FUNCTIONAL DESIGN REPORT

FOR THE

I-95/I-93 TRANSPORTATION IMPROVEMENT PROJECT (BRIDGE V)

ROUTE 9/HIGHLAND AVENUE/KENDRICK ST. SECTION
NEEDHAM AND WELLESLEY, MASSACHUSETTS

AUGUST 2010

PREPARED FOR:

MASSACHUSETTS DEPARTMENT OF TRANSPORTATION

PREPARED BY:

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Introduction

This project represents the last and most northerly segment of the overall I-95/Route 128 Transportation Improvement Project (Bridge V), commonly referred to as the "Route 128 Add-a-Lane" improvements that extend from Route 24 in the south to Route 9 in the north. The project involves widening I-95/Route 128 from six to eight lanes, eliminating the use of the breakdown lanes for general travel during weekday peak periods.

The subject section of I-95/Route 128 is the last remaining section that has a six lane cross section. Completion of this project will result in I-93/ I-95 providing a consistent eight-lane cross section from Route 3 in Braintree to I-95/Route 128 in Peabody except for the portion of I-95/128 in Reading, Wakefield, and Lynnfield, which is still three lanes in each direction.

This project will eliminate the need to allow travel in the breakdown lanes during peak periods on weekdays. This practice has been on-going since 1992 as an interim measure until this project could be constructed. Travel along the shoulder/breakdown lane is currently allowed between the hours of 6:00-10:00 AM and 3:00-7:00 PM.

A study prepared by Central Transportation Planning Staff (CTPS) in December of 2003 was the foundation for selection of the preferred improvement plan. For that study, detailed information of the transportation and land use systems was collected to provide traffic flow forecasts, which were used to evaluate alternatives and ultimately used to select the preferred alternative. The CTPS Final Report was referenced extensively in the preparation of this report. CTPS did make minor adjustments to the earlier traffic forecast model to reflect updated land use projections as well as the refinements to the preferred alternative.

The purpose of this report is to document the parameters for the design to provide an additional travel lane in each direction for approximately 3.5 miles on I-95/Route 128 in Needham, Newton and Wellesley. The limits of this project are defined as I-95/Route 128 from the MBTA overpass north of Great Plain Avenue, on the south, to the Route 9 interchange on the north. Figure 1 presents the study area for this project. This report is a second submission of the Functional Design Report and will therefore also discuss design modifications from the previously submitted report. The major design modifications are:

- I-95/Route 128 will have 10-foot median and right shoulders throughout the project limits with the exception of approximately 1000 feet in the vicinity of Route 9 where ledge exists in close proximity to the roadway.
- The Route 9 interchange will be modified to a partial cloverleaf and these modifications will be permanent.
- The right turn restriction on the I-95/Route 128 southbound off-ramp to Kendrick Street will be eliminated.

The project is broken down into three sections, the I-95/Route 128 mainline, the Highland Avenue/Kendrick Street Interchange and the Route 9 interchange and will be discussed as such in this report.

J:\Analysis\Edwards & Kelcey\Route 128\Graphics\figure 1 Study Area.dwg 31/06/10

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Figure 1
Study Area
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

I-95/Route 128 Mainline

Existing Conditions

Route I-95 /128 south of Kendrick Street

I-95/Route 128 travels in a northwest-southeast direction with a speed limit of 55 miles per hour (mph). South of the Route 9 Interchange, I-95/Route 128 provides three travel lanes in each direction. From 6:00 AM until 10:00 AM and again between 3:00 PM and 7:00 PM, travel is allowed in the breakdown lanes in both directions. With travel permitted in the breakdown lanes, I-95/Route 128 operates with four through travel lanes during the morning and evening peak hours. To insure that motorists have locations to pull over out of the active traffic stream, there are "pullouts" spaced at approximately ½ mile intervals in both the northbound and southbound directions.

Highway Structures

Five structures over I-95/Route 128 need to be reconstructed as part of this project. The structures include:

- Kendrick Street over I-95/Route 128, Needham
- Highland Avenue over I-95/Route 128, Needham
- MBTA railroad tracks over I-95/Route 128, Needham
- I-95/Route 128 over Central Avenue, Needham
- I-95/Route 128 over Route 9, Wellesley

Additionally, a new structure is included as part of the preferred alternative that will separate the northbound off ramp to the C-D roadway from the northbound on-ramp from Kendrick Street. The following is a general description of the MBTA Railroad Bridge and the Bridge over Central Avenue. The other structures will be discussed in further detail in their respective report segments.

MBTA Railroad Bridge

Two existing bridge spans carry a single rail line over I-95/Route 128. These spans are steel through girder with floor beam bridges separated by a narrow median with a center pier. The eastern structure was part of the 1953 corridor construction, when the northbound roadway was added to the existing Southern Circumferential Highway. The original single span bridge was constructed in 1932 and had its eastern abutment converted into the center pier in 1953.

Both bridges have approximately 60 feet of clear distance between substructures and the roadway center in between. There are 3 full-time travel lanes and a shoulder in each direction of I-95/Route 128 with the right lane in each direction being wider as it is part of an on or off ramp transition. The existing vertical clearance above both sides of I-95/Route 128 is approximately 14 feet. The challenge for the reconstruction of this structure will be the limited right of way. Level 3 utilities are present behind the west abutment of the bridge and Town of Needham sewer lines are located in the median.

I-95/Route 128 over Central Avenue

The existing bridges carrying I-95/Route 128 over Central Street are concrete rigid frames, separated by a 36 foot wide open median and were part of the 1953 corridor construction. The two independent rigid frames span Central Avenue and have a 52 foot square clear span between walls. Both structures carry the three travel lanes and shoulders of I-95/Route 128 in a 51 foot curb-to-curb width. Increasing the vertical clearance over Central Avenue is not required. Steep embankments on the east and west side of the alignment suggest that widening to the outside of this structure is not desirable.

Traffic Volumes

As mentioned previously, the current conditions of this area were studied in great detail by CTPS. As such, this report has used the traffic counts collected by CTPS and factored them to reflect conditions in 2007. Automatic Traffic Recorders (ATRs) were deployed by MassDOT at key locations in order to accomplish this task. The ATR data from the counts completed by MassDOT in July of 2007 can be found in Appendix A of this report. The existing traffic flow networks are presented on Figure 2 for the morning and evening peak hours.

J:\Analysis\Edwards & Kelcey\Route 128\Graphics\Revised FDR - 8.13.2010\figure 2 - 2007 Existing Volumes.dwg 26/13/10

AM(PM)

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Figure 2
2007 Existing Volumes
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Traffic Safety

As shown in Table 1, there were 403 reported crashes along I-95/Route 128 in the study area. The crash data for I-95/Route 128 was summarized by the following locations: Between MBTA Needham Line Overpass to Interchange 19(Highland Avenue); Interchange 19; Between Interchanges 19 and 20 (Route 9); and Interchange 20. The crashes that occurred at the two interchanges account for 94 percent of the crashes on I-95/Route 128 with 43 percent having occurred at Interchange 20 and 51 percent have occurred at Interchange 19. The higher percentage of crashes at interchanges versus segments between interchanges is expected since there are more conflicts with merging, diverging, and weaving in interchange areas. In addition, Figure 3 displays the number of crashes that occurred from 2006 through 2008 along I-95/Route 128 in the study area. Figure 4 shows the number of crashes that occurred along each of the corridors in the study area between 2006 through 2008.

One fatal crash occurred along I-95/Route 128 in the study area during the three year period from 2006 through 2008 at the Route 9 Eastbound ramp. More than half of the crashes resulted in property damage only. Approximately 55 percent (215 crashes) were rear-end crashes. On freeway facilities, rear-end crashes are often a result of congestion.

In addition, crash rates were calculated for the sections of I-95/Route 128 between the interchanges. Crash rates were not calculated for the interchanges because the crash data often does not provide information specific enough to know whether a crash occurred on I-95/Route 128 or on one of the ramps.

Table 1. I-95/Route 128 Crash Summary

	MBTA Needham Line Overpass to Interchange 19*	Interchange 19	Between Interchange 19 & 20**	Interchange 20	Total
2006	8	76	3	62	149
2007	6	71	3	51	131
2008	1	59	3	60	123
Total	**15**	**206**	**9**	**173**	403
Type					
Rear-end	6	116	4	95	215
Sideswipe, same direction	5	23	3	25	51
Angle	0	13	0	12	25
Single vehicle crash	3	35	1	28	64
Head-on	1	1	0	0	1
Rear-to-rear	0	0	0	0	0
Sideswipe, opposite direction	0	1	0	0	1
Not reported	0	16	1	12	29
Unknown	0	1	0	1	2
Total	**15**	**206**	**9**	**173**	**403**
Severity					
Fatal	0	0	0	1	1
Injury	6	54	3	46	103
PDO	8	134	5	114	253
Not Reported	1	16	1	10	27
Unknown	0	2	0	2	4
Total	**15**	**206**	**9**	**173**	**403**
Weather					
Clear	8	149	5	117	271
Cloudy	5	25	2	34	61
Rain	2	19	1	10	30
Snow	0	5	1	2	8
Fog	0	0	0	0	0
Sleet, hail	0	4	0	1	5
Not reported	0	4	0	9	13
Total	**15**	**206**	**9**	**173**	**403**
Time					
7:00 AM to 9:00 AM	3	64	4	31	99
9:00 AM to 4:00 PM	4	69	1	58	128
4:00 PM to 6:00 PM	1	27	1	24	52
6:00 PM to 7:00 AM	7	46	3	60	109
Total	**15**	**206**	**9**	**173**	**403**
Crash Rate	**0.05**		**0.07**		
District 4 Average Crash Rate	**0.88**				

Source: MassDOT

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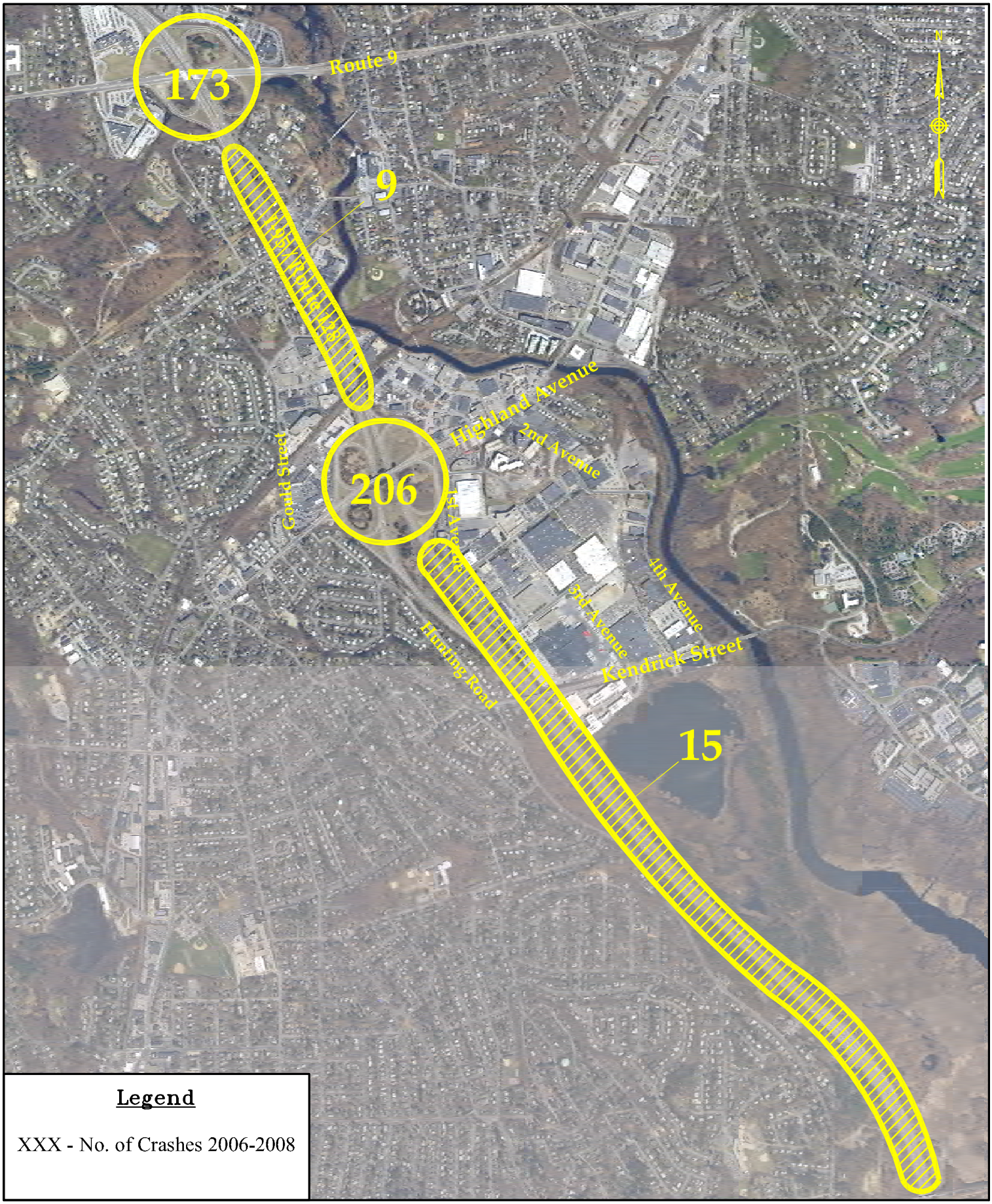

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Figure 3
Route 128 Crashes by Location
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

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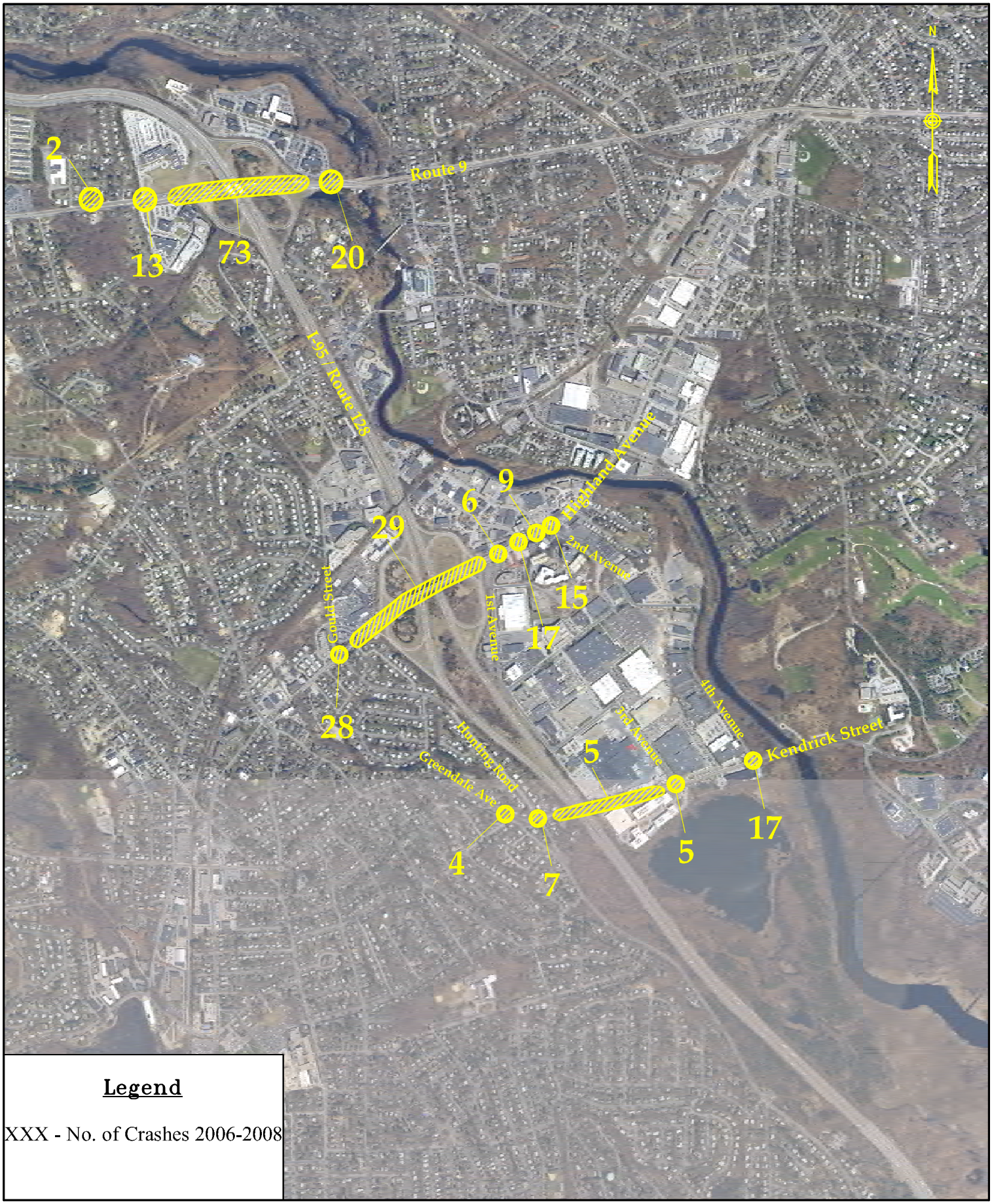

Legend

XXX - No. of Crashes 2006-2008

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Figure 4
Corridor Crashes by Location
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Traffic Operations

Based on standard methodologies contained in the *Highway Capacity Manual* (HCM), a detailed capacity/level-of-service analysis was performed for the existing morning and evening peak hour traffic volumes for the freeway sections of I-95/Route 128 in the study area. Basic freeway sections are characterized by three performance measures: density (passenger cars per mile per lane), speed, and volume-to-capacity ratio. These measures provide an indication of how well traffic is being accommodated by the freeway. Level-of-service for freeway sections is estimated based on density. Level-of-service thresholds for freeway sections are summarized as follows:

Table 2. Level of Service Criteria for Freeway Sections

Level of Service	Density (pc/mi/ln)
A	0 – 11
B	> 11 – 18
C	> 18 – 26
D	> 26 – 35
E	> 35 – 45
F	> 45

Table 3 summarizes the analysis results for the existing morning peak hour for I-95/Route 128. As shown in Table 3, I-95/Route 128 between Route 9 and Highland Avenue operates at LOS F in the northbound direction and LOS E in the southbound direction. South of Highland Avenue, I-95/Route 128 operates at LOS F in the northbound direction and LOS D in the southbound direction.

Table 3. 2007 Existing Freeway Levels of Service

	Morning Peak Hour		Evening Peak Hour	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128				
Between Route 9 and Highland Avenue				
Northbound	F	> 45	E	44.0
Southbound	E	35.7	E	42.5
I-95/Route 128				
South of Highland Avenue				
Northbound	F	> 45	D	34.2
Southbound	D	28.5	F	> 45

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

Table 3 also summarizes the analysis results for the existing evening peak hour for I-95/Route 128. Table 3 shows that between Route 9 and Highland Avenue, I-95/Route 128 operates at LOS

E in both the northbound and southbound directions. South of Highland Avenue, I-95/Route 128 operates at LOS D in the northbound direction and LOS F in the southbound direction.

