressible soils are present and large ground deformations are prone to occur during and after construction.

While it may be possible to place a two-lane tunnel between the existing tunnels, it is likely that this would disturb the existing tunnels. Even if this could be done, it does not allow for future replacement of the existing tunnels without complications. Utilizing a tunnel boring machine to add a tunnel is not likely a practical solution as the soils in this region are not conducive to boring due to the looseness of the upper layers. If tunnel boring were utilized the tunnel would need to be lower than the existing tunnels to provide adequate cover over the new tunnel. This increased depth would result in a significantly longer tunnel. Given those considerations it is recommended that the new tunnel be placed as shown in the proposed alignments.

The proposed bridge-tunnel segment consists of the following:

- Existing islands will be expanded to accommodate the addition of the proposed tunnel.
- Expansion of South Island will require ground treatment using surcharge and wick drains to avoid excessive settlement.
- Tunnel length will match the existing at approximately 7500 feet portal to portal.
- Rectangular concrete immersed tubes will be utilized.
- It is assumed that the top elevation of the new tunnel matches that of the existing eastbound tunnel.
- Backfill and stone blanket over tunnel will be 5 feet thick to match existing tunnel.
- Cast-in-place concrete boat sections will tie the tunnel to the trestle.
- Each traffic cell in the tunnel consists of 2 traffic lanes, each 12 feet in width.
- Shy distance (offset from travel lane) to the barriers is 2 feet each side.
- Roadway vertical clearance is 16.5 feet, with a 1.5 foot allowance for roadway signage.
- Tide gates will be required.
- Base slab, walls and roof to be waterproofed.
- Ancillary Facilities consisting of a ventilation building and storm water pump station at both ends of the tunnel that house Mechanical and Electrical Systems.
- Mechanical Systems will include tunnel drainage, portal drainage, semi-transverse tunnel ventilation and fire suppression.
- Electrical Systems will include tunnel power, tunnel lighting and tunnel control and communication.
- Approach trestles similar to the existing bridges consist of precast beams on pile bents and are approximately 3300 feet in length on the north end and 6000 feet in length on the south end.
- Emergency egress is provided by a separate corridor separated from the traffic lanes by a firewall and fire-rated doors.

See Appendix B for additional general construction information with regards to tunnel alternatives.

Bridges

This alternative will require all bridges to be modified from I-664 to I-564. An additional 2 lanes plus shoulders will be needed for the whole corridor. Most of the standard grade separation structures on the south side of the bridge-tunnel can be widened to the inside, however, on the north side, the existing structures sit side-by-side and so the new improvements will have to occur to the outside. The structures over water will have to be widened to the outside. The necessity for outside widening is due to the size and amount of equipment that is required to drive large diameter piles into water. The construction will go much more efficiently if there is no inside widening on the structures over water. Also, piles driven next to the bridges over water may have to be battered in a direction that is parallel to the bridge in order to miss the existing piles that are battered transversely to the bridge. These new piles will have to be installed in opposing pairs with a pile cap that straddles the existing piles.

The inside to outside bridge widening will impact areas where there is existing concrete pavement. The existing pavement markers and markings are established along the longitudinal concrete joints. If the existing pavement is maintained through the widening operations, the new lane transitions will create areas where the pavement markings will deviate from the concrete joints, increasing the risk of “lane drifting” by motorists following the joints instead of the lane markings, thus increasing the risk of side-swipe incidents. This should be addressed in the later design stages if this alternative is further considered.

On the Willoughby Bay bridge, all the new bridge lanes on this alternative will be added to the water side of this structure. Very little construction activity will occur on the land side and the property owners around the bay will experience minimal inconvenience (except for personal boating movement). The private piers in the area should not be affected.

As with Alternative 1, the bridge that carries S. Mallory St. over I-64 will have to be replaced as well as sections of the westbound I-64 to I-664 ramp. The widening of I-64 will conflict with the pier locations and the bridge spans will have to be lengthened. One of the eastbound bridges over the Hampton River will have to be replaced because of the substandard curve in the bridge.

Traffic Analysis:

Travel demand forecasts were developed for the Hampton Roads Bridge-Tunnel and traffic analysis was performed for the 2018 and 2030 conditions. For Alternative 2, the analysis showed the following Level of Service (LOS) results for the AM (PM) peak hours for an average weekday:

	2018		2030	
	EB	WB	EB	WB
No Build	**F(F)**	**F(F)**	**F(F)**	**F(F)**
No Build with 3rd Crossing	D(E)	C(E)	D(E)	C(**F**)
Alternative 2 (4-2)	B(**F**)	**F**(B)	C(**F**)	**F**(B)
Alternative 2 w/3rd Crossing	B(**F**)	**F**(B)	B(**F**)	**F**(B)

Right-of-Way Impacts:

The existing right-of-way limits for the study area were provided by the Department and are shown on each alternative display. Since the information provided is limited to only right-of way limits and does not include property or parcel information, the best assessment of impacts can only be quantified based on potential impacts to buildings and existing sound walls based on assumptions of side slope designs and roadside treatments. While not an optimal assessment, it does provide an order of magnitude of the potential impacts that may be expected by the implementation of this alternative. Thus, based on the available information, Alternative 2 will potentially impact 70 to 105 buildings and about 7,400 LF of existing sound barrier.

Mainline, Ramp and Shoulder Deficiencies:

The existing eastbound bridge crossing the Hampton River (Station 209+00 to 236+00) has deficient radii on the approaches. The radii are less than the minimum 1821' required for a design speed of 70 mph. For Alternative 2 the radii would have to be increased to meet current design standards and a new bridge would need to be constructed to replace the existing substandard facility.

The existing westbound bridge approaching the tunnel (Station 475+00 to 490+00) has substandard curvature as it departs the Willoughby Spit area. Also, the existing westbound tunnel has a substandard height restriction. The concept assumes that these will be retained through design exceptions due to the cost of modifying the structures to meet current standards.

The existing interchange ramps were analyzed based on AASHTO and VDOT requirements. The design criteria investigated for each ramp consisted of:

1. Taper length
2. Deceleration/Acceleration lane lengths
3. Ramp radii

Alternative 2 has 4 ramps with deficient radii and 13 ramps with inadequate acceleration or deceleration lengths. The majority of the taper lengths on the corridor are 200 feet in length which meets the AASTHO requirement of 180 feet but not the VDOT length of 300 feet.

Further Study Considerations:

The operation of the eastbound inspection area will need to be further addressed if the design of this area is progressed beyond this stage.

The direct connections to both I-664 and I-564 will need to be addressed further if the design of this alternative is progressed.

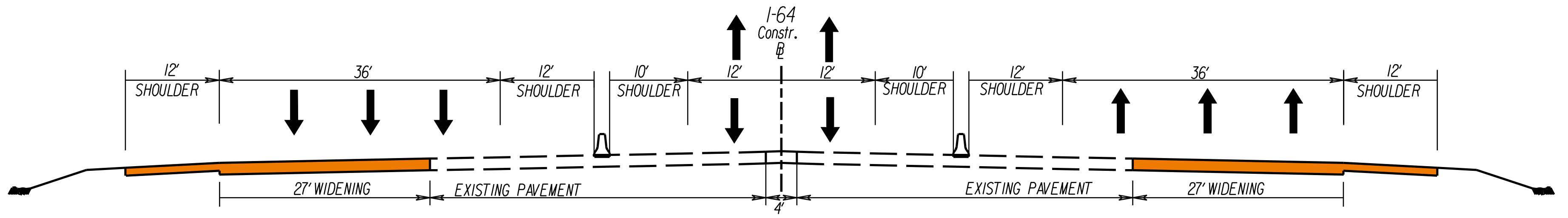
Incident management operations would need to account for the lack of intermediate access points to the reversible lanes. Additional access points near the bridge-tunnel facility only to be used during incidents, for example, may alleviate some of the operational challenges. Similarly, hurricane evacuation operations need to account for this as well.

Estimated Construction Cost and Implementation Schedule:

The following is the general construction cost estimate for Alternative 2:

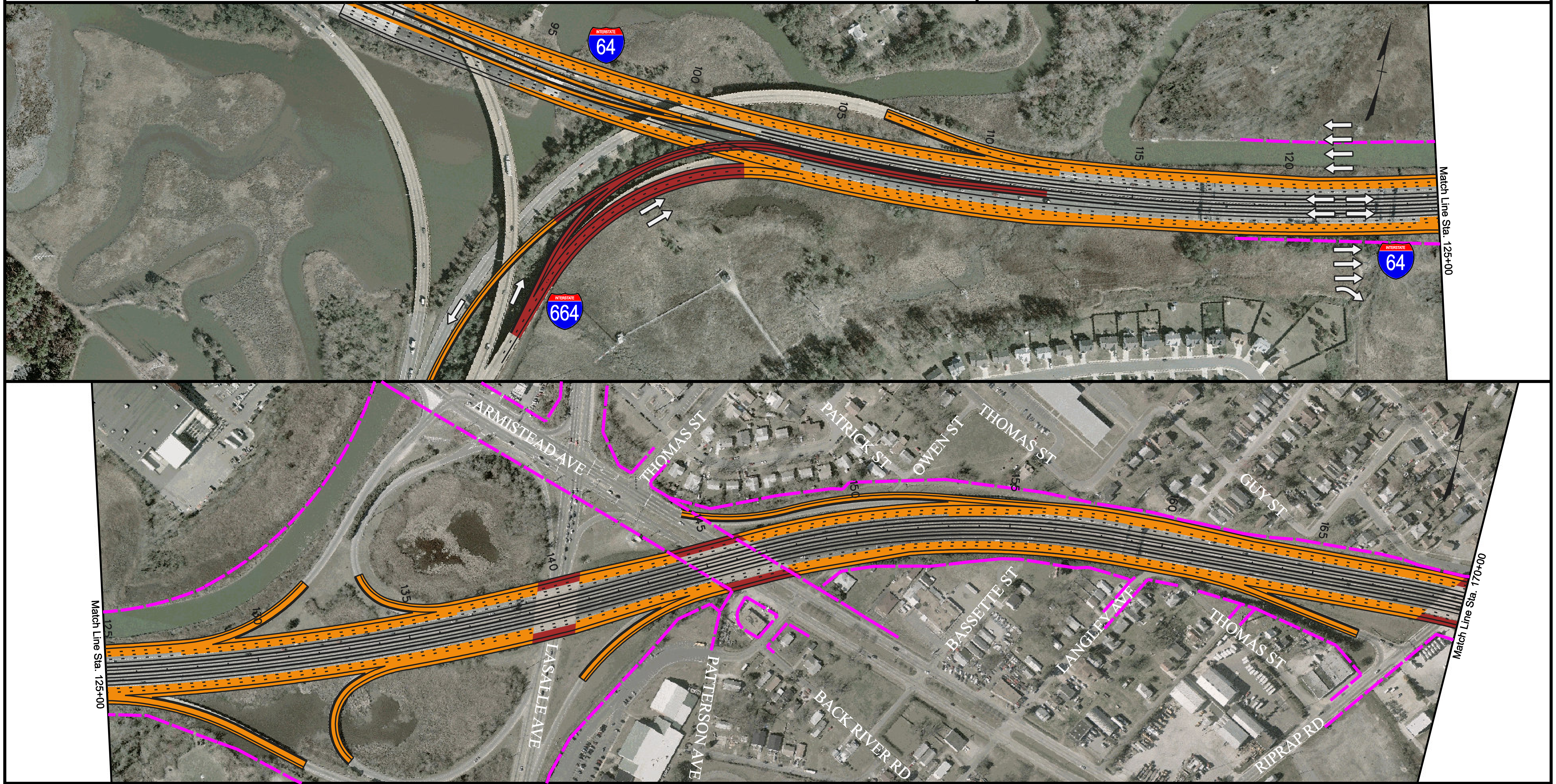
Roadway:	$101 million
Bridges:	$148 Million
Tunnel:	$2.0 Billion
Total:	**$2.25 Billion**

The construction schedule for Alternative 2 is estimated to be 6 years.



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Virginia Department of Transportation

JMT
JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing RW

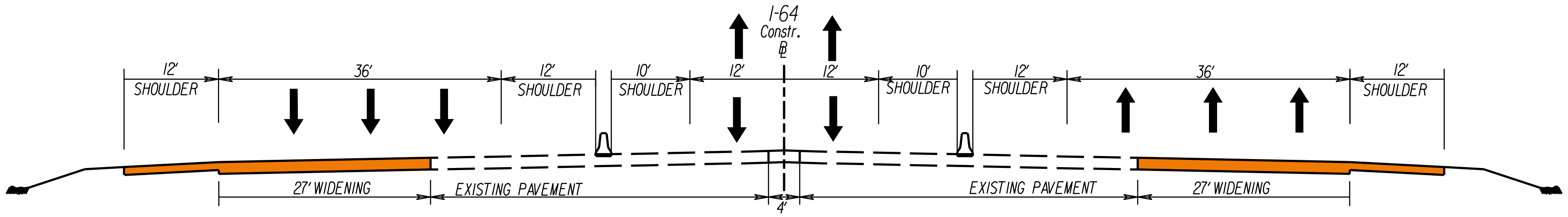
ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

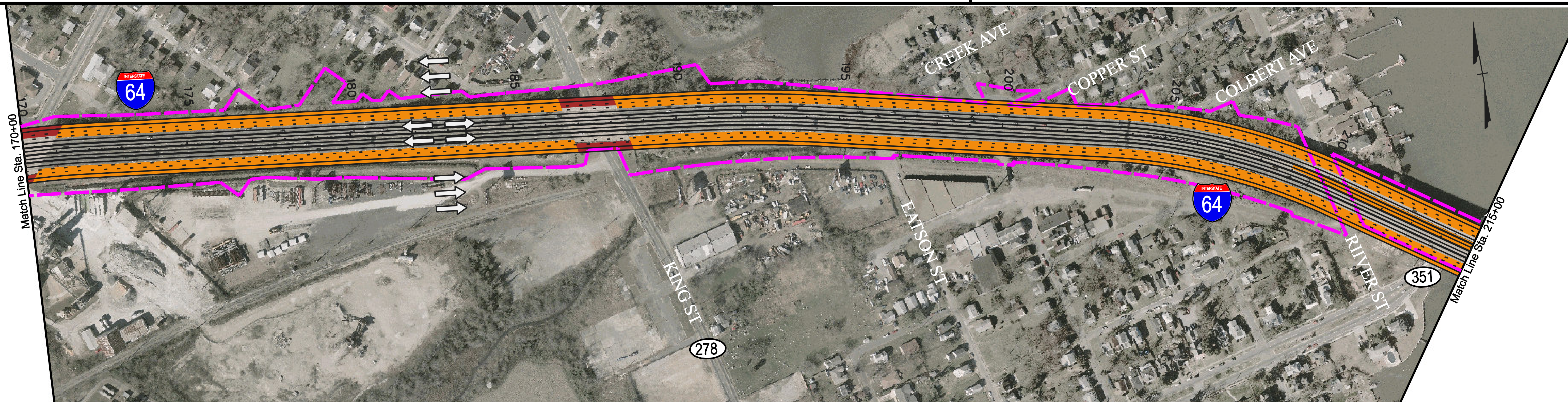
SCALE
0 300' 600'

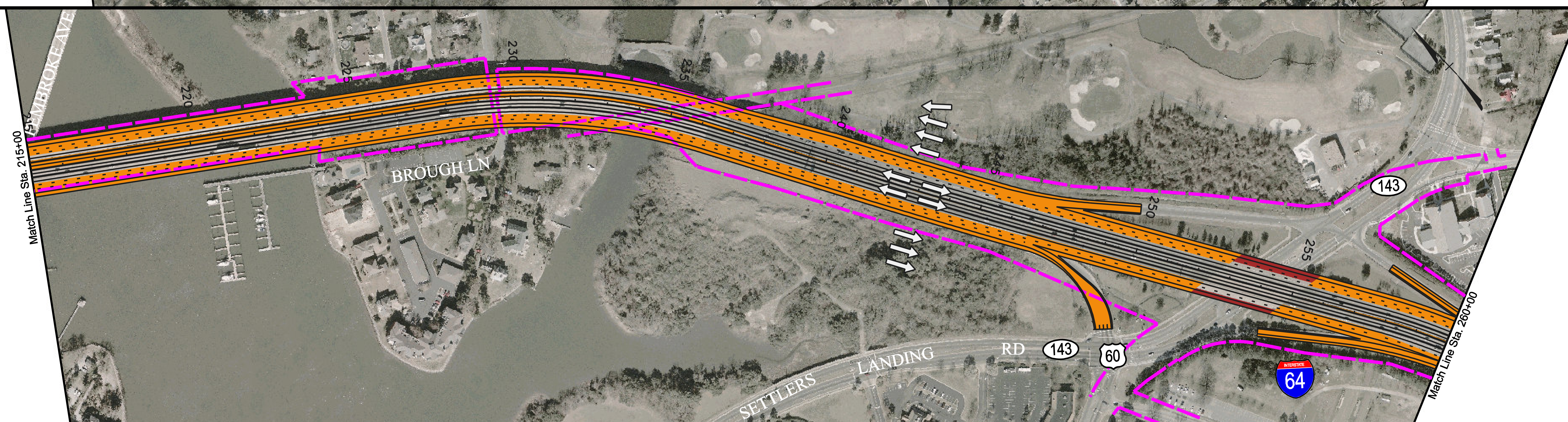
PLAN SHEET NO. 2(1)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64







VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

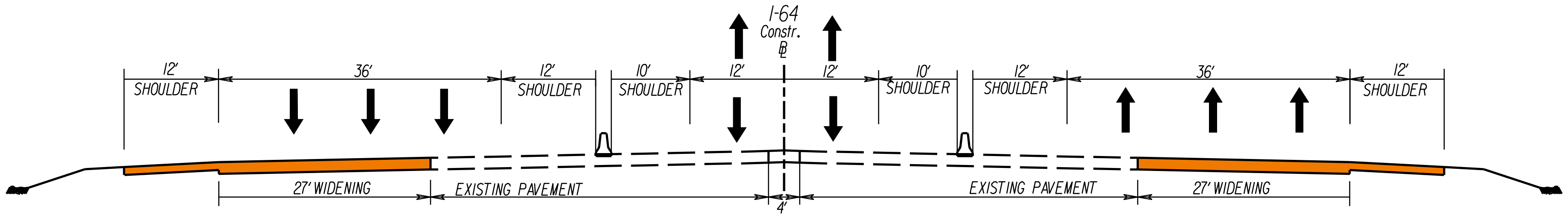
ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

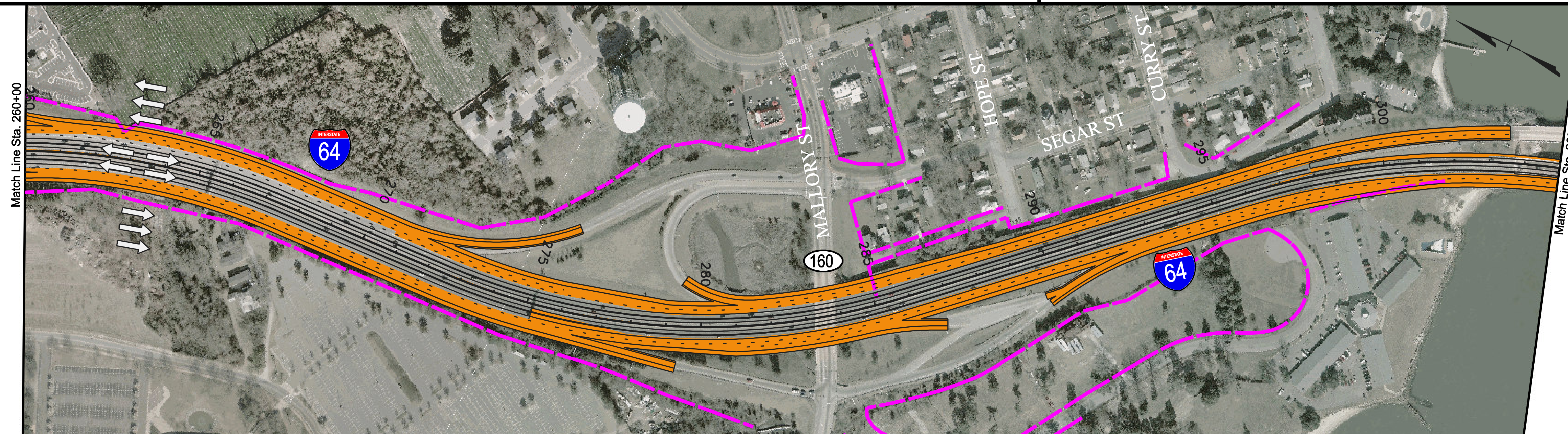
SCALE 0 300' 600'

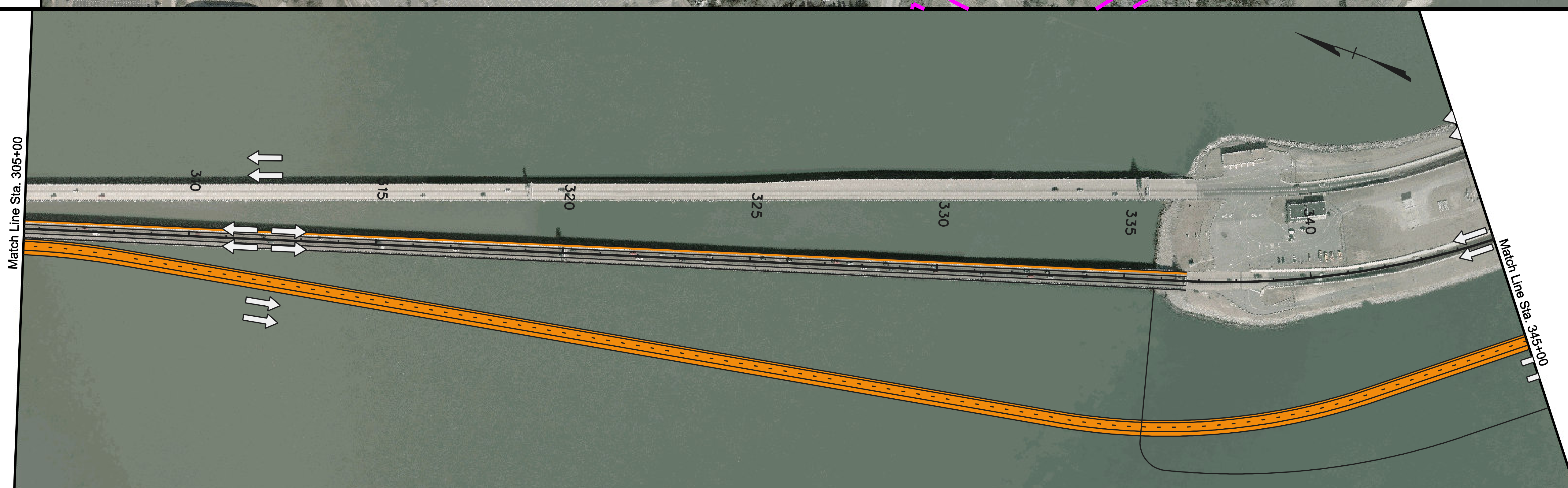
PLAN SHEET NO. 2(2)

HAMPTON ROADS BRIDGE–TUNNEL
EXPANSION FEASIBILITY STUDY

INTERSTATE 64







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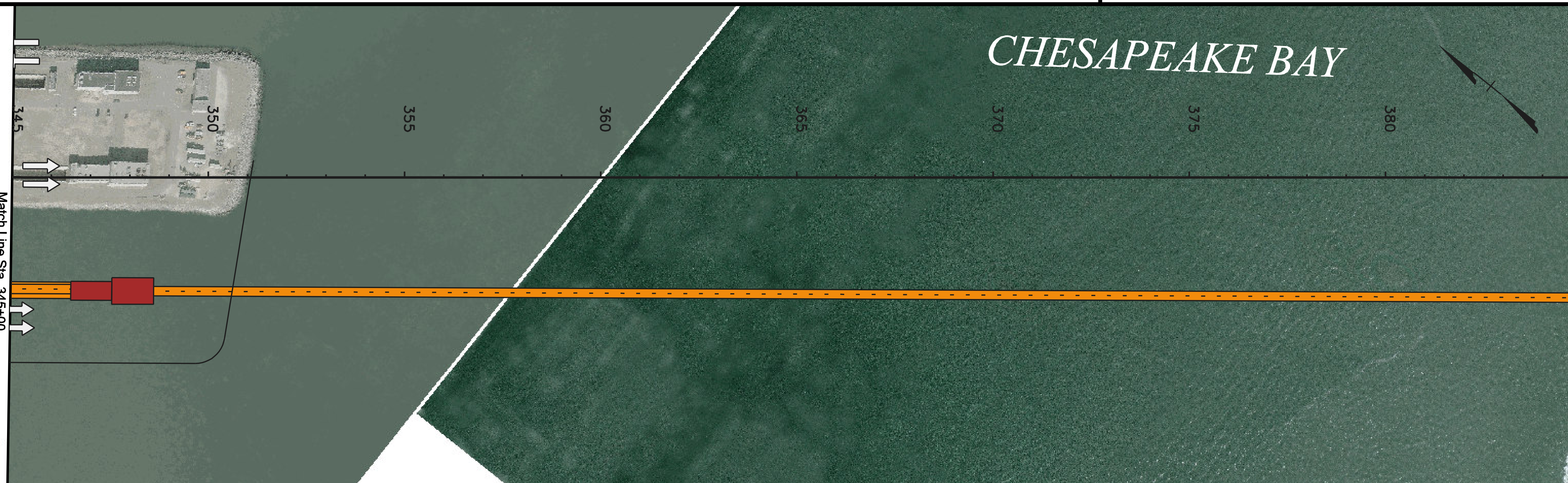
Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

SCALE
0 300' 600'

PLAN SHEET NO.
2(3)

HAMPTON ROADS BRIDGE–TUNNEL
EXPANSION FEASIBILITY STUDY



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JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

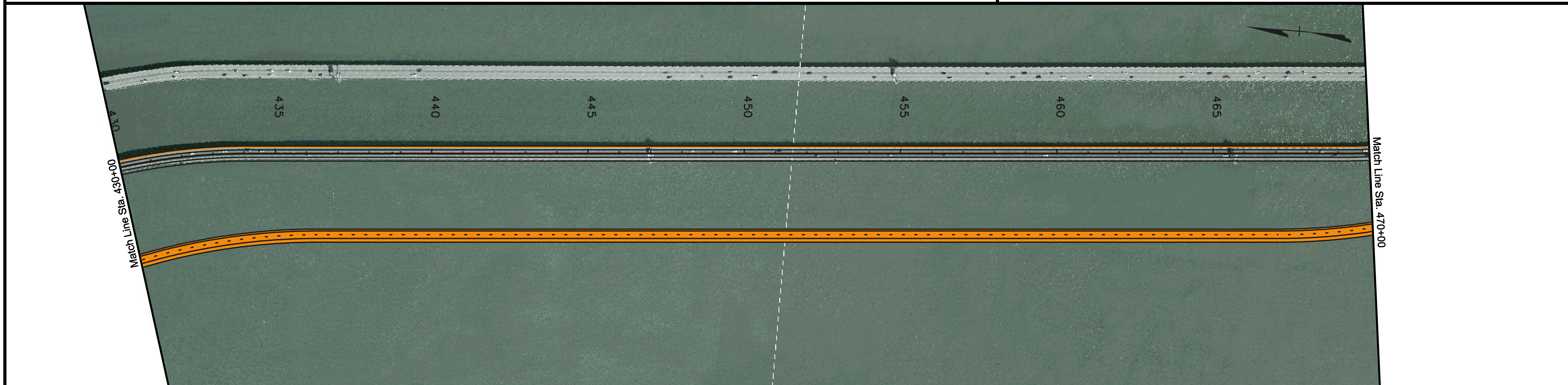
Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

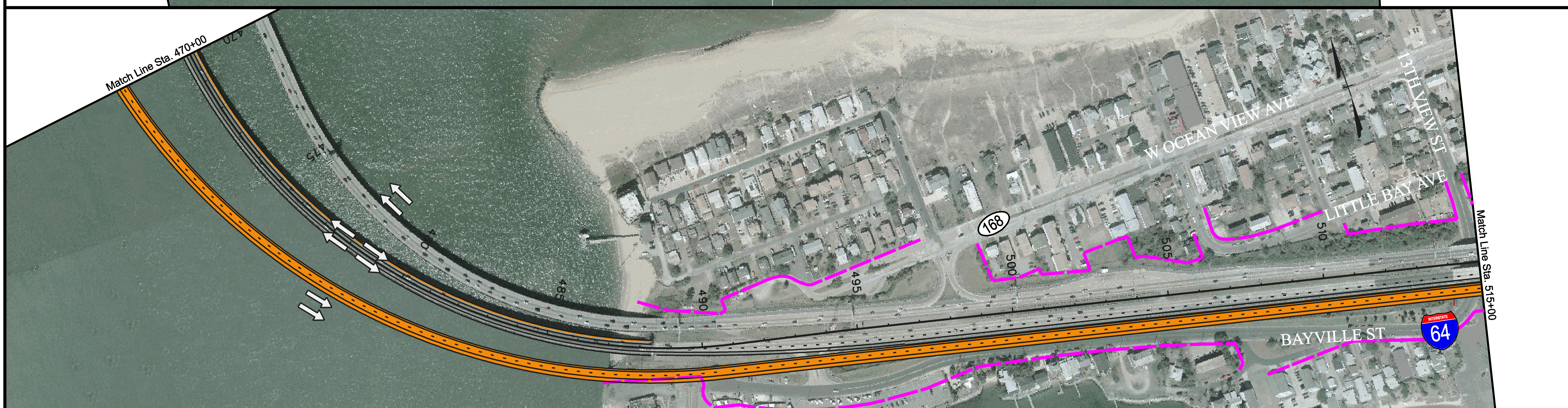
ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

SCALE
0 300' 600'

PLAN SHEET NO. 2(4)

HAMPTON ROADS BRIDGE–TUNNEL
EXPANSION FEASIBILITY STUDY





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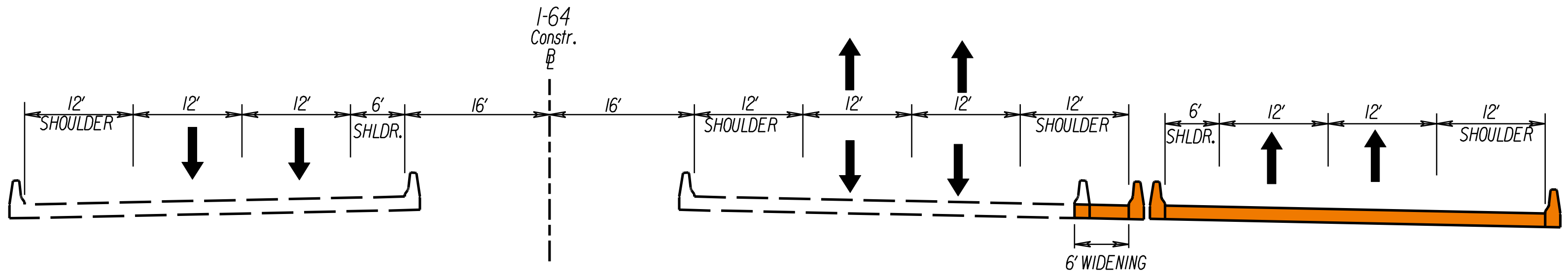
JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening	
Proposed Structures and Bridges	
Existing R/W	

ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

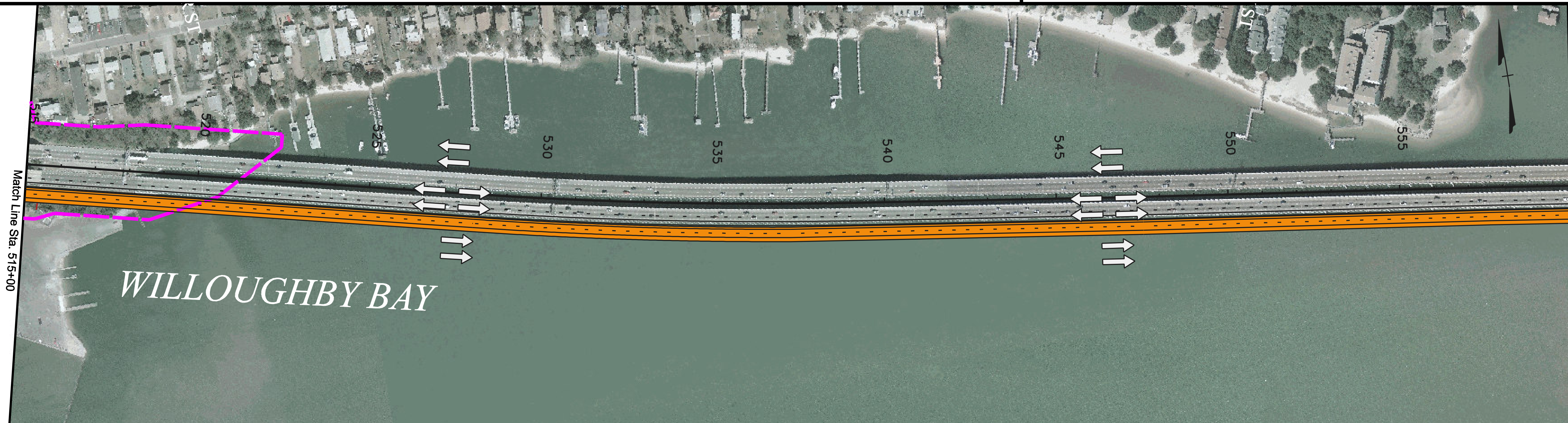
SCALE
0 300' 600'

