I-95/I-476 Interchange Improvement Feasibility Study

Phase 2 Executive Summary

Produced by RK&K for DVRPC

January 2013

The Delaware Valley Regional Planning Commission is dedicated to uniting the region's elected officials, planning professionals, and the public with a common vision of making a great region even greater. Shaping the way we live, work, and play, DVRPC builds consensus on improving transportation, promoting smart growth, protecting the environment, and enhancing the economy. We serve a diverse region of nine counties: Bucks, Chester, Delaware, Montgomery, and Philadelphia in Pennsylvania; and Burlington, Camden, Gloucester, and Mercer in New Jersey. DVRPC is the federally designated Metropolitan Planning Organization for the Greater Philadelphia Region — leading the way to a better future.

The symbol in our logo is adapted from the official DVRPC seal and is designed as a stylized image of the Delaware Valley. The outer ring symbolizes the region as a whole while the diagonal bar signifies the Delaware River. The two adjoining crescents represent the Commonwealth of Pennsylvania and the State of New Jersey.

DVRPC is funded by a variety of funding sources including federal grants from the U.S. Department of Transportation's Federal Highway Administration (FHWA) and Federal Transit Administration (FTA), the Pennsylvania and New Jersey departments of transportation, as well as by DVRPC's state and local member governments. The authors, however, are solely responsible for the findings and conclusions herein, which may not represent the official views or policies of the funding agencies.

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Feasibility Study Purpose

The I-95/I-476 interchange is located just north of the City of Chester, in Delaware County, Pennsylvania, at the intersection of two of the most heavily traveled highway corridors in the Delaware Valley. Traffic congestion at the I-95/I-476 interchange and its immediate vicinity occurs on a daily basis and is a major impediment to the traveling public. The Delaware Valley Regional Planning Commission (DVRPC), in conjunction with the Delaware County Planning Department (DCPD), is conducting this feasibility study of potential congestion mitigation and operational improvements to the I-95/I-476 interchange. The purpose of the I-95/I-476 Interchange Improvement Feasibility Study is to develop small-scale interchange improvements to help reduce the current traffic congestion issues. The feasibility study outcome anticipates the identification of low-cost geometric and safety improvements that may be fiscally affordable for regional consideration in the Transportation Improvement Program (TIP).

Phase 1 Study Results

The I-95/I-476 Interchange Improvement Feasibility Study was conducted in two study phases. The first study phase consisted of traffic and roadway data collection, an assessment of existing conditions, identification of potential improvements, traffic analysis, development of preliminary cost estimates, identification of potential impacts, consideration of implementation time, prioritization of the improvements, and guidance for the improvements to be further evaluated in a second study phase. A report summarizing the first phase study results was published and made available by DVRPC (Publication number 11026). The improvements ranked 1, 2, and 3 were recommended for further detailed evaluation during the Phase 2 Study. Improvements 9 and 10 were combined into Package A and represent roadway improvements for the southbound I-476 to southbound I-95 ramp. Improvements 2, 4, and 5 were combined into Package B and represent roadway improvements for the northbound I-95 to northbound I-476 ramp. Improvement 6 represents implementation of a northbound I-476 hard shoulder running lane. The study team was asked to evaluate Improvement 8 (southbound I-476 hard shoulder running lane) simultaneously during the Phase 2 Study to better understand the operational and engineering issues of the I-476 shoulder use lane concept. **Table 1** from the Phase 1 Study report (dated April 2012) shows the improvements for further study in Phase 2.

Table 1: Summary Ranking of the Improvements

Rank	Improvement	Cost	Priority
1	***Package A*** – Improvements 9 and 10	$3.8M to $5.1M	High
2	***Package B*** – Improvements 2, 4, and 5	$1.9M to $2.6M	High
3	***Improvement 6***	$5.6M to $7.4M	High
4	Improvement 13	$15K to $300K	High
5	Improvement 1 – *no longer in consideration; a ramp relocation study is suggested instead*	$170K to $200K [Ramp Closure Only]	Medium
6	Improvement 12	$25K to $365K	Medium
7	Improvement 7	$530K to $700K	Medium
8	***Improvement 8***	$5.4M to $7.2M	Low
9	Improvement 11	$75K to $100K	Low
10	Improvement 3	$15K to $300K	Low

Phase 2 Study

The purpose of the Phase 2 Study was to prepare more detailed conceptual engineering and traffic analysis, and gather further stakeholder input of the Phase 1 Study recommendations. By completing further conceptual engineering details and traffic analysis, the study team will be able to provide DVRPC and DCPD with a better understanding of the transportation improvement benefits to motorists and the anticipated implementation costs, and whether any fatal flaws existed in the recommended improvements. With this information, DVRPC staff will determine if the improvements are candidate projects to be added to the region's TIP.

Phase 2 Study Scope

The Phase 2 Study scope was focused on the detailed evaluation of Package A, Package B, and Improvements 6 and 8. Stakeholder input was also continued during the Phase 2 Study with two Study Advisory Committee meetings (April 18, 2012, and May 23, 2012) and an Environmental Justice outreach meeting (May 23, 2012). The two stakeholder groups were comprised of local government agencies, emergency responders, civic organizations, and private citizens.

The detailed traffic operations analyses used more sophisticated traffic simulation modeling software to confirm the traffic and operational benefits for the potential improvements. Additional roadway engineering analysis were completed for improvement Package A (Improvements 9 and 10) and Package B (Improvements 2, 4 and 5) to better detail the pavement additions, signing/striping changes, typical section, shoulder widths, geometric spacing at ramp gores and tapers, horizontal and vertical sight distance, and potential right-of-way limits. A geometric feasibility analysis and an existing condition field review was conducted for Improvements 6 and 8 (I-476 hard shoulder running lane concept) that included an expanded study limit from north of the I-476/MacDade Boulevard interchange northward to the I-476/West Chester Pike (Exit 9) interchange. Planning-level cost estimates with detailed planning quantities were also assembled for Package A, Package B, and Improvements 6 and 8 to support a subsequent TIP project submission. In addition, for improvements that include operational changes, such as shoulder lane use during peak periods, the study team assembled an initial description of hard shoulder use lane operations for I-476.

I-95/I-476 Interchange Package A (Improvements 9 & 10)

Description

Improvement Package A includes Improvements 9 and 10 as recommended in Phase 1, and provides a two-lane ramp from southbound I-476 to southbound I-95. Improvement Package A figures are presented in **Appendix A**. Currently, three lanes are provided along southbound I-476 approaching the split to northbound and southbound I-95. The three lanes split with two lanes directed to northbound I-95 and two lanes directed to southbound I-95 (the center lane is a choice lane). South of the diverge, southbound I-476 drivers are notified that the left lane of the two-lane ramp ends and that they must begin to merge into the right lane. This lane drop begins concurrently with the merge of the MacDade Boulevard entrance ramp to southbound I-476. Improvement 9 would eliminate the left-lane drop along the ramp and thereby eliminate friction between ramp traffic merging right with traffic entering from MacDade Boulevard.

The southbound I-476 ramp continues south and passes under the existing CSX Railroad bridge. The horizontal alignment of the ramp through this area would be maintained under the proposed improvements. The existing pavement width under the CSX Railroad bridge is sufficient to accommodate two 12-foot-wide travel lanes; a 10-foot wide right shoulder; and a four-foot wide left shoulder. With the exception of signing and striping modifications, no additional changes would be required in this area. Physical modifications to the ramp alignment would begin approximately 370 feet south of the CSX Railroad bridge. The modifications would include removing the tapered portion of the ramp and increasing the ramp curve radius from approximately 830 feet to approximately 1,175 feet. Removing the taper and increasing the radius will enable the ramp to tie into southbound I-95 north of the existing merge location. Because of the earlier tie-in, full-depth pavement reconstruction of approximately 330 feet along the left ramp shoulder and widening of ramp gore area would be required.

The second improvement associated with Improvement Package A provides additional capacity for southbound I-95 between the I-476 entrance and the Chestnut Street exit by providing a four-lane section. Currently, southbound I-95 has two through lanes and the ramp from southbound I-476 adds a third (right-most) lane. The three-lane section continues along southbound I-95 with 12-foot-wide lanes, a one-foot wide offset to the concrete median barrier, and a 10-foot-wide right shoulder. Through this section, the combination of heavy peak-period traffic volumes along southbound I-95 and the single-lane merge from southbound I-476 produces substantial traffic friction that results in congestion along southbound I-95 and the entrance ramp from southbound I-476.

Proposed Southbound I-95 Roadway Section – South of I-476 Merge: The proposed southbound I-95 roadway section would provide four lanes with both lanes from the modified southbound I-476 ramp, adding to the two southbound I-95 through lanes. The typical section would provide 12-foot-wide lanes, a 1.5-foot-wide left offset, and a 10-foot-wide right shoulder. This section would extend from the I-476/I-95 merge for approximately 465 feet, at which point the 10-foot-wide shoulder would taper to a one-foot offset on the I-95 bridges over Bullens Lane and Ridley Creek, a length of approximately 380 feet. The travel lanes would begin to transition from 12-foot widths to 11-foot widths approximately 150 feet south of where the shoulder taper begins. The median barrier offset would simultaneously increase in width from one foot to 1.5 feet. The lane and left offset transitions would occur over a length of approximately 350 feet. The decrease in lane and shoulder widths is required to fit the proposed typical section within the width of the existing bridges and to avoid widening along southbound I-95 adjacent to the Pennsylvania Department of Transportation (PennDOT)/CSX right-of-way line south of the I-95 bridges.

Based on as-built documentation, the PennDOT/CSX right-of-way line is located along the edge of existing I-95 pavement south of Ridley Creek. As a result, the study team identified two typical section options to be considered: short-term and long-term. These were developed to avoid a protracted timeframe to complete right-of-way acquisition/negotiation with CSX. The two typical section options are described here and illustrated in Appendix A.

Short-term Southbound I-95 Typical Section Option: In order to implement the proposed improvements in the short-term, reduced lane and shoulder widths will be required. The short-term typical section will extend for approximately 1,100 feet south of the I-95 bridge over Ridley Creek, will provide a 1.5-foot offset to the barrier, and will require reconstruction of the right shoulder to provide full-depth pavement for the proposed fourth lane. The short-term typical section will extend to approximately 300 feet north of the Chestnut Street exit ramp and, at this point, the PennDOT/CSX right-of-way begins to taper away from the roadway. The lanes would then transition back to a 12-foot width and the right shoulder to a 10-foot width. The right lane would exit at the Chestnut Street ramp and three lanes would continue on southbound I-95.

During the Phase 2 Study, a commitment was made to implement the short-term typical section improvement on a trial basis in order to evaluate potential traffic/operational impacts resulting from providing no shoulder for approximately 1,500 feet along southbound I-95. A before/after analysis of safety issues and impact on emergency management and response times was promised. If a negative impact on roadway safety due to the elimination of the roadway shoulder is experienced, the agencies are committed to removing the typical section change until the long-term typical section solution can be implemented.

Long-term Southbound I-95 Typical Section Option: While the short-term improvement is in operation, right-of-way acquisition and retaining wall structure design could be undertaken to facilitate the long-term typical section option, which would provide four 11-foot wide lanes, a one-foot-wide left offset, an eight-foot-wide right shoulder, and an approximately two-foot-wide earth retaining wall/barrier. An eight-foot-wide right shoulder is proposed due to the existing CSX Railroad running parallel to I-95 in this location. Currently, there is one active rail line and one abandoned rail line. CSX standards require a minimum 30-foot-wide railroad bed for its track. This requirement means that a 15-foot-wide offset from the centerline of the track must be maintained to the edge of the rail bed or nearest proposed roadway feature. By implementing the proposed long-term typical section, the proposed right-of-way line can be set outside of the rail bed of the abandoned rail line. Further discussion will be required with CSX to determine its long-range plans for the abandoned line and confirm the typical section requirements.

Traffic Analysis - No-Build 2015/Build 2015

Using the VISSIM microsimulation software, Improvement Package A was modeled and analyzed for both the AM and PM peak hours. The VISSIM model created by the I-95 Master Plan team for PennDOT was obtained and used as the base, and I-476 was added to this model from I-95 to Exit 9 (West Chester Pike). The existing models were calibrated to replicate field-observed travel conditions, which were obtained from vehicle probe data (INRIX) from the I-95 Corridor Coalition. Once the existing models were completed, future-year (2015) models were developed for both the AM and PM peak. A No-Build model was developed, and a Build model combining Improvement Packages A and B was also developed and analyzed to assess the traffic improvements resulting from the implementation of both packages.

The model results show enhancement in the roadway Level of Service (LOS) and a reduction in the travel time for the specific movements targeted by the improvement packages, specifically I-95 northbound to

I-476, and I-476 southbound to and through I-95 southbound. In particular, the travel times for these targeted movements are reduced by up to 38 percent (see **Table 2**). For the remaining movements through the interchange, travel times are expected to remain fairly constant, with travel time differences within five percent of the No-Build conditions. Travel time results for all movements can be found in the Phase 2 Technical Reference.