Detailed capacity analysis worksheets for the existing conditions freeway analysis may be found in Appendix B.

Roadway Design

Freeway Widening

The project involves widening of the current six lane cross section of this Interstate Highway to eight lanes. Within the limits of this project, the additional travel lane is expected to be constructed primarily within the existing median. The design of geometric features for the additional lane will adhere to current AASHTO and FHWA standards as set forth in the latest addition of the MassDOT Design Guidebook, with one exception. A design exception is required for the shoulder width on I-95/Route 128 near Route 9, where the right shoulder has been reduced to six feet to avoid the removal of ledge. The six-foot shoulder occurs for approximately 1000 feet on the northbound and southbound side of I-95/Route 128. For the remainder of the project, ten-foot shoulders are provided for the right shoulder and the median shoulder.

The section of roadway between the Route 9 Interchange and the Highland Avenue interchange will be widened to ten lanes, providing five lanes in each direction. This cross section is necessary to handle the current and projected freeway traffic volumes. The redesign of this segment of I-95/Route 128 is a piece of a larger project, the Route 128 Add-a-Lane Project. With existing volumes and three lanes in each direction, the roadway is over capacity. Excessive delays are encountered along the freeway segment. The freeway widening will better accommodate the traffic demand.

I-95/Route 128 at Route 9 Overpass

The design of the I-95/I-93 Transportation Improvement Project (Bridge V) in Newton and Wellesley has generally conformed to the previous design alternative, including elements such as the frontage road near Kendrick Street and Highland Avenue. However, the I-95/Route 128 bridges over Route 9 have required additional analysis to improve the roadway geometrics and safety. A detailed description of the alternative analysis is outlined below.

A detailed design analysis was conducted for the bridges that carry I-95/Route 128 over Route 9. Various alternatives were considered to improve the highway geometrics and safety of the roadway without affecting the traffic operations on either Route 9 or I-95/Route 128. Since the publication of the EA/FEIR, MassDOT has determined that the bridges (W-13-023 2FQ and A7V) over Route 9 need to be replaced. In addition, the scope of the project includes improving the substandard horizontal alignment on the southern approach to the bridge.

Approaching Route 9 from the south, the mainline alignment is on a reverse horizontal curve with no tangent section in between. Continuing north, the bridges over Route 9 are on a short tangent section creating a broken-back alignment. This alignment and associated superelevation does not meet AASHTO guidelines for a 55-mph design speed.

The design objectives of the Route 9 interchange are the following:

- Remove the reverse curve
- Provide 15 feet (minimum) clearance over Route 9
- Design for a minimum of 55 mph mainline design speed (60 mph preferred)
- Maintain four lanes of traffic each way during construction
- Minimize ramp(s) reconstruction
- Design within the available right-of-way
- Reduce Costs and minimize constructability issues

Mainline Horizontal Alignment Alternatives

Several alternatives for the mainline horizontal alignment were investigated and presented to MassDOT. Those that were deemed most favorable are described below:

Alternative 1 extends the existing tangent from the south, proceeding northerly toward Route 9. See Figure 5. A series of three horizontal curves (R= 3,600', 2,400' and 1,600') tie into the existing mainline alignment approximately 1400 feet north of Route 9. This option removes the existing reverse curve. However, it places the proposed bridge on a new skew angle and is therefore still a "footprint" replacement with the new bridge alignment completely on a horizontal curve (R=3,600'). In order to achieve the desired fifteen-foot clearance over Route 9 and to minimize the approach fill required the proposed bridge over Route 9 utilizes separate bridge decks for the northbound (NB) and southbound (SB) barrels. This allows the "low side" of each deck to be set at the elevation to provide the desired clearance and minimizes the approach fill required for the mainline (approx. 12,000CY) and adjacent off-ramps. However, it creates significant traffic control/staging issues which require a reduction to three travel lanes and/or low design speeds (<35 MPH), and awkward pavement rollovers that vehicles may experience when traveling through the construction zone.

In order to provide four lanes of traffic in each direction during the construction of the proposed bridge, a temporary structure(s) and significant amounts of approach fill would be required. This alternative was not chosen due to the high costs of the traffic management during construction.

ALTERNATIVE 1 HORIZONTAL ALIGNMENT

PRO:
1) ELIMINATES REVERSE CURVE ON MAINLINE
2) MAINTAINS SIMILAR MAINLINE FOOTPRINT
3) SPLIT BRIDGE AIDS SUPERELEVATION TRANSITIONS
4) MINIMAL EARTHWORK REQUIRED

CON:
1) QUESTIONABLE CONSTRUCTABILITY BASED ON TRAFFIC MANAGEMENT PLANS
2) SPLIT BRIDGE DECK COMPROMISES TRAFFIC MANAGEMENT DURING CONSTRUCTION

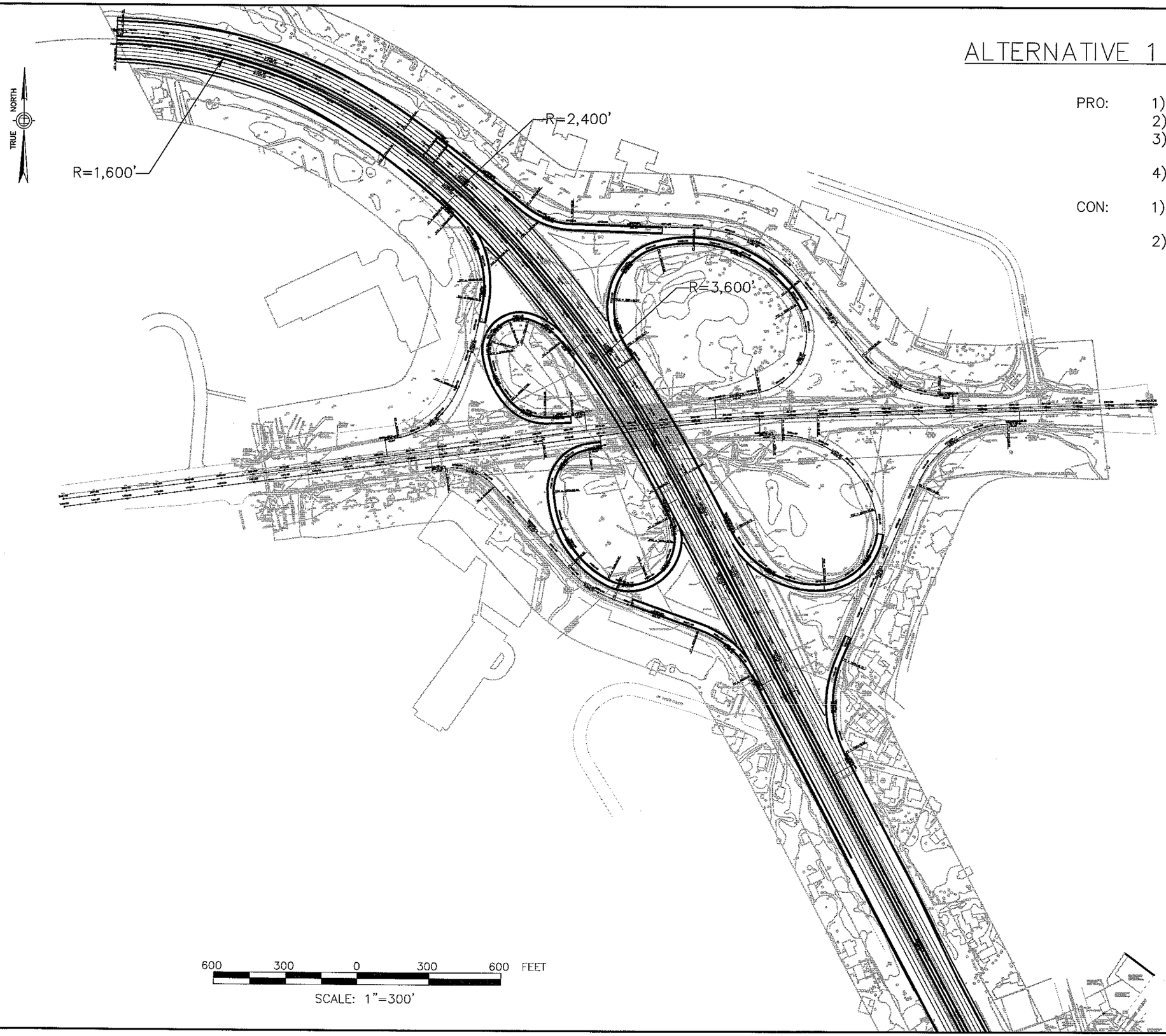


Figure 5
Mainline Horizontal Alignment 1
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Alternative 2 is shown in Figure 6 and utilizes a large radius curve (R>10,000') which requires no superelevation on the southern approach and allows the proposed bridge to be situated to the east. While this curve can only achieve approximately half of its desired length (L=15V), the proposed alignment is a significant improvement over the existing condition. The alignment to the north of Route 9 is similar to Alternative 1, utilizing the same series of three horizontal curves in order to tie back into the existing mainline alignment. Shifting the proposed bridge to the east will require additional mainline fill of approximately 20,000 CY and retaining walls are required between ramps. However, this alternative offers significant improvements to traffic control/staging. Vehicles are allowed to stay in their respective NB and SB barrels (no crossovers). The SB lanes can be shifted to the far west of the existing bridge and remain there during all phases of construction before moving onto the proposed final structure. In addition, this option makes moderate improvements to the horizontal alignments of several ramps. An additional 12,500 CY of material is required to transition the ramps to existing grade at a 45 mph design speed. The limit of work on the ramps does not extend to Route 9. However, in order to keep the limits of work within the existing ROW, a small six-foot retaining wall is required to run for approximately 400 feet between the ramps in the northeast quadrant. The maximum height of the wall could be reduced by approximately two feet if the design speed of the ramp is set at 35 mph.

Alternative 3 was developed at the request of the MassDOT District 4 office and investigated the possibility of performing a "footprint" bridge replacement. This option would perpetuate the existing horizontal alignment conditions and bridge skew angle and would only modify the vertical alignment to achieve the 15-foot vertical clearance. See Figure 7.

This option results in similar mainline fill quantities as Alternative 1, and provides no improvements to the horizontal alignment of the mainline or ramps. In addition, the traffic control/staging requires multiple lane switches/phases due to the limited construction work zone available. It is expected that the Contractor will need to construct approximately one travel lane at a time.

Given the existing poor horizontal mainline alignment (reverse curve), the magnitude of work required to raise the mainline grades to achieve the 15-foot vertical clearance and the number of phases required to complete the "footprint" bridge replacement, Alternative 3 is not seen as a favorable option.

Mainline Revisions

It is important to note one change to the mainline design since the onset of the project. This change includes maintaining a full 12-foot lane from the Route 9 SB on-ramp south to the Frontage Road off-ramp. There is not sufficient distance between these two ramps to provide adequate taper lengths and a more uniform condition can be achieved by maintaining the full 12-foot lane.

ALTERNATIVE 2 HORIZONTAL ALIGNMENT

PRO:
1) BRIDGE CONSTRUCTABILITY INCREASES DUE TO LATERAL SHIFT IN ALIGNMENT
2) SEVERAL SUBSTANDARD RAMP ALIGNMENTS ARE IMPROVED
3) SPLIT BRIDGE DECK AIDS SUPERELEVATION TRANSITIONS

CON:
1) REVERSE CURVE ON MAINLINE REMAINS
2) SPLIT BRIDGE DECK COMPROMISES TRAFFIC MANAGEMENT DURING CONSTRUCTION
3) LENGTH OF 10,000' RADIUS CURVE REQUIRES DESIGN EXCEPTION
4) SUBSTANTIAL QUANTITIES OF FILL REQUIRED

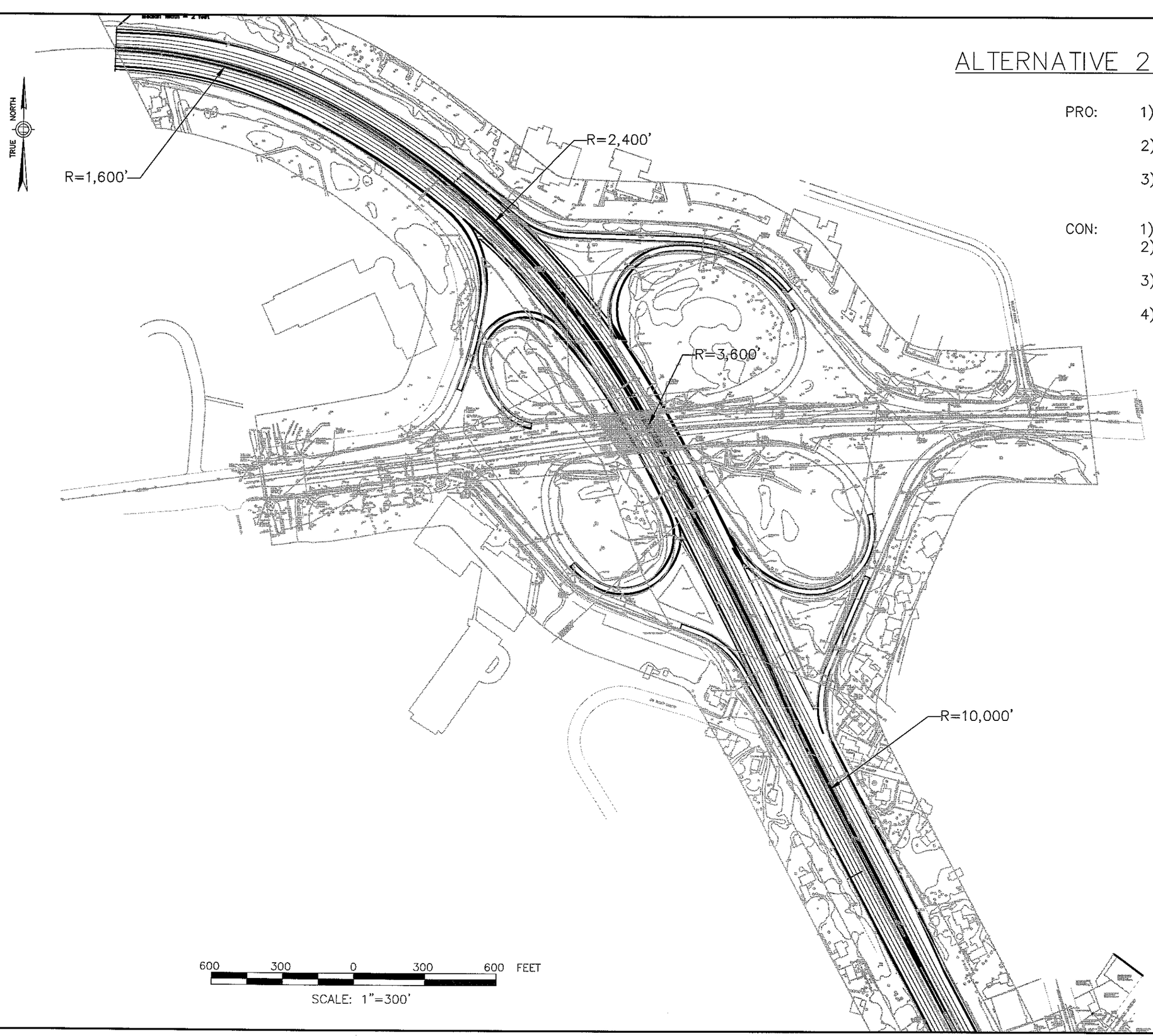


Figure 6
Mainline Horizontal Alignment 2
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

ALTERNATIVE 3 HORIZONTAL ALIGNMENT

PRO:
1) LOWEST–COST ALTERNATIVE
2) BRIDGE RECONSTRUCTED IN–PLACE
3) MINIMAL EARTHWORK REQUIRED

CON:
1) REVERSE CURVE ON MAINLINE REMAINS
2) NO IMPROVEMENTS MADE TO ROUTE 9 INTERCHANGE

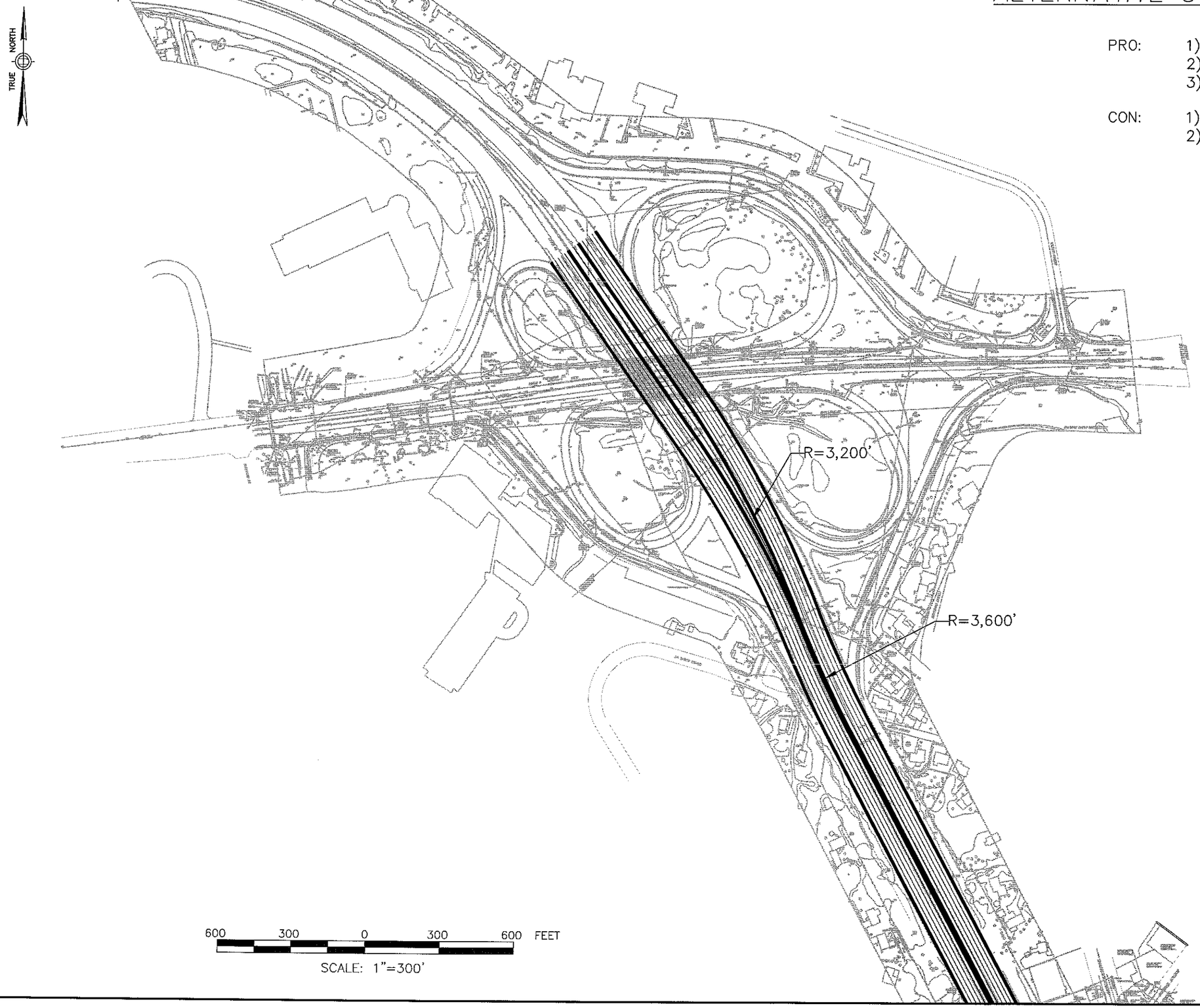


Figure 7
Mainline Horizontal Alignment 3
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Alternative 2A - The Preferred Option

Both MassDOT and the design team generally favored Alternative 2. However, during a meeting held at the MassDOT District 4 office, a request was made to explore the possibility of utilizing a single bridge deck along the Alternative 2 alignment.