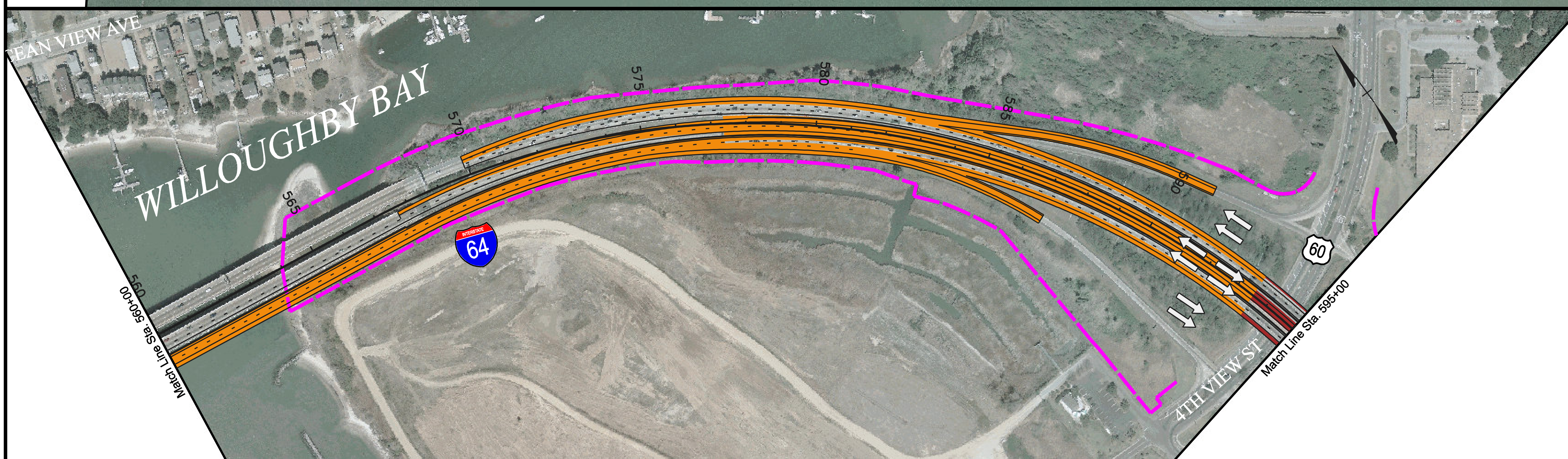
PLAN SHEET NO. 2(5)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





VDOT Virginia Department of Transportation

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Proposed Pavement Widening	
Proposed Structures and Bridges	
Existing R/W	

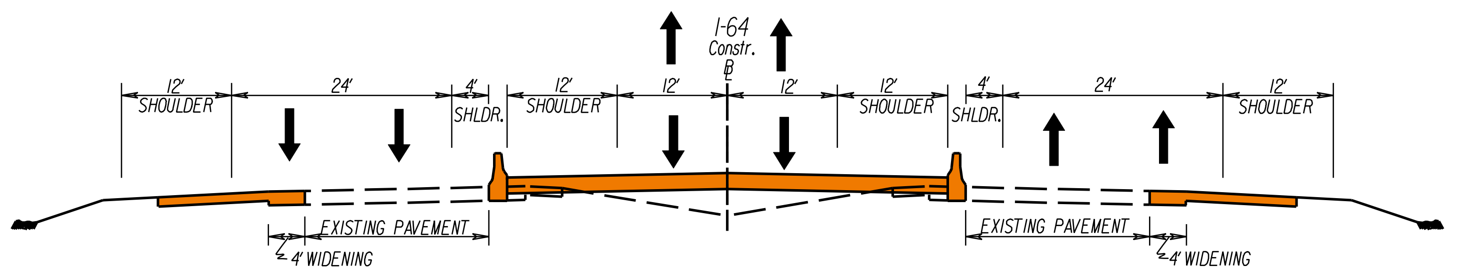
ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

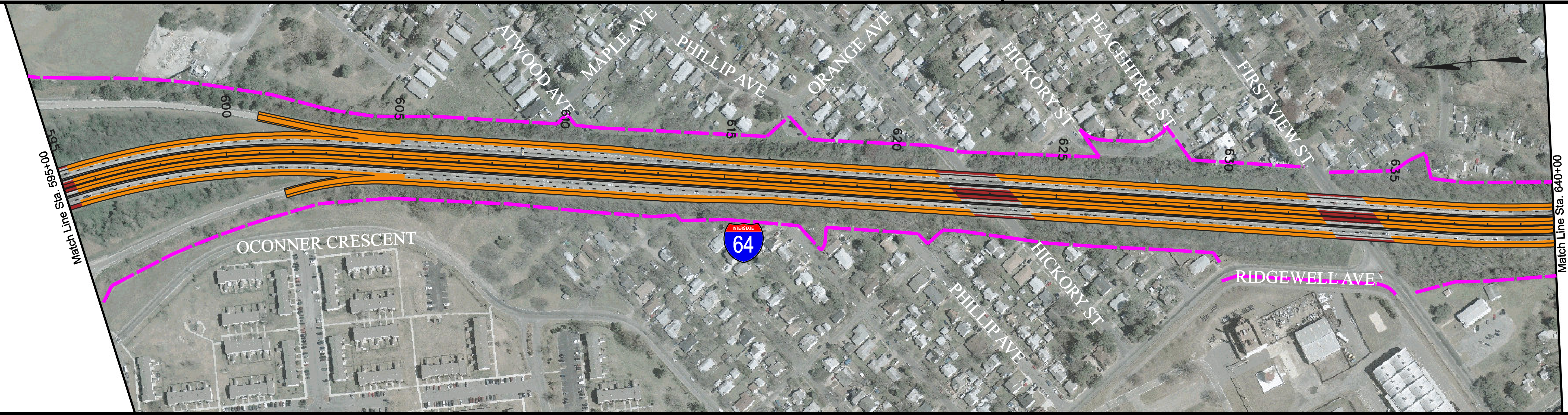
SCALE

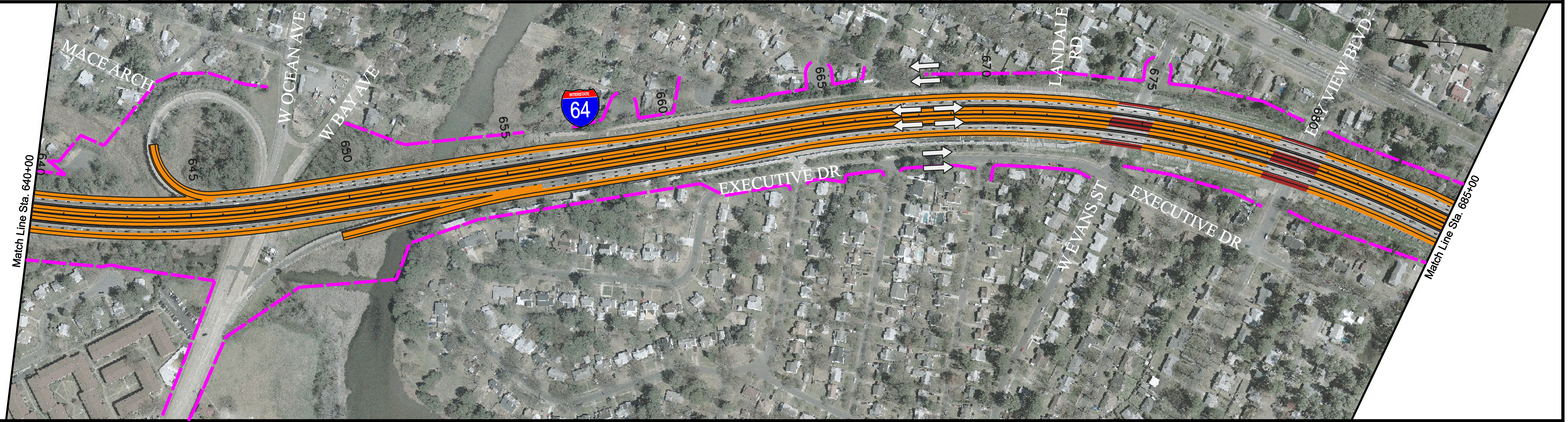
0 300' 600'

PLAN SHEET NO. 2(6)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







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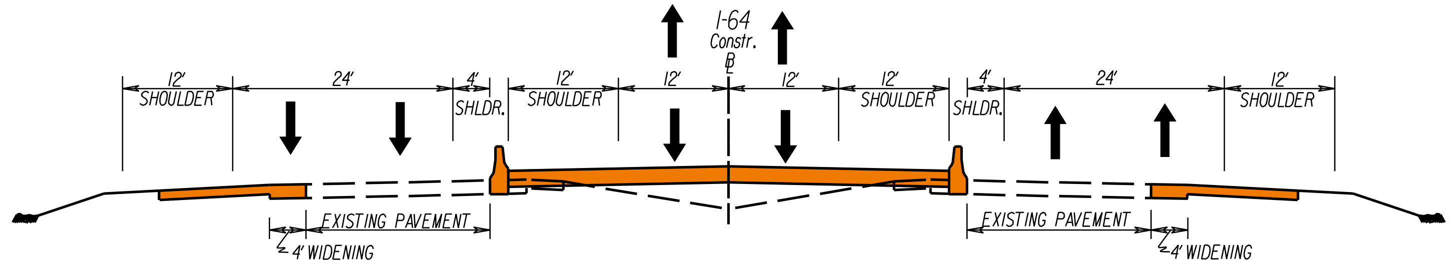
JMT JOHNSON, MIRMIRAN & THOMPSON *Engineering A Brighter Future*

- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

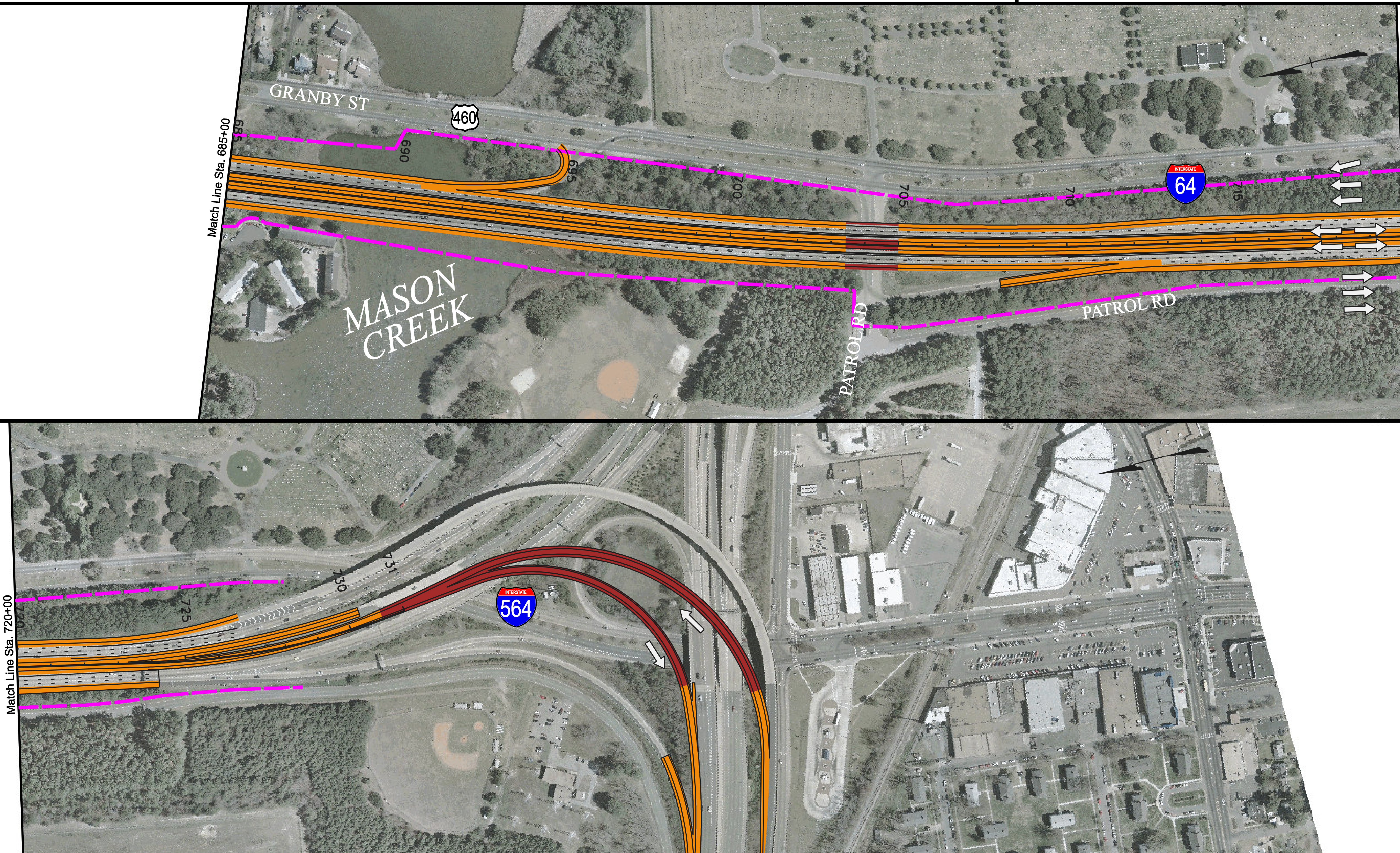
SCALE
0 300' 600'

PLAN SHEET NO. 2(7)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 2 : Two Additional Lanes of Reversible Bridge -Tunnel Capacity to Provide Greater Peak Hour and Evacuation Capacity

SCALE
0 300' 600'

PLAN SHEET NO.
2(8)

DGN $DGNLEV $REF001 $LEV001 $REF002 $LEV002 $REF003 $LEV003 $REF004 $LEV004 $REF005 $LEV005 $REF006 $LEV006

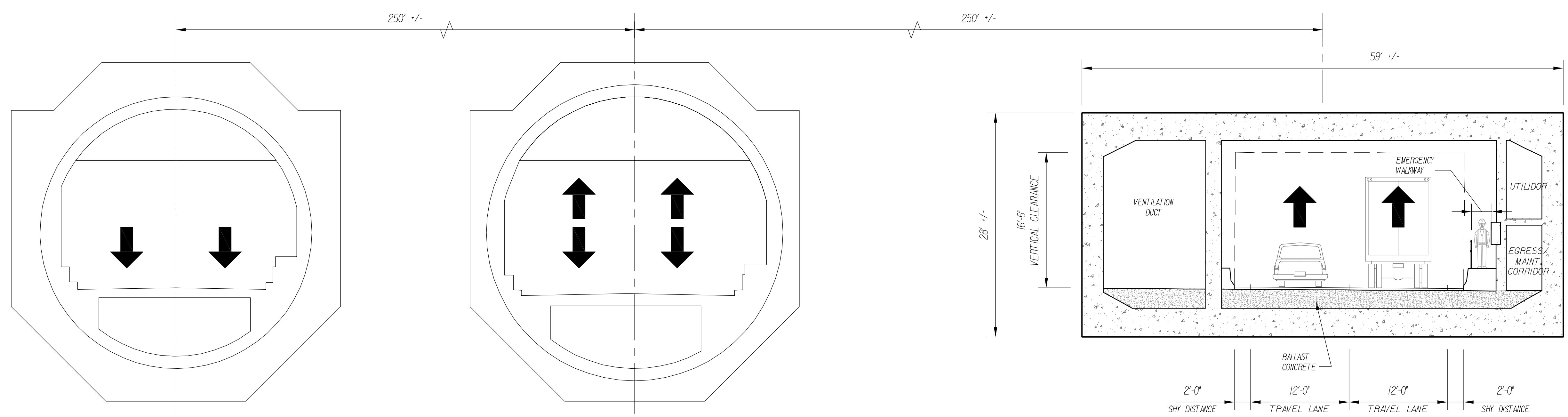
SURVEYED BY
SUPERVISED BY VDOT
DESIGNED BY PB Americas, INC.

DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	VA.				2(9)

PARSONS BRINCKERHOFF

TYPICAL SECTIONS
ALTERNATIVE 2



WEST BOUND LANES

EXISTING TUNNEL

WEST/EAST BOUND LANES
(REVERSIBLE LANES)

EXISTING TUNNEL

EAST BOUND LANES

PROPOSED EAST BOUND TUNNEL

BRIDGE TUNNEL TO I-64/I-564

Virginia Department of Transportation

$TIME$STAMP$

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
			2(9)

ALTERNATIVE 3

General Alternative Information:

This alternative would provide four additional lanes of bridge-tunnel capacity connecting the Peninsula and Southside. The additional lanes would be provided through the entire study area limits, connecting at I-664 and I-564.

The existing eastbound bridge-tunnel facility and Willoughby Bay bridge would be converted to carry all westbound traffic while a new bridge-tunnel facility and new bridge over Willoughby Bay would carry all eastbound traffic.

The conceptual layout and roadway typical section for Alternative 3 is shown on Plan Sheet Nos. 3(1) thru 3(8). Plan Sheet No. 3(9) shows the typical sections for the tunnels for Alternative 3.

Structural:

Tunnels

The proposed location for the addition of a new tunnel crossing has been set at 250 feet from the existing eastbound tunnel. This approximately matches the distance used between the existing eastbound and westbound tunnels. This allows the excavation for and the placement of the proposed tunnel to proceed without impacting the existing tunnels. This also provides flexibility in the future should the existing tubes be replaced with wider sections similar to the ones proposed in this study. Further reduction of the distance between the new and the existing eastbound tunnels would require complex numerical analyses for estimating the magnitude and distribution of ground deformations, due to the dredging and excavation, as well as detailed structural analysis for evaluating the impacts of the ground deformations to the existing structures. This is particularly important in the south island area as soft and compressible soils are present and large ground deformations are prone to occur during and after construction.

While it may be possible to place a tunnel between the existing tunnels, it is likely that this would disturb the existing tunnels. Even if this could be done, it does not allow for future replacement of the existing tunnels without complications. Utilizing a tunnel boring machine to add a tunnel is not likely a practical solution as the soils in this region are not conducive to boring due to the looseness of the upper layers. If tunnel boring were utilized the tunnel would need to be lower than the existing tunnels to provide adequate cover over the new tunnel. This increased depth would result in a significantly longer tunnel. Given those considerations it is recommended that the new tunnel be placed as shown in the proposed alignments.

The proposed bridge tunnel segment consists of the following:

- Existing islands will be expanded to accommodate the addition of the proposed tunnel.
- Expansion of South Island will require ground treatment using surcharge and wick drains to avoid excessive settlement.
- Tunnel length will match the existing at approximately 7500 feet portal to portal.
- Rectangular concrete immersed tubes will be utilized.
- It is assumed that the top elevation of the new tunnel matches that of the existing eastbound tunnel.
- Backfill and stone blanket over tunnel will be 5 feet thick to match existing tunnel.
- Cast-in-place concrete boat sections will tie the tunnel to the trestle.
- Each traffic cell in the tunnel consists of 2 traffic lanes, each 12 feet in width.
- Shy distance (offset from travel lane) to the barriers is 2 feet each side.
- Roadway vertical clearance is 16.5 feet, with a 1.5 foot allowance for roadway signage.
- Tide gates will be required.
- Base slab, walls and roof to be waterproofed.
- Ancillary Facilities consisting of a ventilation building and storm water pump station at both ends of the tunnel that house Mechanical and Electrical Systems.
- Mechanical Systems will include tunnel drainage, portal drainage, semi-transverse tunnel ventilation and fire suppression.
- Electrical Systems will include tunnel power, tunnel lighting and tunnel control and communication.
- Approach trestles similar to the existing bridges consist of precast beams on pile bents and are approximately 3300 feet in length on the north end and 6000 feet in length on the south end.
- Emergency egress is provided by a high level walkway in each two-lane traffic cell, as well as cross-passages between the traffic cells.

See Appendix B for additional general construction information with regards to tunnel alternatives.

Bridges

This alternative will require all bridges to be modified from I-664 to I-564. On the Peninsula, an additional lane plus widened shoulders on each side of the median will be needed. Two lanes plus shoulders will be needed on the south side. Most of the standard grade separation structures on the south side can be widened to the inside; however, on the north side, the existing structures sit side-by-side and so the new improvements will have to occur to the outside. The structures over water will have to be widened to the outside. The necessity for outside widening is due to the size and amount of equipment that is required to drive large diameter piles into water. The construction will go much more efficiently if there is no inside widening on the structures over water. Also, piles driven next to the bridges over water may have to be battered in a direction that is parallel to the bridge in order to miss the existing piles that are battered transversely to the bridge. These new piles will have to be installed in opposing pairs with a pile cap that straddles the existing piles.

The inside to outside bridge widening will impact areas where there is existing concrete pavement. The existing pavement markers and markings are established along the longitudinal concrete joints. If the existing pavement is maintained through the widening operations, the new lane transitions will create areas where the pavement markings will deviate from the concrete joints, increasing the risk of “lane drifting” by motorists following the joints instead of the lane markings, thus increasing the risk of side-swipe incidents. This should be addressed in the later design stages if this alternative is further considered.

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As with Alternative 1, the bridge that carries S. Mallory St. over I-64 will have to be replaced. The widening of I-64 will conflict with the pier locations and the bridge spans will have to be lengthened. One of the east bound bridges over the Hampton River will have to be replaced because of the substandard curve in the bridge.

Traffic Analysis:

Travel demand forecasts were developed for the Hampton Roads Bridge Tunnel and traffic analysis was performed for the 2018 and 2030 conditions. For Alternative 3, the analysis showed the following Level of Service (LOS) results for the AM (PM) peak hours for an average weekday:

	2018		2030	
	EB	WB	EB	WB
No Build	**F(F)**	**F(F)**	**F(F)**	**F(F)**
No Build with 3rd Crossing	D(E)	C(E)	D(E)	C(**F**)
Alternative 3 (4-4)	C(B)	B(B)	B(B)	B(B)
Alternative 3 (4-4)w/3rd Crossing	B(B)	B(B)	B(B)	B(B)

Right-of-Way Impacts:

The existing right-of-way limits for the study area were provided by the Department and are shown on each alternative display. Since the information provided is limited to only right-of way limits and does not include property or parcel information, the best assessment of impacts can only be quantified based on potential impacts to buildings and existing sound walls based on assumptions of side slope designs and roadside treatments. While not an optimal assessment, it does provide an order of magnitude of the potential impacts that may be expected by the implementation of this alternative. Thus, based on the available information, Alternative 3 will potentially impact 70 to 105 buildings and about 7,400 LF of sound barrier.

Mainline, Ramp and Shoulder Deficiencies:

The existing eastbound bridge crossing the Hampton River (Station 209+00 to 236+00) has deficient radii on the approaches. The radii are less than the minimum 1821' required for a design speed of 70 mph. For Alternative 3 the radii would have to be increased to meet current design standards and a new bridge would have to be constructed to replace the existing substandard facility.

The existing westbound bridge approaching the tunnel (Station 475+00 to 490+00) has substandard curvature as it departs the Willoughby Spit area. Also, the existing westbound tunnel has a substandard height restriction. The concept assumes that these are retained through design exceptions due to the cost of modifying the structures to meet current standards.

The existing interchange ramps were analyzed based on AASHTO and VDOT requirements. The design criteria investigated for each ramp consisted of:

1. Taper length
2. Deceleration/Acceleration lane lengths
3. Ramp radii

Alternative 3 has 4 ramps with deficient radii and 13 ramps with inadequate acceleration or deceleration lengths. The majority of the taper lengths on the corridor are 200 feet in length which meets the AASTHO requirement of 180 feet but not the VDOT length of 300 feet.

Further Study Considerations:

The operation of the eastbound inspection area will need to be further addressed if the design of this area is progressed beyond this stage.

The westbound and eastbound traffic splits outlined in this alternative are not common, but not without precedent, along interstate roadways. The splits would mimic the traffic splits that occur at Baltimore's Fort McHenry Tunnel (I-95) and other tunnels on the national highway system. Additional signing will be necessary to alert travelers of these conditions.

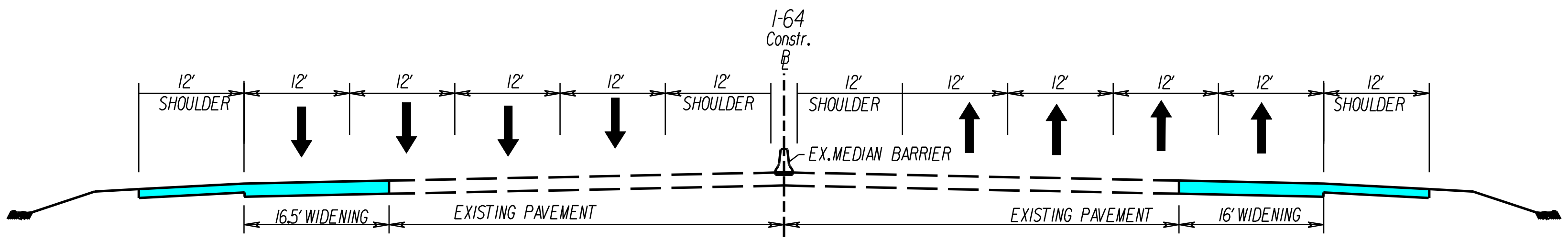
Incident management and hurricane evacuation operations will be slightly impacted with this alternative. It appears that the operations will function much the same as they do today with only slight modifications due to the additional lanes. The design of the new bridge-tunnel portion will need to account for these operations. If the incident management plans are to utilize the additional capacity provided by the use of two of the eastbound lanes to go westbound, the new facility will need to be designed to accommodate this operation.

Estimated Construction Cost and Implementation Schedule:

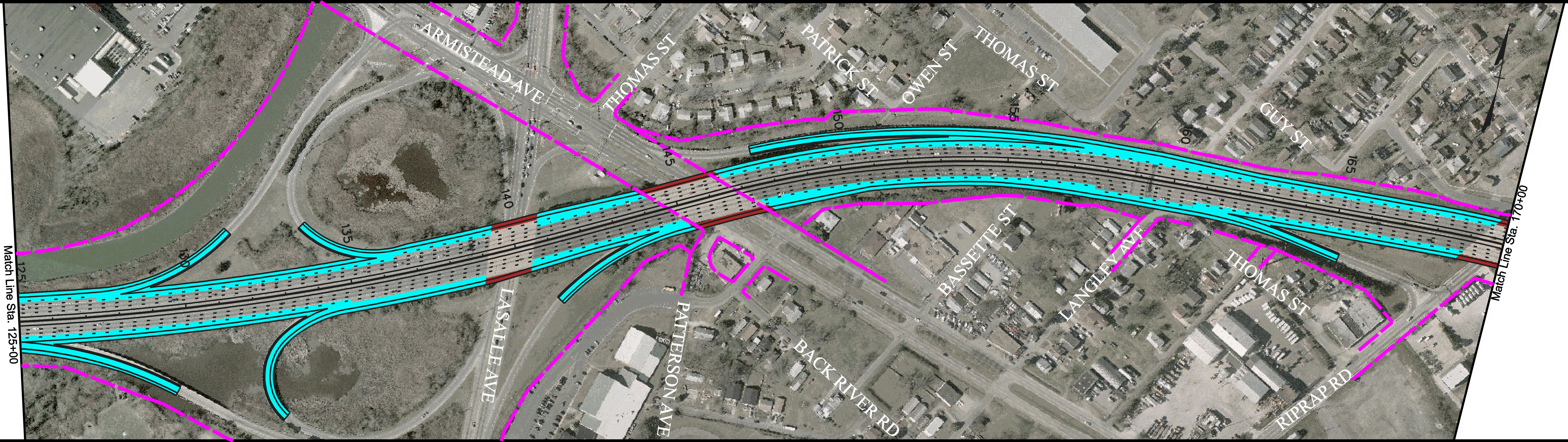
The following is the general construction cost estimate for Alternative 3:

Roadway:	$83 million
Bridges:	$159 Million
Tunnel:	$3.0 Billion
Total:	**$3.24 Billion**

The construction schedule for Alternative 3 is estimated to be 6 years.