Table 2: Travel Time Improvements – Package A

Location AM[PM]	No-Build Travel Time (min)	Build Travel Time (min)	Travel Time Improvement
I-476 Southbound Exit 1 to I-95 Exit 6	1.77 [4.05]	1.30 [2.49]	27% [38%]
I-95 Southbound Exit 8 to Exit 6	2.56 [5.67]	2.55 [5.89]	0% [-4%]
Overall	2.24 [3.89]	2.15 [3.74]	4% [4%]

Source: RK&K, 2012

LOS results for the entire interchange can also be found in the Phase 2 Technical Reference. As expected, the greatest improvements in LOS can also be found in the locations targeted by Improvement Packages A and B, including:

- I-476 Southbound to I-95 Southbound – Two-lane section LOS improves from LOS F/[F] to LOS D/[C].
- I-95 Southbound between I-476 Southbound On-Ramp and Chestnut Street Off-Ramp – LOS improves from LOS E/[F] to LOS D/[D].

Cost Estimates

The estimated costs of Improvement Package A were prepared for both the short-term and long-term typical section options and are shown in **Table 3**. The estimated cost range for the short-term typical section option is $1.5 million to $2.0 million. The estimated cost range for the long-term typical section option is $5 million to $6 million. Since they are detailed planning level cost estimates, derived from the conceptual engineering drawings, the costs in Table 3 are more precise than the initial generalized cost estimate from the Phase 1 Study shown in Table 1.

The estimates were derived using conceptual engineering drawings and detailed planning-level quantities for roadway construction (paving, grading), structures (retaining wall), traffic (pavement markings, signing), stormwater management, landscaping, Maintenance of Traffic (MOT), erosion and sediment control, and drainage. A 50 percent construction contingency was applied to the neat (excluding right-of-way) construction cost. Construction inspection, preliminary engineering/design, project administration, and right-of-way acquisition/right-of-way contingency (long-term typical section) were added to the construction costs for the estimated total project cost.

It is noted that the long-term typical section option improvement cost estimate includes a lump sum estimate to purchase a sliver of CSX property for construction of an eight-foot shoulder. The study team estimated $1 million for the land based on an "across the fence" value method of adjacent property. The study team also added a 25 percent contingency. A more detailed appraisal method will be required to accurately assess the CSX property.

Table 3: Estimated Project Cost – Improvement Package A

	Short-Term Typical Section	**Long-Term Typical Section**
Construction Cost	$573,633	$1,603,430
50% Construction Contingency	$286,816	$801,715
Total Construction Cost	*$860,449*	*$2,405,145*
Construction Inspection (15% of Total Construction Cost)	$129,067	$360,772
Preliminary Engineering/Design (15% of Total Construction Cost)	$129,067	$360,772
Project Administration (15% of Total Construction Cost)	$129,067	$360,772
Right-of-Way Acquisition (Lump Sum estimate)	$0	$1,000,000
Right-of-Way Contingency (25% of ROW estimate)	$0	$250,000
Estimated Total Project Cost	$1,248,000	$4,738,000
Project Cost Range	$1.5M to $2.0M	$5.0M to $6.0M

Source: RK&K, 2012

I-95/I-476 Interchange Package B (Improvements 2, 4 & 5)

Description

Improvement Package B conceptual drawings are presented in **Appendix B**. Improvement Package B includes Improvements 2, 4, and 5 recommended from Phase 1, and modifies the northbound I-95 lane configuration at the ramp diverge to northbound I-476. Currently, I-95 is comprised of three lanes approaching this diverge: the right lane drops at the ramp and the left two lanes continue as northbound I-95. This improvement would modify the diverge to create an even split, with two lanes continuing on northbound I-95 and two lanes exiting to the ramp to northbound I-476, the center lane would be converted to a shared lane, where drivers could continue on I-95 or exit to I-476. The reconfiguration of this split would provide additional capacity to northbound I-476 and reduce friction from traffic attempting to merge from the Chestnut Street entrance ramp south of the split.

To implement this improvement, northbound I-95 would have to be restriped in the vicinity of the split (Improvement 2). These improvements can be implemented without reconstruction of the pavement within the existing gore area. However, full-depth reconstruction and widening of approximately 1,000 feet of the left shoulder of the I-476 exit ramp will be required to accommodate the second exit lane and provide for an eight-foot-wide left shoulder. Currently, the I-476 exit ramp widens to two lanes approximately 1,000 feet after the exit; the proposed improvement will tie into the existing two-lane ramp alignment. The advance guide signing along northbound I-95 would have to be modified to accommodate the reconfigured split. These modifications would include new overhead and cantilever sign structures and sign panels.

Continuing north, the lane configuration would be modified at the merge of the ramps from I-95 to northbound I-476 (Improvement 4). Currently, the left lane of the ramp from northbound I-95 drops at the merge with the two-lane ramp from southbound I-95; three lanes continue as northbound I-476, two from southbound I-95, and one from northbound I-95. This lane configuration would not be compatible with Improvement Package B, which would provide two lanes for the northbound I-95 to northbound I-476 movement. Therefore, the lane configuration would be modified to maintain the two lanes of the northbound I-95 ramp through the merge. The right lane of the ramp from southbound I-95 would drop prior to the merge as an exit-only lane to MacDade Boulevard. The left lane of the southbound I-95 exit ramp would continue and merge with the two northbound I-95 ramp lanes. These three lanes would continue as northbound I-476. There is significant peak-period congestion along northbound I-95 and the ramp to northbound I-476. Providing additional capacity between northbound I-95 and northbound I-476 may alleviate some of this congestion. Both ramps from I-95 would have to be restriped prior to the merge, and northbound I-476 would have to be restriped through the merge. Signing changes, including new cantilever sign structures, would be required on the ramps to accommodate the modified lane configuration.

The final improvement associated with Improvement Package B, Improvement 5, would modify the lane drop on northbound I-476 prior to the entrance ramp from MacDade Boulevard. Currently, the left lane of I-476 drops prior to MacDade Boulevard, leaving two lanes on northbound I-476. Effectively, these two lanes represent one lane from northbound I-95 (right lane) and one lane from southbound I-95 (left lane). The modified lane configuration would instead drop the right lane of northbound I-476 prior to the MacDade Boulevard entrance ramp. Modifying the location of the lane drop would provide two benefits. First, as noted by the American Association of State Highway and Transportation Officials (AASHTO), a right-side lane drop is more standard and more expected by drivers. Second, a right-lane drop would be consistent with the other modifications to the northbound I-95 and northbound I-476 lane configurations, effectively maintaining one lane from northbound I-95 (right lane) and one lane from southbound I-95 (left lane) beyond the lane drop.

The lane drop would occur approximately 1,000 feet north of the I-95 ramp merge, thus providing a 1,000-foot auxiliary lane prior to the lane drop. The right lane would be dropped over a total length of 600 feet. The lane drop would be completed approximately 650 feet south of the MacDade Boulevard gore area.

Traffic Analysis - No-Build 2015/Build 2015

Traffic impacts of Improvement Package B were analyzed in the same manner as Improvement Package A. As previously stated, Improvement Packages A and B were analyzed in VISSIM concurrently. The model results (see **Table 4**) show enhancement in the roadway LOS and a reduction in the travel time for the specific movements targeted by Improvement Package B, specifically I-95 northbound to I-476, with the travel times for this targeted movement reduced by up to 33 percent.

Table 4: Travel Time Improvements – Package B

Location AM[PM]	No-Build Travel Time (min)	Build Travel Time (min)	Travel Time Improvement
I-95 Northbound Exit 6 to I-476 Exit 1	2.83 [3.24]	1.89 [3.02]	33% [7%]
I-95 Northbound Exit 6 to Exit 8	2.17 [2.82]	2.05 [2.79]	6% [1%]
Overall	2.24 [3.89]	2.15 [3.74]	4% [4%]

Source: RK&K, 2012

As expected, the greatest improvements in LOS can also be found in the targeted locations:

- I-95 Northbound immediately approaching the I-476 exit area: LOS improves from LOS F/[E] to LOS E/[D].
- I-476 Northbound – Three-Lane Section (Between I-95 and MacDade): LOS improves from LOS D/[C] to C/[C].

An area of concern prior to Phase 2 was the level of anticipated degradation of the I-95 southbound to I-476 northbound ramp. The model results indicate that this movement will degrade from an LOS D to LOS E during the PM peak; however, queues resulting from this reconfiguration are not expected to reach the I-95 mainline.

Cost Estimate

The Improvement Package B cost estimate was prepared using the same methodology as Improvement Package A (see **Table 5**). The estimated project cost is $1.8 million to $2 million and includes pavement reconstruction, resurfacing, and restriping of I-95 and I-476, as noted on the concept drawings in Appendix B. Signing changes, including new cantilever sign structures, would be required to accommodate the modified lane configuration. Again, the Table 5 cost estimate is more precise than the generalized cost estimate generated in the Phase 1 Study which is shown in Table 1.

Table 5: Estimated Project Cost – Improvement Package B

	Estimated Cost
Construction Cost	$853,200
50% Construction Contingency	$426,600
Total Construction Cost	*$1,279,800*
Construction Inspection (15% of Total Construction Cost)	$191,700
Preliminary Engineering/Design (15% of Total Construction Cost)	$191,700
Project Administration (15% of Total Construction Cost)	$191,700
Estimated Total Project Cost	$1,856,000
Project Cost Range	$1.8M to $2.0M

Source: RK&K, 2012

I-476 Hard Shoulder Running (HSR) Lane Feasibility

Description

Along both northbound and southbound I-476, the peak-period traffic demand exceeds the capacity of the two through lanes in each direction. One of the major constraints along northbound I-476 is the two-lane segment north of MacDade Boulevard and the two-lane segment between Baltimore Pike and the Media Bypass. Similarly, vehicles traveling southbound experience congestion at the West Chester Pike interchange, where the third through lane drops, and again further south approaching MacDade Boulevard and I-95.

Accommodating travel demand by providing a full-time third lane along I-476 would be extremely costly. Additionally, the Federal Highway Administration's final Record of Decision for the original I-476 construction included provisions that downsized I-476 between West Chester Pike and MacDade Boulevard to reduce the footprint of the right-of-way, minimizing impacts to parklands, historic resources, and streams.

The improvements proposed in the Phase 2 Study include peak period shoulder operations along I-476 so that the roadway would facilitate general purpose traffic on the existing shoulders during hours of peak traffic. The limits of peak-period shoulder operations would extend from MacDade Boulevard at the south to West Chester Pike at the north (a total distance of approximately eight miles).

The Phase 2 Study included an examination of available construction documents, study of current shoulder-use implementation, and development of a set of design criteria. A windshield survey of the corridor was conducted to identify and develop a list of required improvements, along with associated costs.

Baseline Criteria: Seven criteria were developed as the baseline requirements for implementation of peak-period shoulder use. The criteria are:

1) Shoulder lane to travel lane transitions;
2) Shoulder width and pinch points;
3) Shoulder condition/pavement smoothness and cross slope;
4) Shoulder use design speed;
5) Emergency pull-offs;
6) Interchange entrance and exit ramp design;
7) Operational considerations, such as signing, signaling, speed control, and incident detection.

Existing Conditions: Multiple locations and features along the corridor were identified as having potential issues that would require additional investigation in order for shoulder use to be implemented. The issues include horizontal stopping sight distance around curves, adverse cross slope and/or superelevation, pinch points where the shoulder is narrower than 10 feet, drainage inlets located within, or adjacent to, the shoulder, and communication junction boxes located within the shoulder.

During the windshield survey, potential locations for emergency pull-off areas were also identified. The emergency pull-off locations were selected based on compatible flat roadside topography along tangent sections of I-476 that appeared to be well suited for the location of an emergency pull-off area. The study team developed a conceptual layout of the northbound and southbound I-476 HSR lane, which is presented on the engineering feasibility concept drawings found in **Appendix C.**

The following describes the existing conditions along I-476 and the modifications identified to implement the hard shoulder lane along the northbound and southbound roadways.

1) Shoulder Lane to Travel Lane Transitions

The proposed HSR lanes would extend from the West Chester Pike interchange to the north to the MacDade Boulevard interchange to the south. The travel lanes would require modification at the project termini in order to begin and end peak-period shoulder use lanes seamlessly. At the West Chester Pike interchange, the right lane of southbound I-476 currently drops as an exit-only lane. Under peak-period shoulder use, this lane would continue as a shoulder-lane and would be open during peak-period shoulder use hours of operation. Traveling northbound on I-476, the existing West Chester Pike entrance ramp acceleration lane is added to the roadway. This ramp currently becomes the third northbound travel lane. Under proposed peak-period shoulder use operations, the shoulder use lane would continue through the West Chester Pike interchange and, at this point, peak-period shoulder use operations would end and the shoulder use lane would tie into the existing third/right northbound I-476 travel lane.

At the southern project limit, the peak-period shoulder use lane for northbound I-476 would begin where the right lane drop is proposed under Interchange Improvement Package B. Under normal operations, the third lane would end at this point and vehicles would be directed to merge into the two through lanes via proposed signage; however, under peak-period shoulder operations, the existing third/right lane would extend onto the existing shoulder and would continue as the peak-period shoulder use lane.