This concept, referred to as Alternative 2A and shown in Figure 8, provides a significant advantage to traffic control/staging of future bridge deck replacements. In addition, it provides a smoother "roll over" at the high side of roadway. However, this option will require additional fill associated with the "high side" of a single bridge deck. Taking into account the revisions made to the mainline described above, the single deck alternative results in an additional 1.5 feet of fill required on the "high side" (northeast quadrant). The associated volume of material is approximately 34,000 CY for the mainline and an additional 32,000 CY for the ramps. Also, in order to keep the limits of work within the existing ROW, a larger (8 feet max) retaining wall is required for approximately 450 feet between the ramps in the northeast quadrant. Some relief on the extents of this wall could be had by decreasing the design speed of the ramps from 45 to 35 mph and MassDOT supported the design speed reduction.

By moving the proposed SB and NB bridge decks together, the alignment was shifted further to the east in order to facilitate construction phasing. The radius of the proposed curve was increased from 10,000 feet to 12,000 feet and the proposed curve length was extended from 240 feet to 840 feet to achieve the alignment shift. This proposed curve still requires no superelevation, however an additional curve is added (R=5,400') in order to tie into the existing compound curves to the north (R=3,600' 2,400' 1,600'). While the existing reverse curve alignment is perpetuated, this alternative is a significant improvement over the existing condition and removes the appearance of the "kink" in Alternative 2.

In providing the superelevation for the mainline, the 6% e_{max} table is used, a maximum relative gradient of 0.45 (60mph) is utilized and the profile gradeline is the axis of rotation. From the south, the mainline transitions from normal crown to a super of 2.84% (R=5,400 feet) with a standard two-third/one-third distribution about the point of reverse curve (PRC). (Note that the radius of the curve to the south is large enough for the normal crown). The runoff transition from 2.84% to 3.84% occurs entirely up station of the point of compound curve (PCC) (R=3,600 feet). Although the curve is less than 500 feet, it remains advantageous to transition immediately up station rather than to provide a uniform longitudinal gradient due to the fact that the low point of the vertical sag curve occurs in this area. By placing all the runoff just up station of the PCC, the area where the longitudinal profile (gutter) grades are less than 0.4% is minimized. The required (3.84%) superelevation is carried over the bridge and then transitions north of the bridge to 6.0% (R=2,400', 1,600') tying into the existing cross slopes.

Figure 9 and Figure 10 show the relative profile gradient for the southbound and northbound mainline, respectively.

Figures 8, 9 and 10 depict the preferred mainline alternative. Note that the design of the Route 128/Route 9 interchange has been modified, as discussed under the "Route 9 Interchange" portion of this report.

ALTERNATIVE 2A HORIZONTAL ALIGNMENT

PRO:

1) BRIDGE CONSTRUCTABILITY INCREASES DUE TO FAVORABLE TRAFFIC MANAGEMENT PLANS AND LATERAL SHIFT IN ALIGNMENT
2) SEVERAL SUBSTANDARD RAMP ALIGNMENTS ARE IMPROVED
3) CONTINUOUS BRIDGE DECK AIDS TRAFFIC MANAGEMENT DURING CONSTRUCTION AND FUTURE DECK REHABILITATION

CON:

1) REVERSE CURVE ON MAINLINE REMAINS
2) CONTINUOUS BRIDGE DECK LENGTHENS SUPERELEVATION TRANSITIONS AND INCREASES EARTHWORK QUANTITIES
3) LENGTH OF 12,000' RADIUS CURVE REQUIRES DESIGN EXCEPTION
4) SUBSTANTIAL QUANTITIES OF FILL REQUIRED

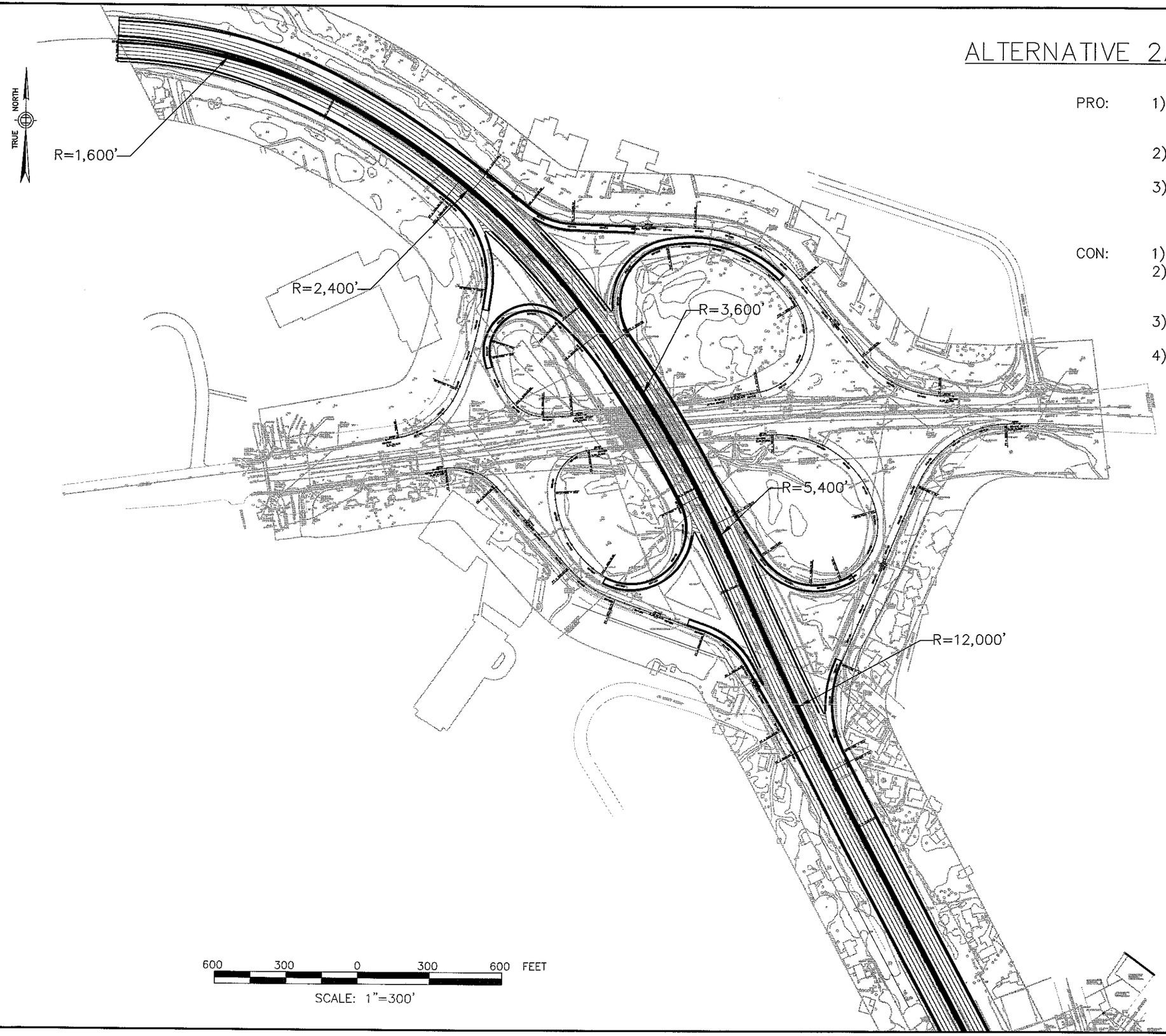
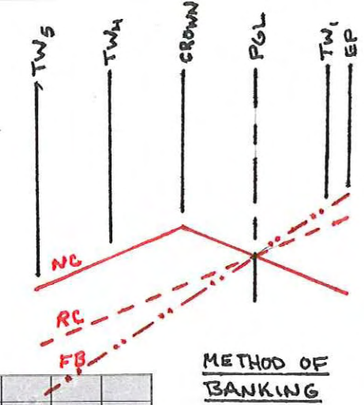


Figure 8
Mainline Horizontal Alignment 2A
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Relative Profile Gradient

Between the Travel Ways/Edges of Pavement and the Profile Grade Line
SOUTH BOUND MAINLINE

MAXIMUM RELATIVE GRADIENT = 0.45 (1:222)



METHOD OF BANKING
NTS

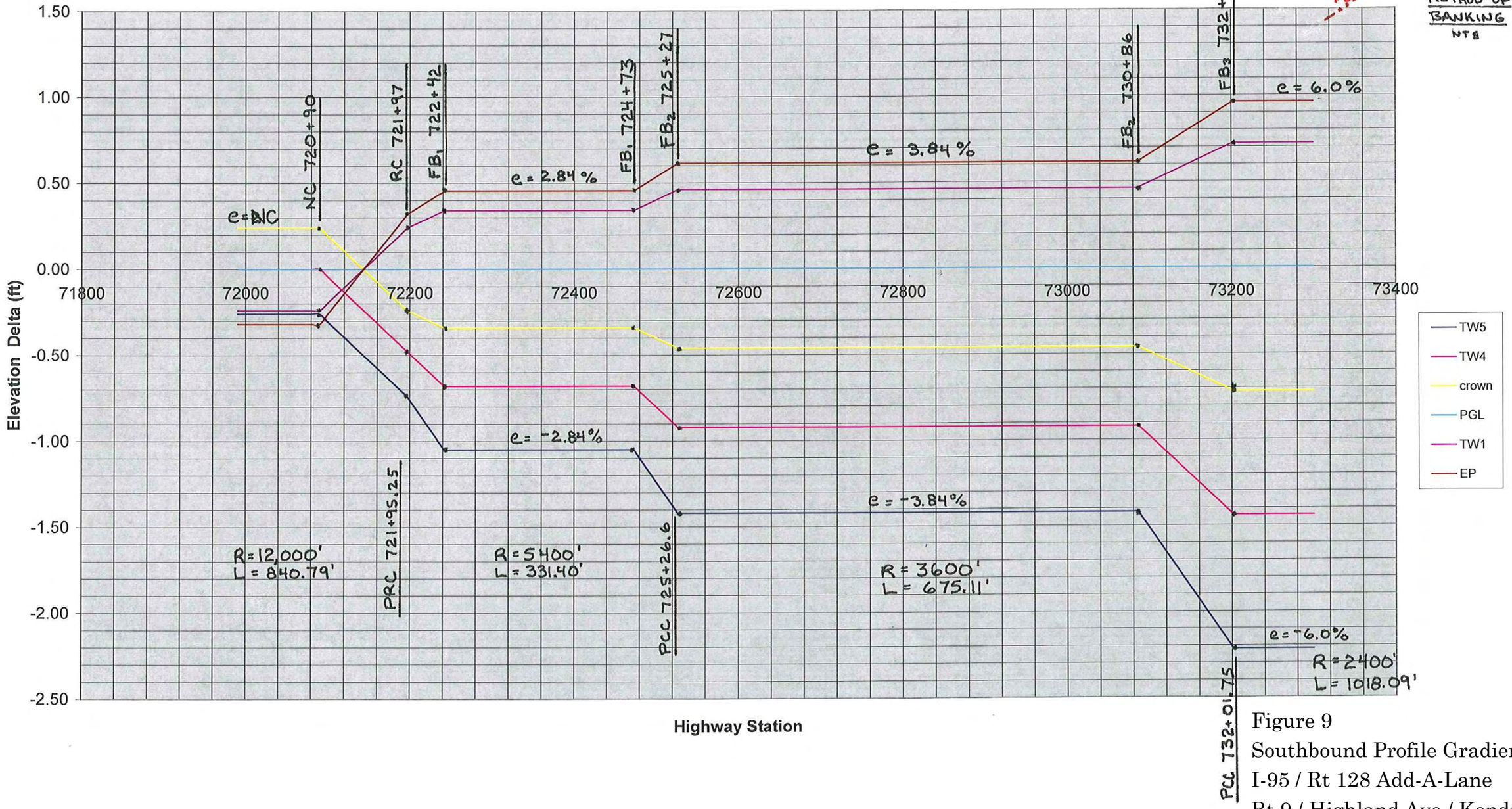
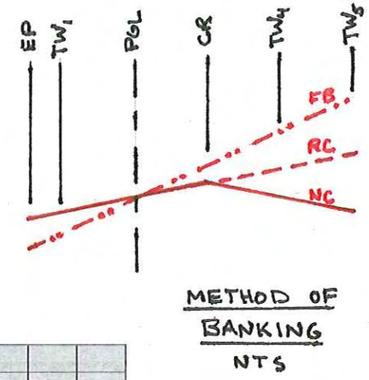


Figure 9
Southbound Profile Gradient
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St



METHOD OF BANKING
NTS

Relative Profile Gradient

Between the Travel Ways/Edges of Pavement and the Profile Grade Line

NORTHBOUND MAINLINE

MAXIMUM RELATIVE GRADIENT = 0.45 (1:222)

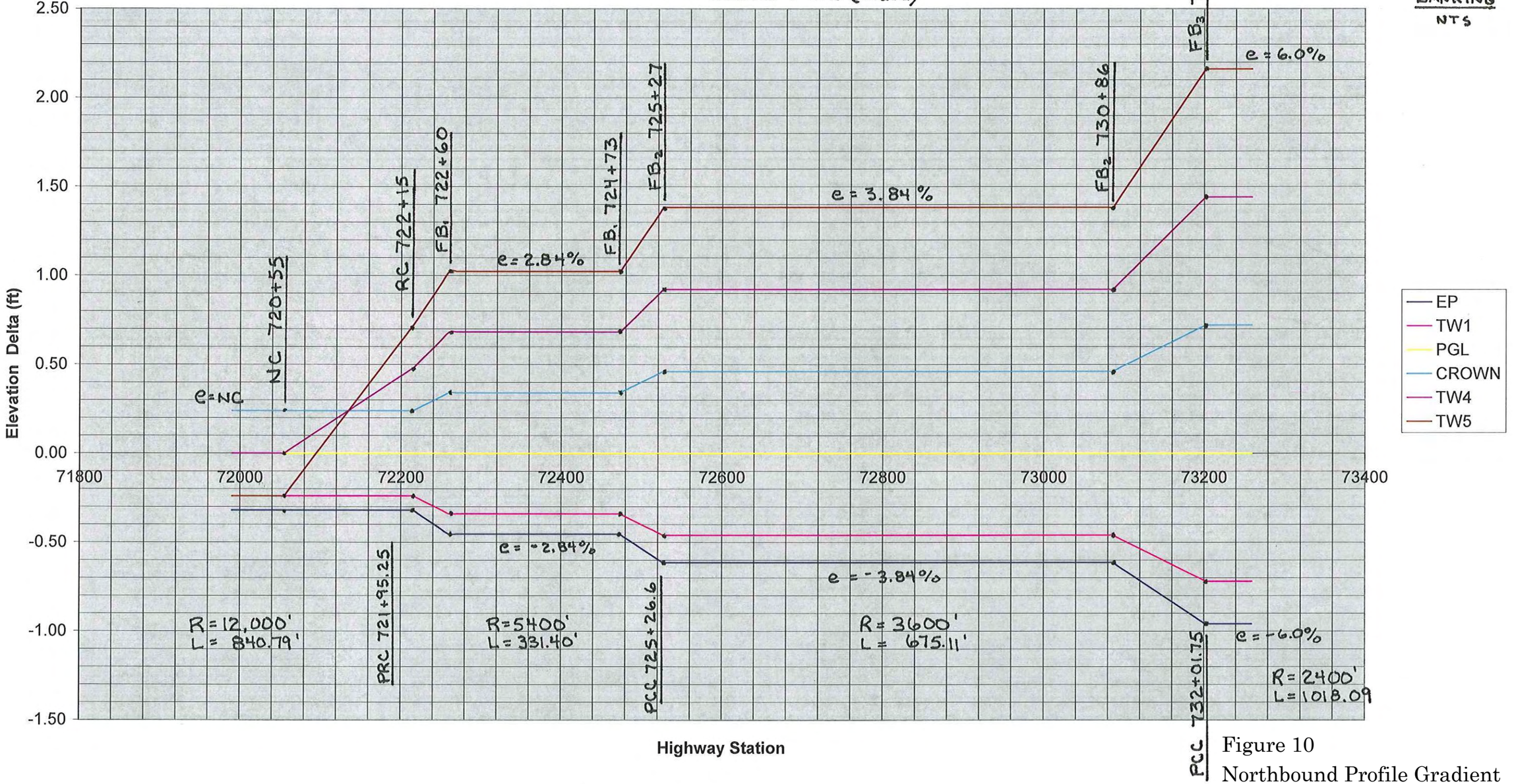


Figure 10
Northbound Profile Gradient
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Future Traffic Volumes

The foundation for the future transportation conditions for this project was the study originally performed by CTPS[1]. The future conditions are primarily related to changes in land use, economic growth, and changes to the transportation infrastructure.

The CTPS regional model was used to estimate the future-year morning and evening peak hour volumes. The section of the regional model covering the project area was updated and divided in order to more accurately model traffic patterns. In addition to widening of the mainline, this project proposes a new interchange at Kendrick Street and a C-D system. The introduction of a new interchange with a C-D roadway will initiate shifts in travel patterns by allowing new opportunities to enter onto and exit more directly from I-95/Route 128.

To consider these future shifts in travel patterns, along with traffic growth, for this project, it was necessary to develop a transportation model to assist in developing future traffic flows. The above noted report contains detailed descriptions of the model and the modeling process used by CTPS in this effort.

The previously noted study contains a description of the transportation model and the calibration. Appendix C contains the appropriate section of the CTPS report that describes the model and calibration process. Minor adjustments were made to the traffic volumes from the CTPS model to reflect more accurate expectations of traffic volumes.

Additional Model Activities

In addition to the previous modeling efforts conducted by CTPS in the above noted study, there was a need for additional model runs to refine the traffic estimates for the preferred alternative. The following is a summary of the additional model runs:

- 2025 Traffic on Preferred Alternative
- 2025 Traffic with updated Land Uses – No-Build
- 2025 Traffic with updated Land Uses - Build
- 2003 Base Year With Preferred Alternative
- 2003 Base Year for Route 9 Interchange

The additional model runs were used to provide the long term no-build and build peak hour traffic projections along with projections for existing volumes on proposed geometries for use in assessing operations during construction. Since this project involved improvements to current traffic signals and a new signal along local streets, traffic flows for an interim build year of 2017 were also estimated.