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY



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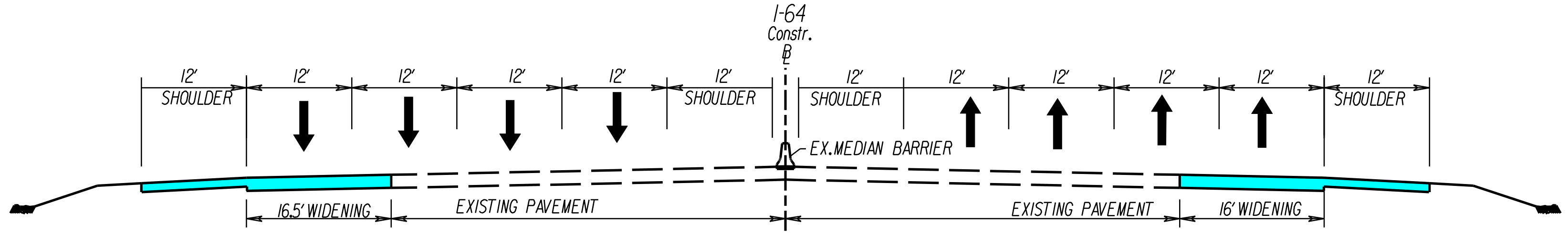
Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

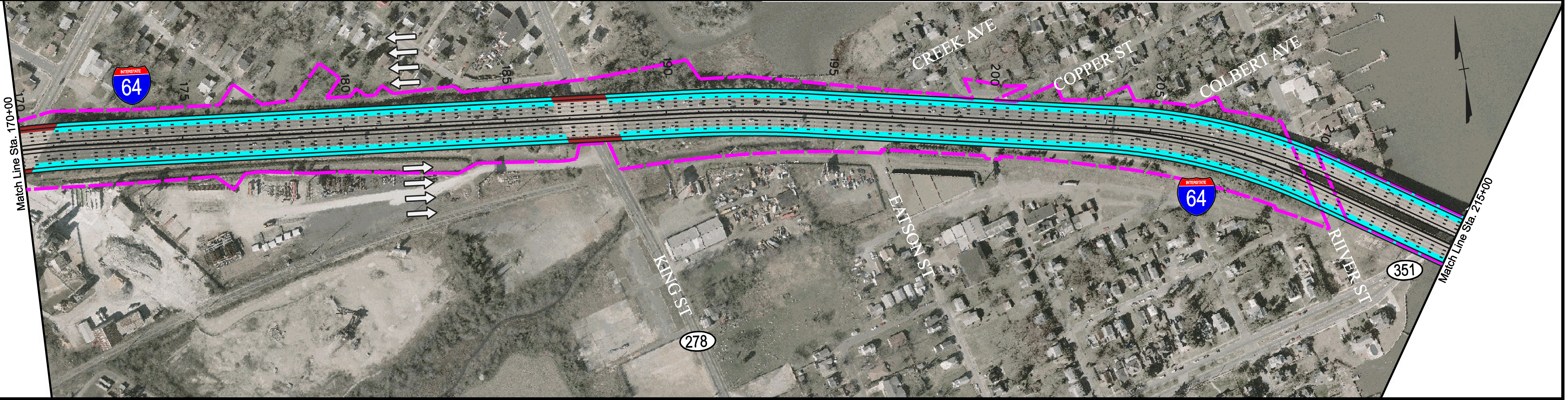
SCALE
0 300' 600'

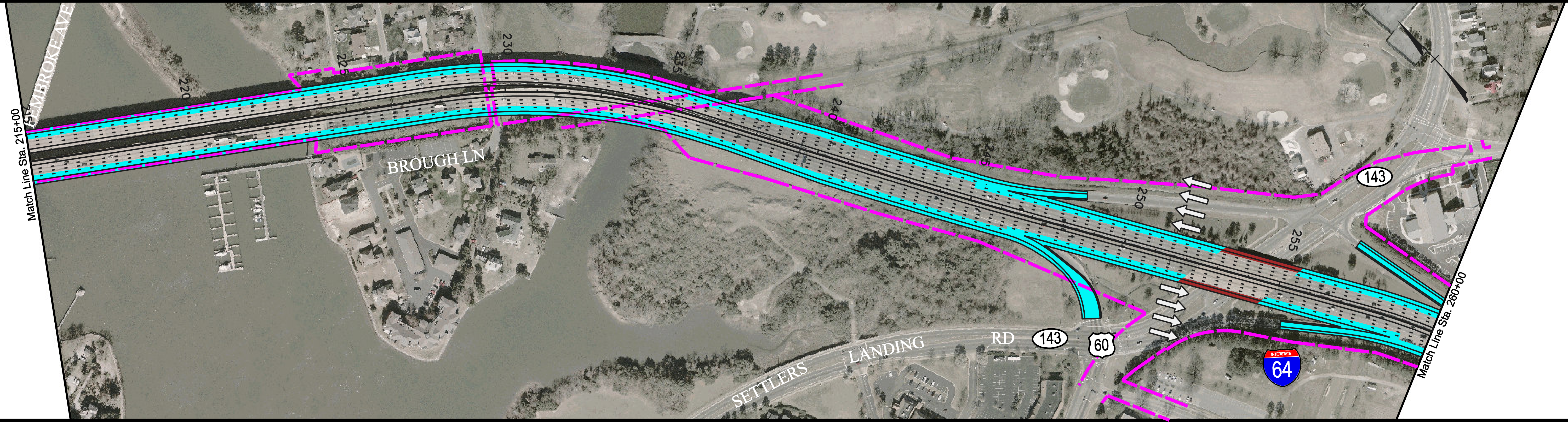
PLAN SHEET NO.
3(1)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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- Proposed Structures and Bridges
- Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

SCALE
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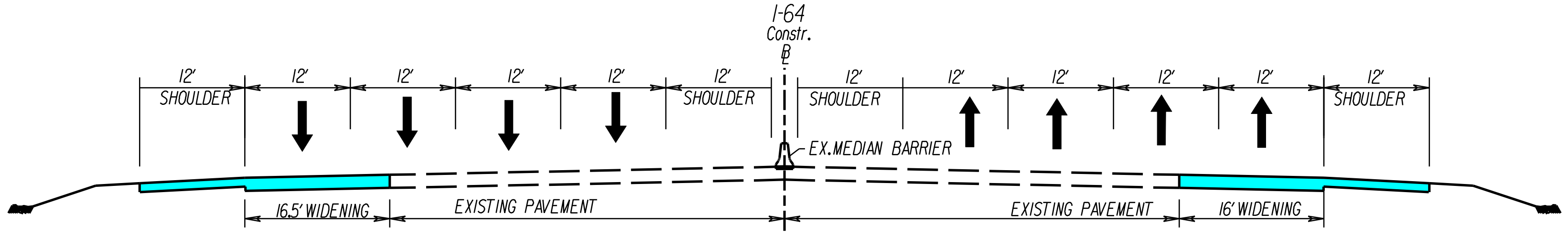
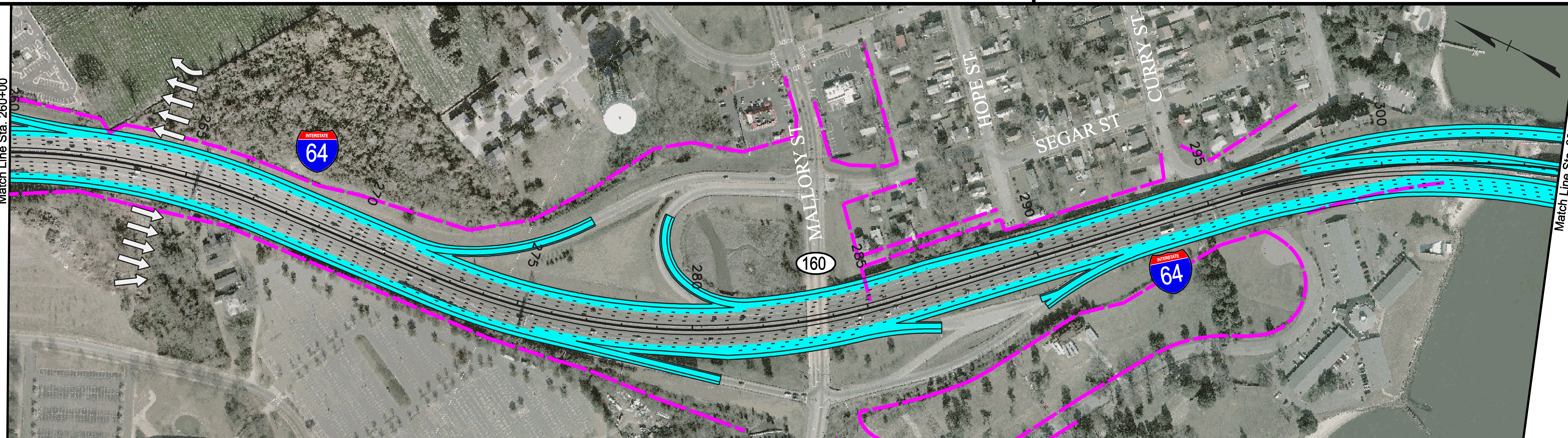
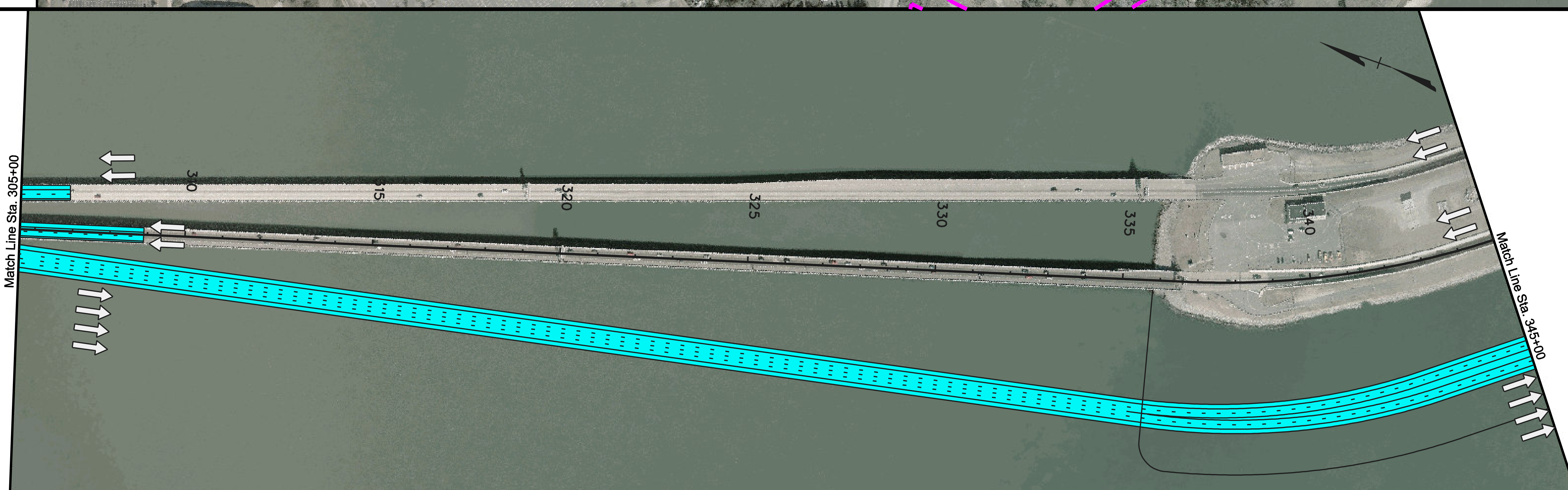
PLAN SHEET NO. 3(2)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

SCALE
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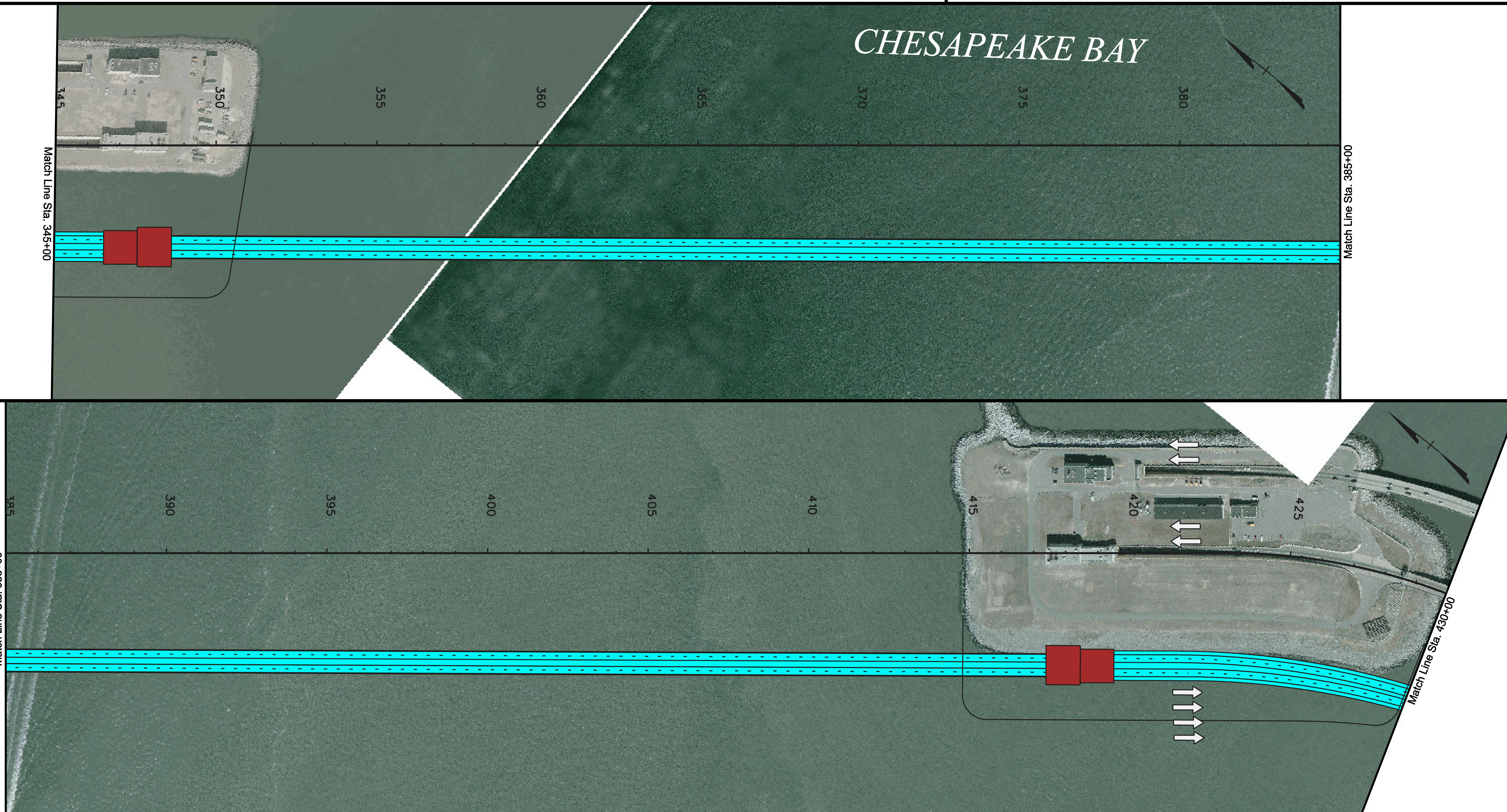
PLAN SHEET NO. 3(3)

HAMPTON ROADS BRIDGE–TUNNEL
EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

SCALE
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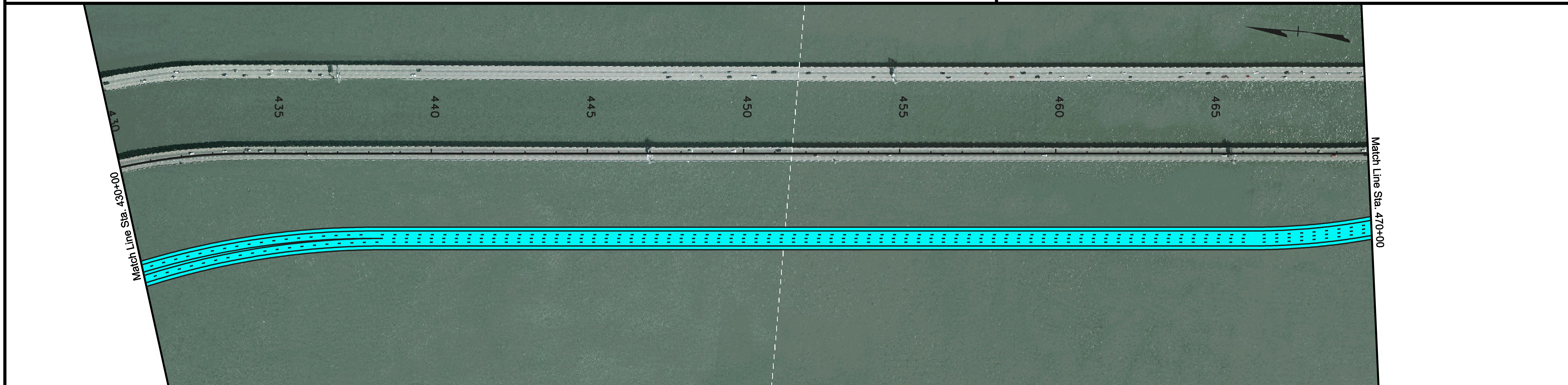
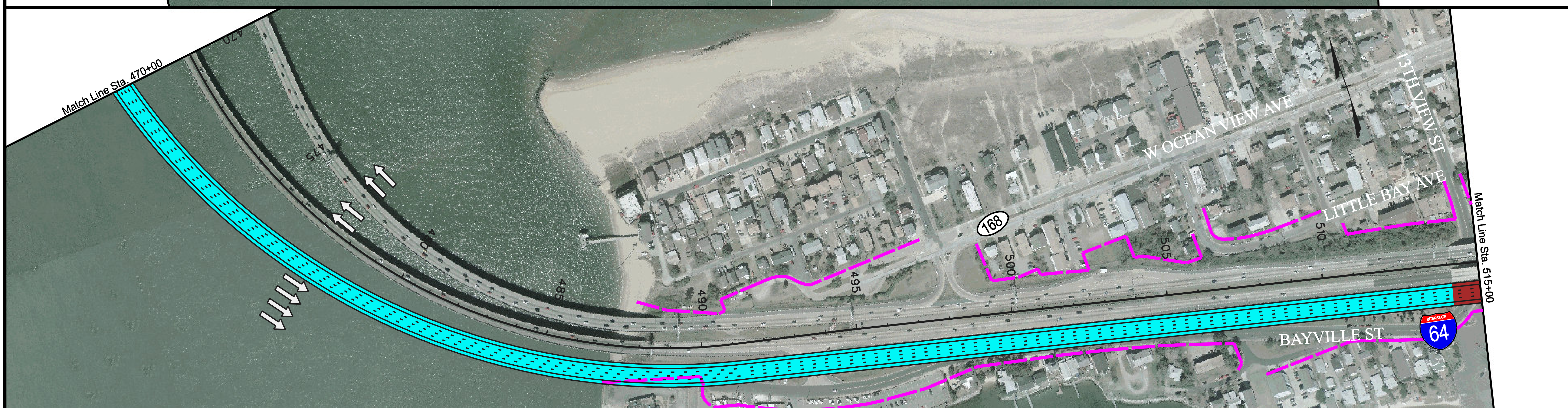
PLAN SHEET NO.
3(4)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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Legend
Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

SCALE
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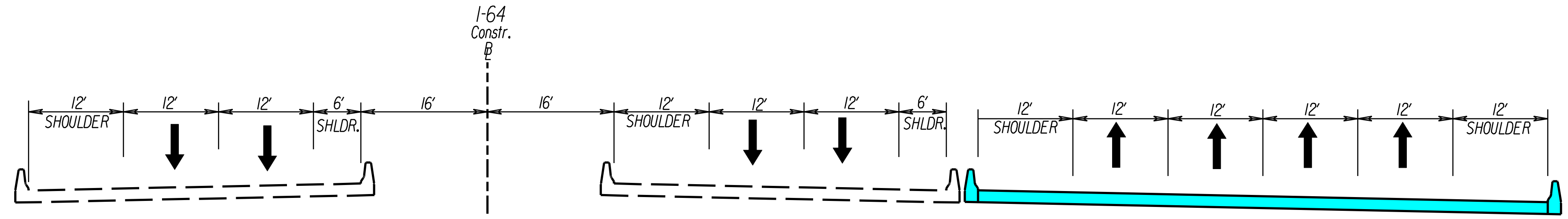
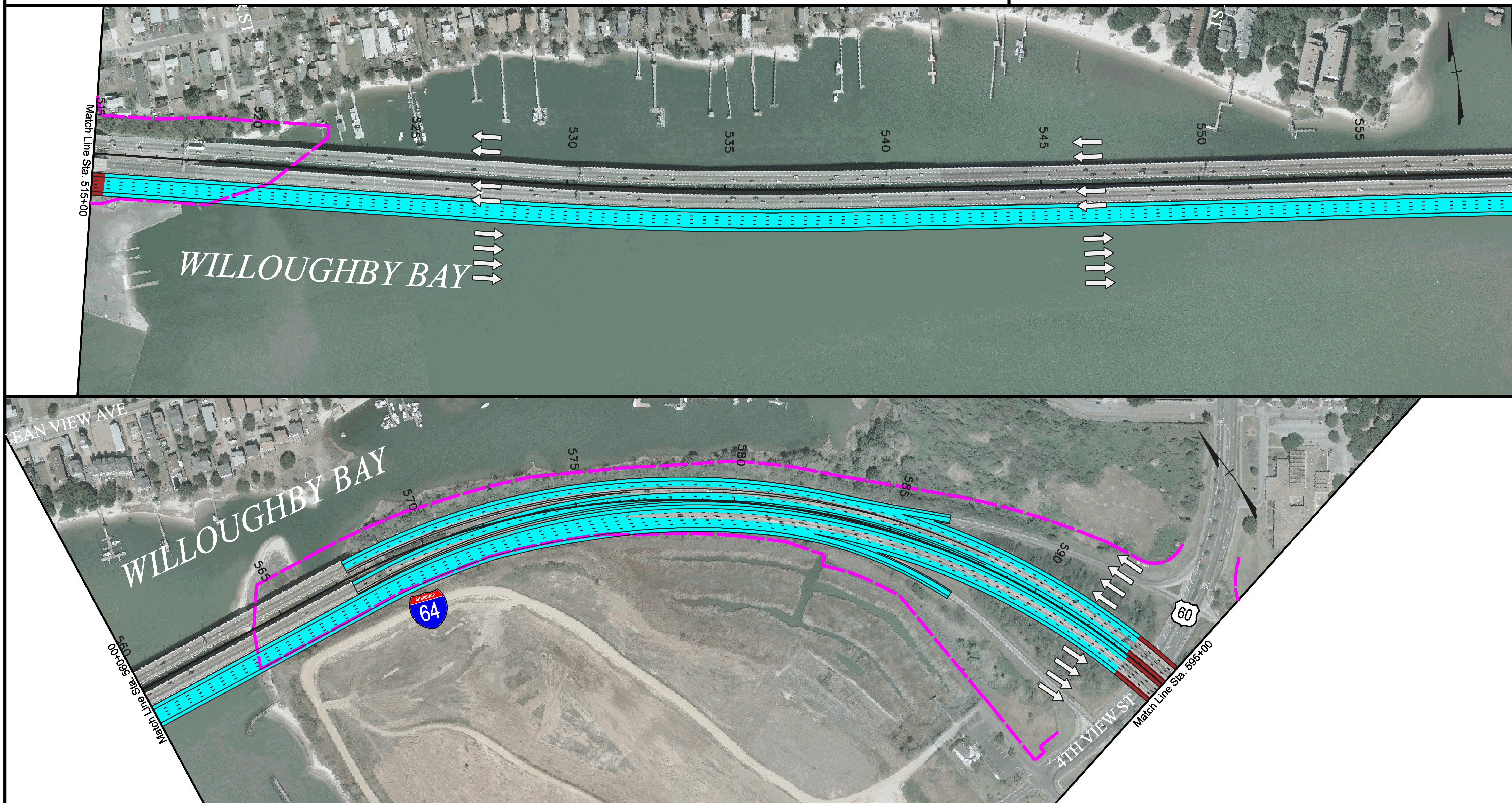
PLAN SHEET NO. 3(5)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY





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- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

SCALE
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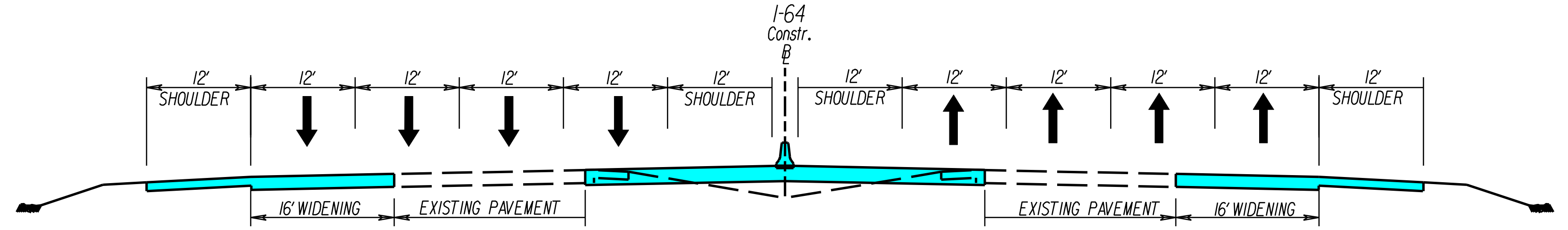
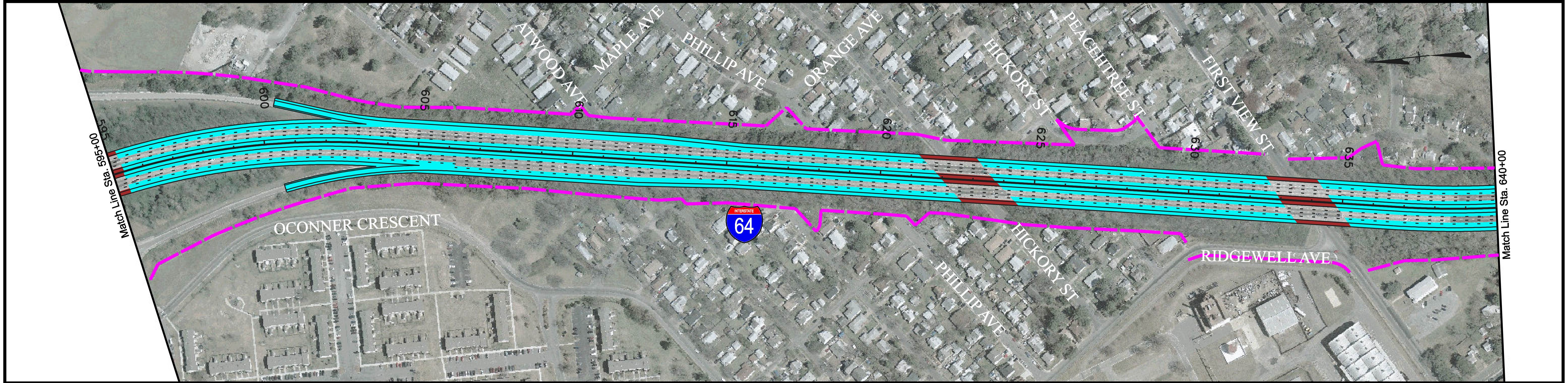
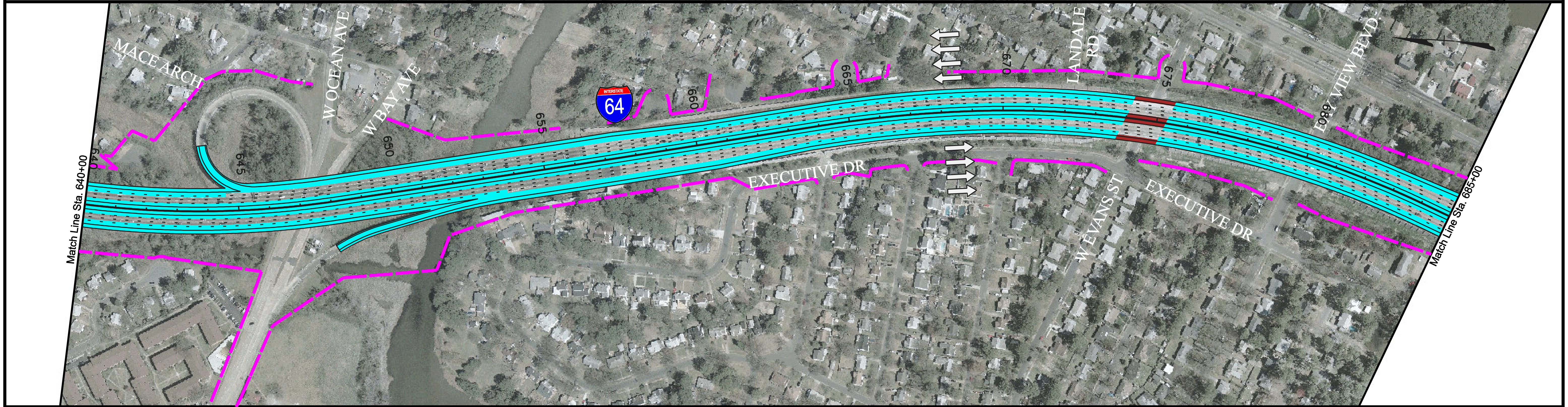
PLAN SHEET NO. 3(6)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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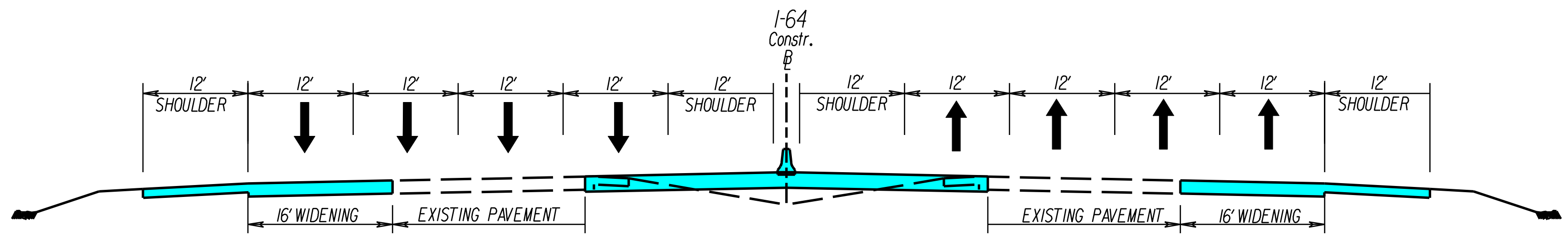
- Existing R/W

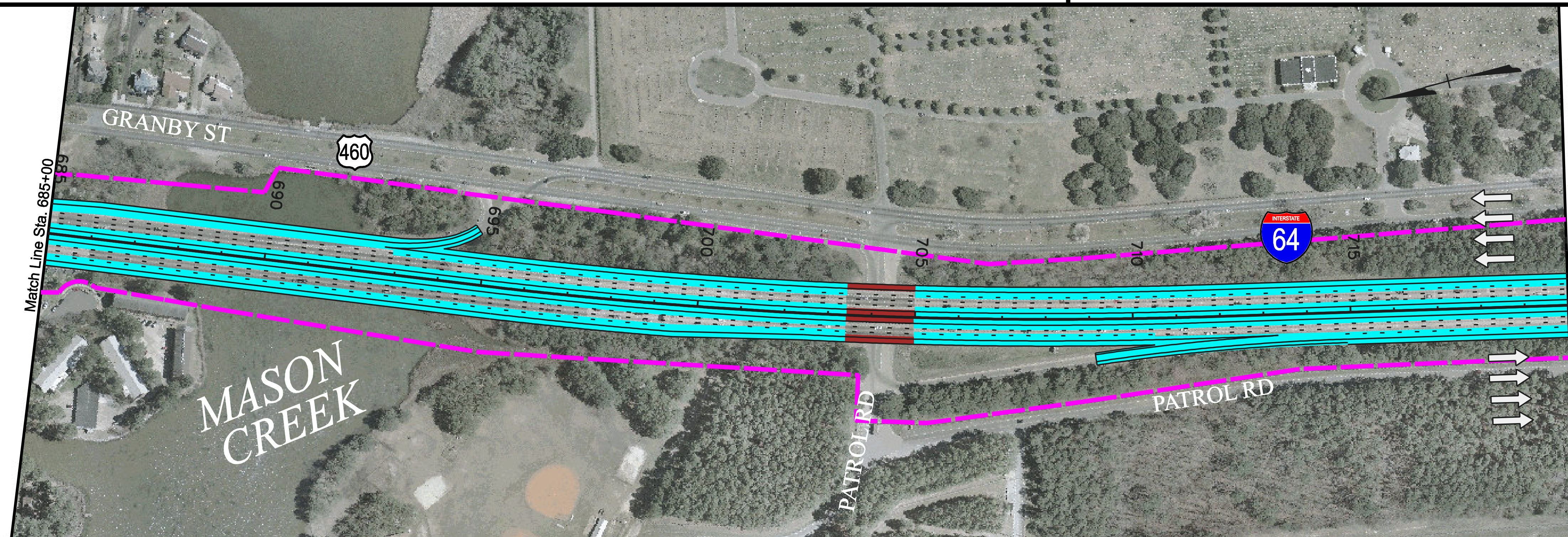
ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

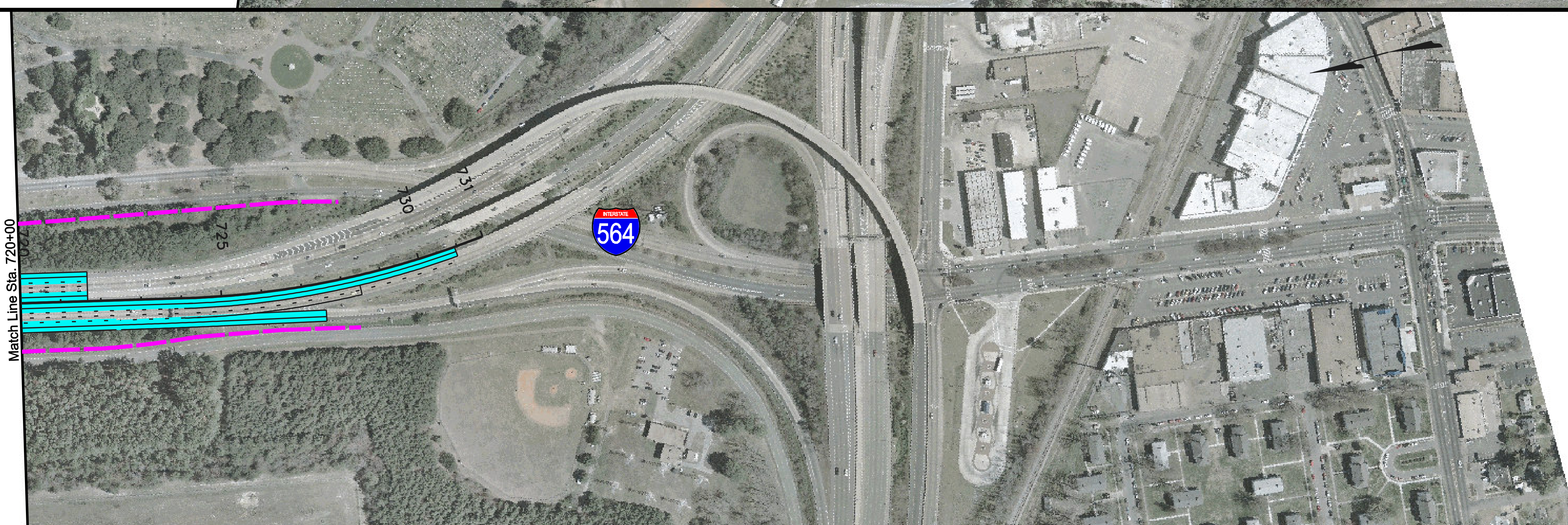
SCALE
0 300' 600'

PLAN SHEET NO.
3(7)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 3 : Four Additional Lanes of Bridge - Tunnel Capacity Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 3(8)

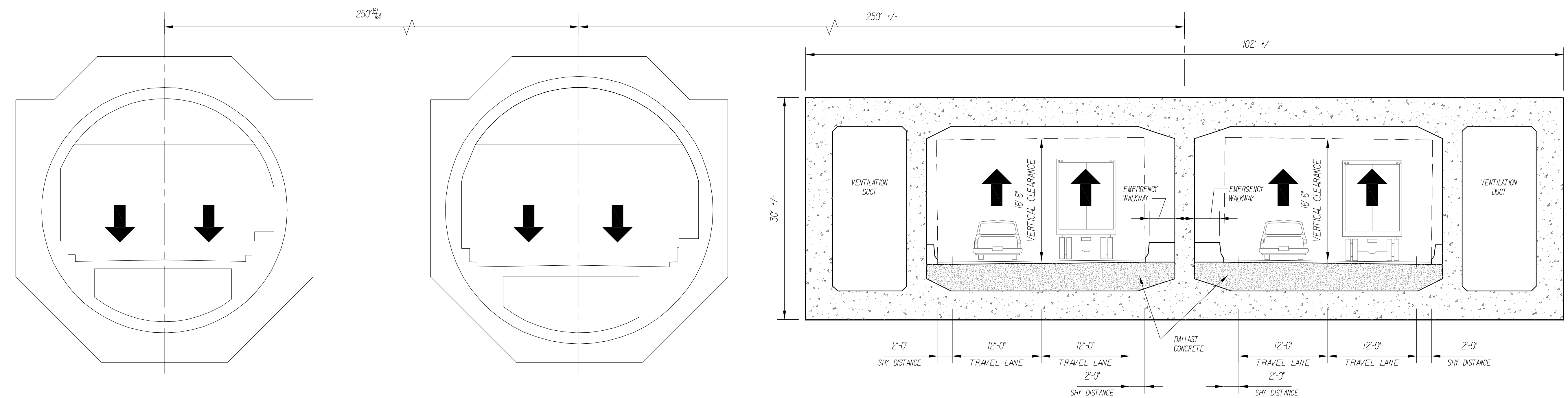
DGN $REF001 $REF002 $REF003 $REF004 $REF005 $REF006
$DGNLEV $LEV001 $LEV002 $LEV003 $LEV004 $LEV005 $LEV006

SURVEYED BY
SUPERVISED BY VDOT
DESIGNED BY PB Americas, INC.

DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	VA.				3(9)

TYPICAL SECTIONS
ALTERNATIVE 3



WEST BOUND LANES

EXISTING TUNNEL

WEST BOUND LANES

EXISTING TUNNEL

EAST BOUND LANES

EAST BOUND LANES

PROPOSED EAST BOUND TUNNEL

BRIDGE TUNNEL TO I-64/I-564

Virginia Department of Transportation

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
			3(9)

$TIME$STAMP$

ALTERNATIVE 4

General Alternative Information:

Similar to Alternative 3, this alternative would provide four additional lanes of bridge-tunnel capacity connecting the Peninsula and Southside, with the inside lanes in each direction being HOV lanes. The additional lanes would be provided through the entire study area limits, connecting at I-664 and I-564.

The existing eastbound bridge-tunnel facility and Willoughby Bay bridge would be converted to carry all westbound traffic while a new bridge tunnel facility and bridge over Willoughby Bay would carry eastbound traffic. The HOV lanes will tie directly into the HOV facilities at either end of the study area.

The conceptual layout and roadway typical section for Alternative 4 is shown on Plan Sheet Nos. 4(1) thru 4(8). The typical sections for the tunnels are shown on Plan Sheet No. 4(9).

Structural:

Tunnels

The proposed location for the addition of a new tunnel crossing has been set at 250 feet from the existing eastbound tunnel. This approximately matches the distance used between the existing eastbound and westbound tunnels. This allows the excavation for and the placement of the proposed tunnel to proceed without impacting the existing tunnels. This also provides flexibility in the future should the existing tubes be replaced with wider sections similar to the ones proposed in this study. Further reduction of the distance between the new and the existing eastbound tunnels would require complex numerical analyses for estimating the magnitude and distribution of ground deformations, due to the dredging and excavation, as well as detailed structural analysis for evaluating the impacts of the ground deformations to the existing structures. This is particularly important in the south island area as soft and compressible soils are present and large ground deformations are prone to occur during and after construction.

While it may be possible to place a tunnel between the existing tunnels, it is likely that this would disturb the existing tunnels. Even if this could be done, it does not allow for future replacement of the existing tunnels without complications. Utilizing a tunnel boring machine to add a tunnel is not likely a practical solution as the soils in this region are not conducive to boring due to the looseness of the upper layers. If tunnel boring were utilized the tunnel would need to be lower than the existing tunnels to provide adequate cover over the new tunnel. This increased depth would result in a significantly longer tunnel. Given those considerations it is recommended that the new tunnel be placed as shown in the proposed alignments.

The proposed bridge-tunnel segment consists of the following:

- Existing islands will be expanded to accommodate the addition of the proposed tunnel.
- Expansion of South Island will require ground treatment using surcharge and wick drains to avoid excessive settlement.
- Tunnel length will match the existing at approximately 7500 feet portal to portal.
- Rectangular concrete immersed tubes will be utilized.
- It is assumed that the top elevation of the new tunnel matches that of the existing eastbound tunnel.
- Backfill and stone blanket over tunnel will be 5 feet thick to match existing tunnel.
- Cast-in-place concrete boat sections will tie the tunnel to the trestle.
- Each traffic cell in the tunnel consists of 2 traffic lanes, each 12 feet in width.
- Shy distance (offset from travel lane) to the barriers is 2 feet each side.
- Roadway vertical clearance is 16.5 feet, with a 1.5 foot allowance for roadway signage.
- Clear height to tunnel roof is approximately 18 feet which would accommodate most multimodal systems.
- No buffer is provided between HOV and normal lanes.
- Tide gates will be required.
- Base slab, walls and roof to be waterproofed.
- Ancillary Facilities consisting of a ventilation building and storm water pump station at both ends of the tunnel that house Mechanical and Electrical Systems.
- Mechanical Systems will include tunnel drainage, portal drainage, semi-transverse tunnel ventilation and fire suppression.
- Electrical Systems will include tunnel power, tunnel lighting and tunnel control and communication.
- Approach trestles similar to the existing bridges consist of precast beams on pile bents and are approximately 3300 feet in length on the north end and 6000 feet in length on the south end.
- Emergency egress is provided by a high level walkway in each two-lane traffic cell, as well as cross-passages between the traffic cells.

See Appendix B for additional general construction information with regards to tunnel alternatives.

Bridges

This alternative will require all bridges to be modified from I-664 to I-564. On the Peninsula, an additional lane plus widened shoulders on each side of the median will be needed. Two lanes plus shoulders will be needed on the south side. Most of the standard grade separation structures on the south side can be widened to the inside; however, on the north side, the existing structures sit side-by-side and so the new improvements will have to occur to the outside. The structures over water will have to be widened to the outside. The necessity for outside widening is due to the size and amount of equipment that is required to drive large diameter piles into water. The construction will go much more efficiently if there is no inside widening on the structures over water. Also, piles driven next to the bridges over water may have to be battered in a direction that is parallel to the bridge in order to miss the existing piles that are battered transversely to the bridge. These new piles will have to be installed in opposing pairs with a pile cap that straddles the existing piles.

The inside to outside bridge widening will impact areas where there is existing concrete pavement. The existing pavement markers and markings are established along the longitudinal concrete joints. If the existing pavement is maintained through the widening operations, the new lane transitions will create areas where the pavement markings will deviate from the concrete joints, increasing the risk of “lane drifting” by motorists following the joints instead of the lane markings, thus increasing the risk of side-swipe incidents. This should be addressed in the later design stages if this alternative is further considered.

On the Willoughby Bay bridge, all the new bridge lanes on this alternative will be added to the water side of this structure. Very little construction activity will occur on the land side and the property owners around the bay will experience minimal inconvenience, except for personal boating movement. The private piers in the area should not be affected.

As with Alternative 2, the bridge that carries S. Mallory St. over I-64 will have to be replaced as well as sections of the westbound I-64 to I-664 ramp. The widening of I-64 will conflict with the pier locations and the bridge spans will have to be lengthened. One of the eastbound bridges over the Hampton River will have to be replaced because of the substandard curve in the bridge.

Traffic Analysis:

Travel demand forecasts were developed for the Hampton Roads Bridge-Tunnel and traffic analysis was performed for the 2018 and 2030 conditions. For Alternative 4, the analysis showed the following Level of Service (LOS) results for the AM (PM) peak hours for an average weekday:

	2018		2030	
	EB	WB	EB	WB
No Build	**F(F)**	**F(F)**	**F(F)**	**F(F)**
No Build with 3rd Crossing	D(E)	C(E)	D(E)	C(**F**)
Alternative 4 (3 SOV+1HOV)	C/A(C/A)*	B/A(C/A)*	C/A(C/A)*	C/A(C/A)*
Alternative 4(3+1) w/3rd Crossing*	C/A(B/A)*	B/A(C/A)*	C/A(C/A)*	C/A(C/A)*

* 3 SOV lanes/ 1 HOV lane level of service

Right-of-Way Impacts:

The existing right-of-way limits for the study area were provided by the Department and are shown on each alternative display. Since the information provided is limited to only right-of way limits and does not include property or parcel information, the best assessment of impacts can only be quantified based on potential impacts to buildings and existing sound walls based on assumptions of side slope designs and roadside treatments. While not an optimal assessment, it does provide an order of magnitude of the potential impacts that may be expected by the implementation of this alternative. Thus, based on the available information, Alternative 4 will potentially impact 70 to 105 buildings and about 7,400 LF of sound barrier.

Mainline, Ramp and Shoulder Deficiencies:

The existing eastbound bridge crossing the Hampton River (Station 209+00 to 236+00) has deficient radii on the approaches. The radii are less than the minimum 1821' required for a design speed of 70 mph. For this alternative the radii would have to be increased to meet current design standards and a new bridge would have to be constructed replacing the existing substandard facility.

The existing westbound bridge approaching the tunnel (Station 475+00 to 490+00) has substandard curvature as it departs the Willoughby Spit area. Also, the existing westbound tunnel has a substandard height restriction. This concept assumes that these would be retained through design exceptions due to the cost of modifying the structures to meet current standards.

The existing interchange ramps were analyzed based on the current AASHTO and VDOT requirements. The design criteria investigated for each ramp consisted of:

1. Taper length
2. Deceleration/Acceleration lane lengths
3. Ramp radii

Alternative 4 has 4 ramps with deficient radii and 13 ramps with inadequate acceleration or deceleration lengths. The majority of the taper lengths on the corridor are 200 feet in length which meets the AASTHO requirement of 180 feet but not the VDOT length of 300 feet.

Further Study Considerations:

The operation of the eastbound inspection area will need to be further addressed if the design of this area is progressed beyond this stage.

Current guidelines, and the existing layout for the I-64 facility through Newport News, suggest a 4' buffer between HOV and general purpose lanes. This will be impossible to provide in the westbound direction since the existing eastbound tunnel lacks the room to provide this spacing, and widening the existing tunnel is not feasible.

The enforcement of the HOV restrictions inside the tunnels and on the bridge portions would be impossible by conventional means. There is also an increased risk of incidents on the bridge-tunnel facility due to the potential speed differential associated with the HOV lane directly adjacent to the general purpose lane.

Incident management and hurricane evacuation operations will be slightly impacted with this alternative. It appears that the operations would function much the same as they do today with only slight modifications due to the additional lanes. The design of the new bridge-tunnel portion would need to account for these operations. If the incident management plans are to utilize the additional capacity provided by the use of two of the eastbound lanes to go westbound, the new facility would need to be designed to accommodate this operation.

Estimated Construction Cost and Implementation Schedule:

The following is the general construction cost estimate for Alternative 4:

Roadway: $89 million

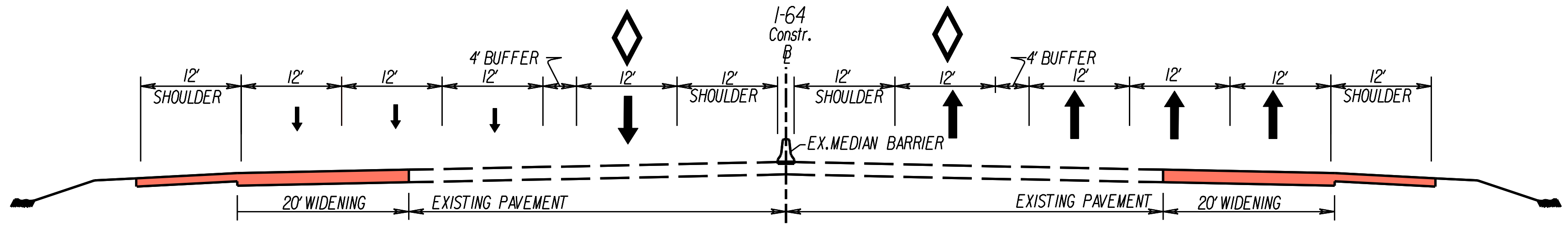
Bridges: $177 Million

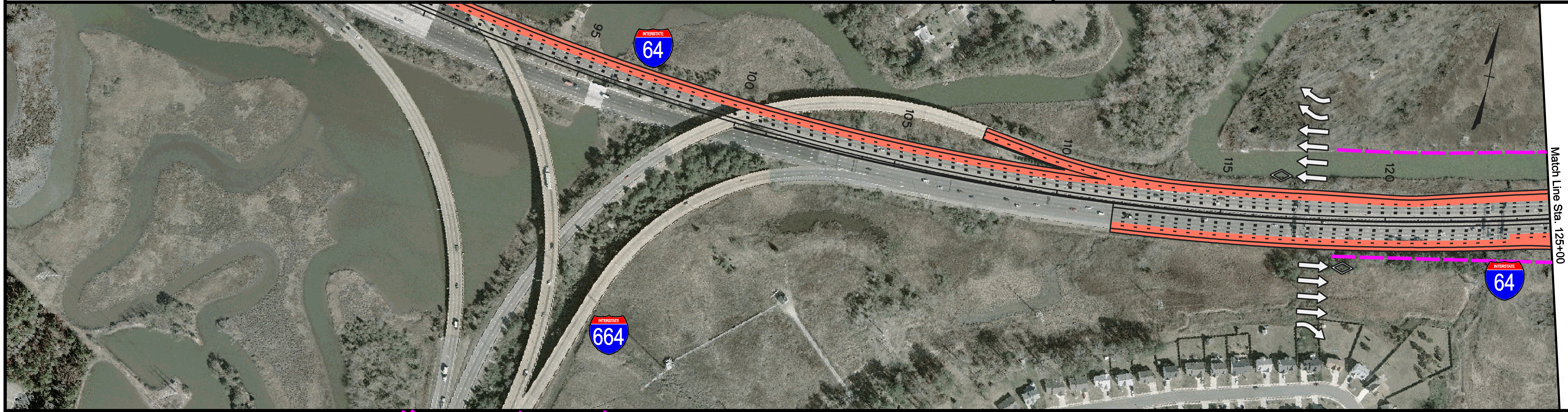
Tunnel: $3.0 Billion

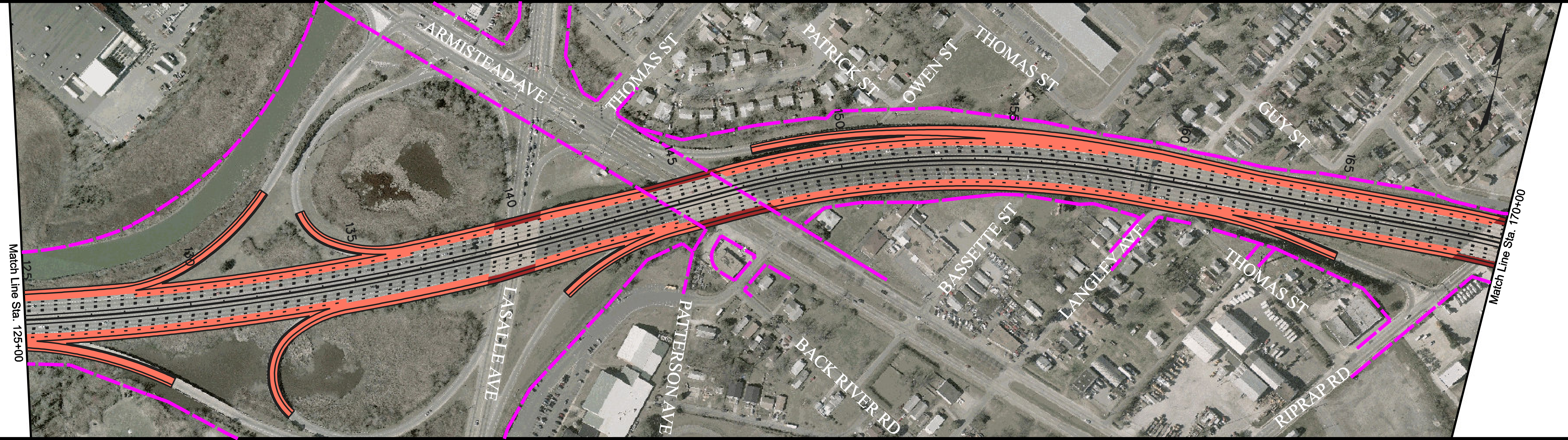
Total: $3.27 Billion

The construction schedule for Alternative 4 is estimated to be 6 years.

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

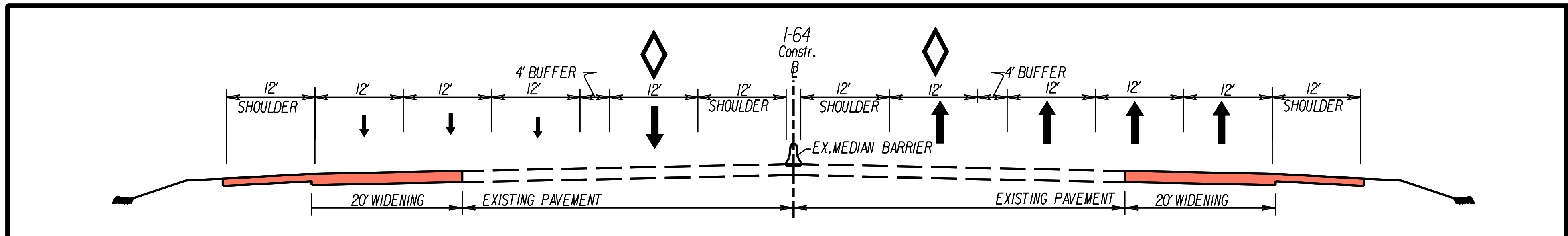
ALTERNATIVE 4 : Four Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Eight -Lane (3+1 1+3) HOV Facility Connecting the Peninsula and Southside

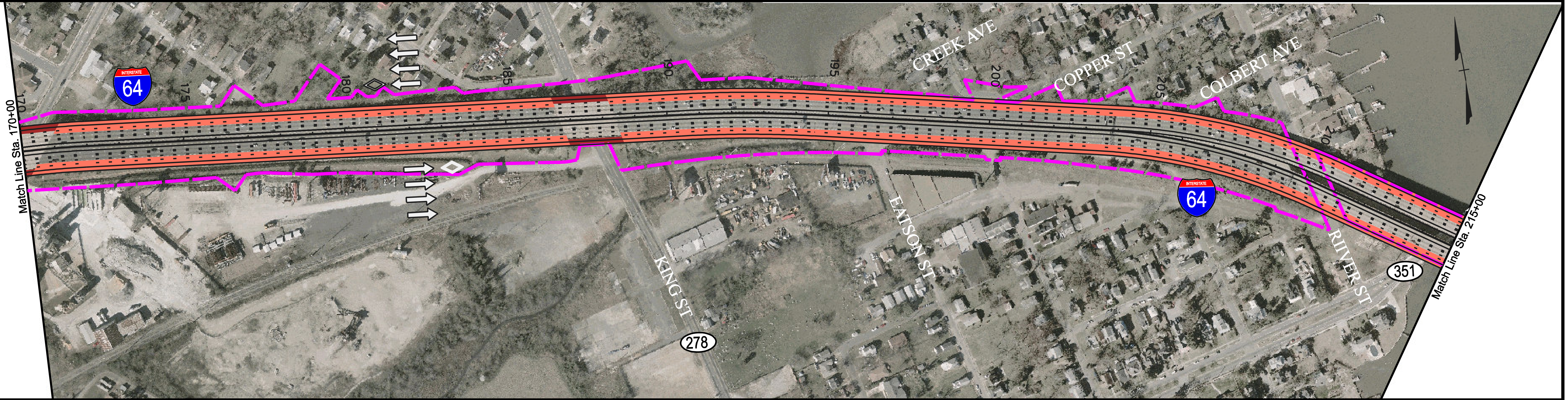
SCALE
0 300' 600'

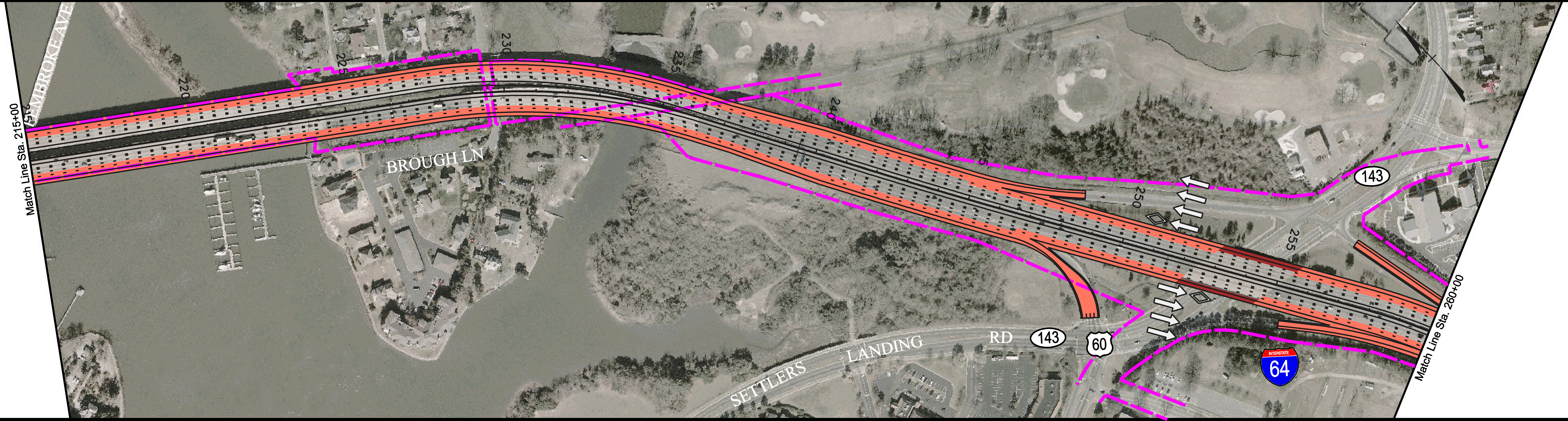
PLAN SHEET NO. 4(1)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64







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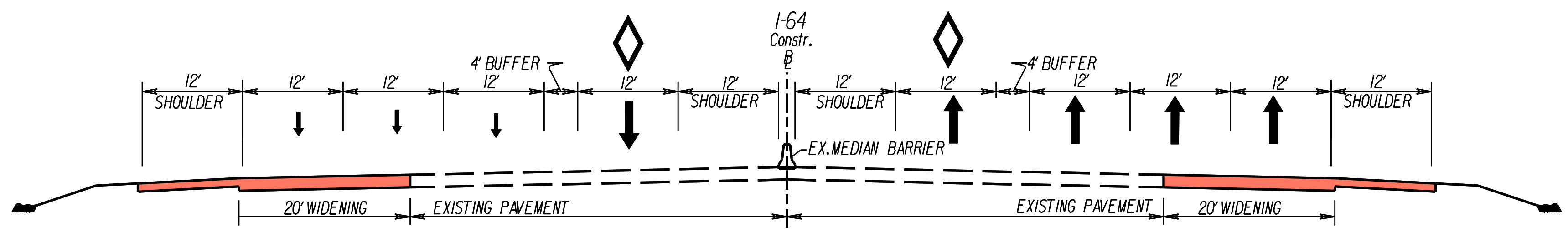
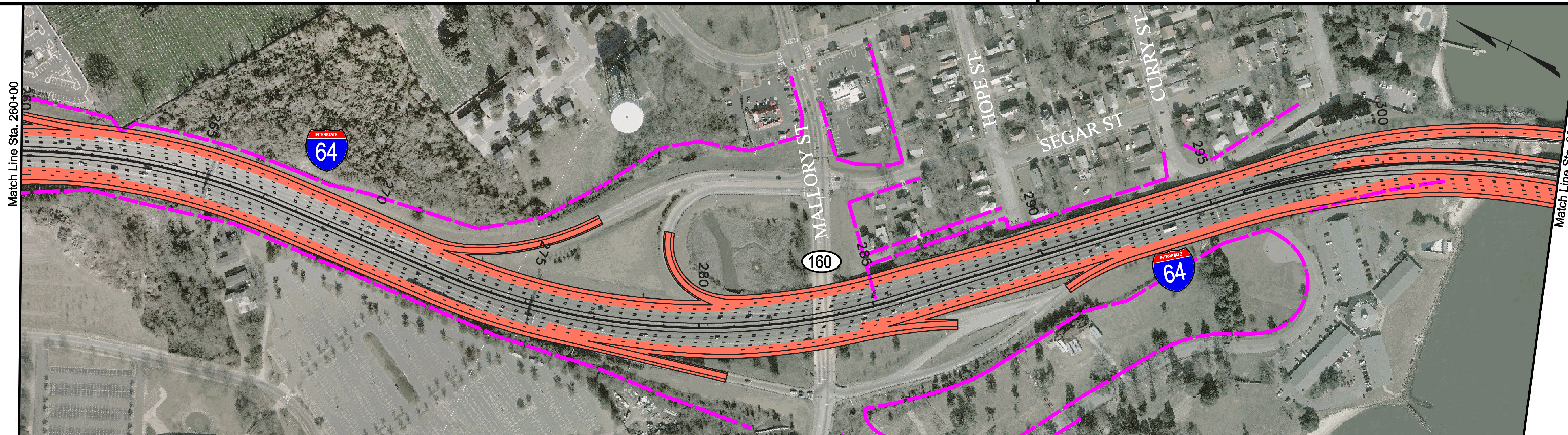
SCALE
0 300' 600'

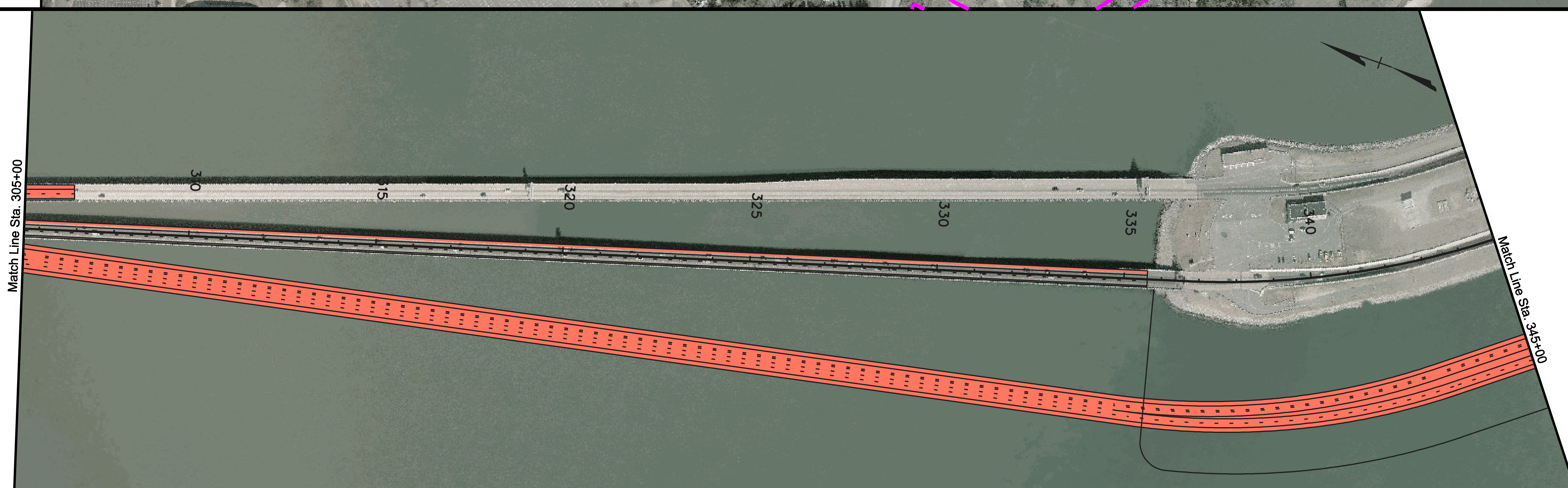
PLAN SHEET NO. 4(2)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

64







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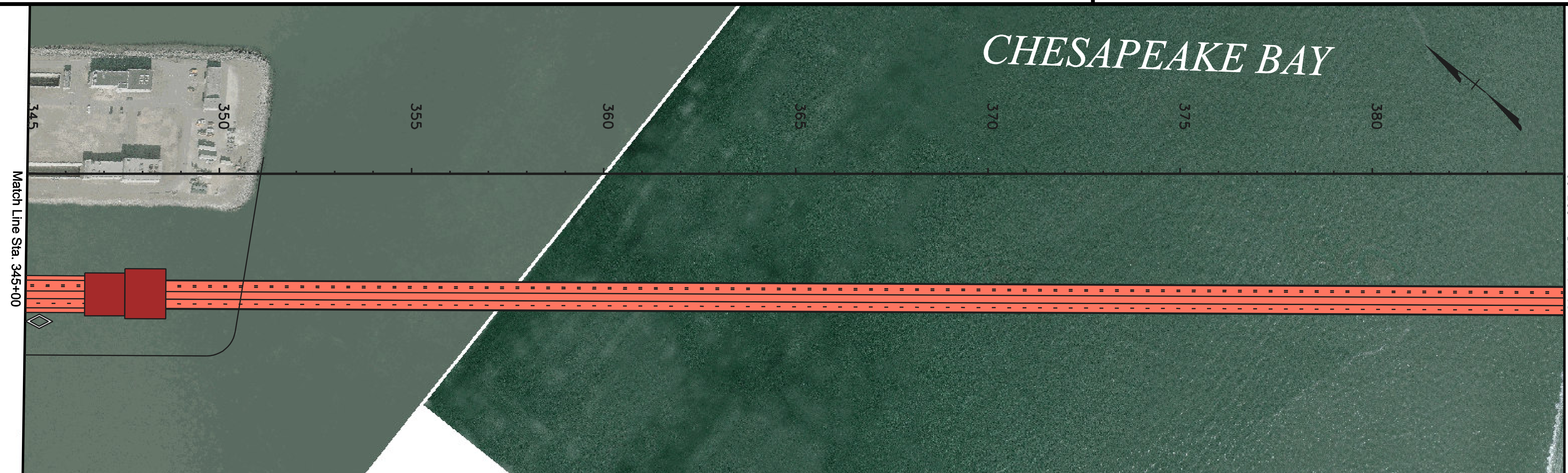
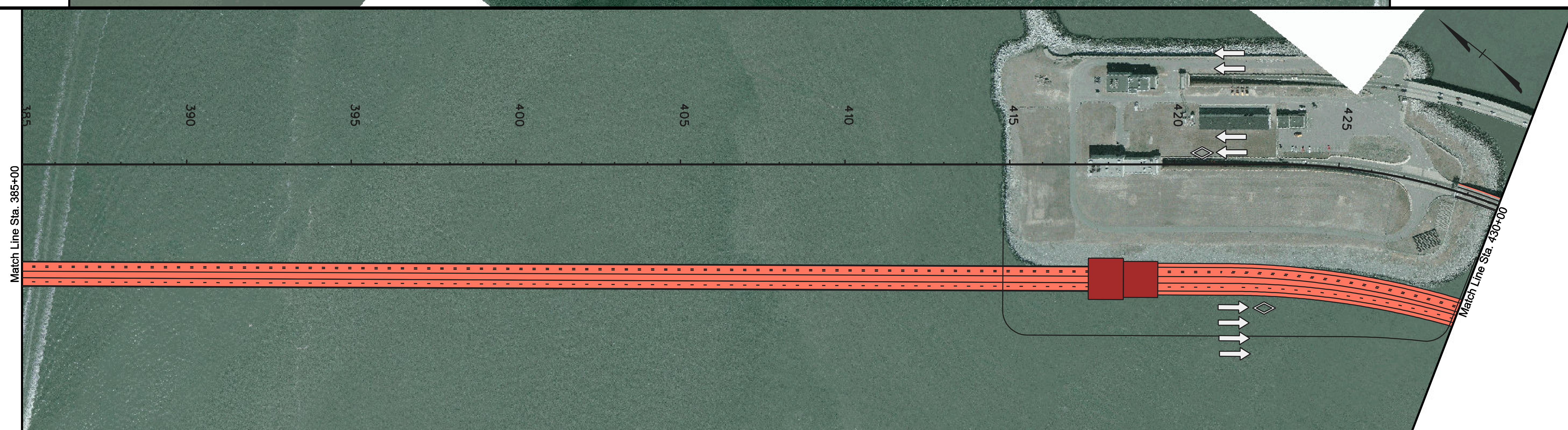
SCALE
0 300' 600'

PLAN SHEET NO.
4(3)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

I INTERSTATE 64





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Proposed Pavement Widening
Proposed Structures and Bridges
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SCALE
0 300' 600'