The peak-period shoulder use lane for southbound I-476 would tie in directly with the existing right lane just south of the MacDade Boulevard exit ramp. Under peak-period shoulder use operations, the shoulder use lane would continue and become the right lane of the existing three-lane section, and the left lane would be restriped and would become a continuous lane. The right lane of the three-lane section would then become a lane-add, or, under proposed peak-period shoulder use operations, a continuation of the peak-period shoulder use lane.

2) Shoulder Width

Based on a review of the design drawings for I-476, the existing shoulder width varies between 10 and 14 feet throughout the corridor. A 12-foot wide lane was established as the minimum width required facilitating HSR operations.

3) Shoulder Condition/Pavement Smoothness

I-476 construction plans indicate that the existing shoulder was constructed utilizing the same pavement section as the travel lanes. Based on this review, it appears that the existing shoulder is structurally capable of supporting live traffic. However, it is recommended that full depth pavement cores of the shoulder be taken to verify the structural capacity of the shoulder. In addition, I-476 was recently resurfaced (2005) and the pavement condition of the shoulder matches that of travel lanes and, therefore, is suitable for live traffic. However, rumble strips are located along the interior edge of the shoulder and would need to be removed prior to implementation of peak-period shoulder use, as this is in the general area of the proposed wheel path under peak-period shoulder use

Also, six curves along northbound I-476 and three curves along southbound I-476 were observed to contain adverse cross slope and/or superelevation. Of those locations, three curves along northbound I-476 and two curves along southbound I-476 traverse a bridge.

Drivers traveling on the shoulder through these curves would experience some discomfort with the cross slope left unmitigated. The adjacent travel lanes contain some level of superelevation. It is understood that the AASHTO recommended values for superelevation represent a threshold of driver discomfort and not the point of impending vehicle skid; therefore, further investigation, i.e., cross slope survey, should be performed to determine the exact value of adverse cross-slope through each curve.

4) Shoulder Use Design Speed

Using the shoulder as a part-time travel lane would place vehicles closer to roadside obstructions and grading than those currently using the dedicated travel lanes. Because of this situation, sight distance around horizontal curves is less than what is available in the adjacent travel lane. Six locations along I-476 were identified as potentially having decreased available horizontal stopping sight distance under peak-period shoulder use. The locations of decreased horizontal stopping sight distance are as follows:

- Northbound north of Chester Road (station 155);
- Northbound at Rose Valley Road (station 165);
- Northbound at SEPTA Line (station 250);
- Northbound at Media Bypass (station 330);
- Southbound at Avondale Road (station 185); and
- Southbound at Crum Creek (station 125).

Based on the geometric evaluation, a maximum design speed of 45 mph is recommended during peak-period shoulder use; consequently, the speed limit on I-476 would become 45 mph.

5) Emergency Pull-Offs

Ten potential emergency pull-off locations were identified during the windshield survey. Four locations would be along southbound I-476 and six locations along northbound I-476. One emergency pull-off area in each direction (included in the total) would be located adjacent to a deceleration lane. Along southbound I-476, that location would be adjacent to the Media Bypass deceleration lane, and along northbound I-476, the emergency pull-off would be located along the Baltimore Pike deceleration lane. Typical mainline emergency pull-off design is presented in Appendix C.

- Northbound by Yale Avenue (station 170);
- Northbound north of Avondale Road (station 195);
- Northbound at Baltimore Pike deceleration lane (station 225);
- Northbound south of Reed Road (station 425);
- Northbound south of Lawrence Road (station 480);
- Northbound/southbound at Media Bypass mezzanine level (station 330);
- Southbound south of Lawrence Road (station 470);
- Southbound at Media Bypass deceleration lane (station 355);
- Southbound south of SEPTA Line (station 200); and
- Southbound south of Rose Valley Road (station 155)

6) Interchange Entrance and Exit Ramp Design

There are four interchanges located within the project limits. Two of the interchanges, MacDade Boulevard and West Chester Pike, are at the proposed termini of peak-period shoulder use.

The remaining two interchanges, Media Bypass and Baltimore Pike, are located within the limits of proposed operations. Operations at the acceleration and deceleration lanes would require modification to operations under peak-period shoulder running. See Appendix C for typical treatments.

Deceleration lanes for northbound and southbound I-476 to Media Bypass, northbound and southbound I-476 to Baltimore Pike, southbound I-476 to MacDade Boulevard, and northbound I-476 to West Chester Pike would all be treated similarly. The deceleration lanes would require pavement restriping only. During peak-period shoulder use, vehicles would exit directly from the shoulder use lane onto the ramp. During normal operation, vehicles would use the ramp as they do currently.

Likewise, acceleration lanes would require reconfiguration in order to facilitate peak-period shoulder use operations. Unlike deceleration lanes, where vehicles will be able to exit directly from the shoulder use lane, vehicles entering I-476 would need an acceleration lane adjacent to the shoulder use lane so that they can achieve an adequate speed to enter the flow of traffic.

7) Operational Considerations

The use of HSR is expected to be limited to times when traffic demand is expected to be high, such as AM and PM peak periods. As part of the Phase 2 Study, RK&K developed high-level operational concepts that can be used to maintain traffic flow in a safe and efficient manner when the shoulder is being used as a travel lane. Through these concepts, traffic flow can be controlled either statically or dynamically. A static system would operate the shoulder using a predetermined time-of-day operation, using static (non-changeable) signage. A fully dynamic system would have the capability to permit shoulder use only when traffic conditions dictate, and incorporate several Active Traffic Management features, such as variable speed limits, overhead lane use control, and automated incident detection.

RK&K, working with DVRPC, identified operational concepts in various United States locations where HSR is being used. The systems vary in the level of dynamic system elements used, as demonstrated in **Table 6**.

Table 6: Hard Shoulder Running - Peer Agency Operational Schemes

Agency	Locations	System Level
Massachusetts Department of Transportation (MassDOT)	I-93, SR 128, I-95	Static – Time of day operation, ground-mounted static signs with dynamic inserts provide entire system control.
Virginia Department of Transportation (VDOT)	I-66	Static – Overhead lane use control and CCTV/vehicle detection currently used. Dynamic – Project to upgrade to Active Traffic Management system underway.
Minnesota Department of Transportation (MnDOT)	Several, including I-35W and I-394	Dynamic – Using several Active Traffic Management techniques, including merge control, speed harmonization, and dynamic lane closures.

Source: FHWA Hard Shoulder Running Workshop at DVRPC, 2012

Additionally, RK&K participated in a May 3, 2012 DVRPC regional workshop on Hard Shoulder Running, at which peers from the agencies listed in Table 6 discussed their experiences in implementing and operating HSR.

Two operational concepts were developed as part the Phase 2 Study. The Lower Cost Option is a primarily static system, with the minimum amount of dynamic elements necessary to operate the I-476 shoulder as a travel lane. The Higher Cost Option represents a more dynamic system, which includes Active Traffic Management systems similar to those proposed for I-95 by the PennDOT I-95 Master Plan. It is important to note that some of the Active Traffic Management equipment is already deployed along I-476. Certain operational elements are common to both concepts, including:

- Full CCTV camera coverage (Existing);
- Dynamic message signs and travel time systems (Existing);
- Travel speed detection (Existing);
- Lane use control signals over shoulder; and
- Static signs denoting exit lanes and pull-off areas.

Other traffic management features included in the Lower Cost and Higher Cost concepts are shown in **Table 7.**

Table 7: Hard Shoulder Running Operational Concepts

	Lower Cost Option	Higher Cost Option
Lane Status Signal Spacing.	½ mile supplemented by static signs with dynamic inserts spaced every ½ mile to provide ¼ mile spacing between static and dynamic signs.	¼ mile supplemented by additional overhead VMS every mile.
Lane Status Signal Type and Location.	Full-Color over shoulder only	Full-Color, Full-Matrix • Separate signal for each lane at ½ mile spacing. • Shoulder only, staggered at ½ mile spacing to provide shoulder at ¼ mile spacing.
Variable Speed Limit Signs needed for 45 MPH speed limit.	Ground mounted.	Overhead gantry mounted.
Incident Detection.	Using existing ITS systems.	Automated incident detection systems.
Times when Shoulder Running is Permitted.	Predetermined; noted on static signs.	Can be opened or closed as necessary.

Source: RK&K 2012

Traffic Analysis – No-Build 2015/Build 2015

Using the Improvement Packages A and B Build models as a base, RK&K created a scenario for both the AM and PM peak hours to analyze the effectiveness of HSR along I-476. RK&K evaluated the efficacy of HSR along the entire length of the studied I-476 corridor, from I-95 to Exit 9 (West Chester Pike). The model parameters used as part of this scenario were consistent with the findings of the description and operating concept of HSR.

The VISSIM model results (see **Table 8**) show significant anticipated improvements in corridor travel times (up to 36 percent) and Levels of Service, particularly during the PM peak in the southbound direction. While travel time improvements do not appear as high as expected, the reduction in free-flow speed to 45 MPH will affect that travel time. The model results show travel at free-flow conditions expected during both peak periods, with travel times now influenced by the reduction in speeds as opposed to traffic congestion. It should be noted that similar traffic management deployments have yielded an additional capacity of 1,000 vehicles per hour per direction using static control means, and an approximate capacity of 1,500 vehicles per hour per direction using more dynamic operational schemes.

Table 8: Hard Shoulder Running Measures of Effectiveness

Location AM[PM]	No-Build LOS	HSR LOS	No-Build Travel Time (min)	HSR Travel Time (min)	Travel Time Improvement
I-476 Northbound Exit 1 to Exit 3	E [E]	D [D]	3.75 [3.23]	3.71 [3.21]	1% [1%]
I-476 Northbound Exit 3 to Exit 5	F [E]	D [D]	2.35 [2.15]	2.22 [2.24]	6% [-4%]
I-476 Northbound Exit 5 to Exit 9	F [D]	D [C]	5.56 [4.48]	4.82 [4.89]	13% [-9%]
I-476 Northbound – Overall			**11.67 [9.86]**	**10.65 [10.34]**	**8% [-5%]**
I-476 Southbound Exit 9 to Exit 5	E [F]	C [D]	4.70 [8.42]	4.71 [4.88]	0%[42%]
I-476 Southbound Exit 5 to Exit 3	E [F]	D [E]	2.29 [4.39]	2.16 [2.28]	6% [48%]
I-476 Southbound Exit 3 to Exit 1	F [F]	D [E]	4.58 [4.48]	3.80 [3.84]	17% [14%]
I-476 Southbound – Overall			**11.58 [17.29]**	**10.67 [11.00]**	**8% [36%]**

Note: No-Build alternative assumes completion of I-95/I-476 Interchange Package A and Package B Improvements
Source: RK&K, 2012

Cost Estimates

The estimated cost of the I-476 HSR Lane concept was prepared for both directions of I-476 and for both the Lower Cost and Higher Cost options. The resulting cost estimates are shown in **Table 9**. The estimated cost for the northbound I-476 shoulder running lane concept is $8.1 million (Lower Cost Option) and $22.5 million (Higher Cost Option). The estimated cost for the southbound I-476 shoulder running lane is $7.5 million and $21.9 million for the Lower-Cost and Higher-Cost options, respectively.

The estimates were derived similarly to Improvement Packages A and B, using concept drawings and a "major quantities" cost estimating methodology. Quantities that could be measured from the concept drawings included grading, pavement, pavement markings, drainage inlet adjustments, concrete/metal traffic barriers, and traffic signing (static/dynamic). Percentage cost values for items that have not been designed were calculated in keeping with PennDOT experience for the following: stormwater management, erosion and sediment control, drainage inlets, landscaping, and MOT. Percentage values were further included for construction inspection, preliminary engineering/design, and project administration. There is no right-of-way acquisition anticipated for the HSR Lane concept.

Table 9: Estimated Cost of Hard Shoulder Running Concept

	I-476 NB Lower Cost	I-476 NB Higher Cost	I-476 SB Lower Cost	I-476 SB Higher Cost
Construction Cost	$3,984,900	$11,089,100	$3,670,400	$10,767,000
40% Construction Contingency	$1,593,900	$4,435,700	$1,468,200	$4,306,800
Total Construction Cost	*$5,578,800*	*$15,524,800*	*$5,138,600*	*$15,073,800*
Construction Inspection (15% of Total Construction Cost)	$836,800	$2,328,700	$770,800	$2,261,100
Preliminary Engineering/Final Design (15% of Total Construction Cost)	$836,800	$2,328,700	$770,800	$2,261,100
Project Administration (15% of Total Construction Cost)	$836,800	$2,328,700	$770,800	$2,261,100
Estimated Total Project Cost	$8,090,000	$22,511,000	$7,451,000	$21,857,000
I-476 NB & SB: Lower Cost Option Range*	$15.5 million to $16.0 million			
I-476 NB & SB: Higher Cost Option Range*	$44.4 million to $45.0 million			

* *Hard Shoulder Running Lane totals a combined 16 to 17 lane-miles of traffic operations for northbound and southbound I -476.*

Source: RK&K, 2012

The Lower Cost Option assumed basic improvements to implement peak-period shoulder use along the corridor. Improvements include milling and resurfacing the outside shoulder, variable speed limit signs at half mile spacing, and construction of emergency pull-off areas. The Higher Cost Option assumed that additional full overhead signing at half mile spacing would be included. In addition, the High Cost Option includes the reconstruction of the existing four-foot wide graded median shoulder to provide a full-depth paved eight-foot-wide median shoulder for emergency vehicle operation.