[1] Central Transportation Planning Staff, Potential I-95 (I-95/Route 128)-Kendrick Street Interchange, Needham, Massachusetts An Evaluation of Traffic Impacts, Boston, Massachusetts, December, 2003.

Land Use Changes

The previous study by CTPS included a build out analysis for considerable redevelopment in Needham. A zoning by law, approved in 2002, for the Town of Needham allows the developable space in the New England Business Center and the Wexford/Charles Industrial District to increase by approximately 2.5 million square feet. Trip generation for the increase in square footage from the proposed expansion would be approximately 2,300 trips during the morning peak hour and 2,300 trips during the evening peak hour. In addition, the previous study by CTPS included one project in Newton: the Avalon at Upper Falls complex, which included 294 apartment units.

This study includes a review of the projected land use changes in the study area. The purpose of the analysis was to determine if any changes have occurred in the past five years that should be included in the long term forecasts. To that end, meetings were held with officials in Needham, Newton and Wellesley to discuss the long term build conditions in their respective municipalities.

The following section highlights the changes to the land use in the long-range model for estimating the no-build and build alternatives that resulted from the meetings with the local communities. The discussions with the Town of Needham indicated that the long range "build out" analyses conducted by CTPS for the 2025 planning horizon were accurate with one new project that will change the land use for the "build out" estimate. That project is called Charles River Landing. For the Town of Wellesley, the Town Planner indicated that the general background growth of approximately one percent per year would be within the expected norm for a long range planning horizon for this project. Discussions with the Town of Newton identified one project that should be refined in the long-range land use estimated in the "build out" estimate: the Northland Redevelopment.

For purposes of this study, the long-range estimates were adjusted for the specific traffic zones in the study area. The following changes were made to the build out estimates:

Charles River Landing

- Will change 217,791 square feet of manufacturing to 350 apartment units
- During the morning peak hour, there will be 87 fewer trips entering and 103 additional trips exiting the site.
- During the evening peak hour, there will be 79 additional trips entering the site and 26 fewer trips exiting the site.

Northland Site

- Existing land use is 256,000 square feet of manufacturing, 174,000 square feet of office, and 62,000 square feet of shopping center.
- Proposed land use is 174,000 square feet of office, 413,000 square feet of shopping center, and 208 condominium units.

- The morning peak hour will have 39 additional trips entering the site and 141 additional trips exiting the site.
- The evening peak hour will experience an additional 367 trips entering the site and an additional 307 trips exiting the site.

Future Traffic Volumes

No-Build

Figure 11 presents the morning and evening peak hour traffic flows for the No-Build condition for the year 2025. This scenario represents full growth in the study area without the improvements to I-95/Route 128 resulting from this project. The volumes used for the 2025 No-Build condition analysis were obtained from the regional traffic model created by CTPS.

Build

Figure 12 shows the estimated traffic flow in the study area for the morning and evening peak hours under the Build condition for the year 2025 with the preferred alternative as refined by the EK/HDR joint venture, discussed later in this report. The traffic volumes for the 2025 Build condition were obtained from the CTPS regional traffic model and adjusted accordingly for the preferred alternative. The following is a discussion of the build traffic volume flows.

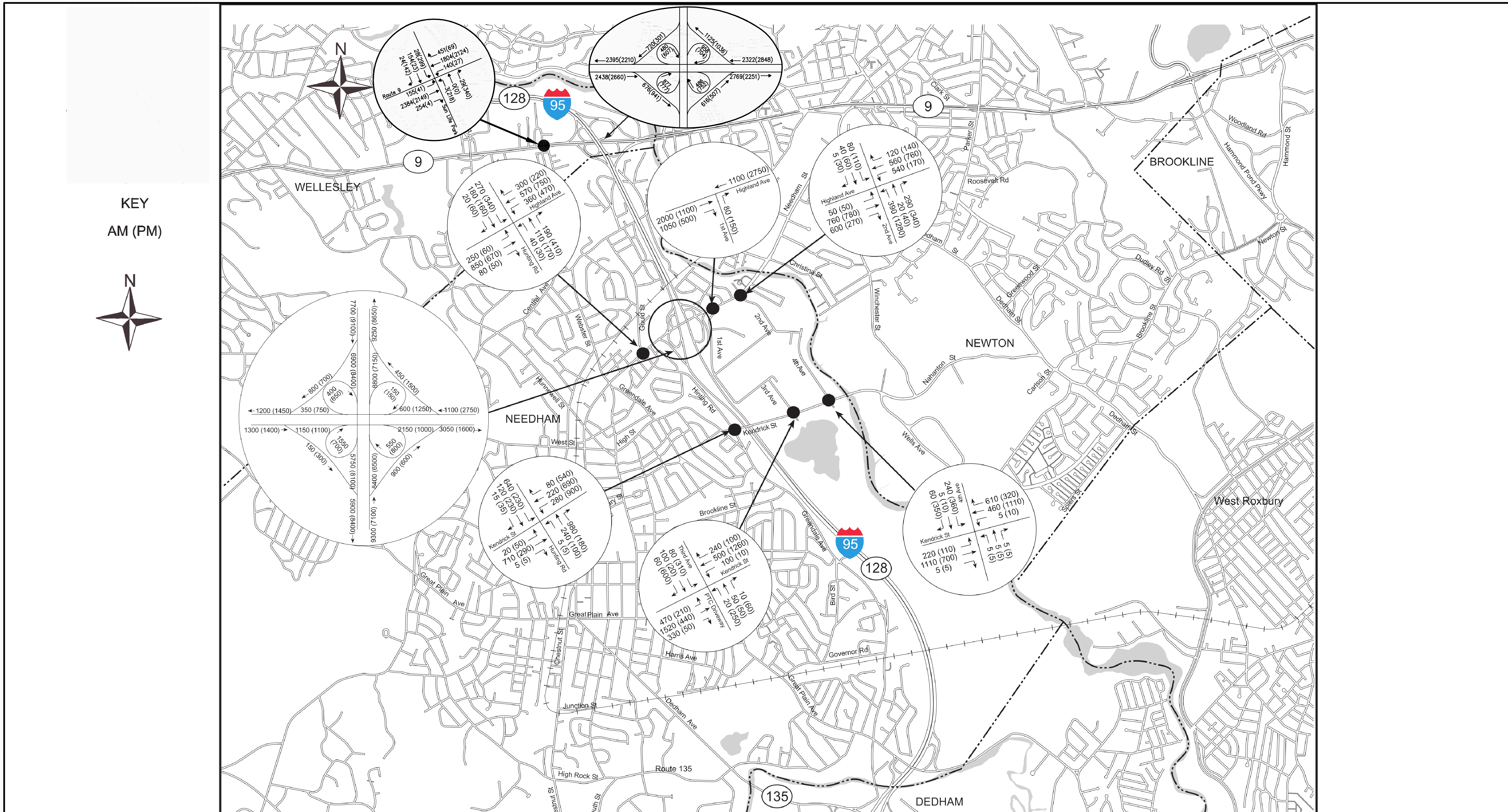


Figure 11
2025 No Build Volumes
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

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TRANSPORTATION ENGINEERS & PLANNERS

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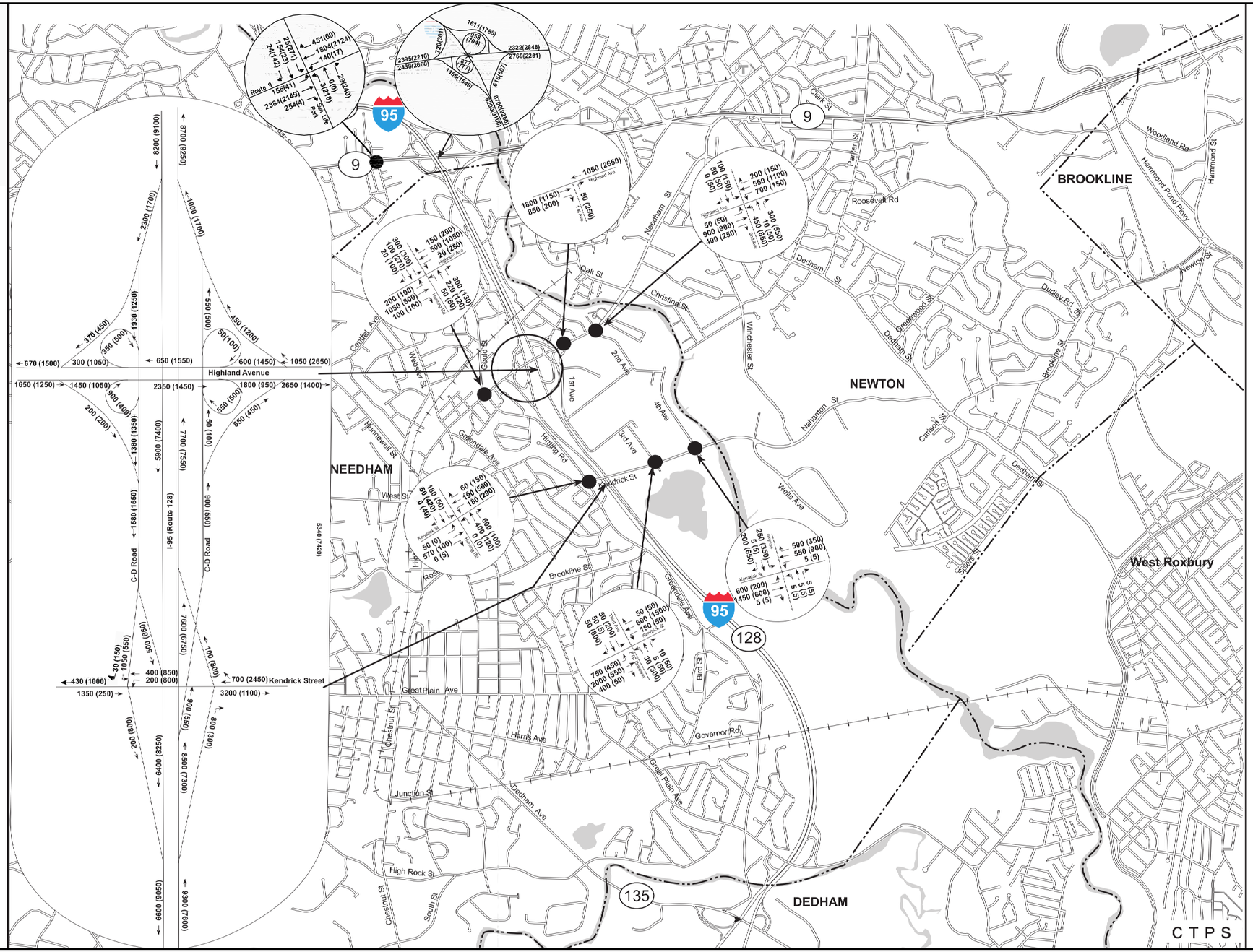

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TRANSPORTATION ENGINEERS & PLANNERS

Figure 12
2025 Build Volumes
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Future Analysis

Table 4 and Table 5 show the levels of service for the freeway operations during the morning and evening peak hours, respectively, for the 2025 no build and build scenarios. As shown in Table 4 and Table 5, I-95/Route 128 northbound between Route 9 and Highland Avenue would be expected to operate at level-of-service (LOS) F in the northbound direction during both the weekday morning and evening peak hours for the 2025 no build scenario. Between Route 9 and Highland Avenue, I-95/Route 128 southbound operates at LOS E during the morning peak hour and at LOS F during the evening peak hour for the no build condition.

Table 4. Freeway Levels of Service for 2025 Morning Peak Hour

	No Build		Build	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128				
Between Route 9 and Highland Avenue				
Northbound	F	> 45	E	35.8
Southbound	E	41.5	D	33.5
I-95/Route 128				
South of Kendrick Street				
Northbound	F	> 45	F	> 45
Southbound	D	30.1	D	33.7
I-95/Route 128				
Between C-D Ramps				
Northbound	n/a	n/a	E	41.5
Southbound	n/a	n/a	D	30.1

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

Table 5. Freeway Levels of Service for 2025 Evening Peak Hour

	No Build		Build	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128				
Between Route 9 and Highland Avenue				
Northbound	F	> 45	E	38.9
Southbound	F	> 45	E	38.0
I-95/Route 128				
South of Kendrick				
Northbound	E	36.7	E	40.6
Southbound	F	> 45	F	> 45
I-95/Route 128				
Between C-D Ramps				
Northbound	n/a	n/a	E	40.2
Southbound	n/a	n/a	E	38.9

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

Table 4 and Table 5 also present the capacity analysis results for I-95/Route 128 south of the Highland Avenue interchange. In the northbound direction, I-95/Route 128 is expected to operate at LOS F in the morning peak hour and at LOS E during the evening peak hour for the 2025 no build condition. In the southbound direction, I-95/Route 128 will operate at LOS D during the morning peak hour and at LOS F during the evening peak hour for 2025 no build.

As shown in Table 4 and Table 5, the levels of service for I-95/Route 128 show little improvement as a result of the proposed changes in the Build condition. It should be noted that for the existing conditions and no build conditions, I-95/Route 128 was analyzed as an eight lane (four lanes in each direction) freeway facility. While the roadway is currently striped as a six lane facility, the shoulders are used during the peak periods as travel lanes. Thus, I-95/Route 128 was analyzed as an eight lane facility for no build conditions. However, while the use of shoulders for travel during peak periods increases the capacity of the roadway, it does not increase the capacity to the same level that would result from adding a full fourth lane in each direction with a shoulder.

The results of the capacity analysis show failing conditions in some locations in the study area and may not show much reduction in density or improvement in level of service from the 2025 No Build to the 2025 Build conditions for I-95/Route 128. However, the improvement will actually be greater than that which is presented because I-95/Route 128 was modeled as an eight lane freeway for the No Build condition to reflect the use of the shoulders during peak periods. The improvements that result from this project would be most accurately reflected in the merge and diverge analysis.

Capacity analysis worksheets for the No Build freeway analysis may be found in Appendix D. The Build condition freeway analysis worksheets are presented in Appendix E.

Highland Avenue / Kendrick Street Interchange

Existing Conditions

Highland Avenue Interchange

The first of two interchanges in the study area is located at Highland Avenue. This interchange has a cloverleaf ramp configuration. The ramp configurations create a weave section within the interchange in each direction of travel. Since travel is permitted in the breakdown lanes of I-95/Route 128 during the morning and evening peak periods, the Highland Avenue weave sections operate as separate, closely spaced, merge and diverge areas during the morning and evening peak periods. As a result of the use of the breakdown lanes for travel, all of the merge and diverge areas in the Highland Avenue interchange function with no acceleration or deceleration area.

<u>Interchange Conditions</u>

Kendrick Street

Kendrick Street at Hunting Road

Kendrick Street provides for east-west travel in the vicinity of I-95/Route 128. The study area includes the following three intersections: Kendrick Street at Hunting Road, Kendrick Street at 3rd Avenue and Kendrick Street at 4th Avenue. The intersection of Kendrick Street at Hunting Road is a four-leg signalized intersection. The eastbound approach has a shared left turn and through lane and a shared through and right lane. The westbound approach has a left turn lane and shared through and right lane. The northbound approach to this intersection has a shared left turn and through lane and a channelized, yield-controlled right turn lane. The southbound approach has a left turn lane and a shared through and right lane.

Kendrick Street at 3rd Avenue

Kendrick Street between Hunting Road and 3rd Avenue provides two lanes traveling eastbound and one lane traveling westbound. The intersection of Kendrick Street and 3rd Avenue is

a four-leg signalized intersection. The eastbound approach has a left turn lane, two through lanes, and a right turn lane. The westbound approach has a left turn lane, and through lane, and a shared through and right turn lane. The northbound approach has a left turn lane and a shared through and right turn lane. The southbound approach has a shared left turn and through lane and a right turn lane.

Kendrick Street at 4th Avenue

Between 3rd Avenue and 4th Avenue, there are two through lanes in each direction on Kendrick Street. The intersection of Kendrick Street and 4th Avenue is a four leg unsignalized intersection. The eastbound approach has a shared left turn and through lane and a shared through and right turn lane. The westbound approach also has a shared left turn and through lane and a shared through and right turn lane. The northbound approach has one shared left turn, through, and right turn lane. The southbound approach has a shared left turn and through lane and a right turn lane. The eastbound and westbound approaches are free-flowing and the northbound and southbound approaches are stop-controlled.

Highland Avenue

Highland Avenue is oriented east-west at a slightly northeast-southwest angle. The study area includes the following intersections: Highland Avenue at Hunting Road and Gould Street, Highland Avenue at the I-95/Route 128 Ramps, Highland Avenue at 1st Avenue and Highland Avenue at 2nd Avenue. The intersection of Highland Avenue at Hunting Road and Gould Street is signalized and has four approaches. The eastbound approach has three lanes: a left turn lane, a through lane, and a shared through and right turn lane. The westbound approach has a left turn lane, and through lane, and a shared through and right turn lane. The northbound approach has a shared left turn and through lane and a right turn lane. The southbound approach has a left turn lane and a shared through and right turn lane.

Highland Avenue at Hunting Road and Gould Street

Highland Avenue at 1st Avenue

Between Hunting Road / Gould Street and 1st Avenue, Highland Avenue is a four lane, median divided roadway. The I-95/Route 128 cloverleaf interchange at Highland Avenue provides right turn ramps within this portion of Highland Avenue. The intersection of Highland Avenue at 1st Avenue is an unsignalized intersection with three legs. Highland Avenue is median-divided through this intersection, so left turns are prohibited in and out of 1st Avenue. The eastbound approach has two lanes: a through lane and a shared through and right turn lane. The westbound approach has two through lanes, which are unaffected by traffic on 1st Avenue. The northbound approach has a single right turn lane. The eastbound and westbound approaches are free-flowing and the northbound approach is stop-controlled.

Just east of 1st Avenue, the median on Highland Avenue ends. Between 1st Avenue and 2nd Avenue, Highland Avenue is a four lane, undivided roadway. There are many curb cuts on this section of Highland Avenue and several small intersecting roads, such as Charles Street and Wexford Avenue, which serve industrial uses to the north of Highland Avenue.

The intersection of Highland Avenue at 2nd Avenue is a four-leg signalized intersection. The eastbound approach has a shared left turn and through lane and a shared through and right lane. The westbound approach has a left turn lane and a shared through and right turn lane. The northbound approach has a left turn lane and a shared left turn, through, and right turn lane. The southbound approach has a shared left turn and through lane and a right turn lane.

Highland Avenue at 2nd Avenue

Highway Structures

Kendrick Street

The existing Kendrick Street Bridge is a two span steel stringer structure which was constructed as part of the Southern Circumferential Highway in 1953. The roadway carries one lane of Kendrick Street traffic in each direction on a concrete deck which is 40′-0″ curb to curb. There is a sidewalk on the south side which currently has a water main traversing the length of the sidewalk. The existing vertical clearance is currently insufficient and is less than 15′-0″ above I-95/Route 128. The I-95/Route 128 roadway width is approximately 51′-0″ for both the northbound and southbound lanes and they each carry three lanes of traffic. In between the

two barrels of roadway is a 36'-0" median which includes the pier which is centered in the median.