PLAN SHEET NO. 4(4)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64

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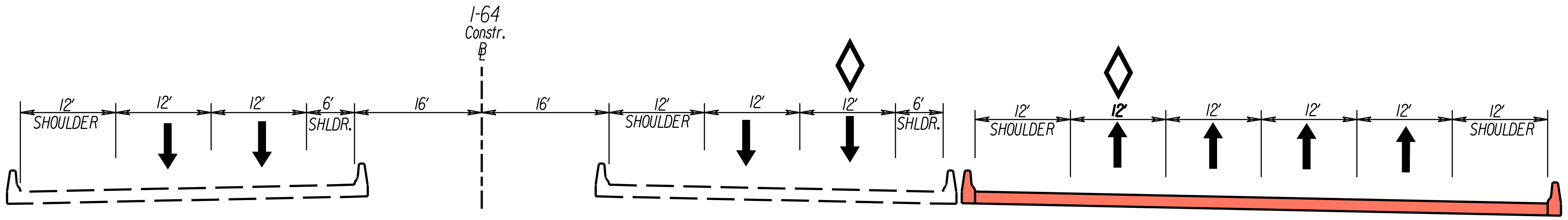
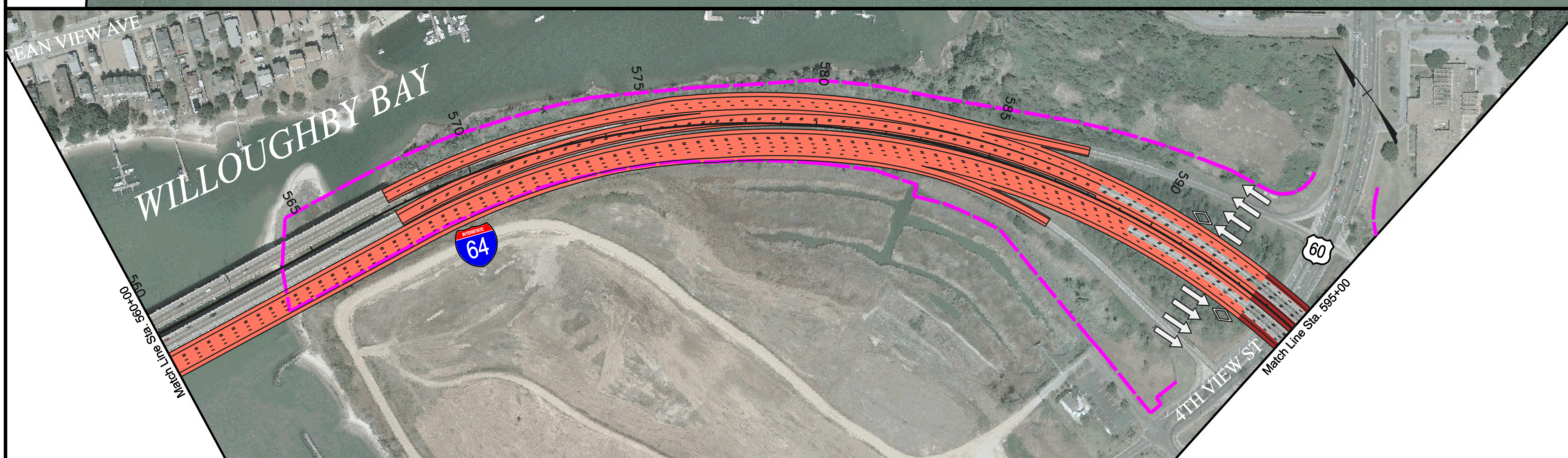
SCALE 0 300' 600'

PLAN SHEET NO. 4(5)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY





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PLAN SHEET NO. 4(6)

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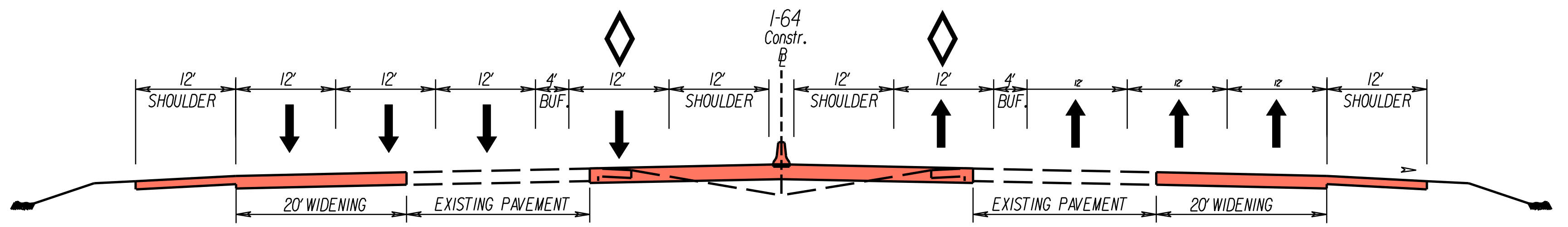
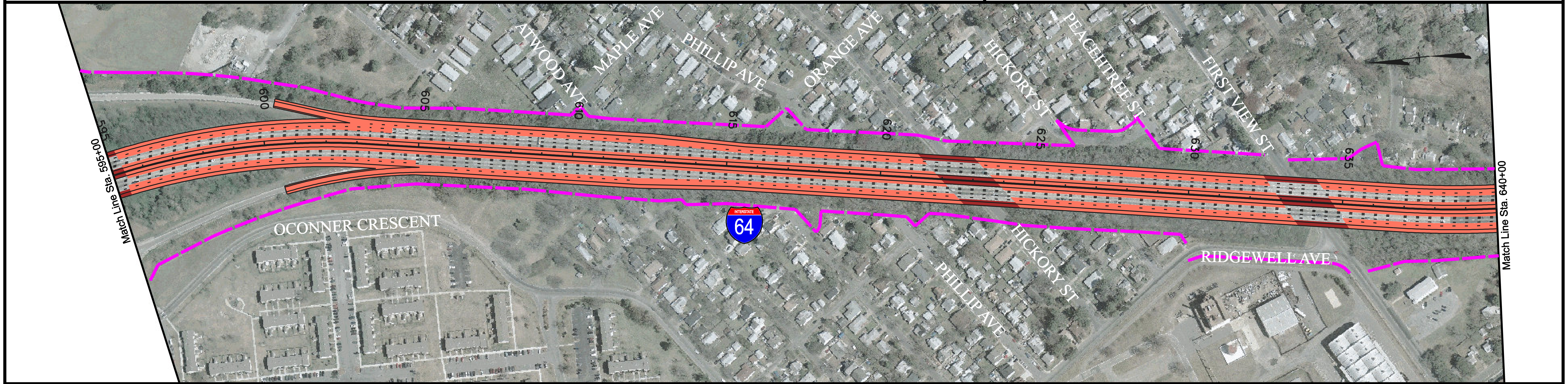
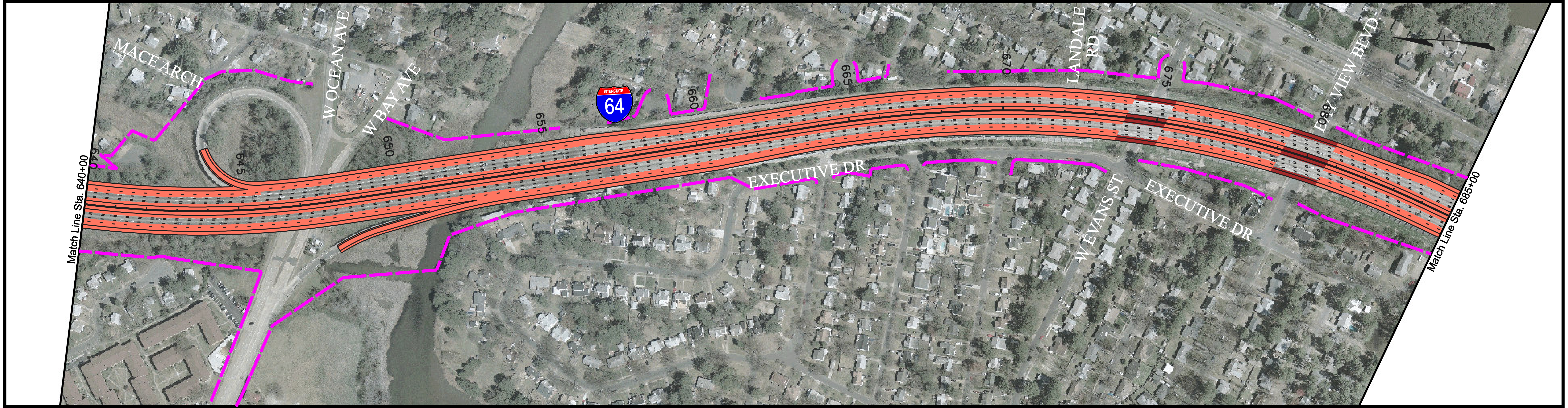
INTERSTATE 64







VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

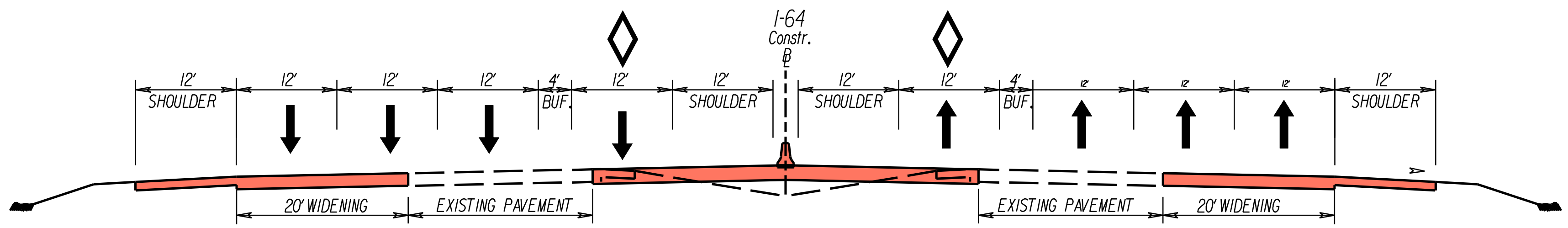
- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing RW

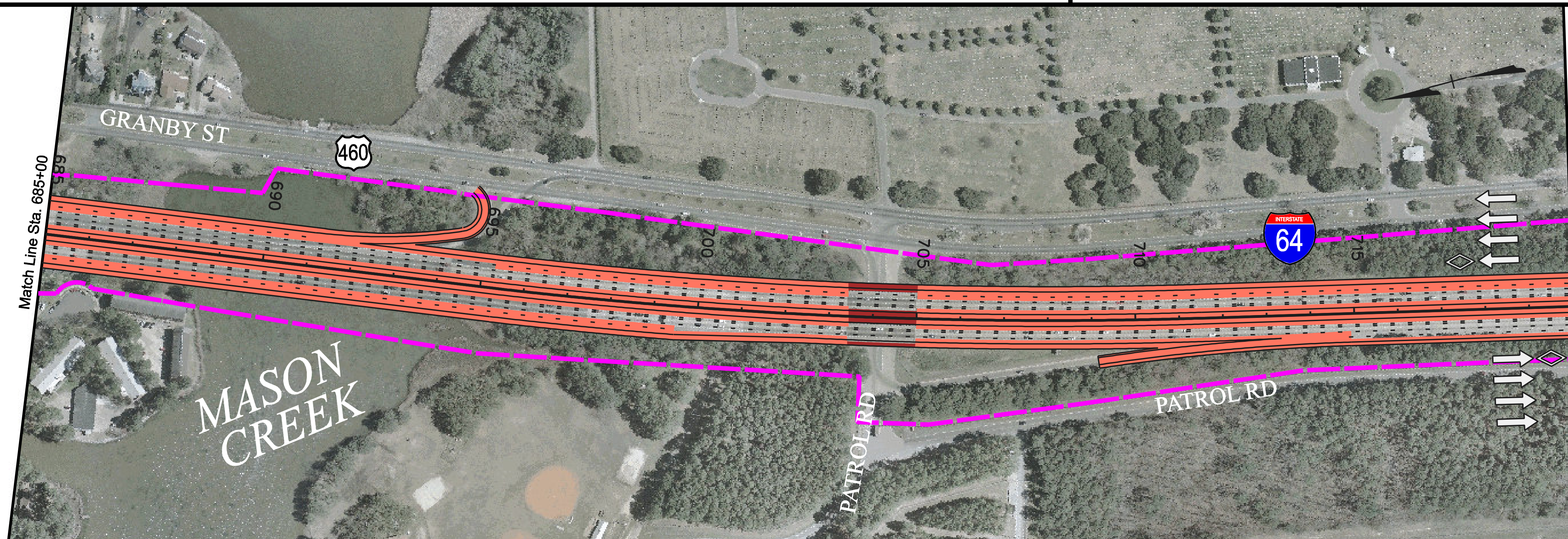
ALTERNATIVE 4 : Four Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Eight -Lane (3+1 1+3) HOV Facility Connecting the Peninsula and Southside

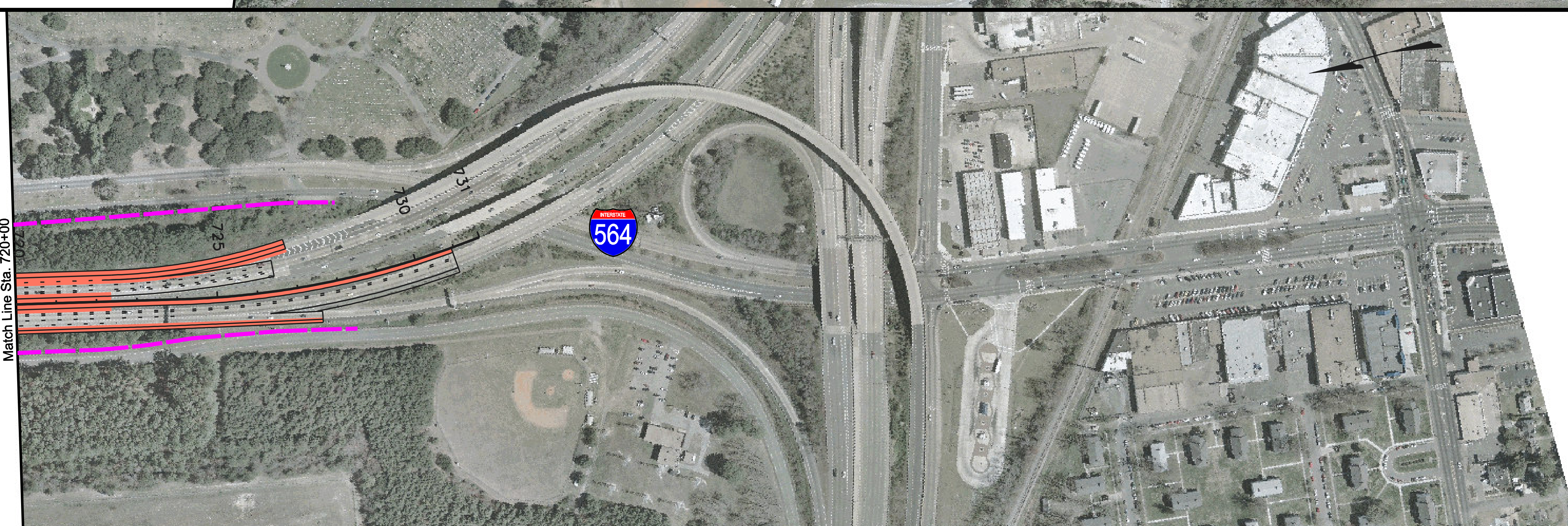
SCALE 0 300' 600'

PLAN SHEET NO. 4(7)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 4 : Four Additional Lanes of Bridge -Tunnel Capacity to Provide a Contiguous, Eight -Lane (3+1 1+3) HOV Facility Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 4(8)

DGN $REF001 $REF002 $REF003 $REF004 $REF005 $REF006
$DGNLEV $LEV001 $LEV002 $LEV003 $LEV004 $LEV005 $LEV006

PB PARSONS BRINCKERHOFF 100 YEARS

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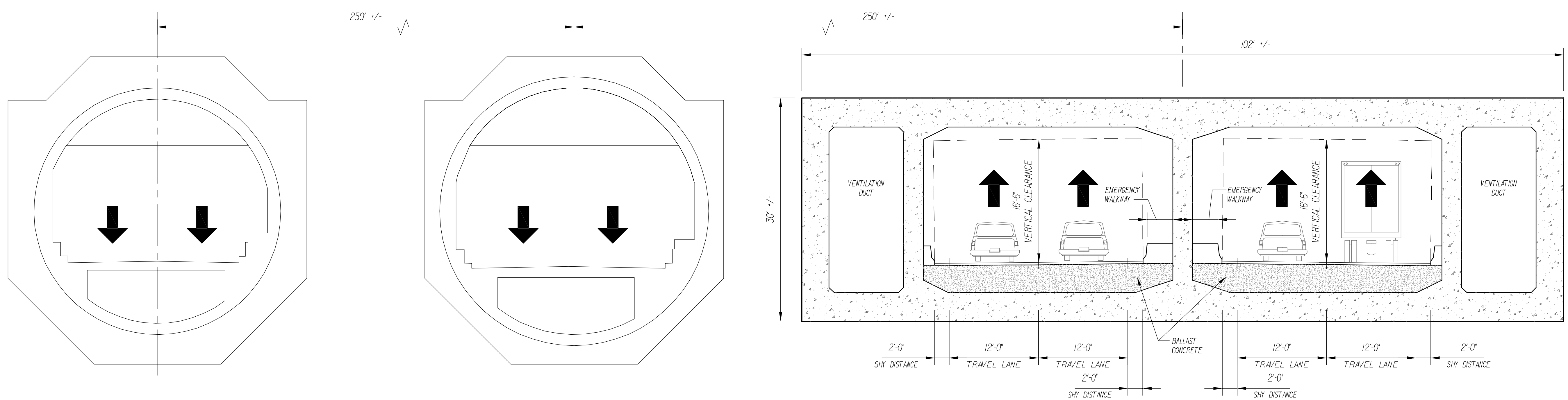
REVISED	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	VA.				4(9)

TYPICAL SECTIONS
ALTERNATIVE 4



WEST BOUND LANES

EXISTING TUNNEL

WEST BOUND LANES

EXISTING TUNNEL

EAST BOUND LANES W/ HOV

EAST BOUND LANES

PROPOSED EAST BOUND TUNNEL

BRIDGE TUNNEL TO I-64/I-564

Virginia Department of Transportation
VDOT

$TIME$STAMP$

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
			4(9)

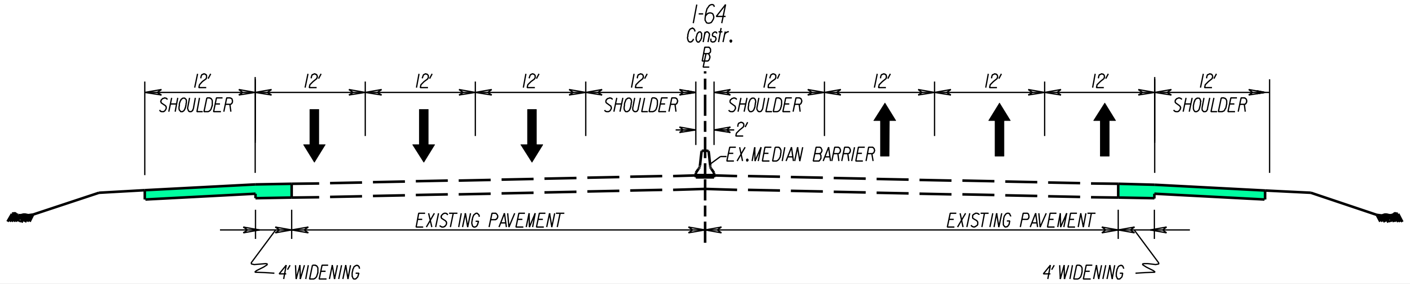
ALTERNATIVE 5

Structural:

Bridges

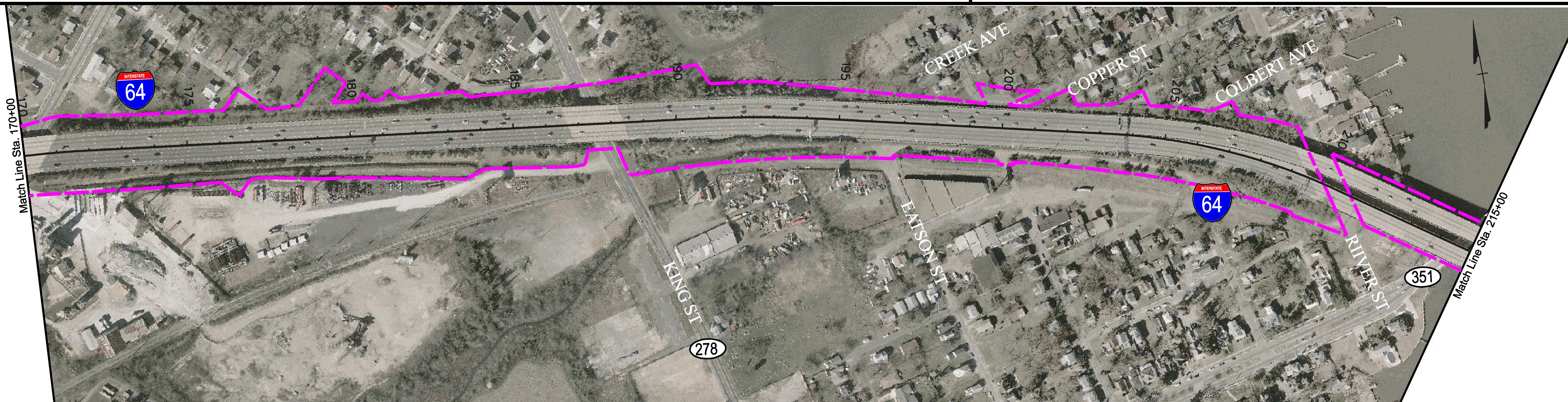
This alternative is the same as Alternative 1 except that the additional lanes over the channel are provided by a high level suspension bridge as opposed to using tunnels. As with Alternative 1, there will still be a reduced speed and two-way traffic in the existing eastbound tunnel. The benefit gained by adding lanes will be canceled by the benefit lost by changing one of the tunnels to two-way traffic. In addition, using a two lane suspension bridge versus a four lane suspension bridge will generate a cost savings of only about 10%. The magnitude of this bridge is not cost effective unless it carries more than 4 lanes of traffic. In fact, it is recommended that a 2-lane bridge not be attempted because of the adverse affect of the aerodynamics on such a narrow structure. Because of the reduced benefit versus cost savings and poor aerodynamics, Alternative 5 has been eliminated from further consideration.

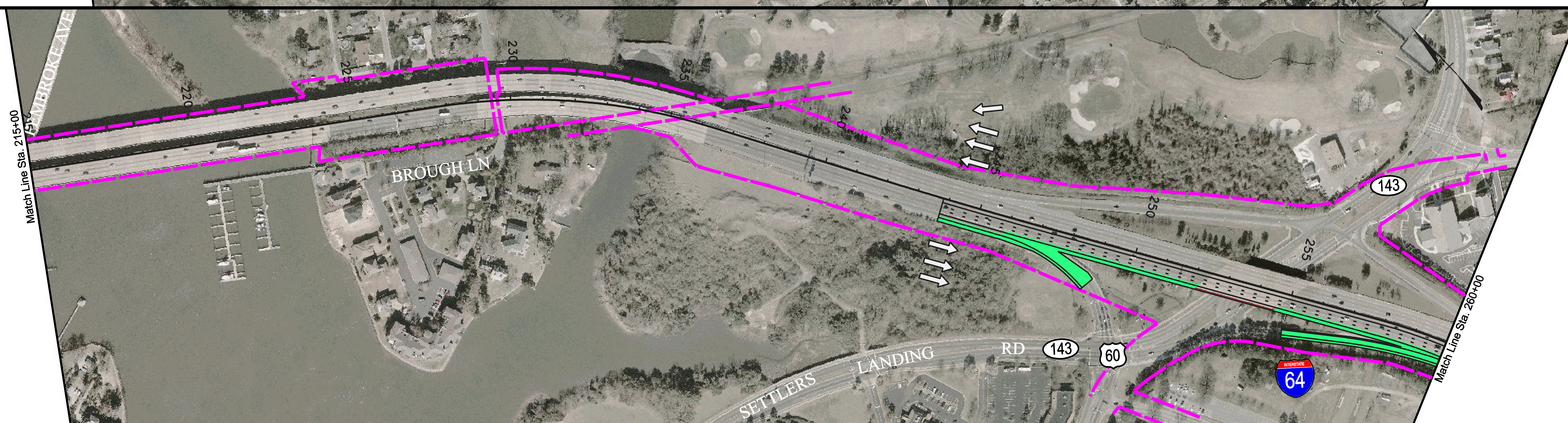
The conceptual layout and roadway typical section for Alternative 5 is shown on Plan Sheet Nos. 5(1) thru 5(9). A typical section for the high level bridge is shown on Plan Sheet No. 5(10).



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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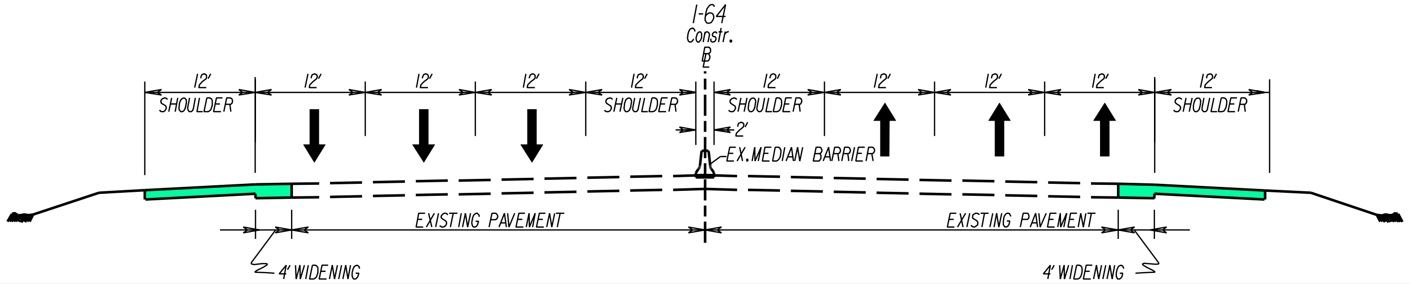
- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

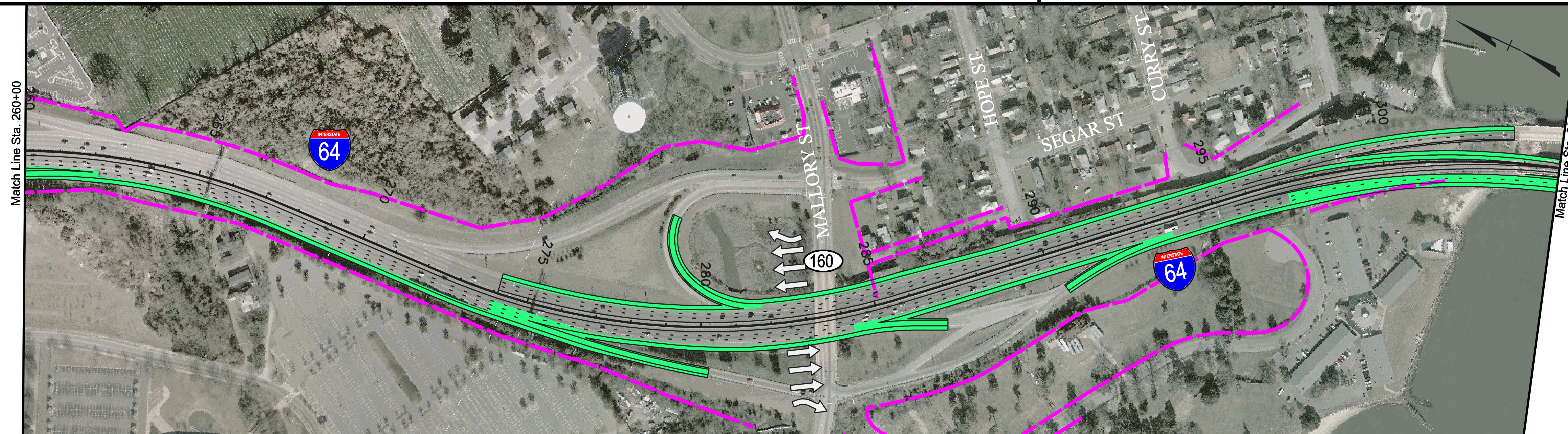
ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

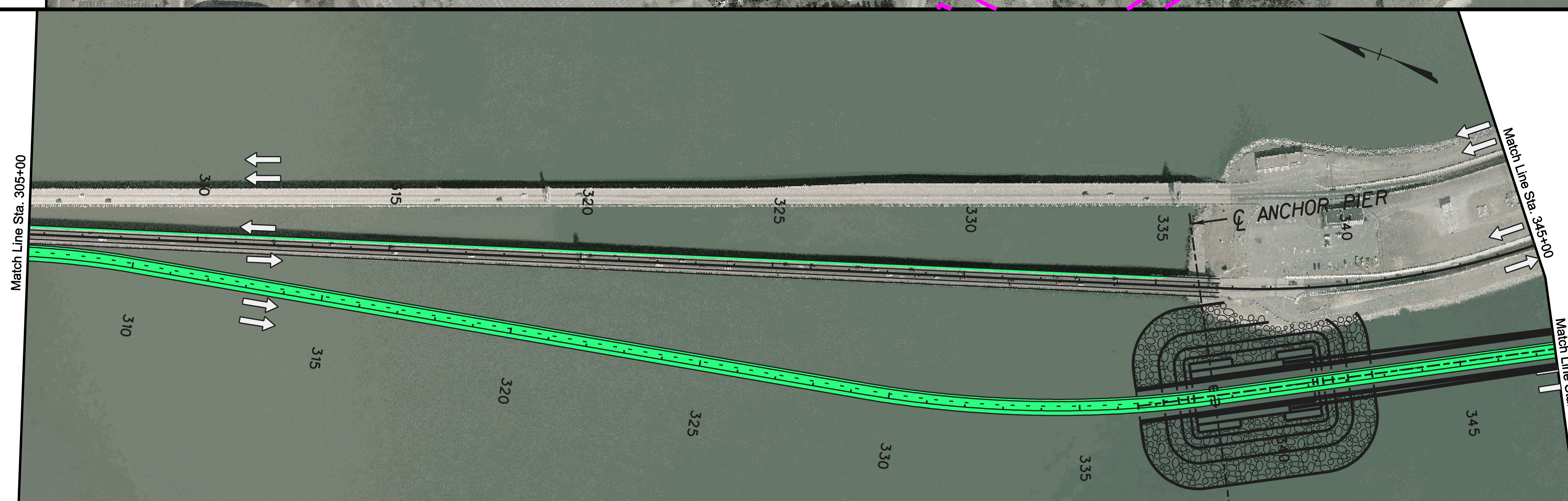
SCALE
0 300' 600'

PLAN SHEET NO. 5(1)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

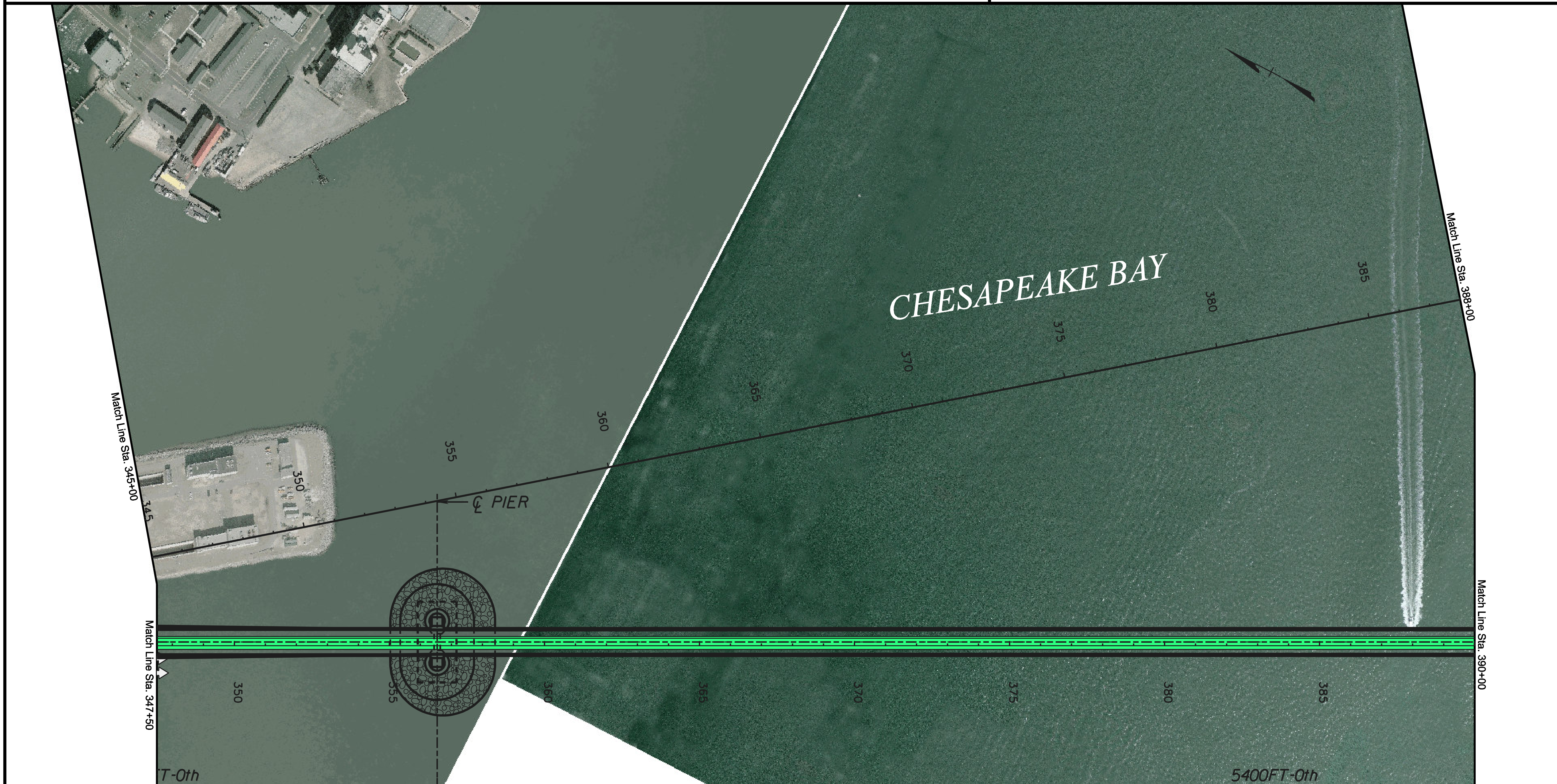
ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO.
5(2)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 5(3)