Implementation Strategies

The operational benefits to I-476 motorists are potentially significant, with up to a 48 percent improvement in segment travel time (see Table 8). DVRPC has researched the possible TIP funding options and concluded the project costs far exceed the available project funding. The study team notes that the VISSIM traffic operations modeling performed for the HSR Lane was limited in scope to meet the Phase 2 Study budget. It is recommended that DVRPC undertake more refined VISSIM traffic modeling to determine if a "less than full length" northbound or southbound operating shoulder lane could be tested on an interim basis and, due to its shorter length, be able to fit within project funding constraints.

Two examples of shorter operating shoulder lane options are southbound I-476 from Exit 5 to Exit 3 and northbound I-476 from Exit 3 to Exit 5. The additional VISSIM traffic modeling results, combined with the geometric assessment/field inventory, will provide a sufficient basis to choose an operational demonstration project segment to implement. Project costs could range from $2 million to $3 million for either of the two shorter operating examples.

Congestion Management Process

DVRPC, as the Philadelphia region's Metropolitan Planning Organization (MPO), is charged with implementing the Congestion Management Process (CMP) for the region. The region's CMP was updated in October 2011, and it provides guidance on how projects move through the CMP, ensuring consistency with the region's CMP. As part of the Phase 2 Study, RK&K completed a brief evaluation of each improvement — Improvement Packages A and B, as well as HSR — to determine each improvement's consistency with the CMP and what steps should be taken as the improvements move to programmed projects included on the TIP.

Each improvement was compared to the "Moving from a Problem to a Project Through the CMP" checklist found in the CMP Procedures Manual. **Table 10** shows each of the improvements as it follows through the CMP checklist:

Table 10: Congestion Management Process

	Improvement Package A	Improvement Package B	Hard Shoulder Running
1. Is the problem in a congested subcorridor? Is the problem in an emerging/regional corridor?	Yes	Yes	Yes
2. Can the problem be addressed without building more road capacity, such as through operations improvement or coordination of other modes?	Yes	Yes	Yes
3. If new road capacity is an alternative, is it likely to be Major SOV Capacity?	No	No	n/a
4. Is the new Major SOV Capacity Consistent with the CMP?	n/a	n/a	n/a
5. Are the supplemental strategies set?	n/a	n/a	No

Source: RK&K, 2012

As shown by Table 10, each of the improvements is consistent with the region's CMP. Improvement Packages A and B are simply bottleneck-reduction measures that do not increase Single Occupant Vehicle (SOV) capacity outside of the interchange. HSR is not a traditional SOV capacity improvement, it is an operational improvement targeted to the four-lane section bottleneck on I-476. It will not add major new SOV capacity to the roadway for two reasons. Studies of HSR have shown that it increases capacity by up to 1,500 vehicles per hour, much less than a typical lane addition. The Lower Cost Option is only anticipated to increase capacity by 1,000 vehicles per hour. Second, reduced speed limit necessitated by sight distance restrictions will further diminish the effect of any capacity increase. The additional capacity is consistent with the region's CMP — and strategies supplementing HSR as an operational strategy may be considered as it develops toward a traditional project.

Initial Purpose and Need

The I-95/I-476 Interchange Improvement Feasibility Study (Study Phases 1 and 2) has been undertaken as a traffic operations study to assess the feasibility of low-cost improvements providing a traffic benefit to roadway users. The study efforts are an example of preliminary study and investigation that may occur prior to a formal announcement of intent by an agency to proceed with a National Environmental Policy Act (NEPA) planning study. The following represents a beginning point for DVRPC and DCPD of a pre-NEPA Purpose and Need to consider if any of the recommended improvements are to be included in the region's TIP.

Project Need I-95/I-476 Interchange Improvements

The need for improving the I-95/I-476 Interchange is based on the following existing conditions documented on its roadways and around the vicinity of the interchange. Locations of high crash rates were compared to roadway deficiencies, and a correlation between roadway deficiencies, high crash rates, and poor traffic operations at the interchange were identified in the DVRPC Feasibility Study.

High Traffic Volumes – Traffic volumes range from 86,800 vehicles per day on I-476 north of MacDade Boulevard (Seg 0002/0003) to 132,169 vehicles per day on I-95 north of Chestnut Street (Seg 0060/0061).

Roadway Deficiencies and Capacity Constraints – Several existing roadway deficiencies contribute to both recurring (capacity/operational) or nonrecurring (incident-based) congestion throughout the interchange, including: substandard horizontal sight distance, insufficient number of travel lanes, lane imbalance on interchange ramps, substandard merging/weaving lengths, and concurrent freeway entrance and lane drop locations.

High Crash Rates – An I-95 Interchange crash data analysis conducted by DVRPC as part of a Road Safety and Operations Audit (RSOA) for the length of I-95 through Delaware County determined that the highest incidence of rear-end crashes for the entire 12-mile corridor occurred within the interchange, with rear-end crashes for this segment occurring at almost four times the statewide average for similar facilities. A supplemental crash analysis for each of the interchange ramps and the segment of I-476 immediately north of the interchange was completed for the 2005 to 2009 period. Findings of this analysis indicate that individual segments range from significantly under (less than 50 percent) to greater than the statewide average, including hit-fixed-object crashes and rear-end crashes.

Traffic Congestion on Local Roadways – I-95 and I-476 serve as central arteries of the Philadelphia region, functioning as both local expressways for commuters living within the surrounding suburban communities of Philadelphia, as well as a north-south regional connector of Philadelphia to cities to the north and south. As a result of studying traffic movement in and around the I-95/I-476 Interchange during the Phase 1 and 2 studies, it was determined that traffic was being generated on local roads within the City of Chester and surrounding communities as a result of travelers trying to detour around the interchange, especially during peak-hour travel intervals. The added congestion and bottleneck conditions within local road networks has had a negative effect on commerce and industry, as well as a lower quality of life for the residents and business owners in the communities within the vicinity of the interchange.

Project Purpose

The Project Purpose is identified as follows based on the existing conditions described above, as well as those described in the DVRPC I-95/I-476 Interchange Improvement Feasibility Study documents:

- Improve Roadway Deficiencies – Low-cost geometric improvements would remedy deficiencies and/or alleviate congestion.
- Improve Roadway Safety – Low-cost geometric improvements would minimize traffic movements resulting from weaving, merging, lane drops, and substandard sight distance, and would alleviate rear-end collisions resulting from congestion, addressing current safety concerns.
- Enhance Economic Development – Low-cost geometric improvements would minimize the desire for *de facto* detouring of the interchange by interstate travelers; improve ingress and egress to the City of Chester; improve the overall quality of life of the surrounding communities; enhance economic development locally within the surrounding area of the interchange; and improve economic development regionally by alleviating interstate congestion.
- Enhance Roadway Capacity – The geometric improvements will not add capacity to existing infrastructure; rather, the improvements are anticipated to move existing vehicles more efficiently during peak traffic periods to alleviate congestion.

Project Need I-476 Hard Shoulder Running Improvement

Since the focus of the Phase 1 Study was on the I-95/I-476 Interchange, and I-476 HSR was only examined in Phase 2 with respect to its feasibility, its project needs are largely anecdotal and require more detailed study. The Final Record of Decision for the original I-476 construction included provisions that downsized I-476 between West Chester Pike and MacDade Boulevard to reduce the footprint of the right-of-way, minimizing impacts to parklands, historic resources, and streams. Due to downsizing, the four-lane section experiences recurring traffic congestion.

Traffic Congestion – INRIX vehicle probe data shows, between 7:00 AM and 9:00 AM, the average travel speed on northbound I-476 between Baltimore Pike and West Chester Pike is 30 to 40 MPH. During the same time on southbound I-476, the average speed from the transition to two lanes to the Media Bypass is also 30 to 40 MPH. Between 4:00 PM and 6:00 PM, the average travel speed southbound between West Chester Pike and the Media Bypass is less than 45 MPH; and at the West Chester Pike Interchange, where the lane drop occurs, it is 30 to 35 MPH. Travel delays of 10 to 15 minutes are common. A VISSIM model analysis of future conditions shows shock-wave conditions, as traffic along the entire length of I-476 approaches capacity.

High Crash Rates – There is a perception of high rear-end crash rates, due to congested conditions. Studies have shown a strong correlation between congestion and rear-end crashes.

Project Purpose

The Project Purpose is identified as follows based on the existing conditions described above:

- Enhance Roadway Capacity – Hard Shoulder Running would increase the roadway throughput, helping to alleviate traffic congestion when it is needed during peak hours.
- Improve Roadway Safety – Hard Shoulder Running would improve traffic flow, alleviating rear-end crashes.
- Improve Roadway Deficiencies – Hard Shoulder Running would mitigate the lane imbalance created by the downsizing of I-476 between MacDade Boulevard and West Chester Pike, the reduction from three to two lanes in each direction.

Next Steps

The Phase 2 Executive Summary brings the conclusion of the I-95/I-476 Interchange Improvement Feasibility Study. The study purpose was to identify low-cost geometric and safety improvements that could alleviate the current traffic congestion conditions. The DVRPC/Delaware County study team has identified Improvement Packages A and B as viable improvements to alleviate interchange congestion. Improvement Package A is estimated to cost up to $6 million. Improvement Package B is estimated to cost up to $2 million. DVRPC transportation programming staff will determine if the TIP and State Transportation Improvement Program (STIP) are able to accept new project proposals for the upcoming budget years. In addition, DVRPC staff will need to obtain the approval of the Regional Technical Committee (RTC) and Board to include these projects in the upcoming TIP.

The I-476 HSR Concept is on a different transportation programming course than Packages A and B. The HSR Concept will require further agency and emergency responder discussion and workshop evaluation to determine if the Delaware Valley Region can incorporate this managed lane strategy onto the region's roadways and I-476. In addition, the region's transportation agencies and emergency responders will need to discuss and develop operational strategies and policies on how they will work together to manage and respond to daily conditions and roadway incidents.

Finally, this study prioritized two packages of improvements and a managed lane strategy that may be considered to provide cost-effective, small-scale improvements for this interchange and portions of I-476. While these improvements appear to provide localized improvement for the interchange, the interchange is part of the larger I-95 and I-476 systems. PennDOT is currently completing a long-term master plan for I-95. The improvements identified in this study will alleviate congestion in a localized segment of the roadway network, while the broader PennDOT study evaluates the full reconstruction/reconfiguration of I-95 to address the long-term I-95 needs in Pennsylvania. Continued coordination should allow for the improvements included in this study to be considered in the overall I-95 Master Plan.