The topography in the vicinity of Kendrick Street is very complex, varying from steep cuts on the westerly side of the bridge to steep fills on the easterly side. Existing property lines are tight against the tops and toes of slopes.

Highland Avenue

Two separate bridges carry Highland Avenue over I-95/Route 128 northbound and southbound. The existing bridges are concrete rigid frames, separated by a wide grass median, and the eastern structure was part of the 1953 corridor construction. This is when the northbound roadway was added to the existing Southern Circumferential Highway. The deck width is 26 feet and carries two lanes of Highland Avenue traffic in each direction. Directional traffic is divided by a 4'-0" median and sidewalks are located on both sides of the bridge. The clear spans of these structures are approximately 64'-6" between the walls of the bridge frame and I-95/Route 128 carries three lanes of traffic plus an on-ramp. As with Kendrick Street, the clearance of Highland Avenue over I-95/Route 128 must be increased since it is currently slightly over 14 feet. The topography in the vicinity of the Highland Avenue Bridge is basically flat due to the construction of this interchange.

Traffic Volumes

As mentioned previously, the current conditions of this area were studied in great detail by CTPS. As such, this report has used the traffic counts collected by CTPS and factored them to reflect conditions in 2007. Automatic Traffic Recorders (ATRs) were deployed by MassDOT at key locations in order to accomplish this task.

The existing traffic flow networks are presented on Figure 2 for the morning and evening peak hours. The ATRs set out by MassDOT on the Highland Avenue and Kendrick Street corridors showed growth of 1.5 percent per year and 1.0 percent per year, respectively, since the last observations were conducted by CTPS.

Traffic Safety

Kendrick Street

As shown in, Crash data for the years 2006 through 2008 was summarized for Kendrick Street from its intersection with Hunting Road to its intersection with 4th Avenue. In total, 38 crashes occurred on this segment of roadway. Twenty-three (61 percent) were angle crashes and ten were rear-end crashes (27 percent). Of the 38 crashes, five (13 percent) resulted in injury, 27 (71 percent) resulted in property damage only, and the severity of the remaining four crashes is unknown. There were no fatal crashes on the Kendrick Street segment.

Table 6. Kendrick Street Crash Summary

	Kendrick Street at Greendale Avenue	Kendrick Street at Hunting Road	Kendrick Street Between Hunting Road and 3rd Avenue	Kendrick Street at 3rd Avenue	Kendrick Street at 4th Avenue	Total
2006	2	5	1	0	7	15
2007	2	0	1	3	1	7
2008	0	2	3	2	9	16
Total	**4**	**7**	**5**	**5**	**17**	**38**
Type						
Rear-end	0	3	2	3	2	10
Sideswipe, same direction	0	1	1	0	0	2
Angle	2	3	2	2	14	23
Single vehicle crash	1	0	0	0	1	2
Head-on	0	0	0	0	0	0
Rear-to-rear	0	0	0	0	0	0
Sideswipe	0	0	0	0	0	0
Not reported	1	0	0	0	0	1
Unknown	0	0	0	0	0	0
Total	**4**	**7**	**5**	**5**	**17**	**38**
Severity						
Fatal	0	0	0	0	0	0
Injury	1	1	1	0	2	5
PDO	3	3	3	4	14	27
Not Reported	0	3	0	1	1	5
Unknown	0	0	1	0	0	1
Total	**4**	**7**	**5**	**5**	**17**	**38**
Weather						
Clear	3	5	5	2	11	26
Cloudy	1	0	0	3	4	8
Rain	0	1	0	0	2	3
Snow	0	1	0	0	0	1
Fog	0	0	0	0	0	0
Sleet, hail	0	0	0	0	0	0
Not reported	0	0	0	0	0	0
Total	**4**	**7**	**5**	**5**	**17**	**38**
Time						
7:00 AM to 9:00 AM	0	3	0	1	3	7
9:00 AM to 4:00 PM	3	1	1	1	8	14
4:00 PM to 6:00 PM	0	0	3	0	4	7
6:00 PM to 7:00 AM	1	3	1	3	2	10
Total	**4**	**7**	**5**	**5**	**17**	**38**
Crash Rate		0.23		0.19	0.62	
District 4 Average Crash Rate		**0.88**		**0.88**	**0.63**	

Source: MassDOT

Of the 38 crashes that occurred on Kendrick Street, a majority of the crashes (63 percent) occurred at two of the intersections: Kendrick Street (7 crashes) at Hunting Road and Kendrick Street at 4th Avenue (17 crashes). Three of the twelve crashes that occurred at the intersection of Kendrick Street and Hunting Road were angle crashes. One of the crashes that occurred at this intersection resulted in injury. The intersection of Kendrick Street at 4th Avenue experienced seventeen crashes from 2006 through 2008. Fourteen (82 percent) of the seventeen crashes that occurred at Kendrick Street and 4th Avenue were angle crashes. Two of the seventeen crashes resulted in injury. While most of the crashes on Kendrick Street occurred at these two intersections, the crash rates for these intersections fall below the District 4 average crash rate and the crash data does not indicate a particular safety deficiency.

Highland Avenue

Crash data for Highland Avenue was summarized by location between its intersection with Hunting Road and Gould Street and its intersection with 2nd Avenue, as shown in Table 7. For the years 2006 through 2008, 120 crashes occurred on this segment of Highland Avenue. An additional 16 crashes occurred on Highland Avenue during the same time period, but specific locations were not included in the crash data. Some of these 16 crashes may have occurred in the study area, but they have not been included as their exact location cannot be determined. Of the 120 crashes summarized in Table 7, the two most common crash types were rear-end (48 percent) and angle (29 percent). Rear-end crashes tend to be common on congested roadways and at signalized intersections. Angle crashes, on the other hand, tend to occur at intersections, where angle-type conflict potential is greatest, and can be more severe crashes than rear-ends. Highland Avenue is a four-lane roadway with many curb cuts east of I-95/Route 128 and a high-volume of traffic which may contribute to the number of crashes.

The intersection of Highland Avenue at Hunting Road and Gould Street experienced 28 crashes during the years 2006 through 2008. Thirteen (46 percent) were rear-end crashes and 8 (28 percent) were angle crashes. Of the study intersections on Highland Avenue, the crash rate for Highland Avenue at Hunting Road and Gould Street is the highest. The crash rate at this intersection is 0.82, which is less than the average crash rate for a signalized intersection in MassDOT's District 4.

Twenty-nine crashes occurred on Highland Avenue between Hunting Road and 1st Avenue. This section of roadway is where the ramps to I-95/Route 128 are located. Sixteen of the crashes were rear-ends. Rear-end crashes at this location are most likely the result of congestion from merging, diverging, and weaving traffic.

Table 7. Highland Avenue Crash Summary

	Highland Avenue at Hunting Road / Gould Street	Highland Avenue Between Hunting Road and 1st Avenue	Highland Avenue at 1st Avenue	Highland Avenue Between 1st Avenue and Wexford Street	Highland Avenue at Wexford Street	Highland Avenue Between Wexford Street and Charles Street	Highland Avenue at Charles Street	Highland Avenue at 2nd Avenue	Highland Avenue No. Location Specified
2006	13	11	5	0	5	0	2	5	5
2007	10	10	1	0	2	0	6	5	3
2008	5	8	0	0	10	0	1	5	8
Total	**28**	**29**	**6**	**0**	**17**	**0**	**9**	**15**	**16**
Type									
Rear-end	13	16	2	0	5	0	4	6	12
Sideswipe, same direction	3	3	1	0	0	0	0	6	0
Angle	8	7	1	0	11	0	3	2	3
Single vehicle crash	1	0	1	0	0	0	1	0	0
Head-on	0	0	0	0	0	0	0	0	0
Rear-to-rear	0	0	0	0	0	0	0	0	0
Sideswipe, opposite direction	0	0	0	0	0	0	0	0	0
Not reported	3	2	1	0	1	0	1	1	1
Unknown	0	1	0	0	0	0	0	0	0
Total	**28**	**29**	**6**	**0**	**17**	**0**	**9**	**15**	**16**
Severity									
Fatal	0	0	0	0	0	0	0	0	0
Injury	7	1	1	0	4	0	3	0	0
PDO	18	27	4	0	10	0	5	11	0
Not Reported	2	1	1	0	3	0	0	4	0
Unknown	1	0	0	0	0	0	1	0	0
Total	**28**	**29**	**6**	**0**	**17**	**0**	**9**	**15**	**0**
Weather									
Clear	19	17	5	0	10	0	7	13	8
Cloudy	4	6	1	0	3	0	1	2	4
Rain	3	5	0	0	2	0	0	0	3
Snow	2	0	0	0	2	0	0	0	0
Fog	0	0	0	0	0	0	0	0	0
Sleet, hail	0	0	0	0	0	0	0	0	0
Not reported	0	1	0	0	0	0	1	0	1
Total	**28**	**29**	**6**	**0**	**17**	**0**	**9**	**15**	**16**
Time									
7:00 AM to 9:00 AM	6	9	2	0	1	0	1	3	2
9:00 AM to 4:00 PM	12	9	4	0	13	0	6	7	9
4:00 PM to 6:00 PM	5	3	0	0	1	0	1	0	3
6:00 PM to 7:00 AM	5	8	0	0	2	0	1	5	2
Total	**28**	**29**	**6**	**0**	**17**	**0**	**9**	**15**	**16**
Crash Rate	0.82		0.16					0.40	
District 4 AverageCrash Rate	**0.88**		**0.63**					**0.88**	

The intersection of Highland Avenue at 1st Avenue experienced six crashes from 2006 through 2008, two of which rear-end crashes. The low occurrence of crashes at this location may be attributed to the restriction of left turns out of 1st Avenue.

Between 1st Avenue and 2nd Avenue, 26 crashes occurred on Highland Avenue. Of those crashes, nine (35 percent) were angle crashes and nine (35 percent) were rear-end crashes. Fifteen (58 percent) of the twenty-eight crashes resulted in property-damage-only accidents. No fatalities occurred on this section of Highland Avenue. The number of crashes east of 1st Avenue and west of 2nd Avenue may in part be due to the lack of a median divider and the density of driveways along this stretch of roadway.

Within this stretch of Highland Avenue, the Highland Avenue / Wexford Street intersection is of particular concern with 17 crashes. Of those 17 crashes, 11 were angle crashes. One-quarter of the crashes at this location resulted in injury. Highland Avenue at Wexford Street is an unsignalized intersection and Highland Avenue carries four lanes. Wexford Street is a common turn-around location for vehicles forced to turn right out of 1st Avenue and intending to travel in the westbound direction. This movement increases the potential for conflicts and may explain the high occurrence of angle crashes.

Fifteen crashes occurred at the intersection of Highland Avenue and 2nd Avenue from 2006 through 2008. Six of the crashes were rear-ends, two were angle crashes, and six were sideswipe, same direction crashes. The crash occurrence at this intersection is below average for a signalized intersection.

Traffic Operations

Merge/Diverge

Capacity/level-of-service analyses were performed for each merge and diverge point for the ramps in the study area based on methodologies contained in the *Highway Capacity Manual*. The level-of-service for merge and diverge areas is based on density for cases of stable operation. Stable operation represents levels-of-service A through E. Level-of-service F exists for a merge area when the total flow departing from the merge area exceeds the capacity on the downstream freeway. Likewise, LOS F exists for diverge areas when the volume entering the diverge area exceeds the capacity on the upstream freeway. Density is not calculated in those cases. Level-of-service criteria for merge and diverge areas are shown in Table 8.

A summary of the merge and diverge analysis results for the existing morning and evening peak hours is presented in Table 9. Detailed capacity analysis worksheets for the existing conditions ramp analysis may be found in Appendix F.

Table 8. Level of Service Criteria for Merge and Diverge Areas

Level of Service	Density (pc/mi/ln)
A	≤ 10
B	> 10 – 20
C	> 20 – 28
D	> 28 – 35
E	> 35
F	Demand exceeds capacity

Table 9. 2007 Existing Highland Avenue Ramp Levels of Service

	Morning Peak Hour		Evening Peak Hour	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Highland Avenue				
I-95/Route 128 NB to Highland Avenue EB	F	*	E	35.2
Highland Avenue EB to I-95/Route 128 NB	F	*	B	17.8
I-95/Route 128 NB to Highland Avenue WB	F	*	D	34.3
Highland Avenue WB to I-95/Route 128 NB	F	*	B	18.3
I-95/Route 128 SB to Highland Avenue WB	E	38.1	F	*
Highland Avenue WB to I-95/Route 128 SB	B	17.4	B	19.2
I-95/Route 128 SB to Highland Avenue EB	E	37.4	E	40.1
Highland Avenue EB to I-95/Route 128 SB	B	16.1	B	19.6

[1] Level-of-Service
[2] Density in passenger cars per mile per lane (pc/mi/ln)
* Volume exceeds capacity. Density is not calculated.

In the morning peak hour at the I-95/Route 128 and Highland Avenue interchange, two of the diverge areas operate at LOS F: I-95/Route 128 northbound to Highland Avenue eastbound and I-95/Route 128 northbound to Highland Avenue westbound. Two of the diverge areas operate at LOS E: I-95/Route 128 southbound to Highland Avenue westbound and I-95/Route 128 southbound to Highland Avenue eastbound. The following two merge areas operate at LOS F: Highland Avenue eastbound to I-95/Route 128 northbound and Highland Avenue westbound to I-95/Route 128 northbound.

In the evening peak hour at the I-95/Route 128 and Highland Avenue interchange, traffic diverging from I-95/Route 128 southbound to Highland Avenue westbound operates at LOS F. Two of the diverge areas operate at LOS E: I-95/Route 128 northbound to Highland Avenue eastbound and I-95/Route 128 southbound to Highland Avenue eastbound. All of the merge areas operate at LOS D or better.

Weave

The Highland Avenue weave sections were not analyzed because travel in the shoulders during the peak hours eliminates the weave segments and these ramps operate as closely spaced merge and diverge points.

Corridor Intersections

In order to achieve acceptable traffic operations for the entire project area, it is necessary to ensure that the local roadways are capable of accepting traffic flows from the improved freeway and ramp systems. In that regard, this section examines the following roadway facilities: Kendrick Street and Highland Avenue. The major intersections along these roadways in the immediate site environs were examined. Upstream and downstream traffic signals were evaluated as necessary. Based on standard methodologies contained in the *Highway Capacity Manual* (HCM), a detailed capacity/level-of-service analysis was performed for the existing morning and evening peak hour traffic volumes for the six local road intersections in the vicinity of the Highland Avenue/Kendrick Street Interchange.

At unsignalized intersections, a methodology for evaluating the relative functioning of intersections controlled by stop or yield signs has been developed, and is based on several assumptions, including:

- Major street flows are not affected by the minor (stop-sign controlled) street movements.
- Left turns from the major street to the minor street are influenced only by opposing major street through flow.
- Minor street left turns are impeded by all major street traffic plus opposing minor street traffic.
- Minor street through traffic is impeded by all major street traffic.
- Minor street right turns are impeded only by the major street traffic coming from the left.

The concept of stop-controlled or yield-controlled intersection analysis is based on the estimate of average total delay on minor streets. The methodology of analysis relies on three elements: the size and distribution of gaps in the major traffic stream, the usefulness of these gaps to the minor stream drivers, and the relative priority of the various traffic streams at the intersection. The results of the analysis provide an estimate of average total delay for the various critical movements at the unsignalized intersections. Correlation between average total delay and the respective levels of service are provided for unsignalized intersections as follows:

Table 10. Level of Service Criteria for Unsignalized Intersections

Level of Service	Control Delay Per Vehicle (seconds)
A	< 10.0
B	10.1 to 15.0
C	15.1 to 25.0
D	25.1 to 35.0
E	35.1 to 50.0
F	> 50.0

At signalized intersections, an additional element must be considered: time allocation. Level of service is based primarily on the average control delay per vehicle for various movements within the intersection. Volume/capacity relationships also affect level of service. Thus, both volume/capacity and delay must be considered to evaluate the overall operation of a signalized intersection. Correlation between average delay per vehicle and the respective levels of service are provided for signalized intersections as follows:

Table 11. Level of Service Criteria for Signalized Intersections

Level of Service	Control Delay Per Vehicle (seconds)
A	< 10.0
B	10.1 to 20.0
C	20.1 to 35.0
D	35.1 to 55.0
E	55.1 to 80.0
F	> 80.0

Weekday Morning Peak Hour

The capacity/level-of-service analysis results for the existing weekday morning peak hour are presented in Table 12. As shown in Table 12, the intersection of Highland Avenue at Hunting Road and Gould Street operates at LOS E with the following movements operating at LOS E or F: eastbound left (LOS F), eastbound shared through and right (LOS F), westbound left (LOS F), northbound shared left and through (LOS E), and southbound left (LOS E).

At the unsignalized intersection of Highland Avenue at 1st Avenue, the eastbound and westbound approaches on Highland Avenue operate at LOS A while the stop controlled northbound approach on 1st Avenue operates at LOS E.

The intersection of Highland Avenue and 2nd Avenue operates at an overall LOS of E, with the westbound left operating at LOS F, both northbound movements operating at LOS F, and the southbound shared left and through operating at LOS E.

The intersection of Kendrick Street at Hunting Road operates at an overall LOS C with all movements operating at LOS D or better. The intersection of Kendrick Street at 3rd Avenue operates at an overall LOS of C with all movements operating at LOS D or better. The intersection of Kendrick Street at 4th Avenue is unsignalized. The free-flowing eastbound and westbound approaches operate at LOS A, while the northbound left, through, and right movement operates at LOS F and the southbound left and through movement operates at LOS F. The southbound right turn operates at LOS B.

Weekday Evening Peak Hour

The capacity/level-of-service analysis results for the existing weekday evening peak hour are also presented in Table 12. The intersection of Highland Avenue at Hunting Road and Gould Street operates at an overall LOS E. The eastbound left and the westbound left movements operate at LOS F. In addition, the following movements operate at LOS E: eastbound shared through and right, northbound shared left and through, and southbound left. The other movements at this intersection operate at LOS D or better.

The intersection of Highland Avenue at 1st Avenue is unsignalized and the eastbound and westbound approaches operate at LOS A. The northbound right turn operates at LOS C.

Highland Avenue at 2nd Avenue operates at LOS F overall. The following movements operate at LOS F: eastbound left/through/right, westbound through/right, northbound left, northbound left/through/right, and southbound left/through. The westbound left movement operates at LOS E and the southbound right movement operates at LOS C.

The intersection of Kendrick Street at Hunting Road operates overall at LOS D. The eastbound shared left, through, and right movement operates at LOS E and the northbound shared left and through movement operates at LOS F. The remaining movements at this intersection operate at LOS D or better.

The intersection of Kendrick Street at 3rd Avenue operates at an overall LOS C. The southbound shared left and through movement operates at LOS E and all movements operate at LOS D or better. The intersection of Kendrick Street and 4th Avenue is unsignalized and the eastbound and westbound approaches are free-flowing and operate at LOS A. The northbound shared left/through/right operates at LOS F and the southbound shared left and through operates at LOS F. The southbound right operates at LOS D.