HAMPTON ROADS BRIDGE–TUNNEL
EXPANSION FEASIBILITY STUDY

VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

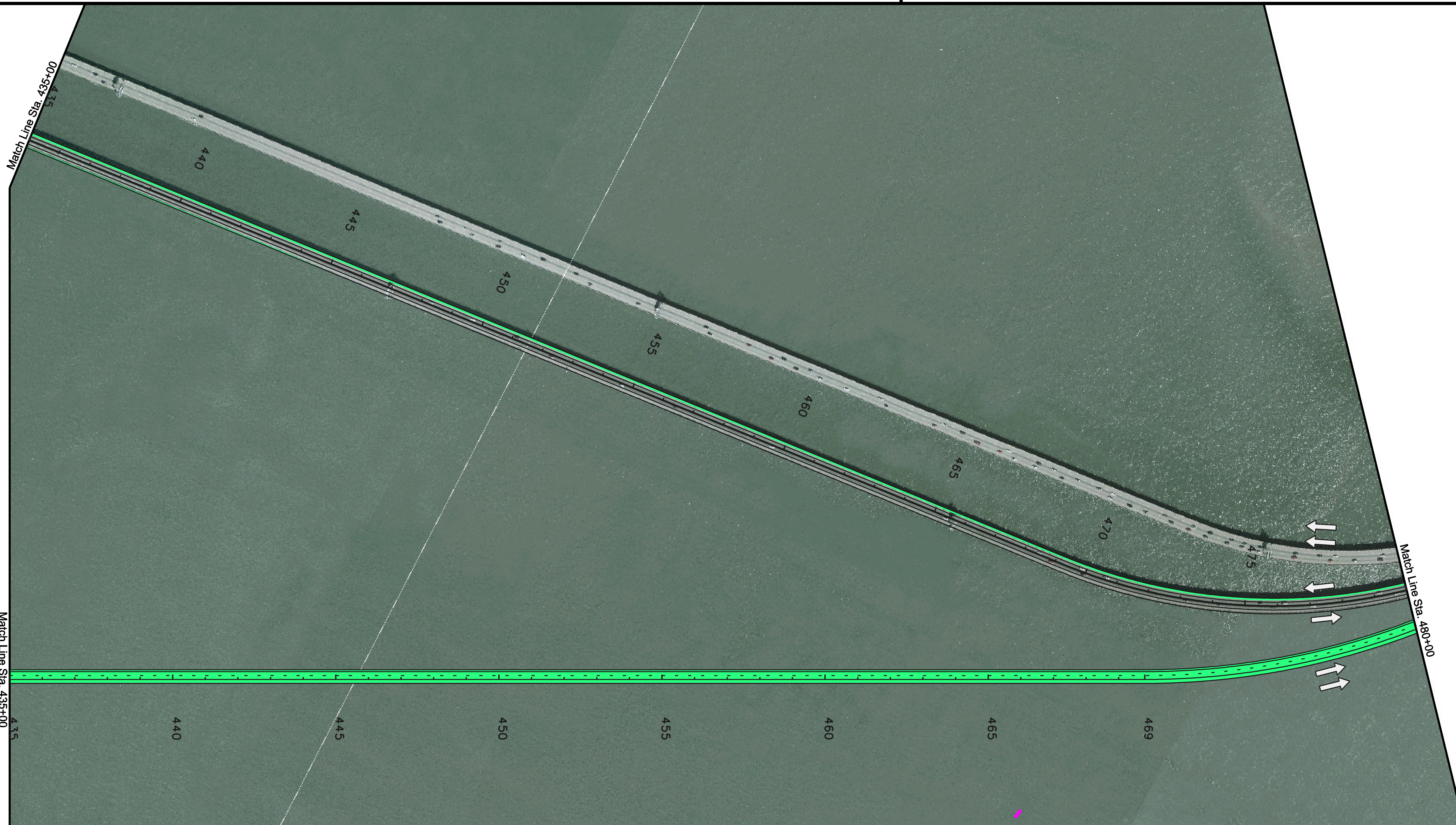
ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO.
5(4)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

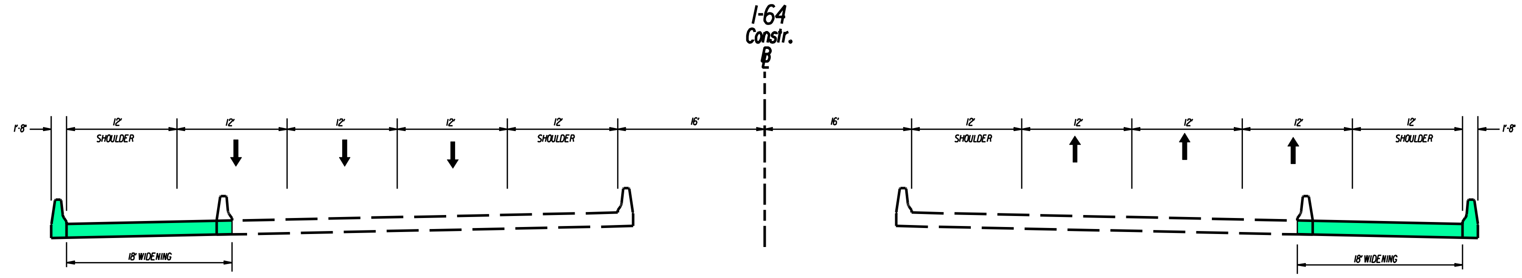
ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 5(5)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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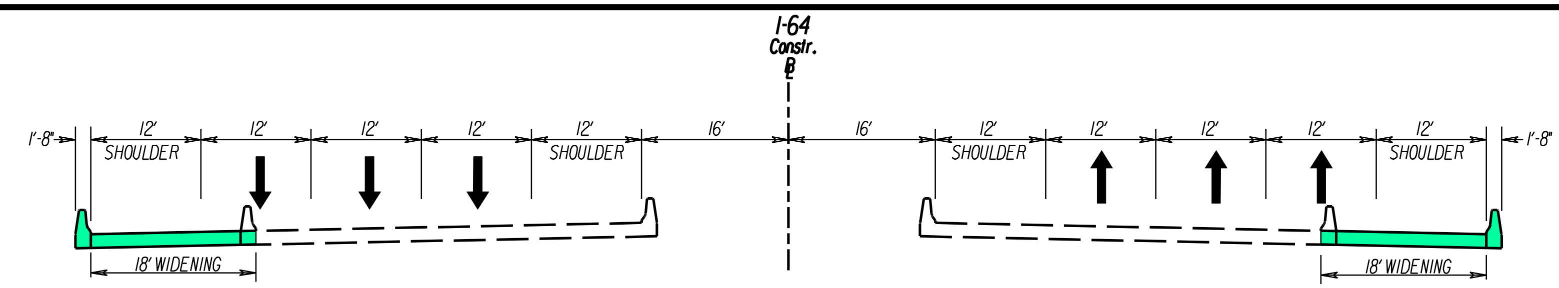
Legend
Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

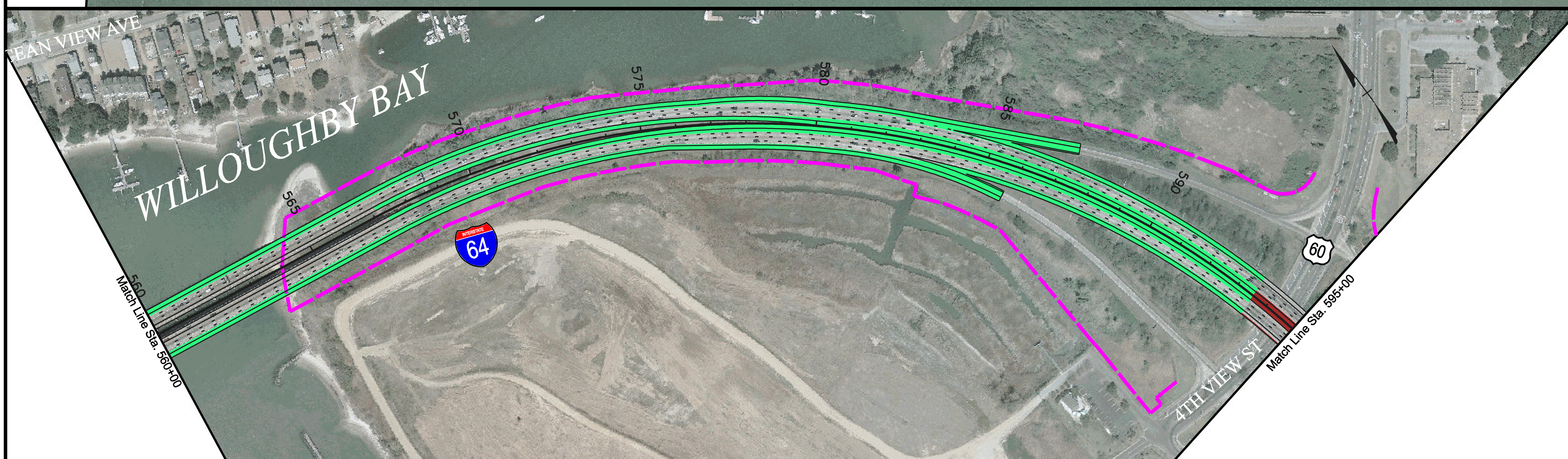
SCALE 0 300' 600'

PLAN SHEET NO. 5(6)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

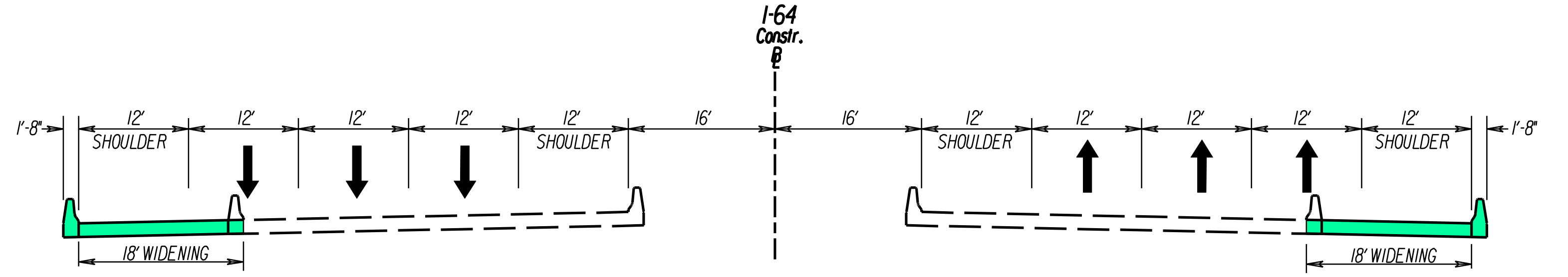
ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

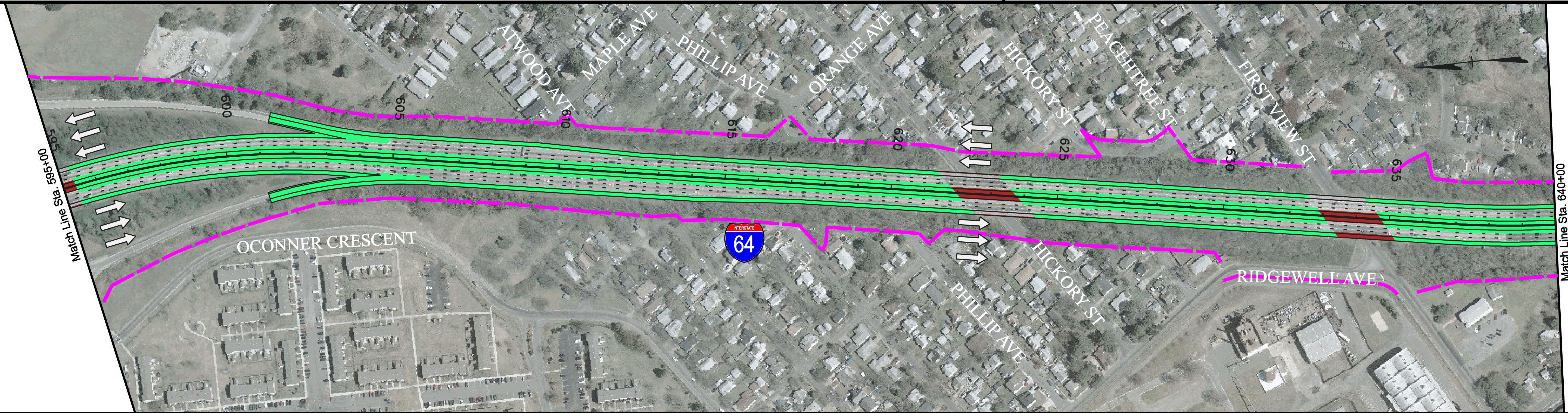
SCALE
0 300' 600'

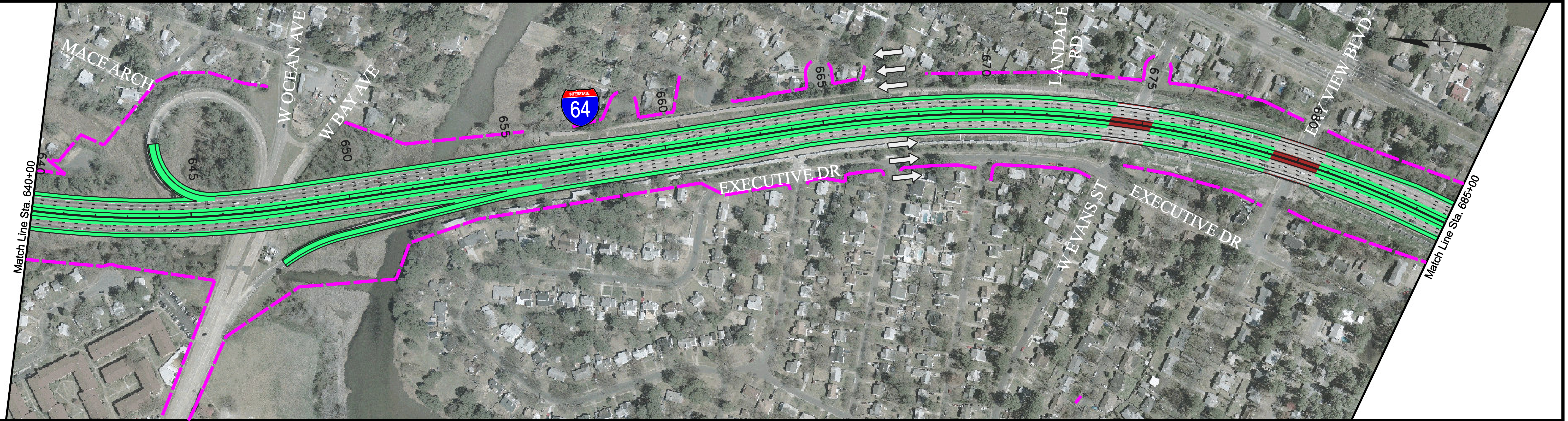
PLAN SHEET NO. 5(7)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64







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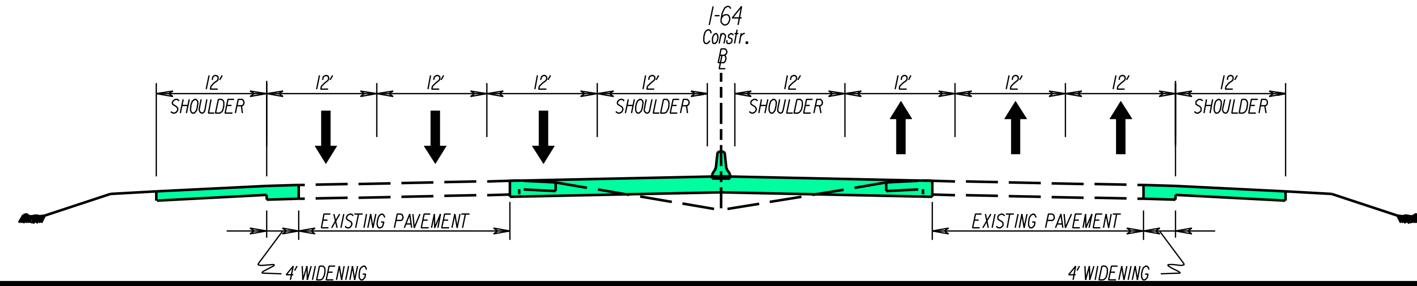
Proposed Pavement Widening	
Proposed Structures and Bridges	
Existing R/W	

ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

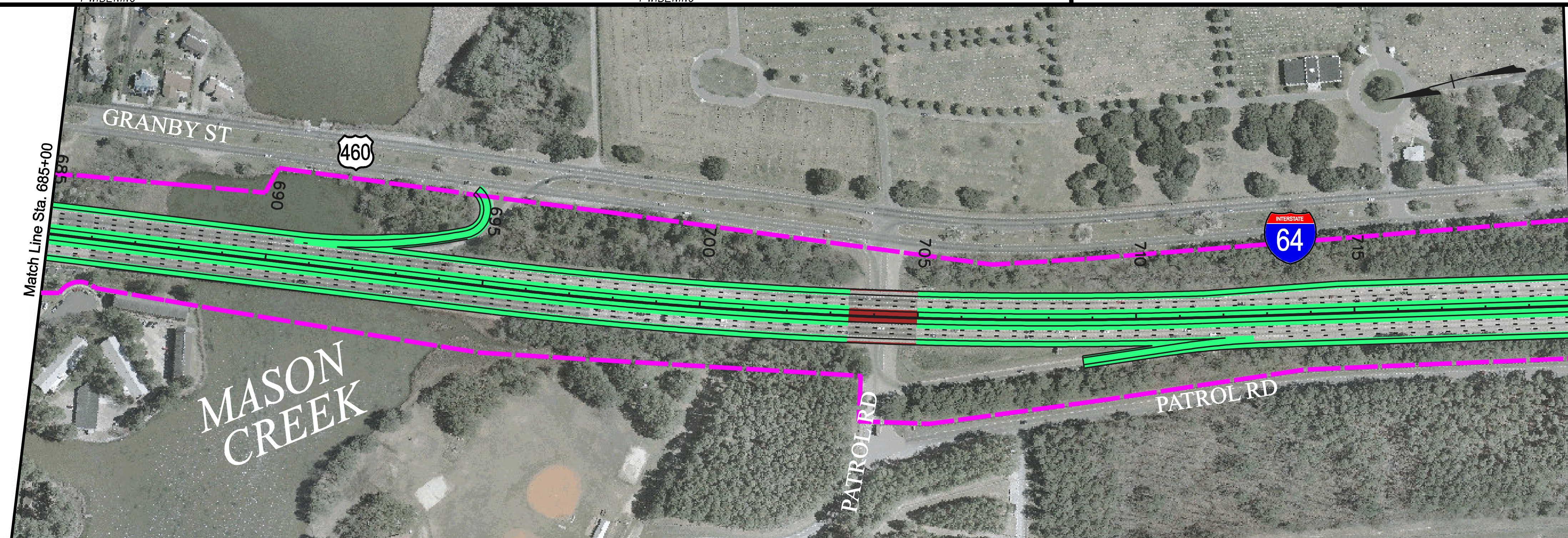
SCALE 0 300' 600'

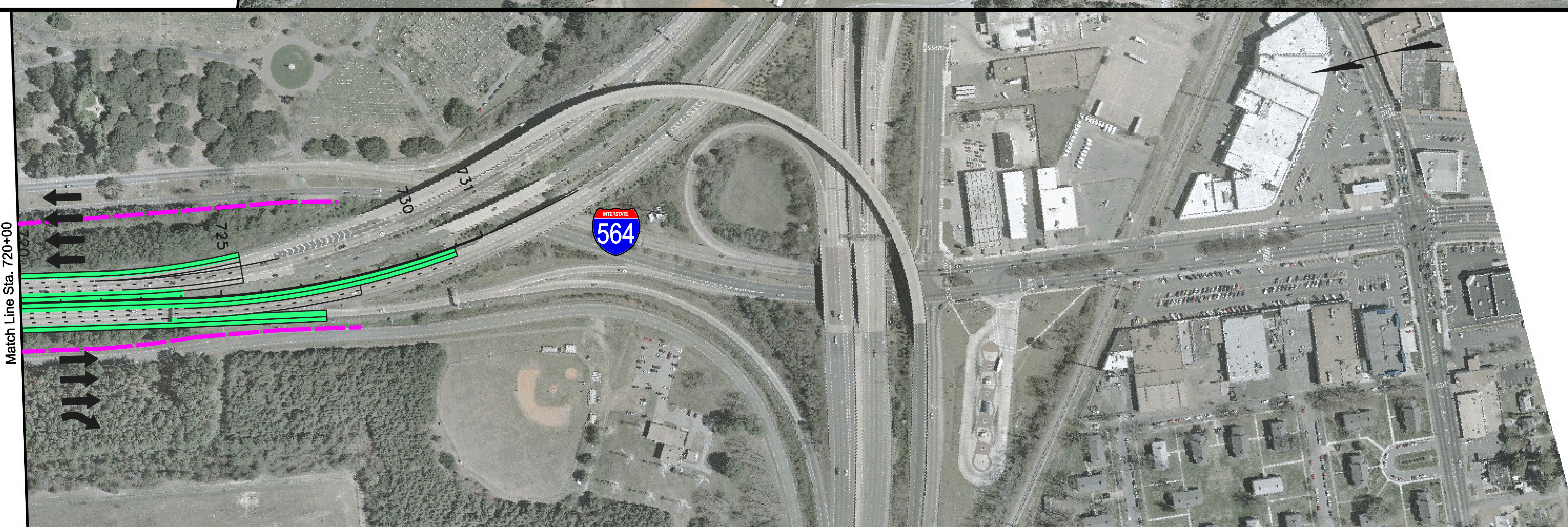
PLAN SHEET NO. 5(8)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 5 : Two Additional Lanes of Bridge Capacity to Provide a Contiguous, Six -Lane Facility Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 5(9)

MOFFATT & NICHOL
RICHMOND, VIRGINIA

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DESIGNED BY JOHNSON, MIRMIRAN & THOMPSON (804) 323-9900

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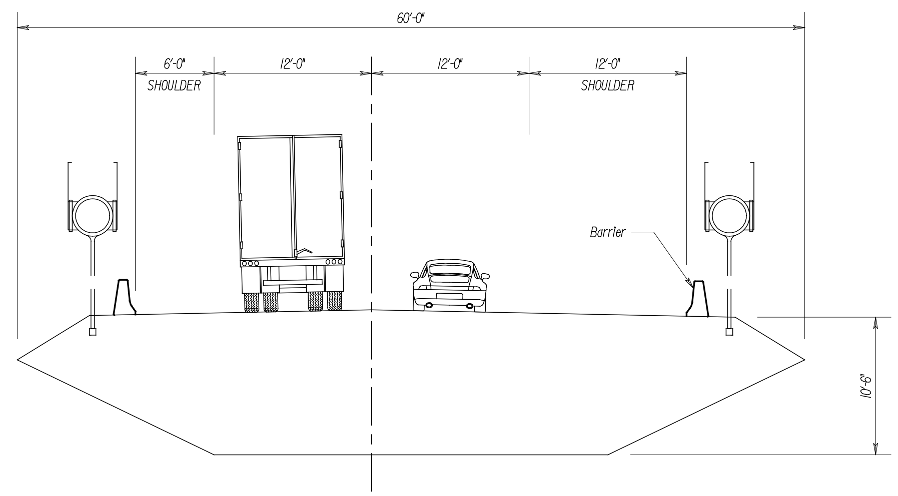
REVISED	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	VA.				5(10)

ALTERNATIVE 5
2 ADDITIONAL LANES ON HIGH LEVEL BRIDGE



Virginia Department of Transportation
VDOT

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PLAN NO.	PROJECT	FILE NO.	SHEET NO.
			5(10)

ALTERNATIVE 6

General Alternative Information:

This alternative would provide four additional lanes of bridge capacity connecting the Peninsula and Southside. The additional lanes would be provided through the entire study area limits, connecting at I-664 and I-564. The existing bridge-tunnel facility and Willoughby Bay bridge would be converted to carry all westbound traffic while a new four-lane bridge facility would carry eastbound traffic.

The conceptual layout with roadway typical sections for Alternative 6 is shown on Plan Sheet Nos. 6(1) thru 6(10). Plan Sheet 6(11) shows the typical section on the high level bridge. A plan and elevation of the suspension bridge and pier details are shown on Plan Sheets 6(12) and 6(13). Also included on Plan Sheet 6(14) is the bridge alignment across the channel.

Structural:

Bridges

This alternative is identical to Alternative 3 except that the additional lanes over the channel are provided by a high level suspension bridge as opposed to using tunnels. This alternative will require all bridges to be modified from I-664 to I-564. On the Peninsula, an additional lane plus widened shoulders on each side of the median will be needed. Two lanes plus shoulders will be needed on the Southside. Most of the standard grade separation structures on the south side can be widened to the inside; however, on the north side, the existing structures sit side-by-side and so the new improvements will have to occur to the outside. The structures over water will have to be widened to the outside. The necessity for outside widening is due to the size and amount of equipment that is required to drive large diameter piles into water. The construction will go much more efficiently if there is no inside widening on the structures over water. Also, piles driven next to the bridges over water may have to be battered in a direction that is parallel to the bridge in order to miss the existing piles that are battered transversely to the bridge. These new piles will have to be installed in opposing pairs with a pile cap that straddles the existing piles.

The inside to outside bridge widening will impact areas where there is existing concrete pavement. The existing pavement markers and markings are established along the longitudinal concrete joints. If the existing pavement is maintained through the widening operations, the new lane transitions will create areas where the pavement markings will deviate from the concrete joints, increasing the risk of “lane drifting” by motorists following the joints instead of the lane markings, thus increasing the risk of side-swipe incidents. This should be addressed in the later design stages if this alternative is further considered.

On the Willoughby Bay bridge, all the new bridge lanes on this alternative will be added to the water side of this structure. Very little construction activity will occur on the land side and the property owners around the bay will experience minimal inconvenience except for personal boating movement. The private piers in the area should not be affected.

As with Alternative 1, the bridge that carries S. Mallory St. over I-64 will have to be replaced. The widening of I-64 will conflict with the pier locations and the bridge spans will have to be lengthened. One of the eastbound bridges over the Hampton River will have to be replaced because of the substandard curve in the bridge.

For the Hampton Roads crossing, there were several issues that affect the choice of structure. Although the authorized navigation channel is 1,000 ft wide and 55 feet deep, the existing waterway that includes the channel, is between 40 to 70 feet deep and is about 5,200 ft wide as indicated on Plan Sheet No. 6(11). The AASHTO Vessel Collision Code has requirements for new bridges over navigable waterways. Main spans are typically 2-3 times the length of the largest vessel in the waterway. For Hampton Roads, new container ship lengths are about 1,200 feet. This would give a main span of 2,400 to 3,600 feet. However, a structure of this length (either a cable-stayed or suspension bridge) would result in all main span piers and many approach piers being placed in water depths in the range of 50-70 feet. It is possible to design and build this type of structure, however, the construction would be very expensive. In addition, each pier (not just the main piers) within 3600 feet of each side of the channel, would require some type of pier protection from potential ship collision. If islands were used for each pier, given the deep water, they would be very large, very expensive, and would cause significant adverse impacts to the flow of water into and out of Hampton Roads. The alternative would be clusters of large diameter sacrificial cofferdams (dolphins) placed on both sides of all piers in the central deep water region. Again, these would be large structures, would be very expensive, and would also have adverse impacts on water flows in the waterway. When the cost of these protection measures are added to the cost of the bridge to get a total cost, it is less expensive to go to a longer span bridge to avoid piers in the waterway, avoid protection structures in the waterway, and minimize environmental impacts.

A good example is the replacement of the Sunshine Skyway Bridge in the late 1980's. The replacement bridge used a 1,200 foot main span cabled-stayed structure within a continuous 4,000 main span bridge unit. The main span unit (in 1980's dollars) cost about $60 million of the total $240m project (the total bridge was about 4 miles long). The cost to protect the central 12 piers of the 4,000-foot main span unit using islands on the main piers and clusters of dolphins on 10 of the approach piers, was approximately $40 million dollars (about 70% of the main span cost for a total of $100 million). In hindsight, it would have been possible to build a bridge that had 3,000 to 4,000 foot main span with a lower total cost. It should be noted that the Sunshine Skyway replacement bridge was designed before AASHTO adopted vessel collision provisions.

The new Hampton Roads Bridge is also near major ship anchorages and would be subject to impacts from vessels breaking loose during storms and potentially hitting the bridge. Another concern might be the possibility for the Norfolk Naval Base submarines transiting Hampton Roads in secrecy if a bridge with a shorter main span and numerous piers in deep water were to be considered as an option.

The existing channel of the waterway is not at the lowest point of the waterway. The existing channel has a 55 foot authorized depth, but future planning by VPA for larger coal ships to use the harbor would require going to a 60 or even a 65 foot deep channel. This could be easily accomplished at the Hampton Roads Crossing by shifting the existing channel northward to the deepest part of the waterway - without any impact on the existing tunnel. The main blockage, or limiting condition to a 60-65 foot channel, then becomes the Chesapeake Bay Bridge Tunnels, so for planning purposes a 65 foot clearance has been used by the CBBT to evaluate a future parallel tunnel, or a replacement tunnel. The proposed bridge layout with a large suspension span would allow this shift to happen - a bridge with a shorter main span in the waterway would prohibit this potential channel shift.

For the Hampton Roads Project, the piers were placed at the 30 foot water depth mark on both sides of the waterway. This met the AASHTO vessel collision planning criteria, as well as avoided the higher total costs of a smaller main span with approach piers in deep water that would need vessel collision protection. The recommended bridge would need to have a main span of about 5,400 ft. The limit for cable stayed bridges is about 3,000 ft. Therefore, the recommended structure would need to be a suspension bridge. This type of structure requires back spans that attach to large anchor blocks. These back spans would be about 1,800 ft which would make the entire structure 9,000 ft long. This part of the bridge has to have a tangent horizontal geometry.

The construction of the towers should have a minimal impact to navigation. The towers are in shallow water and away from the navigation channel. The construction of the superstructure will involve transporting pre-constructed deck sections by barge into the channel and lifting them by cranes to their final position. Navigation through the channel will be impacted. Coordination between the ports, the Navy, the Corps of Engineers, and the contractor during the bridge construction will be required. Water depths in the waterway under the bridge are deep and wide enough, however, that adverse impacts can be minimized.

Based on VDOT's request, the bridge has a 220ft minimum vertical clearance at high tide over the channel. The 220ft clearance starts where the water is 40ft deep and increases towards the mid span of the bridge as the grade of the bridge rises. The minimum vertical clearance is to accommodate the tallest military and commercial ships that are expected to use the channel. For this conceptual study, the minimum vertical clearance is provided for a distance wider than the existing navigation channel so possible future expansion of the channel width and depth will not be restricted. The minimum vertical clearance should also accommodate ships that stray away from the authorized navigation channel.

Traffic Analysis:

Travel demand forecasts were developed for the Hampton Roads Bridge-Tunnel and traffic analysis was performed for the 2018 and 2030 conditions. For Alternative 6, the analysis showed the following Level of Service (LOS) results for the AM (PM) peak hours for an average weekday:

	2018		2030	
	EB	WB	EB	WB
No Build	**F(F)**	**F(F)**	**F(F)**	**F(F)**
No Build with 3rd Crossing	D(E)	C(E)	D(E)	C(**F**)
Alternative 6(4-4)	C(B)	B(B)	B(B)	B(B)
Alternative 6(4-4) w/3rd Crossing	B(B)	B(B)	B(B)	B(B)

Right-of-Way Impact:

The existing right-of-way limits for the study area were provided by the Department and are shown on each alternative display. Since the information provided is limited to only right-of way limits and does not include property or parcel information, the best assessment of impacts can only be quantified based on potential impacts to buildings and existing sound walls based on assumptions of side slope designs and roadside treatments. While not an optimal assessment, it does provide an order of magnitude of the potential impacts that may be expected by the implementation of this alternative. Thus, based on the available information, Alternative 6 will potentially impact 70 to 105 buildings and about 7,400 LF of sound barrier. It is assumed that the elevation for the high rise bridge can be attained along the bridge approaches from the shorelines.

Mainline, Ramp and Shoulder Deficiencies:

The existing eastbound bridge crossing the Hampton River (Station 209+00 to 236+00) has deficient radii on the approaches. The radii are less than the minimum 1821' required for a design speed of 70 mph. For this alternative the radii would have to be increased to meet current design standards and a new bridge would have to be constructed replacing the existing substandard facility.

The existing westbound bridge approaching the tunnel (Station 475+00 to 490+00) has substandard curvature as it departs the Willoughby Spit area. Also, the existing westbound tunnel has a substandard height restriction. This concept assumes that these will be retained through design exceptions due to the cost of modifying the structure to meet current standards.