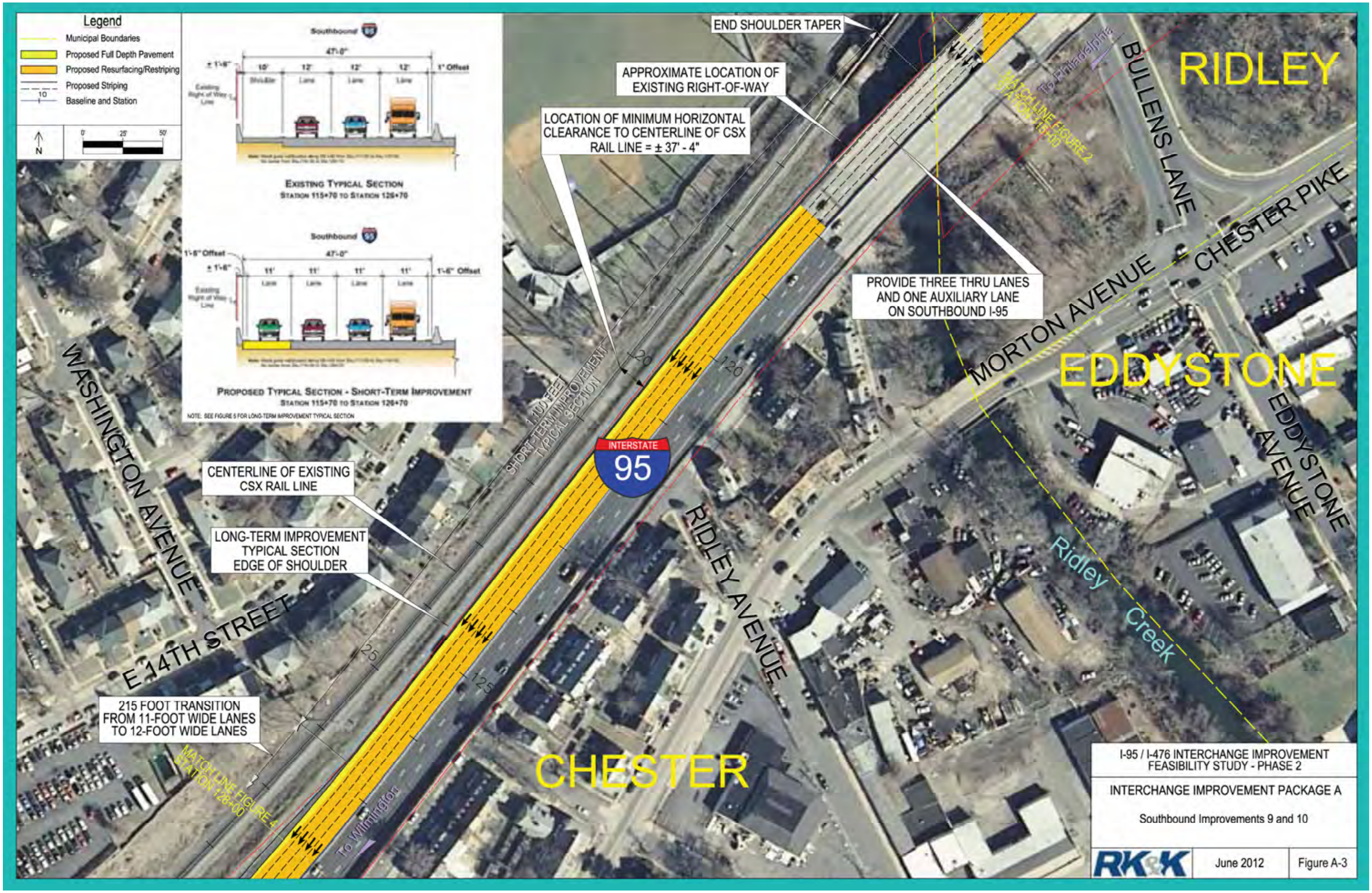
Next Steps to be Considered

1.	Identify TIP and STIP funds to implement Improvement Package A for southbound I-476 to southbound I-95;	$6 million
2.	Identify TIP and STIP funds to implement Improvement Package B for northbound I-95 to northbound I-476;	$2 million
3.	Conduct additional VISSIM traffic modeling to identify I-476 northbound and southbound roadway segment(s) that may serve as a regional demonstration project for HSR Lane Concept;	$50,000
4.	Implement Lower-Cost northbound I-476 Hard Shoulder Running Lane from Exit 1 to Exit 9;	$8.1 million
5.	Implement Lower-Cost southbound I-476 Hard Shoulder Running Lane from Exit 9 to Exit 1; and	$7.5 million
6.	Implement Hard Shoulder Running Lane Demonstration Project between a pair of interchanges (Estimated cost at 30% of Items 4 or 5 above).	$2 million to $3 million

Appendix A: Package A Engineering Concept Drawings


Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
0'
25'
50'
ENTRANCE RAMP FROM MacDADE BOULEVARD
SOUTHBOUND I-476
MAINTAIN EXISTING LANE ARRANGEMENT ON RAMP
INTERSTATE 476
To Plymouth Meeting
SB I-95 TO NB I-476
NB I-95 TO NB I-476
CRUM CREEK DRIVE
EXISTING ACCELERATION LANE 510 FEET
LIMIT OF WORK
SB I-476 TO NB I-95
CSX
BULLENS LANE
To Philadelphia
INTERSTATE 95
IMPROVEMENT 9
REMOVE EXISTING LANE DROP - MAINTAIN TWO LANES ON RAMP
NO WIDENING REQUIRED
MAINTAIN EXISTING PAVEMENT WIDTH UNDER BRIDGE
CENTERLINE OF EXISTING CSX RAIL LINE
95
MATCH LINE FIGURE 2
STATION 21+00
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE A
Southbound Improvements 9 and 10
RK&K
June 2012
Figure A-1

Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
0' 25' 50'
Southbound 95
10' Shoulder
12' Lane
Varies Gore
12' Lane
12' Lane
1' Offset
EXISTING TYPICAL SECTION
STATION 107+00 TO STATION 111+90
Southbound 95
Varies (10' Min.) Shoulder
12' Lane
12' Lane
12' Lane
12' Lane
1' Offset
PROPOSED TYPICAL SECTION
STATION 107+00 TO STATION 111+90
MATCH LINE FIGURE 1
STATION 21+00
PROVIDE SECOND LANE ON SOUTHBOUND I-476 RAMP TO I-95
To Philadelphia
INTERSTATE 95
FULL-DEPTH PAVEMENT WIDENING REQUIRED
MAINTAIN TWO LANES ON SOUTHBOUND I-95
BULLENS LANE
RIDLEY
NB I-95 TO NB I-476
CSX
CENTERLINE OF EXISTING CSX RAIL LINE
465 FEET
MAINTAIN 10-FOOT WIDE SHOULDER
IMPROVEMENT 10
PROVIDE FOUR LANES ON SOUTHBOUND I-95 BETWEEN I-476 AND CHESTNUT STREET
380 FEET
SHOULDER TAPER FROM 10 FEET TO 1 FOOT
MATCH LINE FIGURE 3
STATION 115+00
To Wilmington
PROVIDE THREE THRU LANES AND ONE AUXILIARY LANE ON SOUTHBOUND I-95
BEGIN TYPICAL SECTION TRANSITION SECTION
END 12-FOOT WIDE LANES
CHESTER PIKE
EDDYSTONE
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE A
Southbound Improvements 9 and 10
RK&K
June 2012
Figure A-2



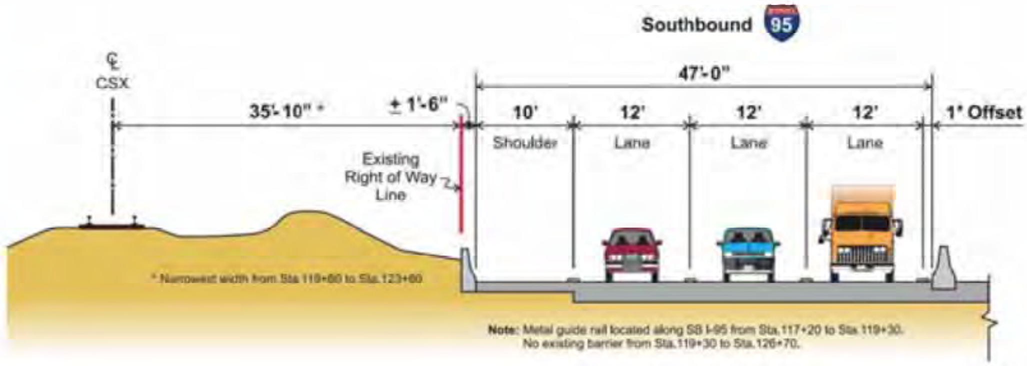
Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
0'
25'
50'
Southbound
47'-0"
± 1'-6"
10'
12'
12'
12'
1' Offset
Shoulder
Lane
Lane
Lane
EXISTING TYPICAL SECTION
STATION 115+70 TO STATION 126+70
Southbound
1'-6" Offset
47'-0"
± 1'-6"
11'
11'
11'
11'
1'-6" Offset
Lane
Lane
Lane
Lane
PROPOSED TYPICAL SECTION - SHORT-TERM IMPROVEMENT
STATION 115+70 TO STATION 126+70
NOTE: SEE FIGURE 5 FOR LONG-TERM IMPROVEMENT TYPICAL SECTION
END SHOULDER TAPER
APPROXIMATE LOCATION OF EXISTING RIGHT-OF-WAY
LOCATION OF MINIMUM HORIZONTAL CLEARANCE TO CENTERLINE OF CSX RAIL LINE = ± 37' - 4"
PROVIDE THREE THRU LANES AND ONE AUXILIARY LANE ON SOUTHBOUND I-95
RIDLEY
EDDYSTONE
CHESTER
BULLENS LANE
MORTON AVENUE
CHESTER PIKE
EDDYSTONE AVENUE
RIDLEY AVENUE
WASHINGTON AVENUE
E 14TH STREET
Ridley Creek
To Philadelphia
To Wilmington
MATCH LINE FIGURE 2 STATION 115+00
MATCH LINE FIGURE 4 STATION 128+00
1.10 FEET SHORT-TERM IMPROVEMENT TYPICAL SECTION
INTERSTATE
95
120
125
CENTERLINE OF EXISTING CSX RAIL LINE
LONG-TERM IMPROVEMENT TYPICAL SECTION EDGE OF SHOULDER
215 FOOT TRANSITION FROM 11-FOOT WIDE LANES TO 12-FOOT WIDE LANES
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE A
Southbound Improvements 9 and 10
RK&K
June 2012
Figure A-3

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

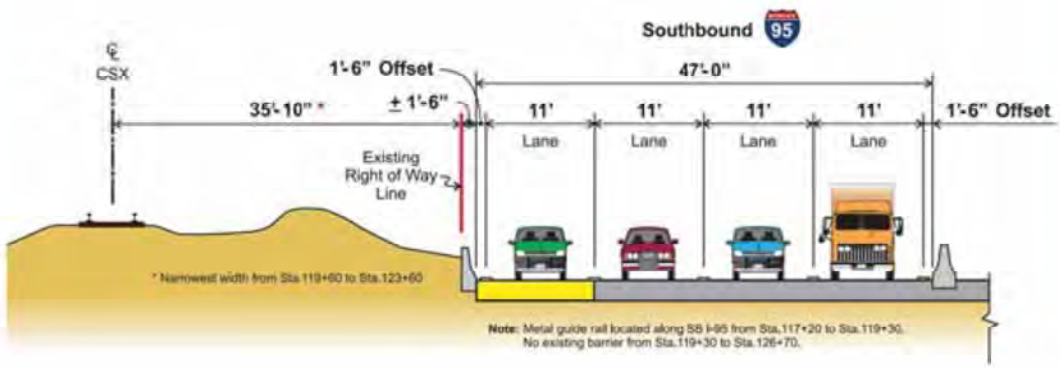
INTERCHANGE IMPROVEMENT PACKAGE A

Southbound Improvements 9 and 10

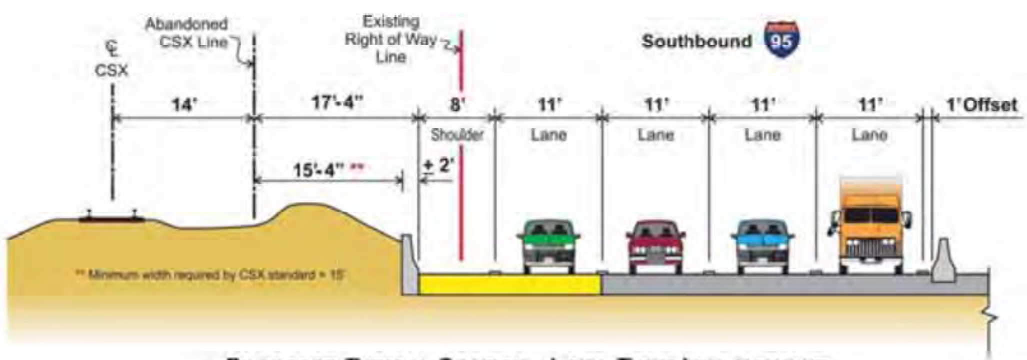
RK&K | June 2012 | Figure A-4



EXISTING TYPICAL SECTION
STATION 115+70 TO STATION 126+70



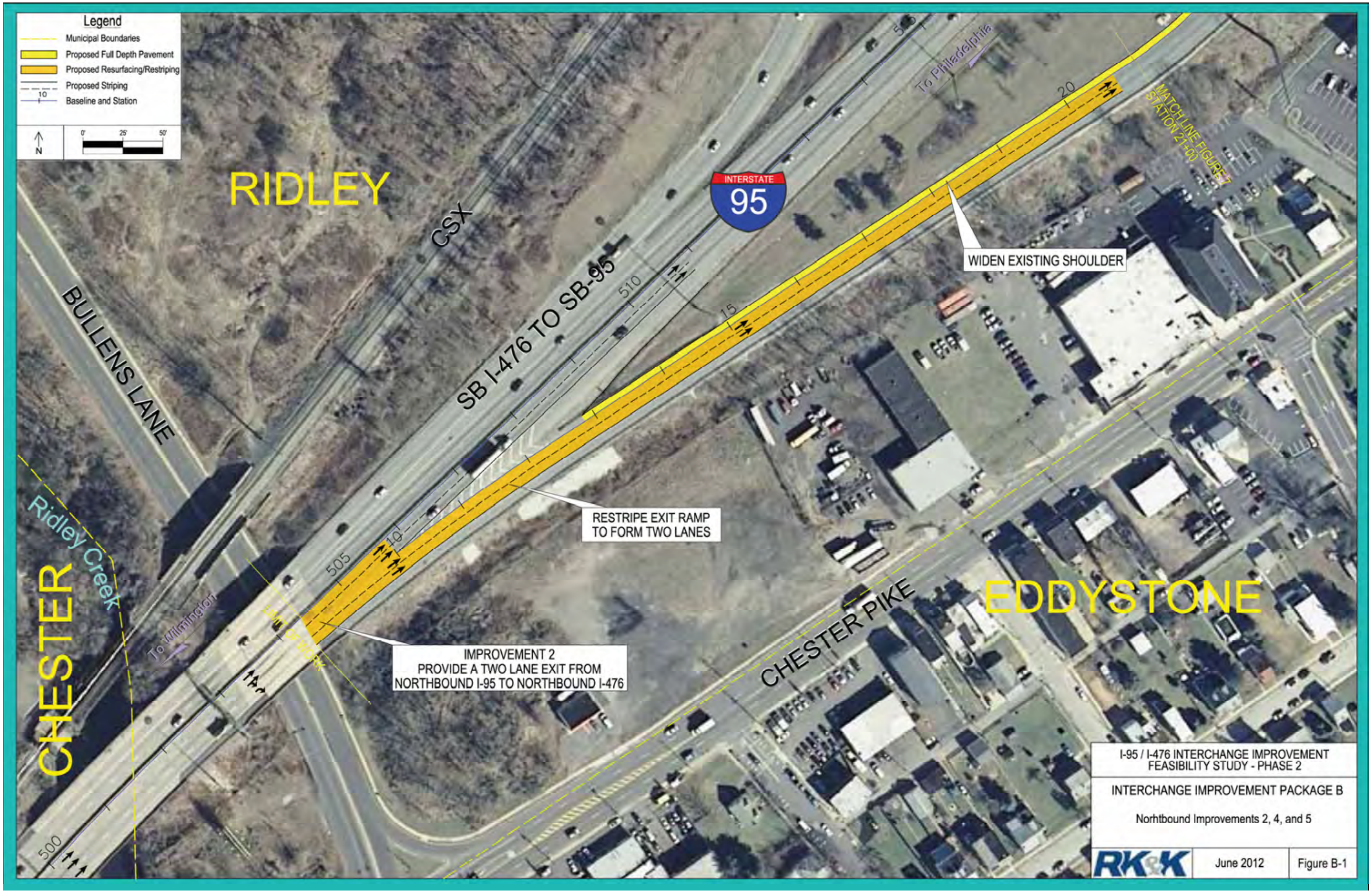
PROPOSED TYPICAL SECTION - SHORT-TERM IMPROVEMENT
STATION 115+70 TO STATION 126+70