Table 12. 2007 Existing Highland Avenue/Kendrick Street Levels of Service

			Morning Peak Hour			Evening Peak Hour		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Highland Avenue at Gould Street	EB	L	F	90.9	0.83	F	83.6	0.58
and Hunting Road	EB	TR	F	102.7	1.10	E	58.2	0.88
	WB	L	F	170.0	1.25	F	172.0	1.26
	WB	TR	C	33.4	0.71	C	27.5	0.54
	NB	LT	E	61.4	0.68	E	66.9	0.47
	NB	R	A	3.4	0.39	A	8.5	0.50
	SB	L	E	62.5	0.78	E	60.9	0.82
	SB	TR	D	39.1	0.30	D	46.9	0.59
	Overall		*E*	*76.3*		*E*	*63.5*	
Highland Avenue at 1st Avenue	EB	TR	A	0.0	0.84	A	0.0	0.46
	WB	T	A	0.0	0.33	A	0.0	0.67
	NB	R	E	38.1	0.33	C	18.6	0.31
Highland Avenue at 2nd Avenue	EB	LTR	B	12.8	0.71	F	87.9	1.11
	WB	L	F	301.7	1.59	E	69.3	0.92
	WB	TR	B	18.4	0.87	F	91.5	1.12
	NB	L	F	163.2	1.21	F	161.3	1.26
	NB	LTR	F	95.5	1.02	F	127.4	1.18
	SB	LT	E	60.9	0.47	F	165.2	1.11
	SB	R	C	27.4	0.06	C	21.1	0.25
	Overall		*E*	*61.5*		*F*	*108.6*	
Kendrick Street at Hunting Road	EB	LTR	D	46.6	0.78	E	64.0	0.77
	WB	L	D	40.6	0.49	D	37.4	0.86
	WB	TR	C	31.2	0.59	D	46.5	0.98
	NB	LT	D	51.1	0.72	F	81.0	0.73
	NB	R	A	7.7	0.68	A	1.2	0.14
	SB	L	D	45.3	0.80	D	43.3	0.58
	SB	TR	B	16.4	0.14	D	49.4	0.79
	Overall		*C*	*31.9*		*D*	*44.2*	
Kendrick Street at 3rd Avenue	EB	L	D	42.8	0.71	D	53.1	0.18
	EB	T	C	35.0	0.90	B	17.2	0.32
	EB	R	A	2.4	0.29	A	2.6	0.03
	WB	L	D	44.9	0.46	D	51.4	0.04
	WB	TR	C	29.5	0.57	D	45.0	0.95
	NB	L	C	22.3	0.07	C	29.2	0.57
	NB	TR	B	18.1	0.03	A	9.6	0.14
	SB	LT	D	46.1	0.67	E	64.8	0.77
	SB	R	A	2.9	0.02	B	17.5	0.38
	Overall		*C*	*32.0*		*C*	*34.7*	

Table 13 Continued. 2007 Existing Corridor Intersections Levels of Service

Intersection	Movement		Morning Peak Hour LOS[1]	Morning Peak Hour Delay[2]	Morning Peak Hour V/C[3]	Evening Peak Hour LOS	Evening Peak Hour Delay	Evening Peak Hour V/C
Kendrick Street at 4th Avenue	EB	LTR	A	6.9	0.37	A	5.4	0.20
	WB	LTR	A	0.2	0.40	A	0.3	0.55
	NB	LTR	F	222.6	0.54	F	321.7	1.22
	SB	LT	F	1009.0	2.88	F	Err	6.90
	SB	R	B	12.9	0.14	D	27.4	0.55

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

Detailed capacity analysis worksheets for the existing conditions intersection analysis may be found in Appendix G.

Roadway Design

Roadway Structure

As part of the new interchange at Kendrick Street, a new structure separating the ramps from the C-D Roadway will be required. Further details on this structure appear in later sections of this document.

As a measure to accommodate existing travel demand in the project area and better serve current and future economic development potential, a new interchange is proposed for Kendrick Street. Due to the proximity of Highland Avenue to the north, a C-D Roadway is proposed for both northbound and southbound traffic flows. Figure 13 shows the general concept to be employed at this location.

Note that this design slightly alters the previously documented preferred alternative by separating the northbound C-D Roadway from the Kendrick Street southbound on-ramp. This separation allows for improved traffic operations as presented later in this document. Another difference from the previous submission of this report is that the right turn restriction to and from Kendrick Street at its intersection with the southbound ramps has been eliminated and the right turn is now permitted. The proposed lane configuration of the southbound off-ramp is to now be a dedicated left turn lane and lane which allows left and right turns.

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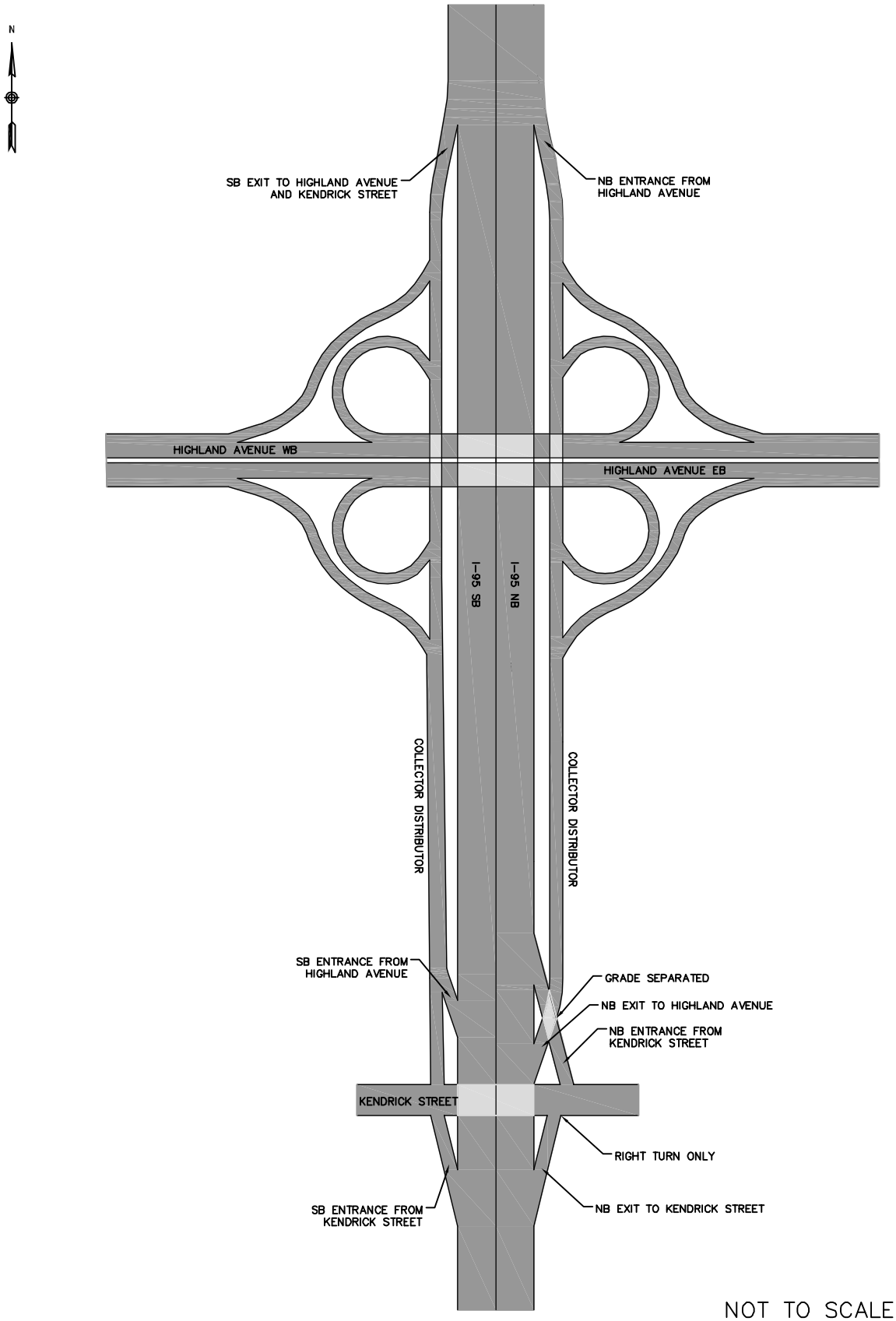

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Figure 13
Collector Distributor Road Concept
I-95 / Rt 128 Add-A-Lane
Highland Ave / Kendrick St

Future Traffic Volumes

No-Build

Figure 11 presents the morning and evening peak hour traffic flows for the No-Build condition for the year 2025. This scenario represents full growth in the study area without the improvements to I-95/Route 128 resulting from this project.

As can be seen during the morning peak hour, there will be an expected growth of approximately 6.6 and 5.9 percent on I-95/Route 128 north and south of Highland Avenue, respectively. During the evening peak hour, the growth is expected to be 10.3 and 7.3 percent north and south of Highland Avenue, respectively. The traffic operations are discussed later in this report.

Build

Figure 12 shows the estimated traffic flow in the study area for the morning and evening peak hours under the Build condition for the year 2025 with the preferred alternative as refined by the EK/HDR joint venture. The following is a discussion of the build traffic volume flows.

Highland Avenue

The new interchange at Kendrick Street will also result in changes to projected traffic volumes at the Highland Avenue interchange. The following are the major traffic volume changes:

- During the morning peak hour there is an expected reduction in exiting traffic from I-95/Route 128 of approximately 150 vehicles northbound and 1080 vehicles southbound. Traffic entering onto I-95/Route 128 from Highland Avenue remains relatively constant.
- During the evening peak hour there are 850 fewer vehicles entering onto I-95/Route 128 from this interchange.

As expected there is very little change in the magnitude of the traffic flow on I-95/Route 128 between the No Build and Build condition. The proposed project does alter travel paths for vehicles traveling to/from Kendrick Street but is not expected to attract new trips to the I-95/Route 128 facility. The differences between the No-Build and Build Conditions are improvements in the traffic operations, not increases in the traffic volumes.

Kendrick Street Interchange

The construction of the new interchange at Kendrick Street along with the proposed C-D roadway will alter travel patterns at Kendrick Street and Highland Avenue. This interchange provides a more direct connection to the industrial/office parks along Kendrick Street. Furthermore, this interchange will result in traffic being diverted from Greendale Avenue, Hunting Road, and Highland Avenue to the new interchange, as it provides a more direct connection for drivers with destinations in the industrial and office parks along Kendrick Street.

As shown on Figure 12, over 1,000 southbound trips and 800 northbound trips will exit from I-95/Route 128 onto Kendrick Street during the weekday morning peak hour in 2025. During the same peak hour 300 vehicles are expected to use the new ramp system to enter onto I-95/Route 128.

During the evening peak hour under the Build condition approximately 1000 vehicles will exit from I-95/Route 128 onto Kendrick Street. Approximately 1,600 vehicles (800 northbound and 800 southbound) will use the new interchange to enter onto I-95/Route 128.

Future Traffic Volumes – Signal Improvements

This project includes new traffic signals at Kendrick Street at the new I-95/Route 128 southbound ramps. This project also includes signal upgrades at the following locations:

- Kendrick Street at Hunting Road
- Kendrick Street at 3rd Avenue
- Highland Avenue at Hunting Road/Gould Street (timing only)

When improvements are proposed for a traffic signal, either for a new installation or improvements to existing signals, MassDOT prefers to use a 10-year planning horizon. In that regard, new forecasts for 2017 were developed using the CTPS model and manual adjustments. The interim year forecasts for 2017 No Build and 2017 Build are summarized in Figure 14 and Figure 15, respectively.

Draft traffic signal plans have been completed as part of this report for all of the signals within the study area which will be proposed new or modified under the Build conditions. These draft traffic signal plans for the intersections listed above can be found in Appendix H. In addition to the draft traffic signal plans, signal warrant analyses have also been completed for each of the proposed and modified traffic signals under the Build conditions. Signal warrant analyses were completed according to the *Manual on Uniform Traffic Control Devices* (MUTCD) and can be found in Appendix I of

this report. These signal warrant analyses show that the existing and proposed signalized intersections meet the MUTCD signal warrants under the 2025 Build condition.

It should be noted that the signal at Highland Avenue and 2nd Avenue is expected to be updated separately from this project through the Needham Street/Highland Avenue Improvement Project. Intersection capacity will be increased by widening the westbound approach to provide a left turn lane and two through lanes. In addition, the northbound approach will be widened to provide a left turn lane, a shared left and through lane, and a right turn lane.

There will also likely be improvements completed at the intersection of Kendrick Street and 4th Avenue in conjunction with future expansions of the Needham Business Park. Based on projected volumes, this intersection will warrant signalization due to the Park expansion. For the purpose of this study, it is assumed that this intersection has been signalized by others in the future year analyses.

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Figure 14
2017 No Build Volumes
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

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Figure 15
2017 Build Volumes
I-95 / Rt 128 Add-A-Lane
Rt 9 / Highland Ave / Kendrick St

Future Analysis

Table 13 displays the levels of service for the ramp merge and diverge movements during the morning peak hour for the 2025 no build and 2025 build scenarios. Table 14 presents the analysis results for the ramps for the evening peak hour for both the 2025 no build and build conditions.

Table 13. Highland Avenue Ramp Levels of Service for 2025 Morning Peak Hour

	No Build		Build	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Highland Avenue				
I-95/Route 128 NB to Highland Avenue EB	F	*	n/a	n/a
Highland Avenue EB to I-95/Route 128 NB	F	*	n/a	n/a
I-95/Route 128 NB to Highland Avenue WB	F	*	n/a	n/a
Highland Avenue WB to I-95/Route 128 NB	F	*	n/a	n/a
I-95/Route 128 SB to Highland Avenue WB	E	41.0	n/a	n/a
Highland Avenue WB to I-95/Route 128 SB	B	18.5	n/a	n/a
I-95/Route 128 SB to Highland Avenue EB	F	*	n/a	n/a
Highland Avenue EB to I-95/Route 128 SB	B	16.6	n/a	n/a
I-95/Route 128 at C-D Road				
I-95/Route 128 NB to C-D Road NB	n/a	n/a	**	**
C-D Road NB to I-95/Route 128 NB	n/a	n/a	F	*
I-95/Route 128 SB to C-D Road SB	n/a	n/a	**	**
C-D Road SB to I-95/Route 128 SB	n/a	n/a	C	23.7
I-95/Route 128 at Kendrick Street				
I-95/Route 128 NB to Kendrick Street	n/a	n/a	F	*
Kendrick Street to I-95/Route 128 NB	n/a	n/a	C	22.4
Kendrick Street to I-95/Route 128 SB	n/a	n/a	C	20.3

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

* Volume exceeds capacity. Density is not calculated.

** Ramp analysis not completed using HCS

Table 14. Highland Avenue Ramp Levels of Service for 2025 Evening Peak Hour

	No Build		Build	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Highland Avenue				
I-95/Route 128 NB to Highland Avenue EB	E	37.4	n/a	n/a
Highland Avenue EB to I-95/Route 128 NB	B	18.1	n/a	n/a
I-95/Route 128 NB to Highland Avenue WB	E	35.8	n/a	n/a
Highland Avenue WB to I-95/Route 128 NB	F	*	n/a	n/a
I-95/Route 128 SB to Highland Avenue WB	F	*	n/a	n/a
Highland Avenue WB to I-95/Route 128 SB	F	*	n/a	n/a
I-95/Route 128 SB to Highland Avenue EB	F	*	n/a	n/a
Highland Avenue EB to I-95/Route 128 SB	F	*	n/a	n/a
I-95/Route 128 at C-D Road				
I-95/Route 128 NB to C-D Road NB	n/a	n/a	D	33.6
C-D Road NB to I-95/Route 128 NB	n/a	n/a	**	**
I-95/Route 128 SB to C-D Road SB	n/a	n/a	**	**
C-D Road SB to I-95/Route 128 SB	n/a	n/a	F	*
I-95/Route 128 at Kendrick Street				
I-95/Route 128 NB to Kendrick Street	n/a	n/a	E	35.3
Kendrick Street to I-95/Route 128 NB	n/a	n/a	C	20.5
Kendrick Street to I-95/Route 128 SB	n/a	n/a	F	*

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

* Volume exceeds capacity. Density is not calculated.

** Ramp analysis not completed using HCS.

During the weekday morning peak hour for the 2025 No Build scenario, the ramp from Highland Avenue westbound to I-95/Route 128 southbound and the ramp from Highland Avenue eastbound to I-95/Route 128 southbound are both expected to operate at LOS B. The remaining ramps in the Highland Avenue Interchange are expected to operate at LOS E or F for the no build scenario. During the weekday evening peak hour, only one ramp will operate at an acceptable LOS. The ramp from Highland Avenue eastbound to I-95/Route 128 northbound is expected to operate at LOS B for the 2025 no build condition. The remaining ramps in the Highland Avenue interchange will operate at LOS E or F during the evening peak hour of the no build condition.

The 2025 Build condition includes construction of Collector-Distributor (C-D) Roads parallel to I-95/Route 128 northbound and southbound at the Highland Avenue Ramps. In addition, a new interchange will also be constructed providing access to Kendrick Street. The Kendrick Street on- and off-ramps will be separate from the C-D Road for I-95/Route 128 northbound. For I-95/Route 128 southbound, the off-ramp to Kendrick Street will utilize the C-D Road, but the on-ramp to I-95/Route 128 will be separate from the C-D Road. Because of the high traffic demand to and from Highland Avenue and

Kendrick Street, this separation of traffic flows allows for better traffic operations. Due to the high demand projected for the southbound C-D ramp, the ramp will be constructed as a two lane off-ramp.

It is expected that the improvements to the ramps in the area of Highland Avenue and Kendrick Street will provide improved access to office parks located along Kendrick Street and will create more direct access to these high traffic generators. By reducing the number of merge and diverge areas along I-95/Route 128 and by separating the Highland Avenue ramps, safety and operations are expected to be improved along I-95/Route 128. By segregating the Highland Avenue ramp traffic from the mainline traffic, ramp traffic to and from Highland Avenue will merge and diverge with vehicles on the C-D Road, which are traveling at lower speeds than those on I-95/Route 128. While merge and diverge conflicts will still occur, those conflicts are expected to be less frequent and will occur at lower speeds. In addition, the number of merge and diverge points that impact the mainline are reduced.

It should be noted that while the results in Table 13 and Table 14 generally show poor levels of service for the merges and diverges in the Build scenario, these results can be somewhat misleading due to limitations in the *Highway Capacity Manual* methodologies. For off-ramps, if the volume upstream of the ramp is over capacity, the density is not calculated for the diverge area, and the LOS reported is F. Similarly for on-ramps, if the volume downstream of the ramp is over capacity, the density of the merge area is not calculated and LOS F is reported. In particular, the off-ramp to the southbound C-D Road and the northbound C-D Road on-ramp cannot be analyzed using these methodologies.