The existing interchange ramps were analyzed based the AASHTO and VDOT requirements. The design criteria investigated for each ramp consisted of:

1. Taper length
2. Deceleration/Acceleration lane lengths
3. Ramp radii

Alternative 6 has 4 ramps with deficient radii and 13 ramps with inadequate acceleration or deceleration lengths. The majority of the taper lengths on the corridor are 200 feet in length which meets the AASTHO requirement of 180 feet but not the VDOT length of 300 feet.

Further Study Considerations:

The operation of the eastbound inspection area will need to be further addressed if the design of this area is progressed beyond this stage.

The westbound traffic split outlined in this alternative is not common, but not without precedent, along interstate roadways. The split would mimic the traffic split that occurs at Baltimore's Fort McHenry Tunnel (I-95) and other tunnels on the national highway system. Additional signing will be necessary to alert travelers of this condition.

Incident management and hurricane evacuation operations will be slightly impacted with this alternative. It appears that the operations would operate much the same as they do today with only slight modifications due to the additional lanes and the high rise bridge. The design of the new bridge would need to account for these operations. If the incident management plans are to utilize the additional capacity provided by the use of two of the eastbound lanes to go westbound, the new bridge facility would need to be designed to accommodate this operation.

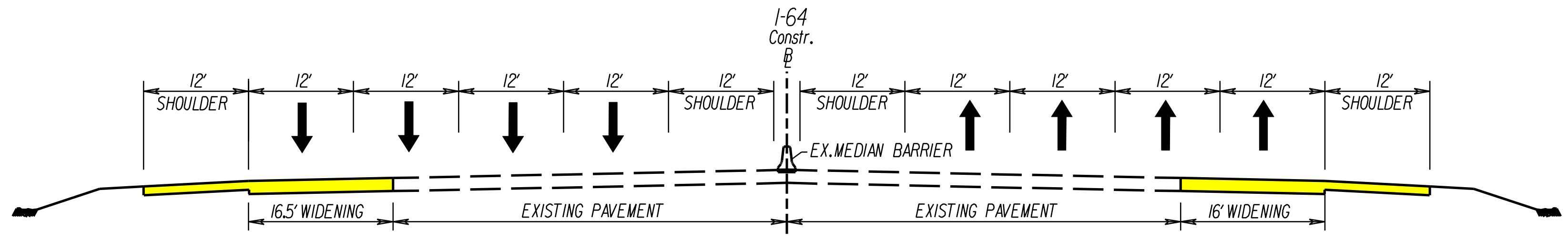
Of greater concern with this alternative is the use of a high rise bridge over a navigation channel used by both commercial and national defense interests. In the past, the US Department of Defense has rejected bridge concepts for this crossing due to national security concerns. These concerns stem from the possibility of the bridge being destroyed and blocking the channel to and from the Norfolk Naval Base situated to the west of the facility. The required height of the bridge is also of concern for air operations around the naval base and surrounding air facilities. The Department of Defense has not been contacted as part of this study, nor has VDOT made any attempts to do so for this alternative at this point in the analysis. This will need to be done if this alternative is to be further pursued.

Estimated Construction Cost and Implementation Schedule:

The following is the general construction cost estimate for Alternative 6:

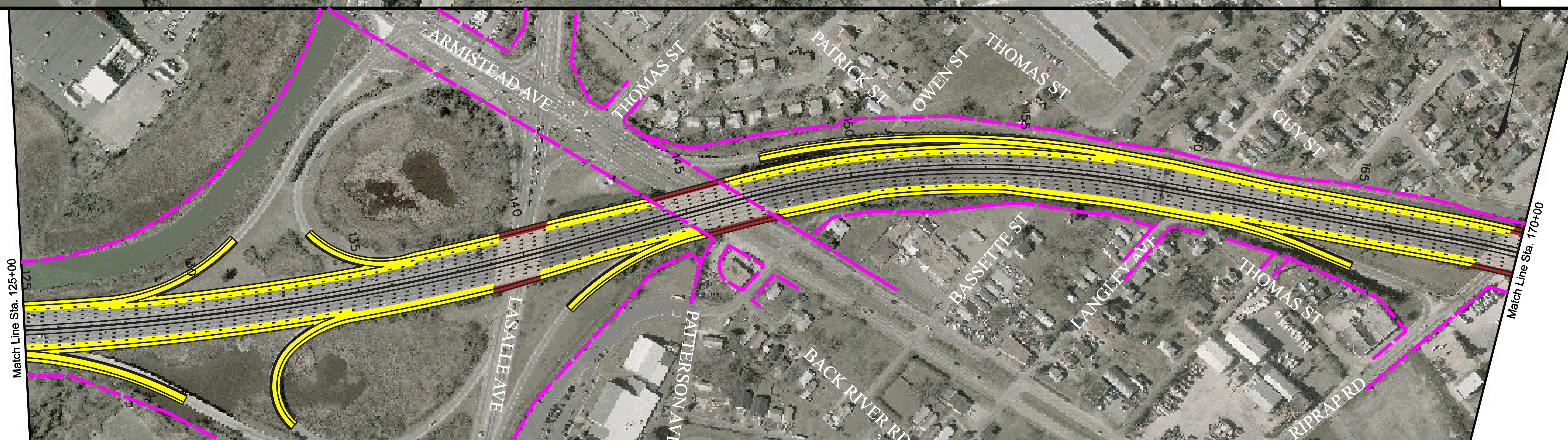
Roadway:	\$84 million
Bridges:	\$159 Million
	\$2.9 Billion (High Level Bridge)
Tunnel:	N/A
Total:	**\$3.14 Billion**

The construction schedule for Alternative 6 is estimated to be 5 years.



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64



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- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

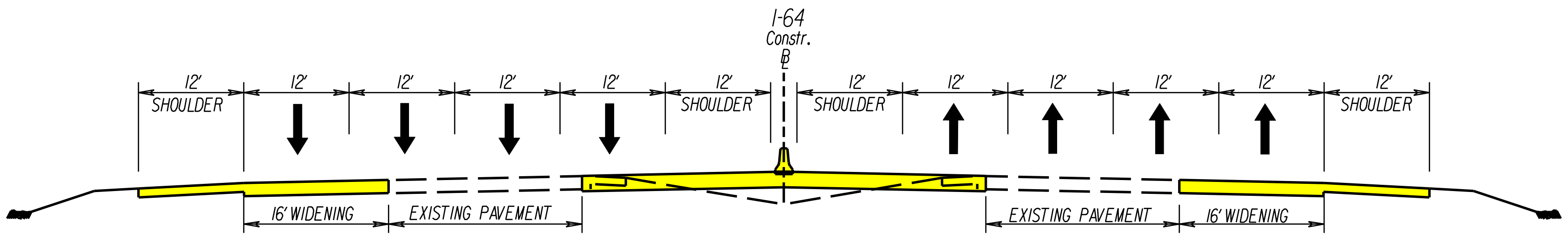
ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

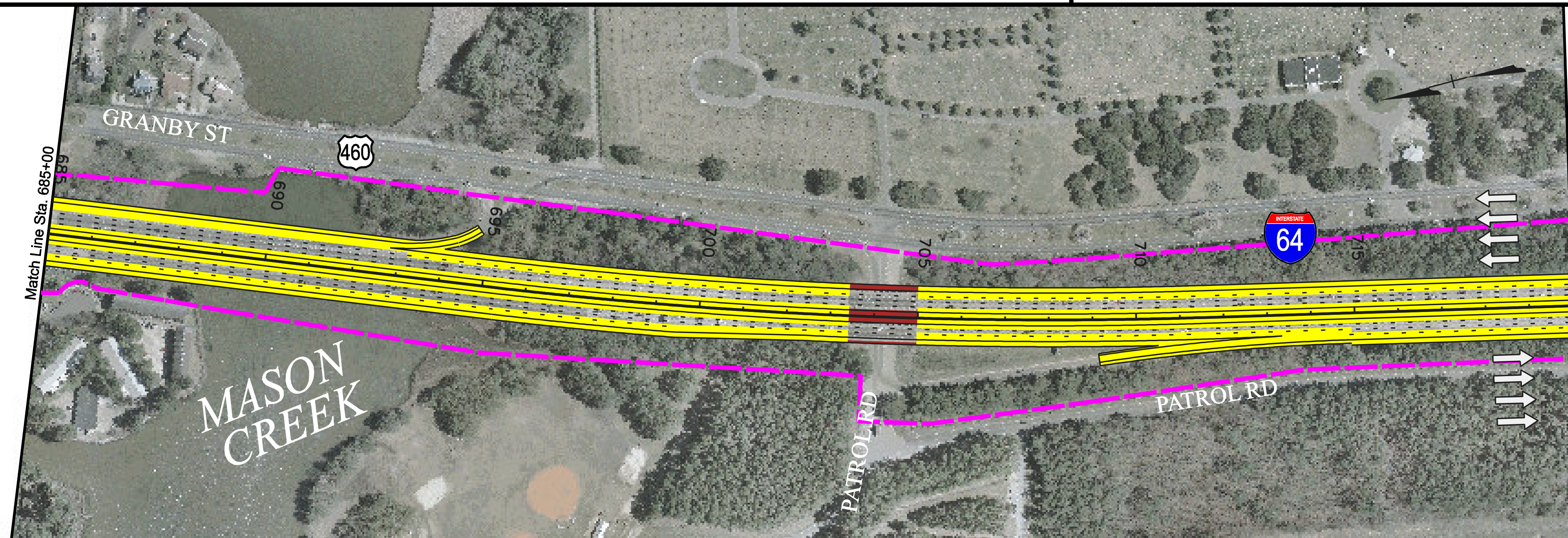
SCALE
0 300' 600'

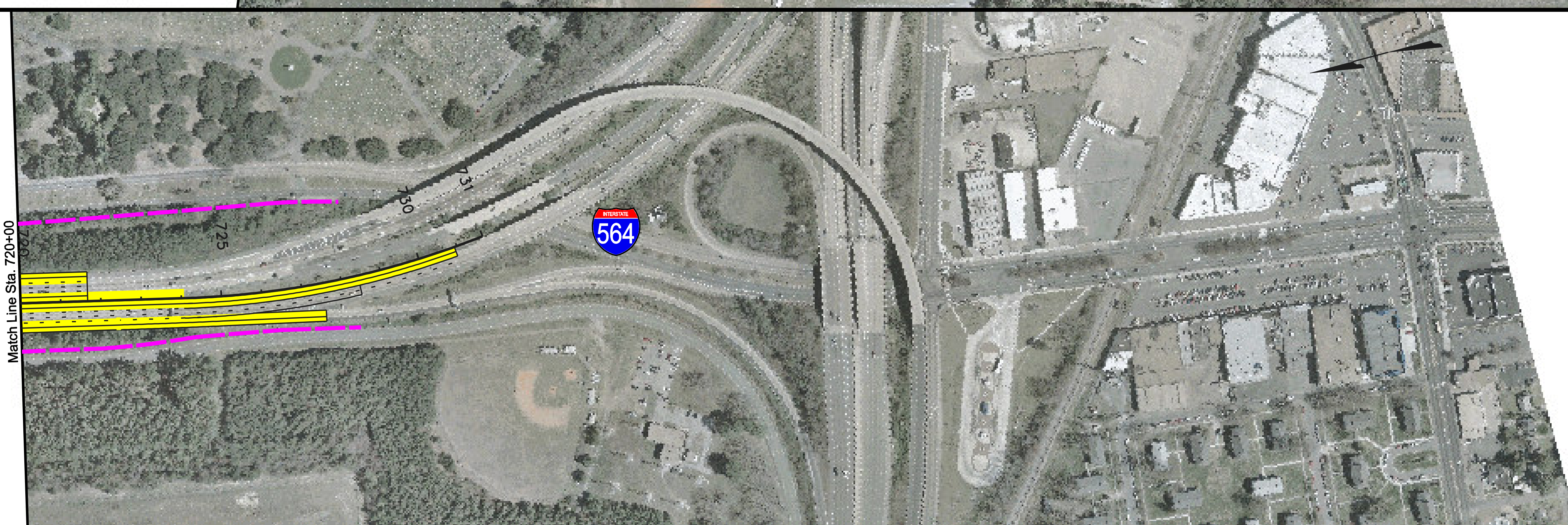
PLAN SHEET NO. 6(1)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64







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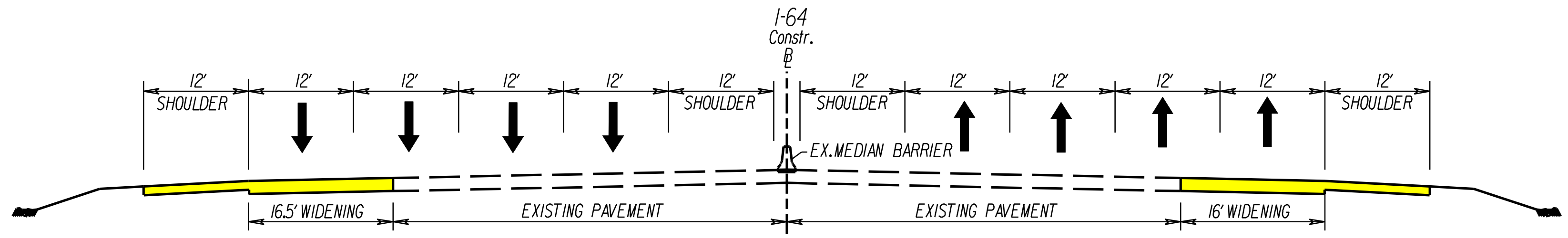
- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

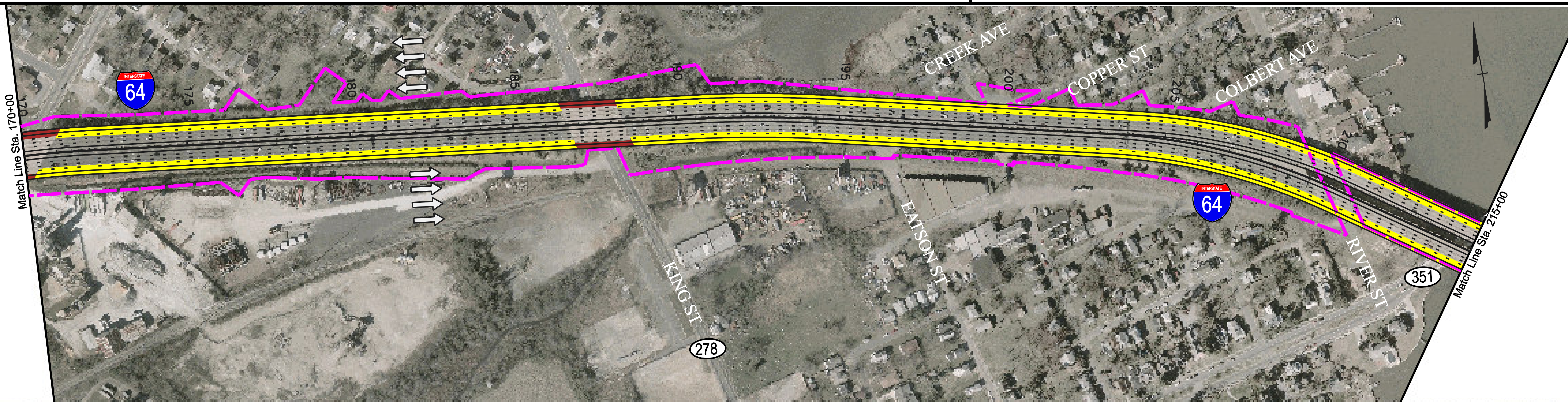
SCALE
0 300' 600'

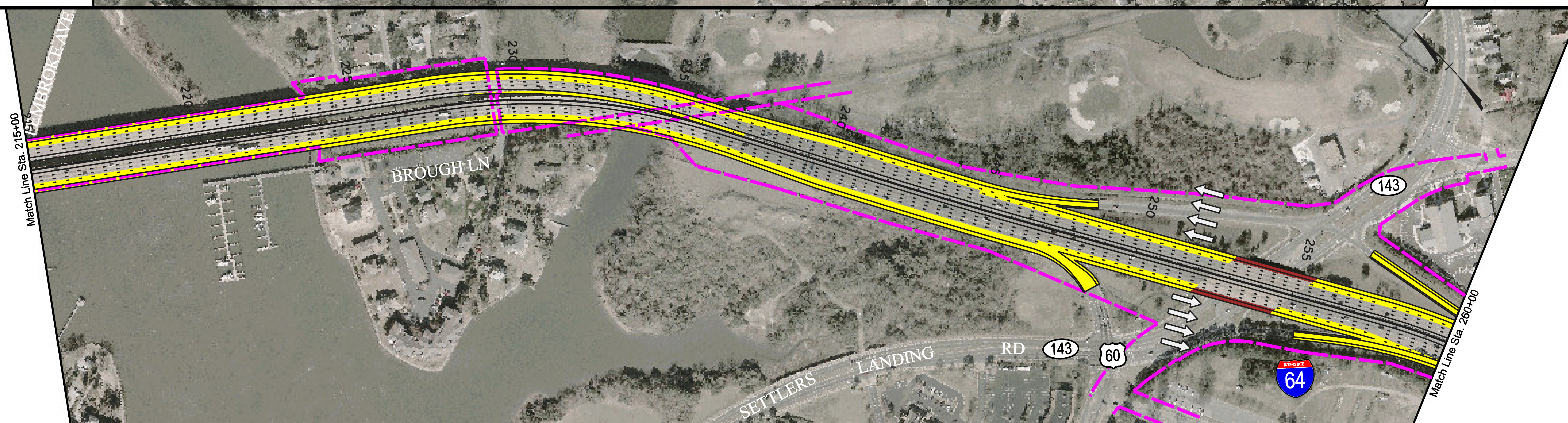
PLAN SHEET NO. 6(10)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





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JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

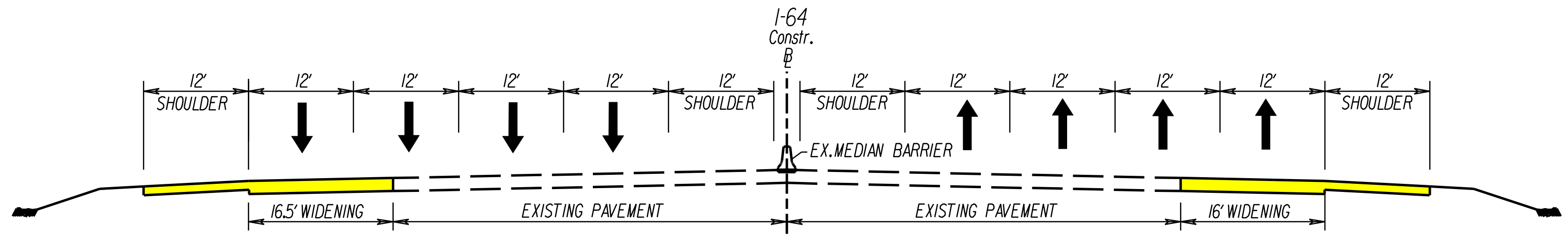
(yellow)	Proposed Pavement Widening
(red)	Proposed Structures and Bridges
(dashed magenta)	Existing R/W

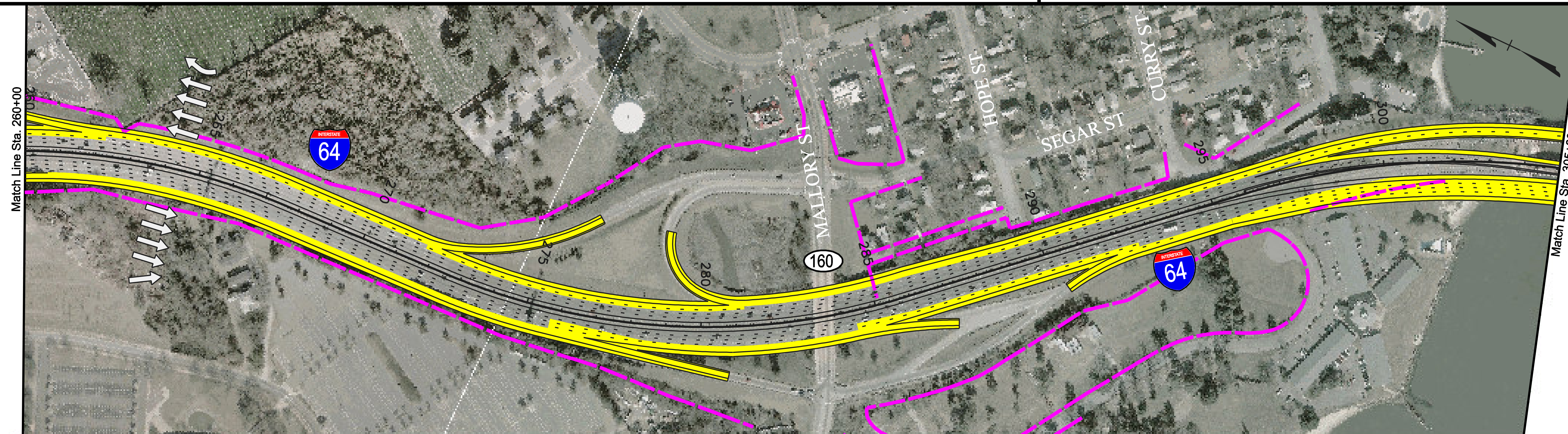
ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

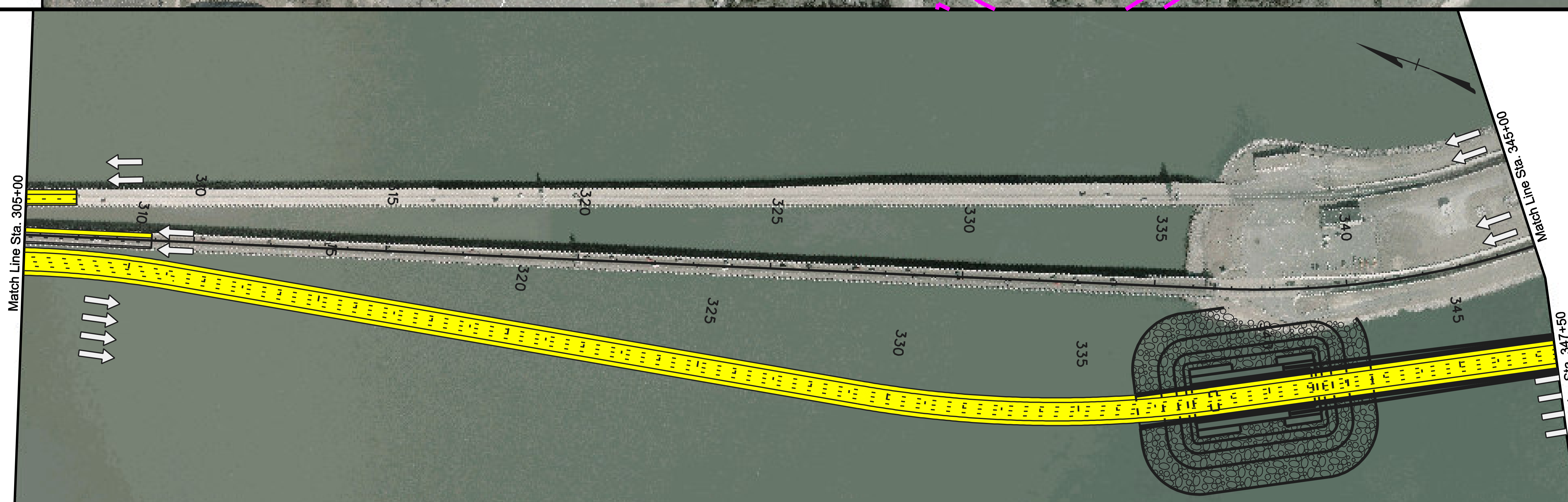
SCALE
0 300' 600'

PLAN SHEET NO. 6(2)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







VDOT Virginia Department of Transportation

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Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

SCALE 0 300' 600'

PLAN SHEET NO. 6(3)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64

VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

SCALE 0 300' 600'

PLAN SHEET NO. 6(4)

HAMPTON ROADS BRIDGE–TUNNEL
EXPANSION FEASIBILITY STUDY

INTERSTATE 64

VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 6(5)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64

VDOT Virginia Department of Transportation

JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

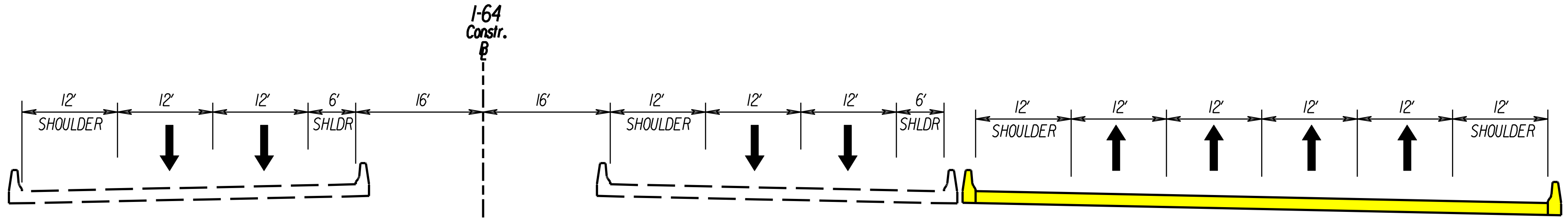
ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

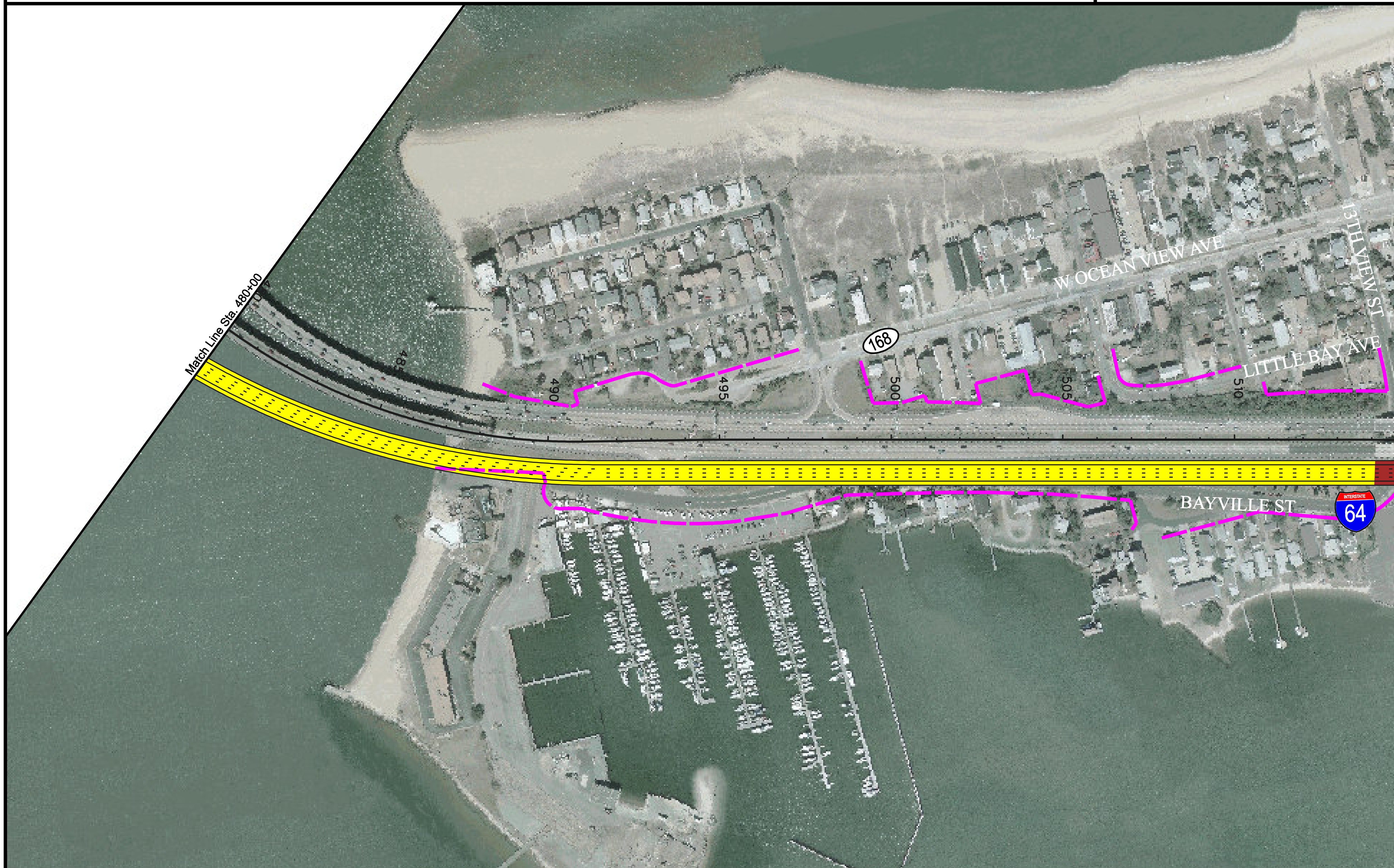
SCALE
0 300' 600'

PLAN SHEET NO.
6(6)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

INTERSTATE 64





VDOT Virginia Department of Transportation

JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

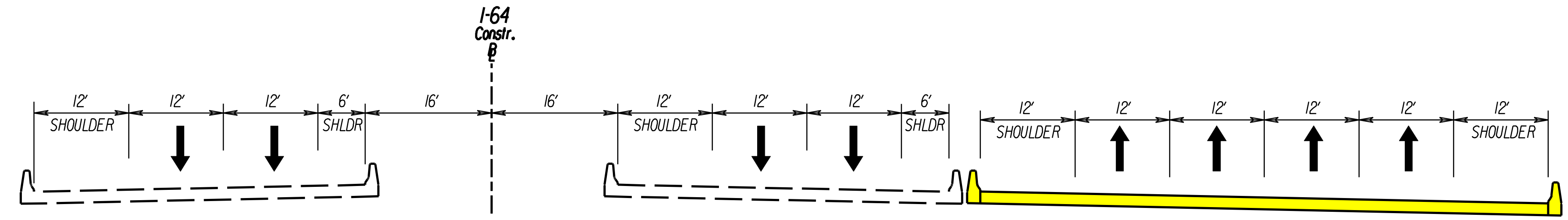
- Proposed Pavement Widening
- Proposed Structures and Bridges
- Existing R/W

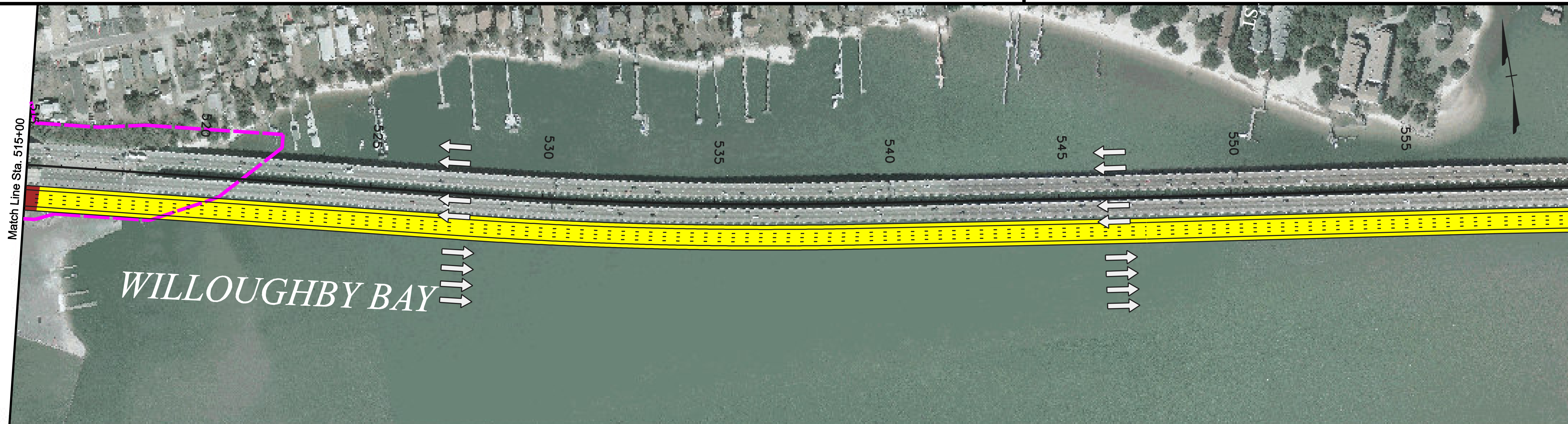
ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