PROPOSED TYPICAL SECTION - LONG-TERM IMPROVEMENT
STATION 115+70 TO STATION 126+70

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2	
INTERCHANGE IMPROVEMENT PACKAGE A	
TYPICAL SECTIONS NOT TO SCALE	
RK&K June 2012	Figure A-5

Appendix B: Package B Engineering Concept Drawings



Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
RIDLEY
CSX
SB I-476 TO SB-95
BULLENS LANE
INTERSTATE 95
To Philadelphia
MATCH LINE FIGURE 7 STATION 21+00
WIDEN EXISTING SHOULDER
RESTRIPE EXIT RAMP TO FORM TWO LANES
Ridley Creek
CHESTER
To Wilmington
LIMIT OF WORK
IMPROVEMENT 2
PROVIDE A TWO LANE EXIT FROM
NORTHBOUND I-95 TO NORTHBOUND I-476
CHESTER PIKE
EDDYSTONE
I-95 / I-476 INTERCHANGE IMPROVEMENT
FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE B
Norhtbound Improvements 2, 4, and 5
RK&K
June 2012
Figure B-1

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

INTERCHANGE IMPROVEMENT PACKAGE B

Norhtbound Improvements 2, 4, and 5

RK&K	June 2012	Figure B-2

Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
0'
25'
50'
To Plymouth Meeting
MATCH LINE I-95 NB RAMP FIGURE 8, STATION 44+00
MATCH LINE I-95 SB RAMP FIGURE 8, STATION 72+00
MacDADE BLVD RAMP
IMPROVEMENT 4
MAINTAIN SECOND LANE ON
NORTHBOUND I-95 RAMP TO NORTHBOUND I-476
SB I-95 TO NB I-476
MacDADE BLVD RAMP
INTERSTATE
476
45
70
40
65
35
60
CSX
NB I-95 TO NB I-476
SB I-476 TO SB I-95
SB I-476 TO NB I-95
SB I-95 TO NB I-476
MATCH LINE I-95 NB RAMP FIGURE 7, STATION 31+00
MATCH LINE I-95 SB RAMP FIGURE 7, STATION 60+00
To
95
IMPROVEMENT 4
DROP RIGHT LANE FROM SOUTHBOUND I-95 RAMP
TO NORTHBOUND I-476 AT MacDADE BOULEVARD
I-95 / I-476 INTERCHANGE IMPROVEMENT
FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE B
Norhtbound Improvements 2, 4, and 5
RK&K
June 2012
Figure B-3

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

INTERCHANGE IMPROVEMENT PACKAGE B

Norhtbound Improvements 2, 4, and 5

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Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
0'
25'
50'
MATCH LINE I-476 NB
FIGURE 11, STATION 66+00
600 FEET
LANE DROP RATE = 50:1
To Plymouth Meeting
MacDADE BLVD
IMPROVEMENT 5
DROP RIGHT LANE OF I-476 PRIOR TO
MacDADE BOULEVARD ENTRANCE RAMP
65
60
To
95
MacDADE BLVD
MATCH LINE I-476 NB
FIGURE 9, STATION 57+00
INTERSTATE
476
I-95 / I-476 INTERCHANGE IMPROVEMENT
FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE B
Norhtbound Improvements 2, 4, and 5
RK&K
June 2012
Figure B-5


Legend
Municipal Boundaries
Proposed Full Depth Pavement
Proposed Resurfacing/Restriping
Proposed Striping
Baseline and Station
N
0'
25'
50'
INTERSTATE
476
To Plymouth Meeting
MAINTAIN EXISTING MacDADE BOULEVARD ENTRANCE RAMP CONFIGURATION
LIMIT OF WORK
NETHER PROVIDENCE
IMPROVEMENT 5
COMPLETE NORTHBOUND I-476 RIGHT LANE DROP
650 FEET SOUTH OF MacDADE BOULEVARD RAMP GORE
CONTINUE TWO NORTHBOUND I-476 LANES
BULLENS LANE
CONSTITUTION AVE.
SB I-476
TO MacDADE BLVD
70
MacDADE BLVD ENTRANCE RAMP
600 FEET
LANE DROP RATE = 50:1
To
95
MATCH LINE I-476 NB
FIGURE 10, STATION 66+00
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
INTERCHANGE IMPROVEMENT PACKAGE B
Norhtbound Improvements 2, 4, and 5
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Figure B-6

Appendix C: I-476 Hard Shoulder Running Concept Engineering Feasibility Drawings

Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
Scale 0 150 300 Feet
To Philadelphia
RIDLEY
To Plymouth Meeting
NETHER PROVIDENCE
476
CONTINUE SOUTHBOUND I-476 PEAK HOUR SHOULDER USE AS RIGHT I-476 THRU-LANE
MACDADE BLVD. RAMP
SB I-476 TO SB I-95
SB I-476 TO NB I-95
SB I-95 TO NB I-476
NB I-95 TO NB I-476
MACDADE BLVD. RAMP
BEGIN NORTHBOUND I-476 RIGHT LANE DROP
BEGIN NORTHBOUND I-476 PEAK HOUR SHOULDER USE
100
110
10-FOOT WIDE SHOULDER WITH ADJACENT CONCRETE DITCH AND INLETS
MATCHLINE - SEE FIGURE 2
BULLENS LN.
10-FOOT WIDE SHOULDER WITH ADJACENT CONCRETE DITCH AND INLETS
MACDADE BLVD
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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Figure C-1

Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
Scale 0 150 300 Feet
To Philadelphia
To Plymouth Meeting
Springhaven Country Club
S CHESTER RD
EAST ROSE VALLEY RD.
YALE AVE.
BLACK ROCK PARK
MATCHLINE - SEE FIGURE 1
MATCHLINE - SEE FIGURE 2
INTERSTATE 476
120
130
140
150
160
DESIGN SPEED AVAILABLE: 50 MPH
LENGTH OF SIGHT OBSTRUCTION: 450 FEET
PROPOSED EMERGENCY PULL-OFF AREA RETAINING WALL REQUIRED
10-FOOT WIDE SHOULDER WITH ADJACENT CONCRETE DITCH AND INLETS
DESIGN SPEED AVAILABLE: 45 MPH
LENGTH OF SIGHT OBSTRUCTION: 550 FEET
DESIGN SPEED AVAILABLE: 45 MPH
LENGTH OF SIGHT OBSTRUCTION: 600 FEET
PROPOSED EMERGENCY PULL-OFF AREA
10-FOOT WIDE SHOULDER WITH ADJACENT CONCRETE DITCH AND INLETS
LOCATION OF ADVERSE CROSS SLOPE ON NORTHBOUND I-476 ON STRUCTURE
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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Figure C-2

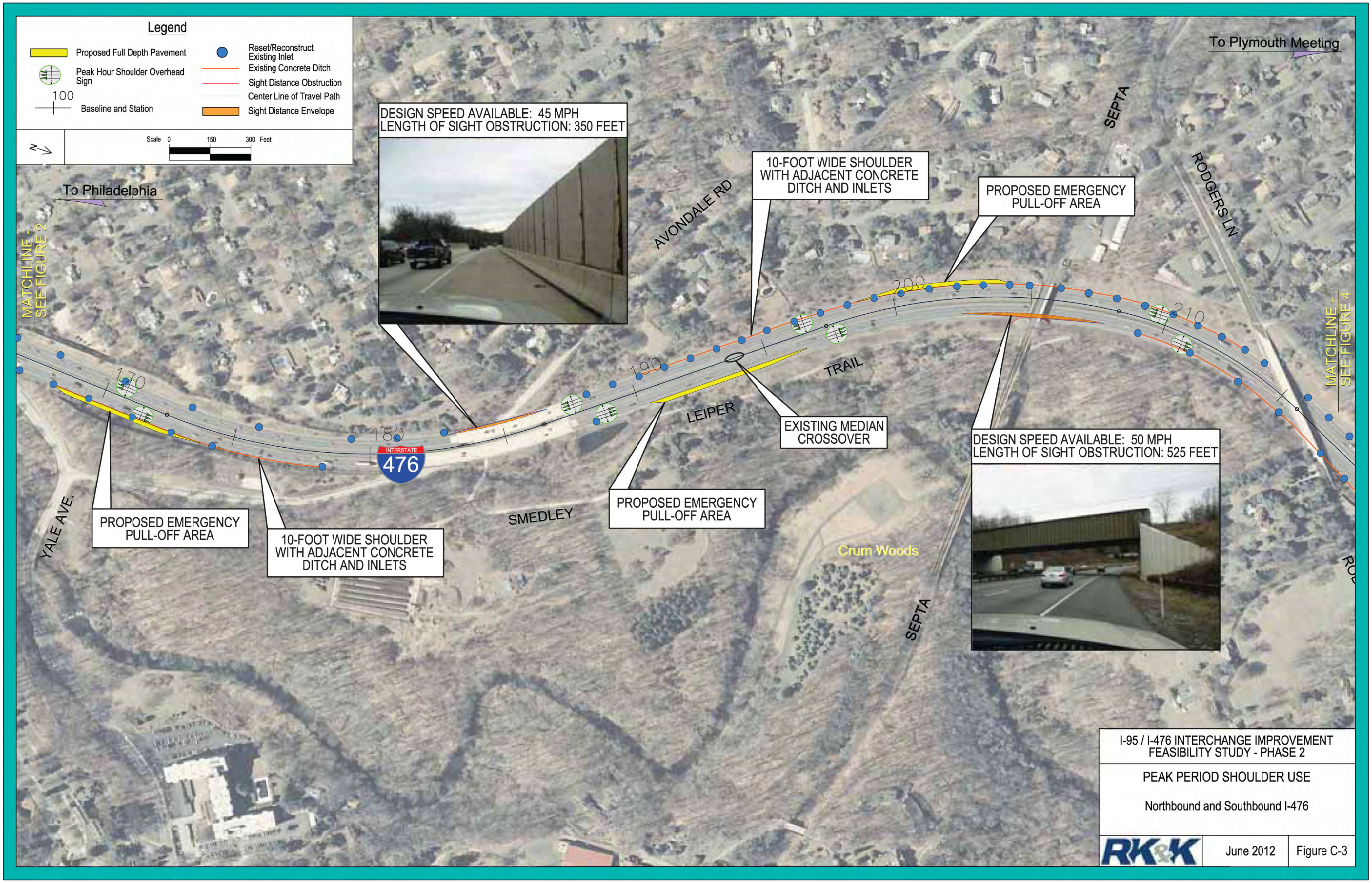
Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
Scale 0 150 300 Feet
To Philadelphia
To Plymouth Meeting
MATCHLINE - SEE FIGURE 2
MATCHLINE - SEE FIGURE 4
DESIGN SPEED AVAILABLE: 45 MPH
LENGTH OF SIGHT OBSTRUCTION: 350 FEET
10-FOOT WIDE SHOULDER WITH ADJACENT CONCRETE DITCH AND INLETS
PROPOSED EMERGENCY PULL-OFF AREA
EXISTING MEDIAN CROSSOVER
DESIGN SPEED AVAILABLE: 50 MPH
LENGTH OF SIGHT OBSTRUCTION: 525 FEET
PROPOSED EMERGENCY PULL-OFF AREA
10-FOOT WIDE SHOULDER WITH ADJACENT CONCRETE DITCH AND INLETS
PROPOSED EMERGENCY PULL-OFF AREA
170
180
190
200
210
INTERSTATE 476
AVONDALE RD
SEPTA
RODGERS LN
LEIPER
TRAIL
SMEDLEY
YALE AVE.
Crum Woods
SEPTA
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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Figure C-3