These two ramps are classified as major merge areas by the *Highway Capacity Manual*, due to the merging and diverging of multiple lanes. The HCS procedure does not adjust for mainline lane additions or lane drops at a ramp junction. Therefore, a major merge analysis was completed to account for the multiple lane ramp and mainline lane addition and drop. As indicated on page 25-9 of the HCM, it should be analyzed by comparing the capacities of each additional entering ramp lane and the departing freeway (Exhibit 25-7) to the peak demand flow.

The CD Road on-ramp in the northbound direction creates an added lane to the mainline, resulting in a five lane cross-section downstream of the ramp. Using the data from Exhibit 25-7, the downstream capacity is approximately 2,400 passenger cars per hour (pc/h) per lane or 12,000 pc/h for the roadway. Demand during the morning peak hour is approximately 9,667 pc/h and the demand during the evening peak hour is approximately 10,278 pc/h. Using this methodology, sufficient capacity has been calculated downstream of the ramp for the demand during both the morning and evening peak hours. In addition to these calculations, the ramp was analyzed with HCS utilizing a 5 lane cross-section. Although this is not accurate depiction of how the ramp

is configured, it does generate an approximate level-of-service for the ramp. Using this analysis, the ramp would operate at a LOS D for the morning peak period and at LOS E during the evening peak period.

This same logic can be applied to C-D Road ramp in the southbound direction. This ramp drops a lane which results in a four lane cross-section south of the ramp. Using the data from Exhibit 25-7, the capacity of the mainline at the ramp is approximately 2400 pc/h per lane or 9,600 pc/h downstream of the ramp and 12,000 pc/h upstream of the ramp. Demand during the morning peak hour is approximately 9,111 pc/h and the demand during the evening peak hour is approximately 10,111 pc/h. Therefore, sufficient capacity has been calculated downstream and upstream of the ramp for the demand during the morning and evening peak hours. Again, using HCS to approximate a level-of-service, the ramp would operate at a LOS E during the morning peak period and LOS D during the evening peak period.

The No Build and Build condition analysis worksheets and major merge calculations for the ramp analyses may be found in Appendices J and K, respectively.

Local Street Corridor Intersections

Highland Avenue

The Highland Avenue corridor intersections were analyzed under the 2017 No Build and Build conditions for the morning and afternoon peak hours. Table 15 presents the results for the morning peak hour and Table 16 shows the analysis results for the afternoon peak hour. Detailed capacity analysis worksheets for the Highland Avenue intersections are presented for the No Build and Build conditions in Appendices L and M, respectively.

Table 15. Highland Avenue Levels of Service for 2017 Morning Peak Hour

			No Build			Build		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Highland Avenue at Gould Street	EB	L	F	220.0	1.32	E	66.7	0.73
and Hunting Road	EB	TR	F	101.2	1.10	D	41.0	0.85
	WB	L	F	93.4	1.01	E	63.9	0.21
	WB	TR	C	32.1	0.68	D	41.9	0.71
	NB	LT	E	60.4	0.65	E	67.1	0.79
	NB	R	A	3.4	0.31	B	10.1	0.54
	SB	L	E	61.7	0.78	E	65.4	0.81
	SB	TR	D	46.7	0.47	D	43.4	0.31
	Overall		*E*	*74.2*		*D*	*44.2*	
Highland Avenue at 1st Avenue	EB	TR	A	0.0	0.99	A	0.0	0.75
	WB	T	A	0.0	0.34	A	0.0	0.32
	NB	R	F	83.7	0.66	E	37.7	0.31
Highland Avenue at 2nd Avenue	EB	LTR	D	52.2	0.99	E	63.0	1.02
	WB	L	F	140.6	1.18	F	146.9	1.20
	WB	TR	A	7.5	0.35	A	8.0	0.33
	NB	L	E	74.0	0.81	E	74.8	0.80
	NB	LT	E	74.4	0.81	E	75.2	0.80
	NB	R	B	10.6	0.56	B	11.0	0.59
	SB	LT	F	197.2	1.15	F	162.5	1.07
	SB	R	D	35.8	0.06	A	0.0	0.00
	Overall		*E*	*57.4*		*E*	*62.9*	

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

Table 16. Highland Avenue Levels of Service for 2017 Evening Peak Hour

			No Build			Build		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Highland Avenue at Gould Street	EB	L	F	87.6	0.63	F	81.0	0.68
and Hunting Road	EB	TR	E	58.5	0.88	D	47.6	0.83
	WB	L	F	141.5	1.17	E	62.8	0.78
	WB	TR	C	31.0	0.64	D	36.3	0.83
	NB	LT	F	94.2	0.86	F	99.9	0.89
	NB	R	A	10.0	0.52	A	4.7	0.22
	SB	L	E	62.7	0.83	E	63.6	0.81
	SB	TR	D	45.7	0.55	E	73.6	0.91
	Overall		*E*	*59.0*		*E*	*50.6*	
Highland Avenue at 1st Avenue	EB	TR	A	0.0	0.48	A	0.0	0.47
	WB	T	A	0.0	0.79	A	0.0	0.75
	NB	R	C	24.1	0.44	C	21.2	0.45
Highland Avenue at 2nd Avenue	EB	LTR	C	33.5	0.89	D	43.5	0.96
	WB	L	F	111.1	1.07	D	36.2	0.70
	WB	TR	B	16.2	0.56	B	19.0	0.72
	NB	L	F	158.1	1.25	D	50.0	0.86
	NB	LT	F	162.2	1.26	D	48.9	0.85
	NB	R	B	19.2	0.59	D	44.4	0.89
	SB	LT	F	217.5	1.29	F	387.7	1.71
	SB	R	B	19.4	0.22	C	21.8	0.35
	Overall		*F*	*77.3*		*D*	*50.6*	

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

Highland Avenue at Hunting Road and Gould Street

Under the No Build condition, the intersection of Highland Avenue at Gould Street and Hunting Road is expected to operate at LOS E overall in the morning and evening peak hours. During the morning peak hour, the following movements are expected to operate at LOS F: the eastbound left, eastbound through/right, and westbound left. During the evening peak hour, the following movements are expected to operate at LOS F: eastbound left, westbound left, and northbound left/through. The remaining movements of the intersection of Highland Avenue at Gould Street and Hunting Road are expected to operate at LOS E or better.

Under the Build condition, this intersection is expected to operate at LOS D during the weekday morning peak hour. The difference between the two scenarios is related to the shifts in traffic patterns as well as adjustments to the signal timing. Under the Build

condition, none of the movements are expected to operate at LOS F during the morning peak hour. During the evening peak hour, signal timings were adjusted to balance overall delays while minimizing delays on the Highland Avenue mainline. The intersection continues to operate at LOS E in the evening peak hour under the 2017 Build condition.

Highland Avenue at First Avenue

Highland Avenue at 1st Avenue is an unsignalized intersection. Under the No Build condition, the stop-controlled northbound movement is expected to operate at LOS F during the morning peak hour and at LOS C during the evening peak hour. Under the Build condition, this intersection will remain unsignalized and the northbound approach is expected to operate at LOS E during the morning peak hour and at LOS C during the evening peak hour. The decreased delay at this intersection is a result of a decrease in traffic volumes that occurs due to the Kendrick Street ramps.

Highland Avenue at Second Avenue

The intersection of Highland and Second Avenue will be improved as part of the Town of Needham's improvement project. The improvements associated with the Town's project include widening to provide an additional westbound through lane and a northbound exclusive right turn lane. Table 15 and Table 16 show the No Build and Build conditions, respectively, as part of this analysis. Even with the Town's improvement project, traffic operations at this location are strained and there will be failing LOS and long delays during peak hours. It is recommended that Highland Avenue receive priority for green time at this signal in order to keep the major arterial delays to a minimum and to prevent long vehicle queues resulting in gridlock. The construction of this project and the improvements such as the new Kendrick Street interchange do not result in any additional delays to this corridor. In fact this project is expected to decrease traffic volumes on Highland Avenue. The long delays at this intersection are a result of projected background growth and the proposed expansion of the New England Business Center. Capacity deficiencies at this location should be addressed during the permitting process for the specific development projects that contribute to the delays.

Kendrick Street

The Kendrick Street corridor is expected to have the most significant changes from this project. The project includes construction of a new interchange at Kendrick Street. Between Hunting Road and 3rd Avenue, two new intersections will be added: one at the I-95/Route 128 southbound ramps and one at the I-95/Route 128 northbound ramps. The new interchange will result in increased traffic on Kendrick Street in the vicinity of the

industrial and office parks. The improvement scheme for Kendrick Street is illustrated in Figure 16. The improvements are listed below:

- Signal timing adjustments at Kendrick Street and Hunting Road
- New traffic signal at Kendrick Street and the I-95/Route 128 southbound off ramp
- No left turn from the I-95/Route 128 northbound off ramp
- Additional eastbound lane on Kendrick Street between the northbound I-95/Route 128 ramps and 3rd Avenue
- Re-stripe northbound approach at Kendrick Street and 3rd Avenue

The morning peak hour 2017 No Build and Build analysis results for the intersections along the Kendrick Street corridor are presented in Table 17. The evening peak hour analysis results are shown in Table 18. Detailed capacity analysis worksheets for the Kendrick Street intersections are presented for the No Build and Build conditions in Appendices N and O, respectively.

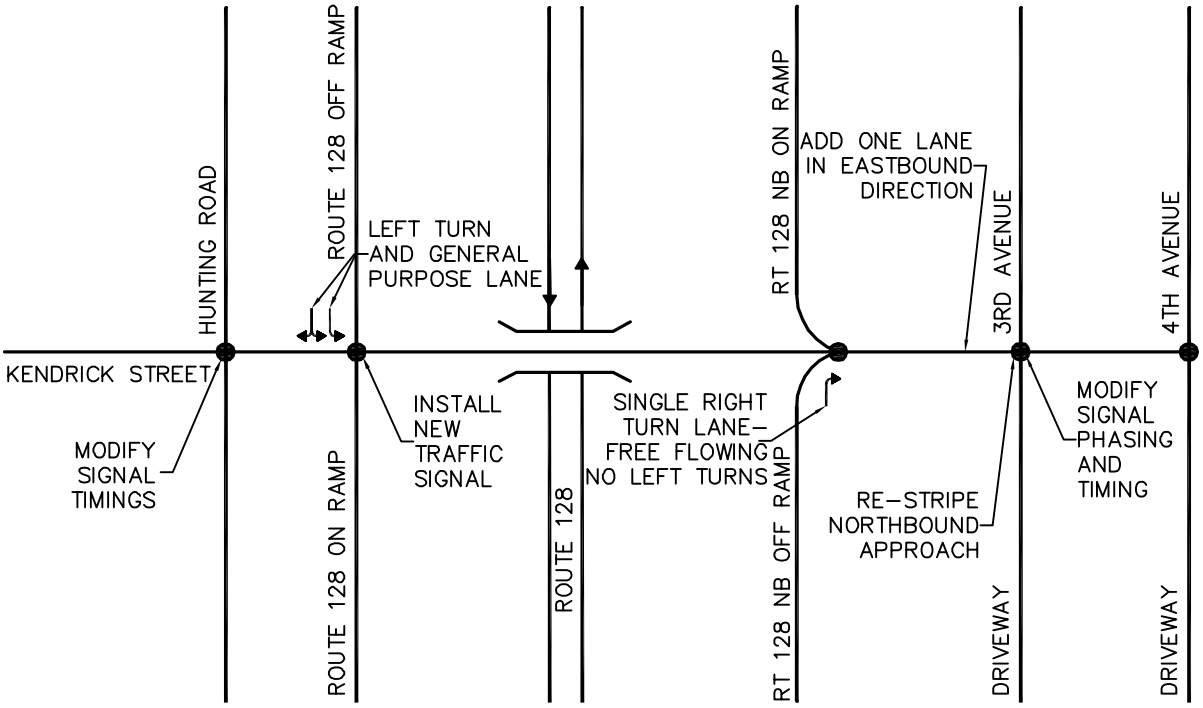

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Figure 16
Kendrick Street Improvement Plan
I-95 / Rt 128 Add-A-Lane
Highland Ave / Kendrick St

Table 17. Kendrick Street Levels of Service for 2017 Morning Peak Hour

			No Build			Build		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Kendrick Street at Hunting Road	EB	LTR	D	46.0	0.78	C	26.4	0.50
	WB	L	E	70.8	0.86	C	33.4	0.46
	WB	TR	C	27.3	0.46	C	23.5	0.33
	NB	LT	D	51.6	0.68	D	49.1	0.84
	NB	R	B	13.0	0.80	A	1.7	0.44
	SB	L	F	94.9	1.07	D	40.6	0.57
	SB	TR	B	18.0	0.16	B	17.1	0.07
	Overall		*D*	*44.5*		*C*	*24.8*	
Kendrick Street at I-95/Route 128	EB	T	n/a	n/a	n/a	D	44.8	0.85
SB Ramps	WB	L	n/a	n/a	n/a	D	50.0	0.64
	WB	T	n/a	n/a	n/a	B	12.3	0.44
	SB	LR	n/a	n/a	n/a	E	62.5	0.97
	Overall		*n/a*	*n/a*		*D*	*46.9*	
Kendrick Street at I-95/Route 128	EB	T	n/a	n/a	n/a	A	0.0	0.00
NB Ramps	WB	TR	n/a	n/a	n/a	A	0.0	0.00
	NB	R	n/a	n/a	n/a	A	0.0	0.00
Kendrick Street at 3rd Avenue	EB	L	D	49.5	0.83	F	119.6	1.16
	EB	T	D	42.5	0.96	E	73.7	1.09
	EB	R	A	2.1	0.32	A	1.6	0.39
	WB	L	D	54.2	0.52	F	163.8	1.13
	WB	TR	D	38.8	0.76	E	55.2	0.91
	NB	L	C	29.2	0.08	D	51.2	0.24
	NB	TR	C	24.9	0.09	n/a	n/a	n/a
	NB	LTR	n/a	n/a	n/a	D	35.2	0.21
	SB	LT	E	58.8	0.73	D	49.6	0.44
	SB	R	A	2.4	0.05	A	0.0	0.03
	Overall		*D*	*39.1*		*E*	*72.6*	
Kendrick Street at 4th Avenue	EB	LTR	A	8.9	0.34	D	25.0	0.75
	WB	LTR	A	0.2	0.01	A	0.3	0.01
	NB	LTR	F	318.1	0.69	F	Err	Err
	SB	LT	F	Err	5.47	F	Err	Err
	SB	R	B	13.6	0.14	C	16.3	0.36

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

Table 18. Kendrick Street Levels of Service for 2017 Evening Peak Hour

			No Build			Build		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Kendrick Street at Hunting Road	EB	LTR	F	81.0	0.93	B	14.7	0.07
	WB	L	E	58.4	1.00	B	16.5	0.26
	WB	TR	F	80.5	1.10	D	40.5	0.70
	NB	LT	F	94.9	0.83	D	47.1	0.52
	NB	R	A	1.2	0.14	A	1.2	0.07
	SB	L	D	48.1	0.65	C	26.7	0.14
	SB	TR	D	43.5	0.66	E	64.1	0.95
	Overall		*E*	*64.5*		*D*	*40.1*	
Kendrick Street at I-95/Route 128	EB	T	n/a	n/a	n/a	C	29.0	0.27
SB Ramps	WB	L	n/a	n/a	n/a	C	33.9	0.80
	WB	T	n/a	n/a	n/a	B	18.9	0.79
	SB	LR	n/a	n/a	n/a	D	48.9	0.81
	Overall		*n/a*	*n/a*		*D*	*35.0*	
Kendrick Street at I-95/Route 128	EB	T	n/a	n/a	n/a	A	0.0	0.00
NB Ramps	WB	TR	n/a	n/a	n/a	A	0.0	0.00
	NB	R	n/a	n/a	n/a	A	0.0	0.00
Kendrick Street at 3rd Avenue	EB	L	F	80.8	0.80	F	162.2	1.22
	EB	T	B	19.0	0.29	B	10.5	0.30
	EB	R	A	2.2	0.04	A	1.4	0.04
	WB	L	E	57.0	0.08	D	50.6	0.29
	WB	TR	F	105.1	1.13	D	50.6	1.00
	NB	L	C	34.5	0.67	F	181.2	1.22
	NB	TR	B	11.4	0.15	n/a	n/a	n/a
	NB	LTR	n/a	n/a	n/a	F	157.3	1.16
	SB	LT	F	139.3	1.13	F	153.1	1.14
	SB	R	C	20.5	0.58	A	0.9	0.45
	Overall		*E*	*70.4*		*E*	*62.5*	
Kendrick Street at 4th Avenue	EB	LTR	A	7.2	0.24	A	8.7	0.31
	WB	LTR	A	0.3	0.01	A	0.2	0.01
	NB	LTR	F	Err	3.08	F	Err	Err
	SB	LT	F	Err	13.40	F	Err	9.77
	SB	R	F	60.1	0.89	F	181.1	1.30

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

Kendrick Street at Hunting Road

Under the no build condition, the intersection of Kendrick Street at Hunting Road is expected to operate at LOS D and E for the morning and evening peak hours, respectively. For both conditions, the volume to capacity ratio is greater than 1.0 for at least one movement during each peak hour.

With the signal timing improvements in place, under the build condition the traffic operations improve at this location to LOS C and LOS D for the weekday morning and evening peak hours, respectively. The improvements to the traffic operations are related to the traffic diversion from Hunting Road onto I-95/Route 128 to the Kendrick Street ramps as well as minor signal timing adjustments.

Kendrick Street at I-95/Route 128 Southbound Off Ramp

This location is to be signalized under the proposed conditions. The off ramp will be constructed to provide one left turn lane and one general purpose lane. This intersection only exists under the build condition as a signalized intersection. Since the signal is part of the proposed design, a signal warrant analysis was completed according to the *Manual on Uniform Traffic Control Devices* (MUTCD). The intersection of Kendrick Street at the proposed southbound off-ramp meets the signal warrants for Eight-Hour, Four-Hour and Peak Hour Volumes. The warrant for signalization at this intersection can be found in Appendix I. It is expected to operate at LOS D during the weekday morning and evening peak hours.

Kendrick Street at I-95/Route 128 Northbound Off Ramp

The current scheme for this ramp is to allow only right turns to Kendrick Street eastbound. Kendrick Street will be constructed with an additional eastbound lane from this ramp terminus easterly to the intersection of Kendrick Street with 3rd Avenue. The traffic operations for the northbound ramp to Kendrick Street eastbound will be free flowing with no delays or operational problems expected.

Kendrick Street at 3rd Avenue

The intersection of Kendrick Street at 3rd Avenue will operate at LOS D and LOS E under the No Build condition for the weekday morning and evening peak hours, respectively. The Build condition with the new interchange requires minor improvements to this location. In addition to signal timing and phasing adjustments, the northbound approach should be re-striped to provide an exclusive left turn lane and a shared left/through/right lane. With these improvements, the intersection will operate at LOS E for the morning and evening peak hours.