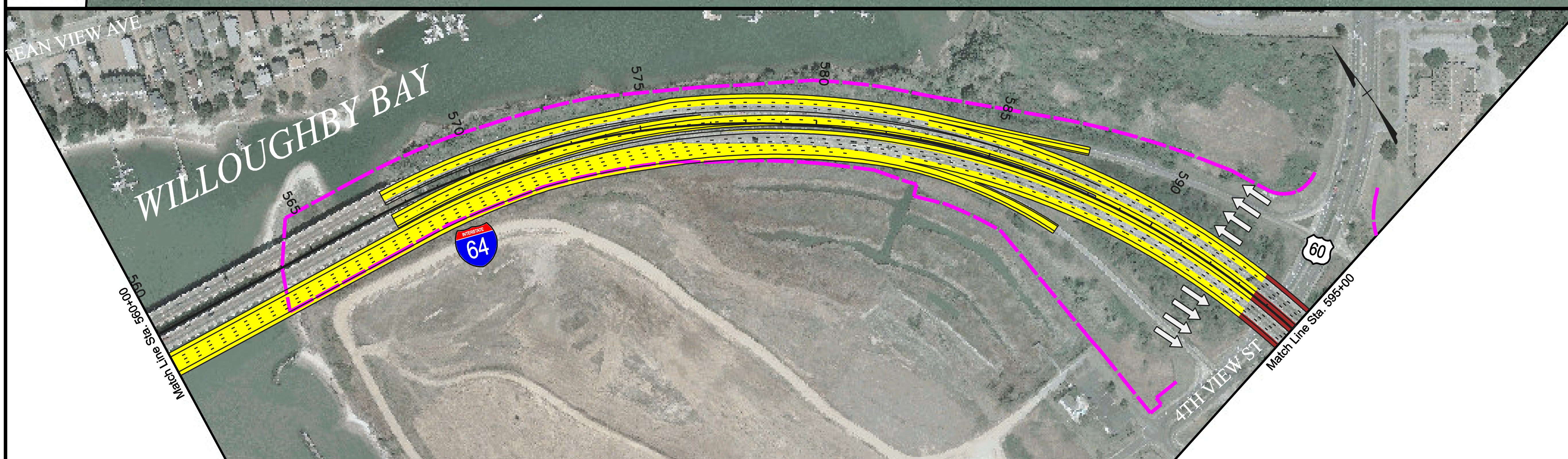
SCALE 0 300' 600'

PLAN SHEET NO. 6(7)

HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY







VDOT Virginia Department of Transportation

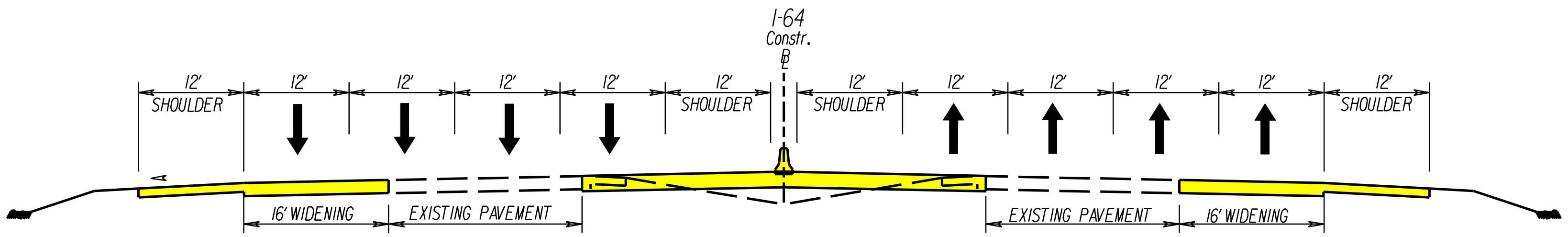
JMT JOHNSON, MIRMIRAN & THOMPSON Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 6(8)



HAMPTON ROADS BRIDGE–TUNNEL EXPANSION FEASIBILITY STUDY

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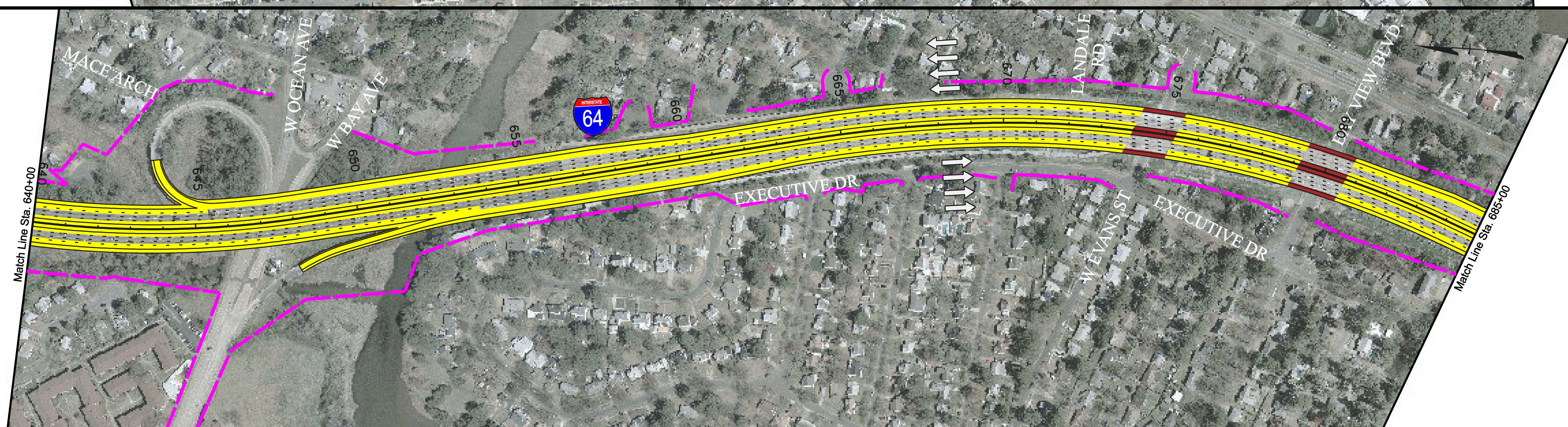

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Virginia Department of Transportation

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Engineering A Brighter Future

Proposed Pavement Widening
Proposed Structures and Bridges
Existing R/W

ALTERNATIVE 6 : Four Additional Lanes of Bridge Capacity Connecting the Peninsula and Southside

SCALE
0 300' 600'

PLAN SHEET NO. 6(9)

DGN $REF001 $REF002 $REF003 $REF004 $REF005 $REF006
$DGNLEV $LEV001 $LEV002 $LEV003 $LEV004 $LEV005 $LEV006

MOFFATT & NICHOL
RICHMOND, VIRGINIA

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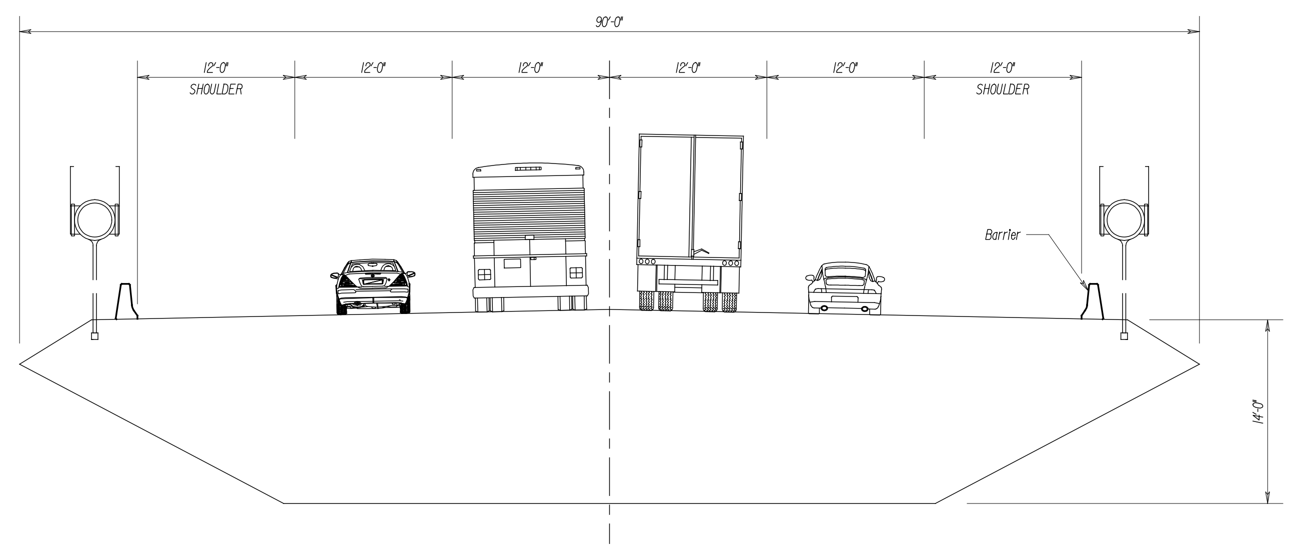
DESIGNED BY JOHNSON,MIRMIRAN & THOMPSON (804) 323-9900

DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	VA.				6(11)

ALTERNATIVE 6
4 ADDITIONAL LANES ON HIGH LEVEL BRIDGE



Virginia Department of Transportation
VDOT

$TIME$STAMP$

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
			6(11)

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$DGNLEV $LEV001 $LEV002 $LEV003 $LEV004 $LEV005 $LEV006

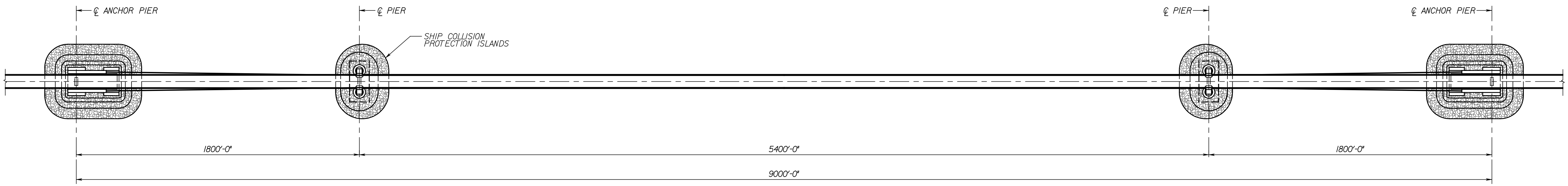
MOFFATT & NICHOL
RICHMOND, VIRGINIA

SURVEYED BY ________________
SUPERVISED BY VDOT ___________
DESIGNED BY MOFFATT & NICHOL (804) 320-1996

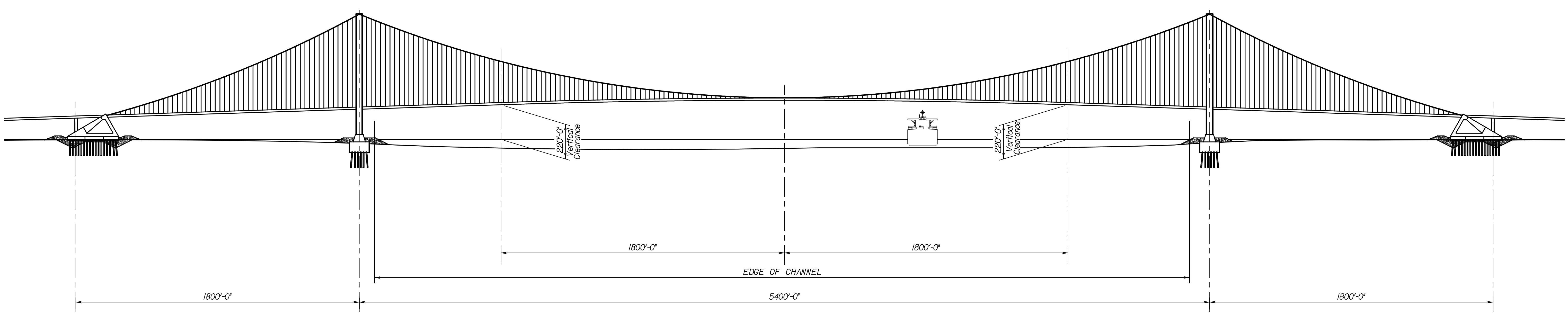
DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	FHWA REGION	STATE	FEDERAL AID PROJECT	STATE ROUTE	STATE PROJECT	SHEET NO.
	3	VA.				6(12)

ALTERNATIVE 6
PLAN AND ELEVATION



PLAN VIEW
Scale: 1" = 300'-0"



ELEVATION VIEW
Scale: 1" = 300'-0"

Virginia Department of Transportation
VDOT

SURVEYED BY ________
SUPERVISED BY AAA ________
DESIGNED BY BBB ________
CADD OPERATOR$$$$$$DESIGN$FILE$SPECIFICATION$$$$$$
REVISED BY ________

$TIME$STAMP$

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
A			6(12)

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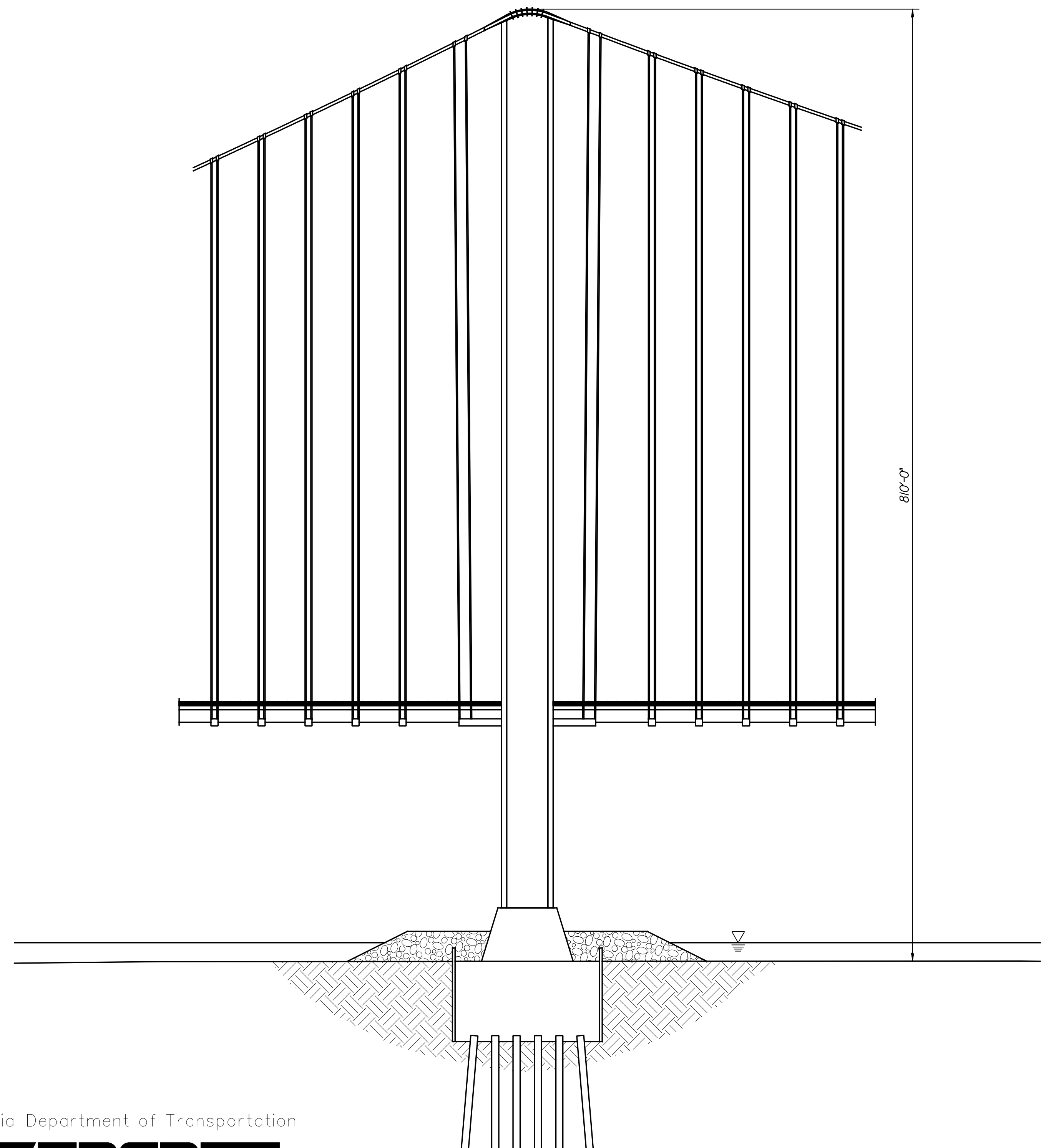
RICHMOND, VIRGINIA

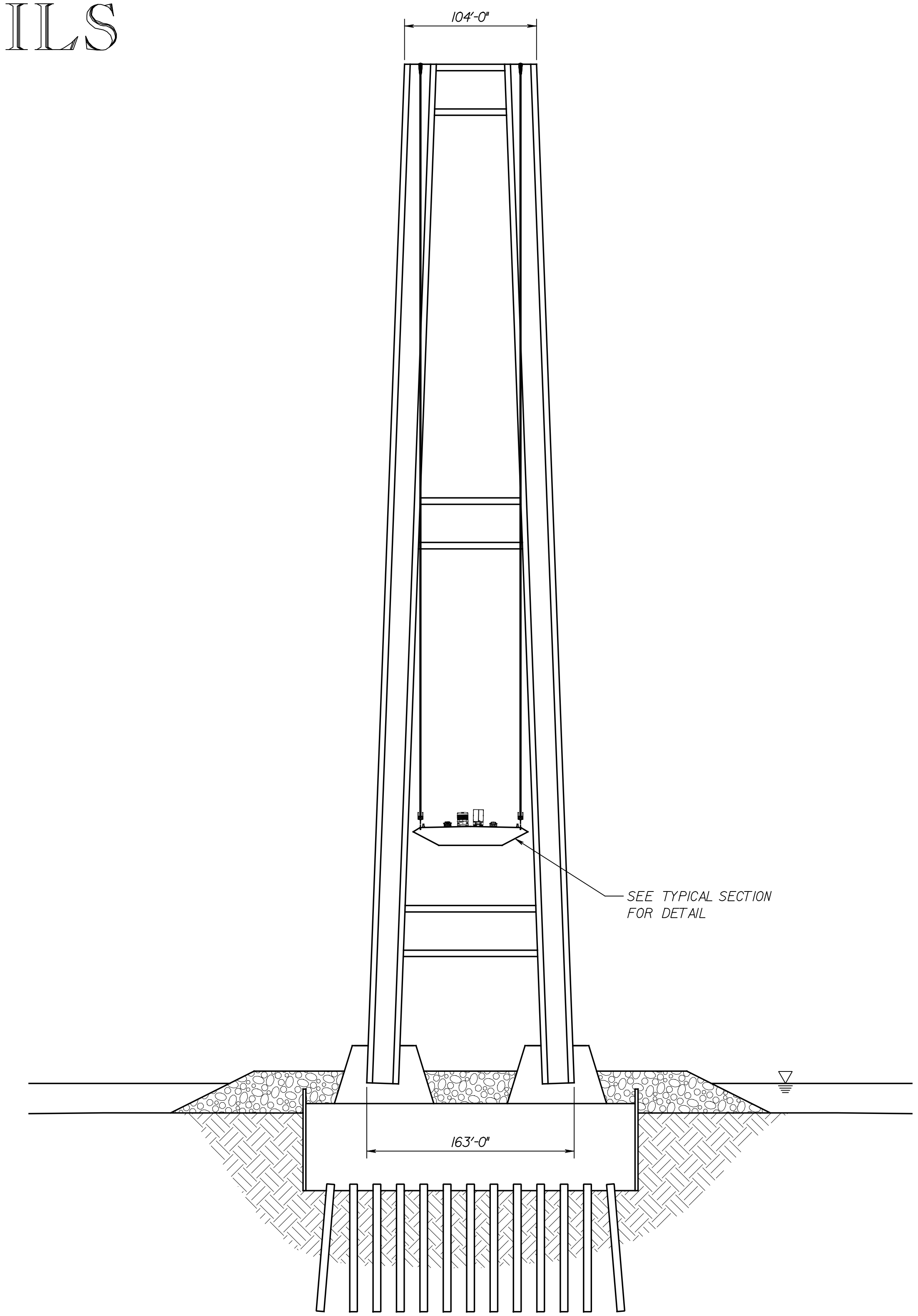
DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	FHWA REGION	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	3	VA.				6(13)

ALTERNATIVE 6
PIER DETAILS



PIER SIDE VIEW
Scale: 1" = 60'-0"



PIER FRONT VIEW
Scale: 1" = 60'-0"

Virginia Department of Transportation

SURVEYED BY
SUPERVISED BY AAA
DESIGNED BY BBB
CADD OPERATOR $$$$$$$$DESIGN$FILE$SPECIFICATION$$$$$$$$
REVISED BY

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DGN $REF001 $REF002 $REF003 $REF004 $REF005 $REF006
$DGNLEV $LEV001 $LEV002 $LEV003 $LEV004 $LEV005 $LEV006

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DESIGN FEATURES RELATING TO CONSTRUCTION OR TO REGULATION AND CONTROL OF TRAFFIC MAY BE SUBJECT TO CHANGE AS DEEMED NECESSARY BY THE DEPARTMENT

REVISED	FHWA REGION	STATE	FEDERAL AID PROJECT	ROUTE	STATE PROJECT	SHEET NO.
	3	VA.				6(14)

ALTERNATIVE 6 CHANNEL GEOMETRY

SURVEYED BY ___
SUPERVISED BY AAA
DESIGNED BY BBB
CADD OPERATOR $$$$$$DESIGN$FILE$SPECIFICATION$$$$$$
REVISED BY ___

$TIME$STAMP$

PLAN NO.	PROJECT	FILE NO.	SHEET NO.
A			6(14)

Summary of Findings:

The following table summarizes the results of this study.

TABLE 1

Alternative	Traffic Analysis (LOS)*								R/W Impacts		Construction Cost
	w/o Third Crossing				w/ Third Crossing						
	2018		2030		2018		2030				
	EB	WB	EB	WB	EB	WB	EB	WB	Impacted Buildings (#)	Impacted Sound Wall (LF)	in Billions
No Build	F (F)	F (F)	F (F)	F (F)	D (E)	C (E)	D (E)	C (F)	0	0	$0.0
1	D/D (C/D)*	C/D (C/D)*	F/E (F/E)*	C/E (F/E)*	D/D (C/D)*	C/D (C/D)*	D/D (C/D)*	C/D (C/D)*	50-75	7,400	$2.13
2	B (F)	F (B)	C (F)	F (B)	B (F)	F (B)	B (F)	F (B)	70-105	7,400	$2.25
3	C (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	70-105	7,400	$3.24
4	C/A (C/A)**	B/A (C/A)**	C/A (C/A)**	C/A (C/A)**	C/A (B/A)**	B/A (C/A)**	C/A (C/A)**	C/A (C/A)**	70-105	7,400	$3.27
5	As noted in the report, Alternative 5 is dismissed due to adverse structural design characteristics										
6	C (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	B (B)	70-105	7,400	$3.14

* Denotes two lanes one direction / two lanes two direction

** Denotes three General Purpose lanes / One HOV lane

(pink)	Denotes LOS over capacity for either AM or (PM) peak. Does not meet FHWA LOS requirement for Interstate facilities
(yellow)	Denotes LOS at or near capacity for AM or (PM) peak. Does not meet FHWA LOS requirement for Interstate facilities
(green)	Denotes AM and (PM) peak LOS meeting minimum FHWA LOS requirements for Interstate facilities
(gray)	Denotes Alternatives recommended to be eliminated from further consideration

Alternative 1 is recommended for elimination from further study due to the fact that the safety concerns with the two-way traffic sections on the bridge tunnel facility cannot be adequately mitigated. The no build alternative and Alternative 2 are recommended for elimination from further study due to the fact that their implementation would not meet the FHWA minimum LOS requirements for Interstate facilities.

Appendix A

TRAVEL DEMAND FORECASTS

Travel demand forecasts were developed by the Department for the Hampton Roads Bridge Tunnel. The forecasts were developed through the use of the Hampton Roads travel demand model based on the 2030 Constrained Long Range Plan. Forecasts were developed based on Average Annualized Weekday Traffic (Monday to Friday) basis. The forecasts were developed for the years 2018 and 2030.

The model volumes were developed for two different scenarios from a roadway network standpoint. This is with and without the so called "third crossing" of Hampton Roads from I-564 to I-664. The 2030 model network improvements include widening I-664 to provide HOV lanes and increasing the Monitor Merrimac Bridge Tunnel capacity. Forecasts were developed for the following alternatives:

- No Build
- Widening to Six Lanes
- Widening to Eight Lanes including 2 HOV lanes
- Widening to Eight Lanes

Tolls were included for all improvement scenarios for the Hampton Roads Bridge Tunnel and for the new third crossing, if it is constructed. The tolls were assumed to be $2.00 in each direction for purposes of the modeling. This toll was converted to an equivalent time penalty in minutes ($16.64/hour in year 2000 dollars) and input into the model. The modeling for the reversible lane alternative was based on a four lane alternative for the Hampton Roads Bridge Tunnel and their approaches. This was due to the limitations of the model to be able to analyze this condition. The average weekday traffic volumes for 2018 and 2030 are shown for the various Alternatives in Table 2.

TABLE 2

HAMPTON ROADS BRIDGE-TUNNEL

AVERAGE DAILY TRAFFIC VOLUMES

ALTERNATIVE	2008	2018	2030
Existing	92,800	-	-
No Build	-	97,900	105,100
No Build with Third Crossing	-	84,300	85,300
6 Lanes	-	94,200	103,600
6 Lanes with Third Crossing	-	92,000	96,000
6 Lanes & HOV	-	95,100	105,000
6 Lanes & HOV with Third Crossing	-	92,900	96,900
8 Lanes	-	96,500	108,500
8 Lanes with Third Crossing	-	96,800	102,200

The forecasted average daily traffic volumes were converted to peak hour volumes in order to conduct traffic analysis. These volumes were developed by multiplying the existing K factor (peak hour percentage) by the forecasted average weekday traffic. The projected high occupancy vehicle volumes were provided by the Virginia Department of Transportation in the form of peak hour volumes. For the alternative with two additional lanes for the Hampton Roads Bridge-Tunnel where the middle tube would operate with one westbound and one eastbound lane, the volumes were calculated separately for each tube. The basis for determining volume of traffic that would use the two way tube was developed utilizing rates for the two way operation for the Maryland Bay Bridge where reversible lanes are operated during peak periods. The lane utilization for that condition is 80 - 85% on the existing two lane structure and 15 - 20% in the reversible lane on the other structure. This rate was used to develop the volumes for the reversible Hampton Roads Bridge Tunnel.

Traffic volumes for the peak hours are shown in Table 3.

TABLE 3
PEAK HOUR TRAFFIC VOLUMES

	AM		PM	
CONDITION	**EB**	**WB**	**EB**	**WB**
2008	3503	2840	3193	3143
2018 No Build	3619	3038	3276	3381
2018 No Build with 3rd Crossing	3100	2807	2604	2926
2018 3 Lanes/Direction				
2 Lane Tunnel (1 way)	2956	2486	2676	2768
1 Lane Shared Tunnel (2 way)	522	439	473	488
2018 3 Lanes/Direction with 3^{rd} Crossing				
2 Lane Tunnel (1 way)	2880	2434	2609	2710
1 Lane Shared Tunnel (2 way)	509	430	460	478
2018 Reversible 4-2	3574	2988	3236	3326
2018 Reversible 4-2 with 3^{rd} Crossing	3552	3025	3216	3367
2018 4 Lanes/Direction				
3 SOV Lanes	3456	2908	3129	3236
1 HOV Lane	200	300	200	300
2018 4 Lanes/Direction with 3^{rd} Crossing				
3 SOV Lanes	3374	2858	3055	3181
1 HOV Lane	200	200	200	200
2018 4 Lanes/Direction (Bridge or Tunnel)	3574	2988	3236	3326
2018 4 Lanes/Direction (Bridge or Tunnel) with 3^{rd} Crossing	3552	3025	3216	3367
2030 No Build	3878	3267	3510	3636
2030 No Build with 3^{rd} Crossing	3138	2660	2841	2960
2030 3 Lanes/Direction				
2 Lane Tunnel (1 way)	3239	2745	2932	3057
1 Lane Shared Tunnel (2 way)	572	485	518	538
2030 3 Lanes/Direction with 3^{rd} Crossing				
2 Lane Tunnel (1 way)	3044	2508	2756	2791
1 Lane Shared Tunnel (2 way)	537	443	487	493
2030 Reversible 4-2	4003	3373	3625	3754
2030 Reversible 4-2 with 3^{rd} Crossing	3759	3187	3404	3547
2030 4 Lanes/Direction				
3 SOV Lanes	3767	3205	3410	3567
1 HOV Lane	400	400	400	400
2030 4 Lanes/Direction with 3^{rd} Crossing				
3 SOV Lanes	3507	2995	3176	3333
1 HOV Lane	200	200	200	200
2030 4 Lanes/Direction (Bridge or Tunnel)	4003	3373	3625	3754
2030 4 Lanes/Direction (Bridge or Tunnel) with 3^{rd} Crossing	3759	3187	3404	3547

Appendix B

TUNNELS – GENERAL CONSTRUCTION INFORMATION

Immersed Tunnels

Since the beginning of last century, more than one hundred immersed tunnels have been built worldwide for road or rail crossings. Immersed tunnels, constructed as float-in structures and then buried, are constructed in two basic types, a steel tunnel, and a concrete tunnel, both of which contain about the same amount of concrete. Both types are usually made up of a number of tunnel elements essentially prefabricated in manageable lengths, each often about 330 feet long, that are eventually joined up below water to form the final tunnel. They have temporary bulkheads across the ends of each element to allow them to float with the insides dry. Fabrication is either completed in a dry dock, or the elements are launched like a ship and then completed afloat close to their final location. In most cases, the completed tunnel elements are barely capable of staying afloat unaided.

Tunnel elements can and have been towed successfully over great distances. After outfitting at their final destination, they are attached to temporary supports capable of lowering the elements into a prepared trench in the bed. The supports may typically be provided by a purpose-built catamaran or barges with winches, or by cranes. Elements are lowered and butted up to preceding elements, after which the joint between them is dewatered. The foundation can be prepared prior to lowering the elements, or it can be completed after placing the elements on temporary supports in the trench. Following this, backfilling of the trench is completed and any necessary protection added to the top of the tunnel and the fill. It is sometimes necessary to make the closing joint underwater, so that the optimum sequence of construction can be adopted.

Steel versus Concrete Tunnels

As mentioned earlier, immersed tunnels come in two types. The choice between them depends very much on local conditions and practice.

- Concrete tunnels are usually constructed within a dry dock or in a dewatered casting basin below sea level, and then floated out when complete. Freeboard in this condition is usually less than half a meter. Although some concrete tunnels have an outer steel plate waterproofing membrane, it does not work compositely with the reinforced or pre-stressed concrete structure.

- Steel tunnels are fabricated initially in much the same way as a ship, essentially a steel hull or shell within which at time of launch there is usually little or no concrete. Draft in this condition is usually only a few meters. Close to the installation site and while afloat or held afloat, concrete is placed within the steelwork to form the final pressure-resistant structure. The steel shell and the concrete work compositely together. Ballast concrete is also placed to provide the necessary weight to prevent the structure from floating up from its final resting place.

Both types perform the same function after installation. While it is usual for the individual steel immersed tunnel elements to cost a few percent more to construct than equivalent concrete elements, this may be more than offset by advantages to be gained from their shorter construction duration.

Immersed tunnels have special advantages since they lie only a short distance below bed level. Approaches can be relatively short and the visual intrusion negligible compared with high level bridges. Tunnels can be made to suit horizontal and vertical alignments, and to match the requirements of road or rail traffic.

Bridge Tunnels

For very long crossings where navigation is important, bridges with immersed tunnel combinations can provide a most economical solution. Generally, long trestle bridges extend out from the shores through relatively shallow water to man-made islands at which the transition between bridge and tunnel is made, with the tunnel extending across the usually deeper navigation channels. The Hampton Roads bridge-tunnel (1957) in Virginia was the first immersed tunnel to be built between two man-made islands, and has since been widened from its initial one lane each way configuration by constructing parallel bridges, widening the islands and laying a parallel tunnel. The nearby Chesapeake Bay bridge-tunnel, which was completed seven years later, is over 17 miles long and has immersed tunnels at each of the two main shipping channels. Its bridges, too, have been widened from their initial one lane each way configuration by constructing parallel bridges. A third bridge-tunnel, the Monitor-Merrimac, was completed in the same vicinity in 1992.

Bridge-tunnels have been proposed for other long crossings, such as across the mouth of the Pearl River near Hong Kong in China; and a bridge-tunnel has been constructed for the Tokyo Bay Crossing in Japan.

Reference: Ingerslev, LCF, “Water Crossings—the Options,” Tunneling and Underground Space Technology, Vol. 13, No. 4, pp. 357-363, Elsevier Science Ltd., 1998

During extension of the islands, there will be no impact to the marine fairway. Any marine plant will be located in relatively shallow water, probably on the upstream side of the islands. Marine works for dredging, screeding and backfilling are unlikely to and need not occur simultaneously. Each of these operations is unlikely to occupy more than the length of 2 or 3 of the 20 or so tunnel elements. At all times therefore, there is plenty of sea room for two-way navigation through the tunnel alignment area. During the operation of placing each tunnel element, the crucial time is slack tide, since tidal currents can be significant; it is highly undesirable for shipping to create significant wakes during this operation that may last some hours, so slow speed in the area would be required. If necessary, special placing equipment with low water-plane areas can be manufactured to eliminate this potential issue. Only some 20 or so operations to place tunnel elements will occur. Coordination with shipping owners and the navy will be required to ascertain suitable timing for such operations and has not been a critical issue for the hundreds of such tunnels constructed to date around the world.