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

PEAK PERIOD SHOULDER USE

Northbound and Southbound I-476

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Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
N
Scale 0 150 300 Feet
To Philadelphia
To Plymouth Meeting
INTERSTATE
476
270
280
290
300
310
MATCHLINE - SEE FIGURE 4
MATCHLINE - SEE FIGURE 6
PAPER MILL RD
BEATTY RD
Springfield Country Club
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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Figure C-5

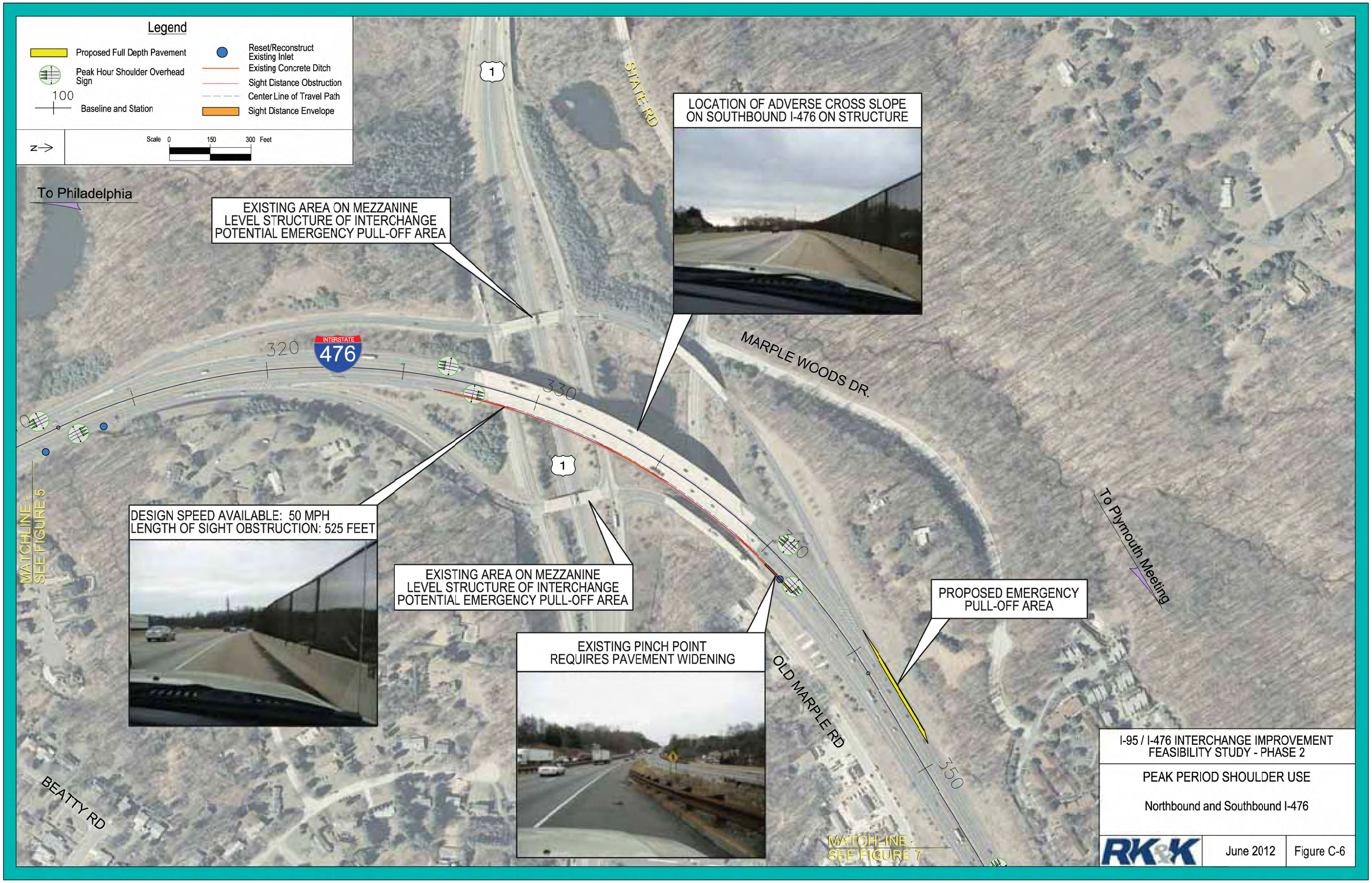
Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
Scale 0 150 300 Feet
To Philadelphia
EXISTING AREA ON MEZZANINE LEVEL STRUCTURE OF INTERCHANGE POTENTIAL EMERGENCY PULL-OFF AREA
STATE RD
LOCATION OF ADVERSE CROSS SLOPE ON SOUTHBOUND I-476 ON STRUCTURE
MARPLE WOODS DR.
320
INTERSTATE 476
330
1
DESIGN SPEED AVAILABLE: 50 MPH
LENGTH OF SIGHT OBSTRUCTION: 525 FEET
EXISTING AREA ON MEZZANINE LEVEL STRUCTURE OF INTERCHANGE POTENTIAL EMERGENCY PULL-OFF AREA
EXISTING PINCH POINT REQUIRES PAVEMENT WIDENING
PROPOSED EMERGENCY PULL-OFF AREA
To Plymouth Meeting
MATCHLINE - SEE FIGURE 5
OLD MARPLE RD
350
BEATTY RD
MATCHLINE - SEE FIGURE 7
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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Figure C-6

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

PEAK PERIOD SHOULDER USE

Northbound and Southbound I-476

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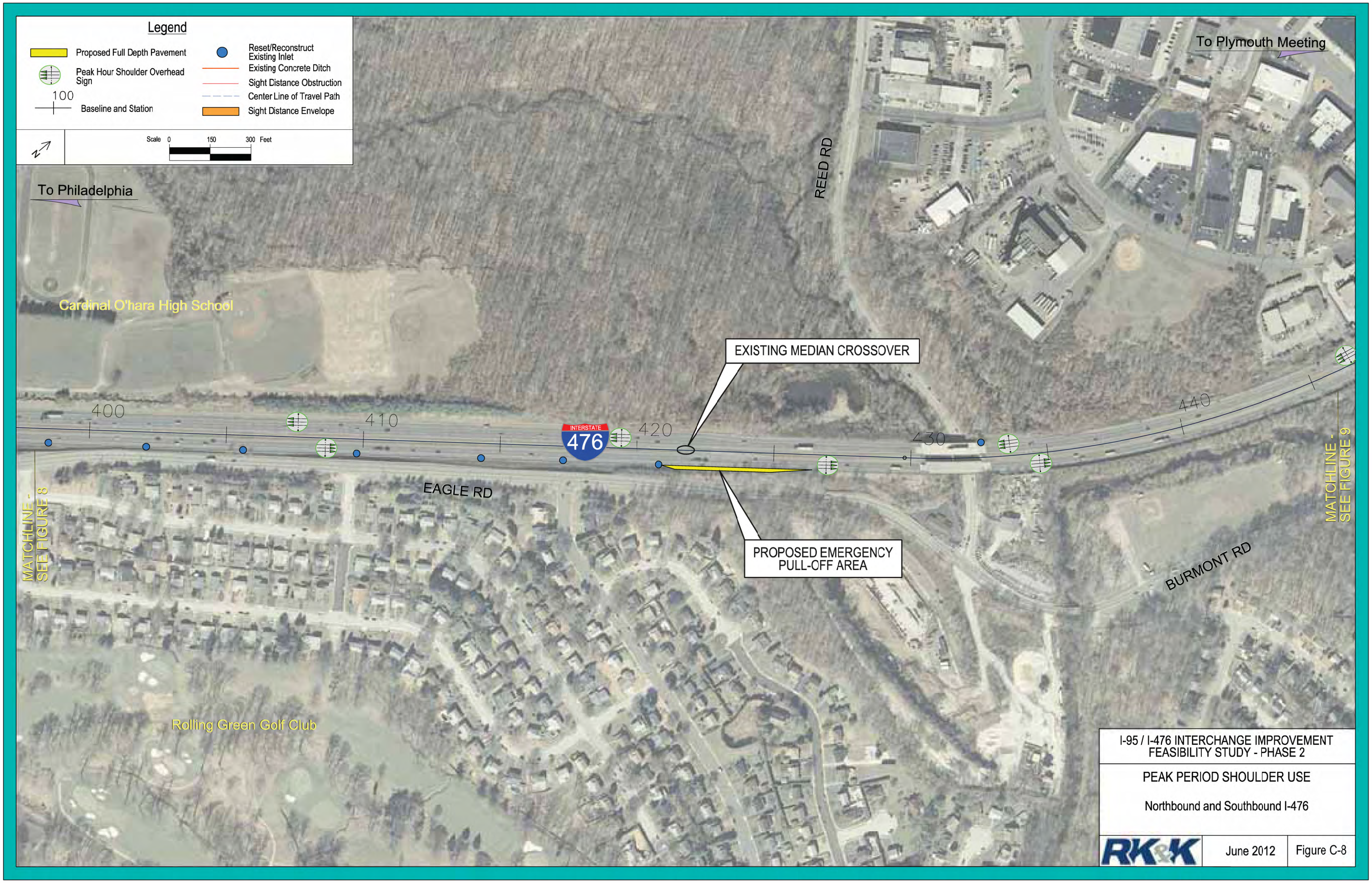

Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
Scale 0 150 300 Feet
N
To Philadelphia
To Plymouth Meeting
Cardinal O'hara High School
REED RD
EXISTING MEDIAN CROSSOVER
400
410
420
430
440
INTERSTATE 476
EAGLE RD
PROPOSED EMERGENCY PULL-OFF AREA
BURMONT RD
MATCHLINE - SEE FIGURE 8
MATCHLINE - SEE FIGURE 9
Rolling Green Golf Club
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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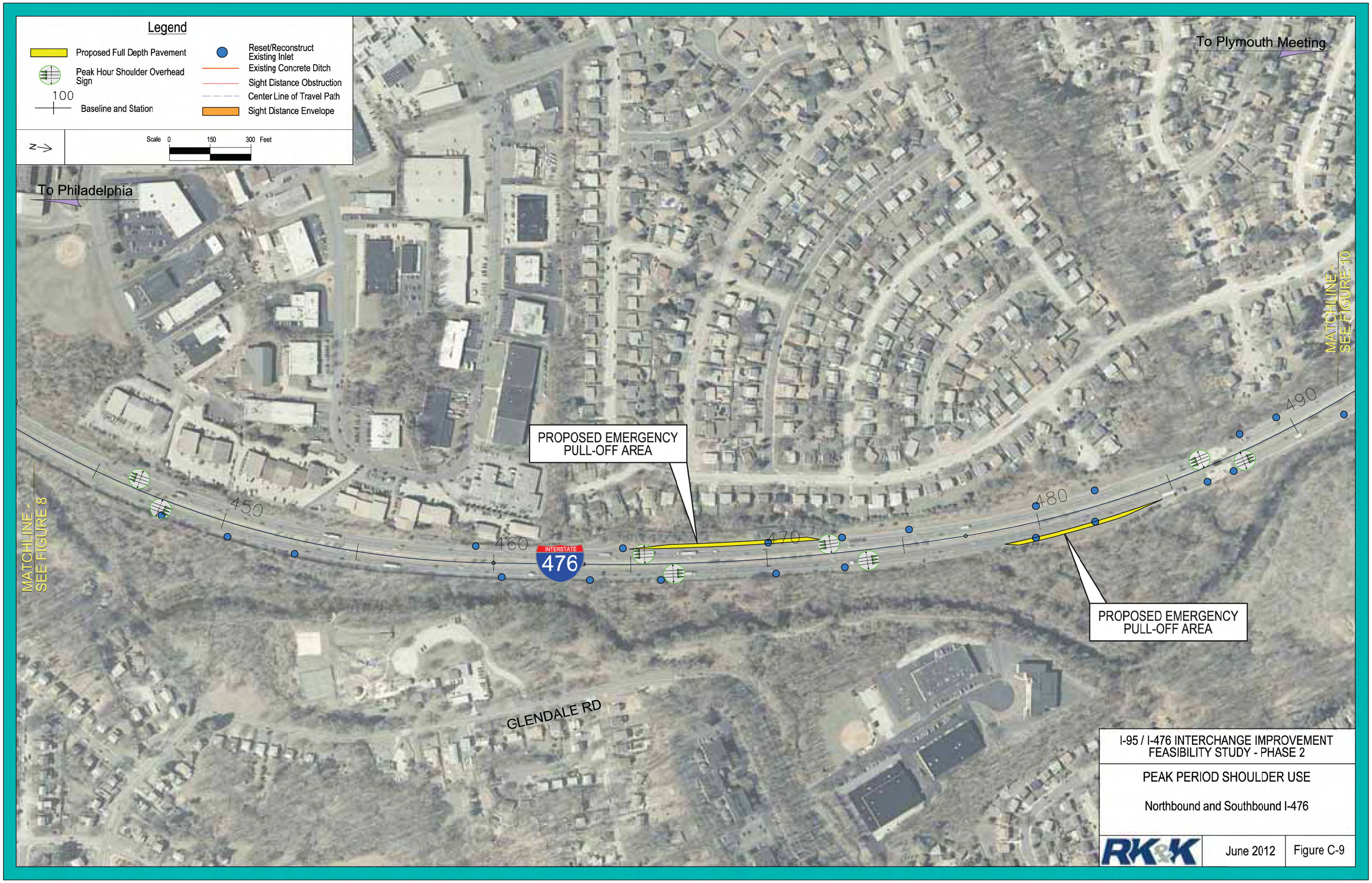
Figure C-8



Legend
Proposed Full Depth Pavement
Peak Hour Shoulder Overhead Sign
100
Baseline and Station
Reset/Reconstruct Existing Inlet
Existing Concrete Ditch
Sight Distance Obstruction
Center Line of Travel Path
Sight Distance Envelope
N
Scale 0 150 300 Feet
To Philadelphia
To Plymouth Meeting
MATCHLINE - SEE FIGURE 8
MATCHLINE - SEE FIGURE 10
450
460
470
480
490
INTERSTATE
476
PROPOSED EMERGENCY PULL-OFF AREA
PROPOSED EMERGENCY PULL-OFF AREA
GLENDALE RD
I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2
PEAK PERIOD SHOULDER USE
Northbound and Southbound I-476
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Figure C-9

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

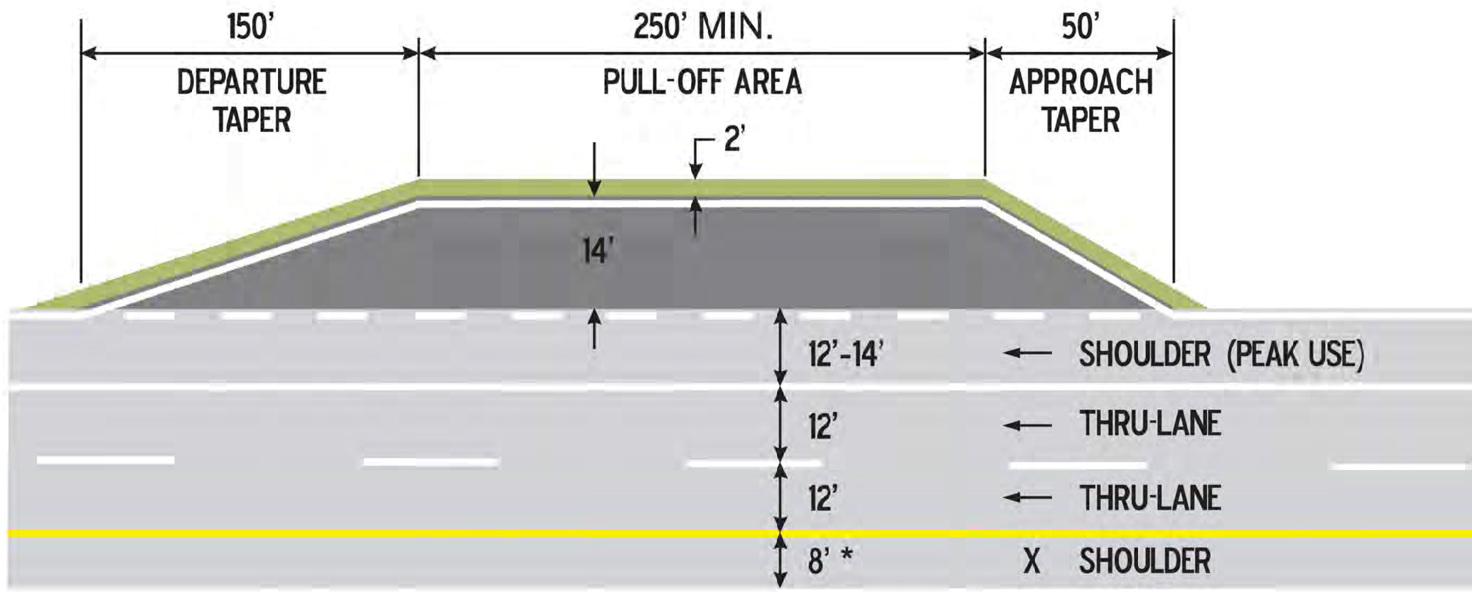
PEAK PERIOD SHOULDER USE

Northbound and Southbound I-476

June 2012 Figure C-10

Legend

- EXISTING PAVEMENT
- PROPOSED PAVEMENT
- PROPOSED GRADING



* 4' PAVED

Notes:

1) Emergency pull-off area modeled after PennDOT Pub. 46 Emergency Pull-Off.
2) Flexible delineator posts installed at 25 foot intervals along emergency pull-off.
3) Vehicles entering pull-off areas at interchanges must exit at interchange upon completion of activities.

I-95 / I-476 INTERCHANGE IMPROVEMENT FEASIBILITY STUDY - PHASE 2

TYPICAL MAINLINE EMERGENCY PULL-OFF

NOT TO SCALE

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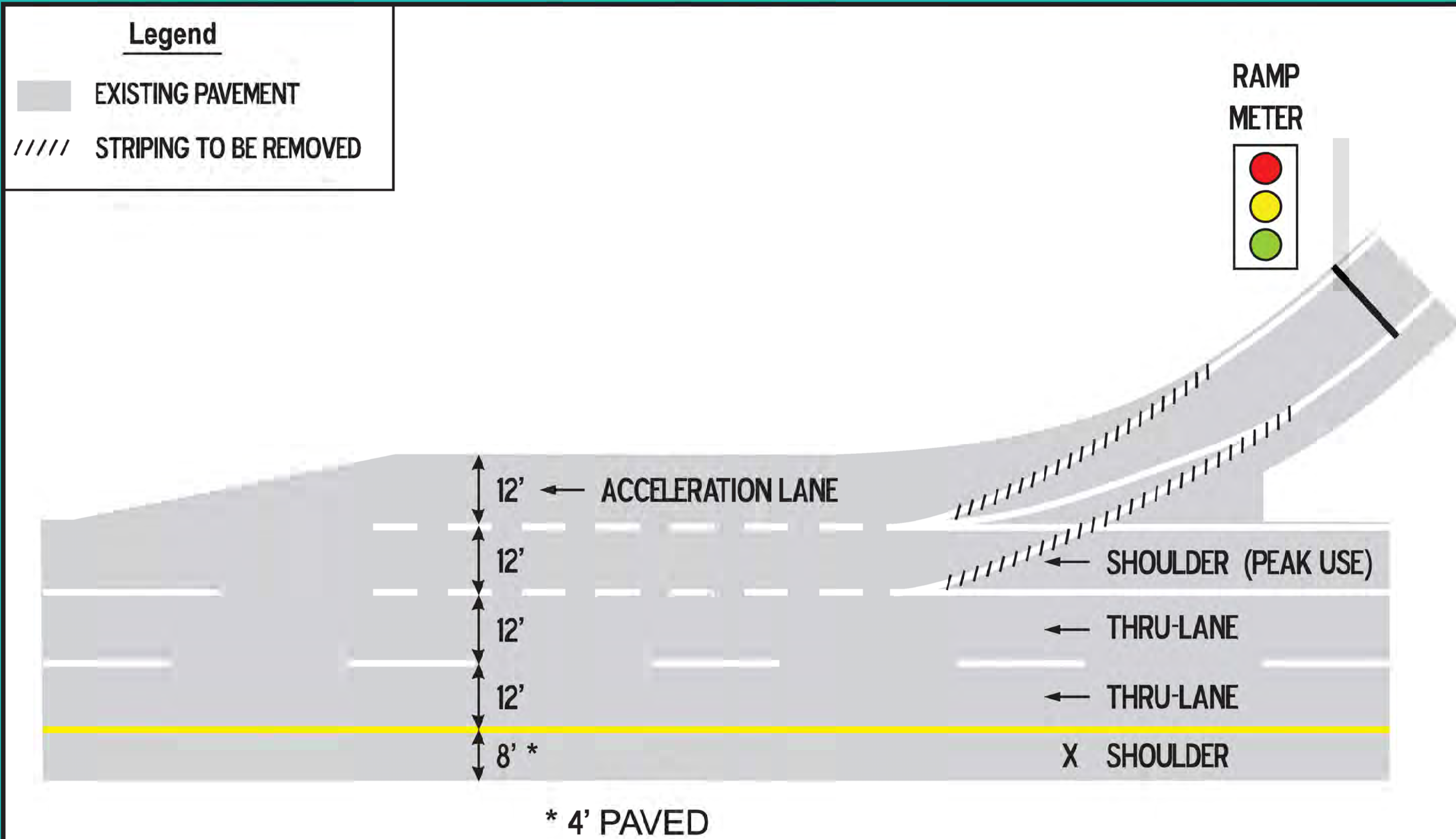

I-95 / I-476 INTERCHANGE IMPROVEMENT
FEASIBILITY STUDY - PHASE 2

TYPICAL ACCELERATION LANE

NOT TO SCALE

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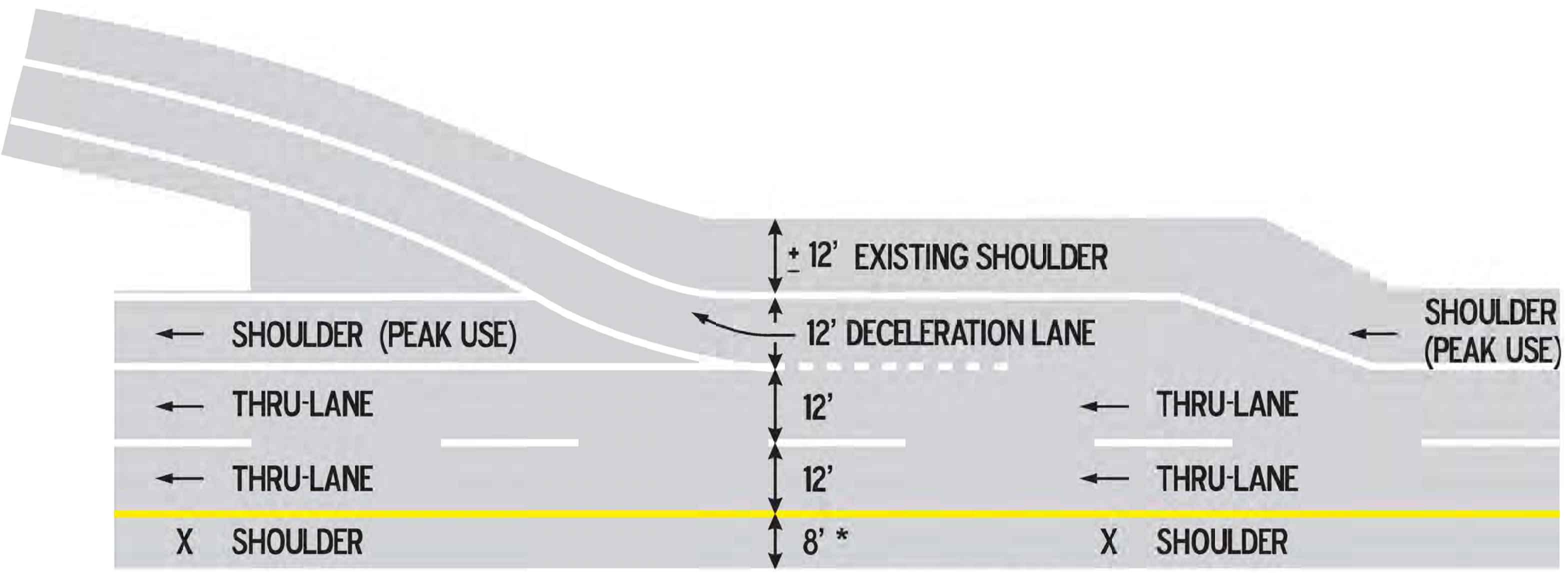
Legend

EXISTING PAVEMENT



* 4' PAVED

I-95 / I-476 INTERCHANGE IMPROVEMENT
FEASIBILITY STUDY - PHASE 2

TYPICAL DECELERATION LANE

NOT TO SCALE

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ABSTRACT

Publication Title:	I-95/I-476 Interchange Feasibility Study: Phase 2 Executive Summary
Publication Number:	12078
Date Published:	January 2013
Geographic Area Covered:	I-95/I-476 Interchange area and I-476 in Delaware County
Key Words:	Traffic operational improvements, interchange improvements, Hard Shoulder Running, traffic analysis, cost analysis
Abstract:	This report documents the benefits, costs, and feasibility of constructing operational improvements to the I-95/I-476 Interchange and its immediate vicinity and I-476 Hard Shoulder Running. High-priority recommendations from the Phase 1 study were investigated in more detail. Through field views and plotting engineering details on high resolution aerial photos, potential constraints and planning-level cost estimates were identified. A VISSIM traffic analysis was conducted to model the impacts of the improvements.
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