It should be noted that the improvements mentioned above are the improvements required for the changes in traffic volumes as a result of the I-95/I-93 Transportation Improvement Project (Bridge V). The 2017 peak hour traffic volumes include significant growth assumed to occur in the New England Business Center. With the redevelopment, additional improvements will be required separate from those required as part of this Project for acceptable operations at this intersection. Those improvements include:

- Additional eastbound left turn lane
- Additional westbound lane between 3rd Avenue and the I-95/Route 128 northbound on-ramp. This ramp will allow the channelized southbound right turn volume from 3rd Avenue to flow freely.

These improvements would be refined during the permitting process for the potential park expansion and would likely be the responsibility of the developer for the park expansion.

Kendrick Street at 4th Avenue

Currently delays and volume to capacity (V/C) ratios are high for the 4th Avenue approach. With additional traffic on Kendrick Street, delays for the stop-controlled approaches will increase. Under the No build condition, the 4th Avenue approach and the northbound driveway approach experience long delays and there are insufficient gaps for those motorists to enter into the Kendrick Street traffic stream. The northbound movements and the southbound left and through movements will operate at LOS F for both peak hours. The southbound right movement will also operate at LOS F during the evening peak hour.

Without improvements, under the Build condition, the northbound movements and the southbound left and through movements will continue to operate at LOS F during both peak hours. The southbound right movement will also continue to operate at LOS F during the evening peak hour. The increases in traffic volumes at this intersection from the existing year to the future build year (2017) can be largely attributed to the expected growth in the New England Business Center. While this intersection will experience some increase in traffic as a result of the Add-A-Lane Project and while a signal is currently warranted, 4th Avenue serves the New England Business Center and its expansion would contribute to degrading operations at this intersection. For this reason, it is expected that future improvements to the intersection of Kendrick Street and 4th Avenue would be the responsibility of the proponent of the Business Center expansion.

As mentioned above, no improvements are recommended for this intersection as part of the Add-A-Lane Project. The improvements required in order to achieve acceptable traffic operations at this intersection include installing a new traffic signal and constructing an eastbound left turn lane.

Route 9 Interchange

Existing Conditions

Route 9 Interchange

The second of the two existing interchanges in the study area is located at Route 9. This interchange has a cloverleaf ramp configuration. The ramp configurations create a weave section within the interchange in each direction of travel. The weave sections were analyzed and are described as follows:

- I-95/Route 128 northbound between the on-ramp from Route 9 eastbound and the off-ramp to Route 9 westbound
- I-95/Route 128 southbound between the on-ramp from Route 9 westbound and the off-ramp to Route 9 eastbound

Interchange Conditions

Route 9 at Sun Life and Harvard Pilgrim Drives

Interstate 95/Route 128 is designated as a north-south highway and travels in a northwest-southeast direction at the study interchange with a speed limit of 55 miles per hour (mph). South of the Route 9 Interchange, I-95/Route 128 currently provides three travel lanes in each direction. From 6:00 AM until 10:00 AM and again between 3:00 PM and 7:00 PM, travel is allowed in the breakdown lanes in both directions. With travel permitted in the breakdown lanes, I-95/Route 128 operates with four through travel lanes and no right-hand shoulder in each direction during the morning and evening peak hours. To assure that motorists have locations to pull over out of the active traffic stream, there are "pullouts" spaced at approximately ½ mile intervals in both the northbound and southbound directions.

The existing interchange provides full access between I-95/Route 128 and Route 9 through a full cloverleaf configuration. The existing ramp configurations create a weave section within the interchange in each direction of travel on both roadways.

Route 9 (Worcester Street) travels east-west and is a median divided four lane roadway. The I-95/Route 128 interchange at Route 9 is a cloverleaf interchange providing right-hand ramps along Route 9. Aside from the I-95/Route 128 ramp intersections, the study area on Route 9 includes one intersection: Route 9 at the Sun Life Driveway. The intersection of Route 9 at the Sun Life Driveway is a four-leg signalized intersection. The eastbound approach has a left turn lane, two through lanes, and a shared through and right turn lane. The right-most eastbound through lane becomes an exit only lane to I-95/Route 128 southbound just east of the intersection. The westbound approach has a left turn lane, three through lanes, and a right turn lane. The three westbound through lanes reduce to two through lanes approximately 0.1 miles west of the intersection. The northbound approach has a shared left turn and through lane and a right turn lane. The southbound approach has a left turn lane, a shared left turn and through lane, and a right turn lane.

Highway Structures

The existing bridges carrying I-95/Route 128 over Route 9 are two span steel stringer structures which were constructed in 1962. Both of the bridges were rehabilitated in 1995. The bridges each carry four lanes of I-95/Route 128 traffic and an additional on off ramp weave lane. Both of these I-95/Route 128 barrels are supported on concrete decks which are 64 feet curb to curb and are separated by a 40 foot open median. These structures span over Route 9, which has a 108-foot wide cross section including a center median of varying width. The median contains a center pier and there is a 6 foot sidewalk adjacent to each abutment. Increase of the vertical clearance over Route 9 is required based on the existing clearance, which is approximately 14 feet.

Traffic Volumes

As mentioned previously, the current conditions of this area were studied in great detail by CTPS. As such, this report has used the traffic counts collected by CTPS and factored them to reflect conditions in 2007. Automatic Traffic Recorders (ATRs) were deployed by MassDOT at key locations in order to accomplish this task. Also, the CTPS study did not include the interchange of I-95/Route 128 at Route 9. New counts were conducted by MassDOT at this location in July 2007. Existing traffic volumes are graphically depicted in Figure 2.

Traffic Safety

Crash data for Route 9 (also called Worcester Street in Wellesley) was summarized by location between its intersection with Maple Street and its intersection with Quinobequin Road, as shown in Table 19. For the years 2006 through 2008, 108 crashes occurred on this segment of Route 9. Of the 108 crashes summarized in Table 19, the

two most common crash types were rear-end (62 percent) and single vehicle crashes (23 percent).

Thirteen crashes occurred on Route 9 at its intersection with Dearborn Street and Sun Life Park, including anything within 200 feet to the east of the intersection. This section of roadway is adjacent to the I-95/Route 128 ramps. Six (46 percent) of the crashes were rear-ends. Rear-end crashes at this location are most likely the result of congestion from merging, diverging, and weaving traffic. Rear-end crashes are not generally severe crashes resulting often in property damage only. The other crashes were sideswipe, same direction, and angle.

There were 14 crashes at the intersection of the I-95/Route 128 southbound ramps with Route 9 from 2006 through 2008. Forty-three percent (6 of them) were rear-end collisions, and seven of the crashes (50 percent) were single vehicle crashes. Six of all crashes at this location were property damage only, and another six resulted in a non-fatal injury and the severity of two crashes is unknown.

Meanwhile, there were 26 crashes that occurred at the intersection of Route 9 with the I-95/Route 128 northbound ramps, the majority of them being rear-end collisions and single vehicle crashes. Thirty-three crashes were known to have occurred in the vicinity of I-95/Route 128, but not enough information existed to know exactly where they occurred. They may have been near the I-95/Route 128 northbound or the I-95/Route 128 southbound ramps or simply near the overpass. Of these collisions, 23 (70 percent) were rear-end collisions and 25 (76 percent) resulted in property damage only. Four crashes resulted in non-fatal injury.

At the intersection of Route 9 and Williams Street there were 20 crashes recorded from 2006 through 2008. Of these, ten (50 percent) were rear-end collisions. The remaining were of the following types: single-vehicle, sideswipe (same direction), and angle. One was unknown. In terms of severity, seventeen (85 percent) were property damage only, and two (10 percent) resulted in non-fatal injury.

Table 19. Route 9 Crash Summary

	Maple / Street	Dearborn Street/ Sun Life Park	I-95 SB Ramps	I-95 Vicinity	I-95 NB Ramps	William Street	Quinobequin Road
2006	1	3	5	14	5	10	0
2007	0	6	2	13	9	5	0
2008	1	4	7	6	12	5	0
Total	**2**	**13**	**14**	**33**	**26**	**20**	**0**
Type							
Rear-end	0	6	6	23	9	10	0
Sideswipe, same direction	1	5	0	5	4	2	0
Angle	1	2	0	2	1	4	0
Single vehicle crash	0	0	7	1	9	3	0
Head-on	0	0	0	0	0	0	0
Rear-to-rear	0	0	0	0	0	0	0
Sideswipe	0	0	0	1	0	0	0
Not reported	0	0	1	1	3	1	0
Unknown	0	0	0	0	0	0	0
Total	**2**	**13**	**14**	**33**	**26**	**20**	**0**
Severity							
Fatal	0	0	0	0	0	0	0
Injury	0	2	6	4	6	2	0
PDO	1	11	6	25	18	17	0
Not Reported	1	0	2	3	2	1	0
Unknown	0	0	0	1	0	0	0
Total	**2**	**13**	**14**	**33**	**26**	**20**	**0**
Weather							
Clear	1	4	7	23	18	8	0
Cloudy	0	5	4	5	2	9	0
Rain	1	3	3	5	4	3	0
Snow	0	0	0	0	2	0	0
Fog	0	0	0	0	0	0	0
Sleet, hail	0	0	0	0	0	0	0
Not reported	0	1	0	0	0	0	0
Total	**2**	**13**	**14**	**33**	**26**	**20**	**0**
Time							
7:00 AM to 9:00 AM	0	1	1	6	3	2	0
9:00 AM to 4:00 PM	0	7	6	16	14	6	0
4:00 PM to 6:00 PM	0	4	2	4	2	9	0
6:00 PM to 7:00 AM	2	1	5	7	7	3	0
Total	**2**	**13**	**14**	**33**	**26**	**20**	**0**

Crash Rate	0.25
District 4 Average Crash Rate	**0.88**

Source: MassDOT

Traffic Operations

Merge/Diverge

Analyses were performed for each merge and diverge point for the ramps at the interchange of I-95/Route 128 and Route 9 based on methodologies contained in the HCM. As described previously, the level of service for merge and diverge areas is based on density for cases of stable operation. Stable operation represents levels of service A through E. Level of service F exists for a merge area when the total flow departing from the merge area exceeds the capacity on the downstream freeway. Likewise, level of service F exists for diverge areas when the volume entering the diverge area exceeds the capacity on the upstream freeway. Level of service criteria for merge and diverge areas was presented in Table 8.

Ramp capacity analyses were performed for existing and projected conditions using the latest version of the Highway Capacity Software, HCS+. The existing conditions ramp capacity analyses worksheets are included in Appendix F.

Results of the existing conditions ramp capacity analyses, summarized in Table 20, indicated that most ramps currently operate at an unacceptable level of service during either the AM and/or PM peak hour, with the exception of the I-95 southbound to Route 9 westbound ramp, and the Route 9 westbound to I-95 southbound ramp.

The following ramps fall within exist weave sections on Route 128 and Route 9:

- Route 9 eastbound to I-95 northbound
- I-95 northbound to Route 9 westbound
- I-95 southbound to Route 9 eastbound
- Route 9 westbound to I-95 southbound

Ramp capacity analyses have not been conducted at these locations. Instead traffic operations at these ramps are analyzed in the weave analysis, which can be found in the following section of this report.

Table 20. 2007 Existing Route 9 Ramp Levels of Service

	Morning Peak Hour		Evening Peak Hour	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Route 9				
I-95/Route 128 NB to Route 9 EB	F	39.0	D	34.1
Route 9 WB to I-95/Route 128 NB	F	37.6	F	33.2
Route 9 EB to I-95/Route 128 SB	D	29.8	F	30.8
I-95/Route 128 SB to Route 9 WB	D	33.7	D	33.0

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

Weave

Capacity/level-of-service analyses were performed for the weave sections on I-95/Route 128 at the Route 9 interchange. The analyses performed are based on *HCM* methodologies. Level-of-service for weave sections is determined by the density of traffic in the weave section, as summarized in Table 21. Parameters that affect density include: weave segment length, number of lanes, type of weaving configuration, and the type of terrain in the weave segment.

A summary of the results is presented in Table 22. As shown in Table 22, the northbound weave section in the I-95/Route 128 and Route 9 interchange operates at LOS F during both the morning and evening peak hours. The southbound weave section in the I-95/Route 128 and Route 9 interchange operates at LOS E in the morning peak hour and at LOS F in the evening peak hour. The capacity analysis worksheets for the existing conditions weave analysis may be found in Appendix P.

Table 21. Freeway Weaving Segment Level of Service Criteria

Level of Service	Density (pc/mi/ln)
A	≤ 10
B	> 10 – 20
C	> 20 – 28
D	> 28 – 35
E	> 35 – 43
F	> 43

Table 22. 2007 Existing Weave Segment Levels of Service

	Morning Peak Hour		Evening Peak Hour	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Route 9				
Northbound	F	77.1	F	69.7
Southbound	E	41.5	F	47.6

Corridor Intersections

Based on standard methodologies contained in the *Highway Capacity Manual* (HCM), a detailed capacity/level-of-service analysis was performed for the existing morning and evening peak hour traffic volumes for the one local road intersection in the vicinity of the Route 9 Interchange.

The signalized intersection capacity analysis methodology was described previously under the Highland Avenue/Kendrick Street Interchange. The level of service criteria for signalized intersections was presented in Table 11.

Weekday Morning Peak Hour

The capacity/level-of-service analysis results for the existing weekday morning peak hour are presented in Table 23. As shown in Table 23, the signalized intersection of Route 9 at the Sun Life and Harvard Pilgrim driveways operated at an overall LOS of C. One movement operates at LOS F: the southbound through movement. The remaining movements operate at LOS D or better.

Table 23. 2007 Existing Route 9 Intersection Levels of Service

			Morning Peak Hour			Evening Peak Hour		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Route 9 at Sun Life/Harvard Pilgrim	EB	L	C	21.3	0.53	A	9.9	0.20
	EB	TR	C	23.1	0.89	C	20.4	0.71
	WB	L	D	35.8	0.64	A	9.0	0.11
	WB	T	B	13.6	0.55	C	21.3	0.75
	WB	R	A	3.9	0.49	A	6.7	0.07
	NB	LT	D	53.0	0.04	F	263.7	1.44
	NB	R	A	9.8	0.06	A	5.7	0.44
	SB	L	D	53.5	0.17	F	271.5	1.44
	SB	T	F	92.5	0.88	F	290.0	1.49
	SB	R	B	10.2	0.06	A	5.0	0.24
	Overall		*C*	*20.4*		*D*	*47.1*	

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

Weekday Evening Peak Hour

The capacity/level-of-service analysis results for the existing weekday evening peak hour are also presented in Table 23. As shown in Table 23, the intersection of Route 9 at the Sun Life and Harvard Pilgrim driveways operates at LOS D. Failing movements include: northbound shared left and through, southbound left, and southbound through. The remaining movements operate at LOS C or better.

Detailed capacity analysis worksheets for the existing conditions intersection analysis may be found in Appendix G.

Roadway Design

Local Roadways

In order to achieve acceptable traffic operations for the entire project area, it is necessary to insure that the local roadways are capable of accepting traffic flows from the improved freeway and ramp systems. In that regard, this section examines the following roadway facilities located at Route 9 (Worcester Street).

The major intersections along these roadways in the immediate site environs were examined. Upstream and downstream traffic signals were evaluated as necessary. Originally, the alterations to the Route 9 at I-95/Route 128 interchange were proposed to be temporary and were primarily related to the traffic management and construction staging elements of this project. However, MassDOT has expressed interest in permanently implementing the temporary improvements at the Route 9 Interchange. Due to the application of the construction staging set up as a permanent interchange configuration, further analysis was conducted and is described in later sections of this report.

Future Alternatives

In an effort to determine the most appropriate interchange configuration for the Route 9 at I-95/Route 128 interchange, several alternatives were considered. A full technical analysis was completed as part of an Interchange Modification Report and can be found in Appendix Q. The following alternatives were considered:

- No Build Alternative: Full Cloverleaf
- Build Alternative 1: Full Cloverleaf Interchange with Compliant Geometry
- Build Alternative 2: Diamond Interchange
- Build Alternative 3: Diverging Diamond Interchange
- Build Alternative 4: Single Point Urban Interchange
- Build Alternative 5: Partial Cloverleaf Interchange

No Build Alternative - Full Cloverleaf

The future No Build roadway network includes an additional travel lane in each direction on I-95/Route 128 (as a result of the I-95/93 (Route 128) Transportation Improvement Plan Project) and the existing full cloverleaf geometry with right-hand maneuvers to and from Route 9 at all I-95/Route 128 ramps. The weave conditions along I-95/Route 128 and along Route 9 will continue to occur for the future No Build condition.

Build Alternative 1 – Full Cloverleaf Interchange with Compliant Geometry

Build Alternative 1 was considered to determine the feasibility of maintaining the existing Full Cloverleaf operations for the study interchange. The configuration, and its expected impacts to the surrounding developments, was reviewed to determine its feasibility. A review of the proposed interchange configuration reveals that, with the redesign of all on and off-ramps to meet AASHTO standards, this configuration would be expected to significantly impact the existing development on all four quadrants of the proposed interchange. The proposed ramp modifications would be anticipated to significantly impact office developments located on the northeast and northwest quadrant of the interchange. On the south side of Route 9, the proposed ramp modifications would be expected to significantly impact Sun Life Financial and residential developments. Given the significant impacts expected as a result of the reconfiguration of the existing ramps to meet AASHTO standards while maintaining a Full Cloverleaf operation, Build Alternative 1 is not a practical solution.

Build Alternative 2 – Diamond Interchange

Build Alternative 2 would be a complete reconstruction of the interchange as a Diamond interchange. All ramps would meet current AASHTO standards. With this geometry, traffic along Route 9 would be controlled by two signals; one at the I-95/Route 128 northbound ramps and one at the I-95/Route 128 southbound ramps. Right turn movements exiting the I-95/Route 128 ramps would operate under yield control. Right turn movements from Route 9 onto I-95/Route 128 would operate as free-flow. Dual left turn lanes would be provided on Route 9 at the signalized intersections. The proposed traffic signals would operate in a coordinated signal system with the existing traffic signal at Route 9/Sun Life/Harvard Pilgrim. Figure 18 shows the proposed interchange design concept for this alternative.

With the removal of the loop ramps connecting Route 9 to I-95/Route 128, the existing weave conditions along mainline I-95/Route 128 would be eliminated in both the northbound and southbound directions of travel. Further, the weave conditions along Route 9 in both the eastbound and westbound directions of travel would also be eliminated with the proposed interchange configuration. This would eliminate any accidents expected to occur as a result of the weave conditions, which could include, among others, rear-end and side-swipe accidents. In addition, the existing safety concern resulting from the weaving maneuver performed from the southbound off-ramp to Route 9 -westbound to the left-turn lane into Sun Life/Harvard Pilgrim, across the Route 9 westbound traffic would be eliminated with the signalization of the southbound off-ramp traffic. Finally, ample queue storage would be provided for the westbound-to-southbound and the eastbound-to-northbound left-turn traffic to assure

that the queues from these movements do not spill back into the through traffic stream. This improvement may also reduce the rear-end accidents currently observed along the corridor. Therefore, safety conditions for this Build alternative are expected to improve in comparison to the No Build conditions.

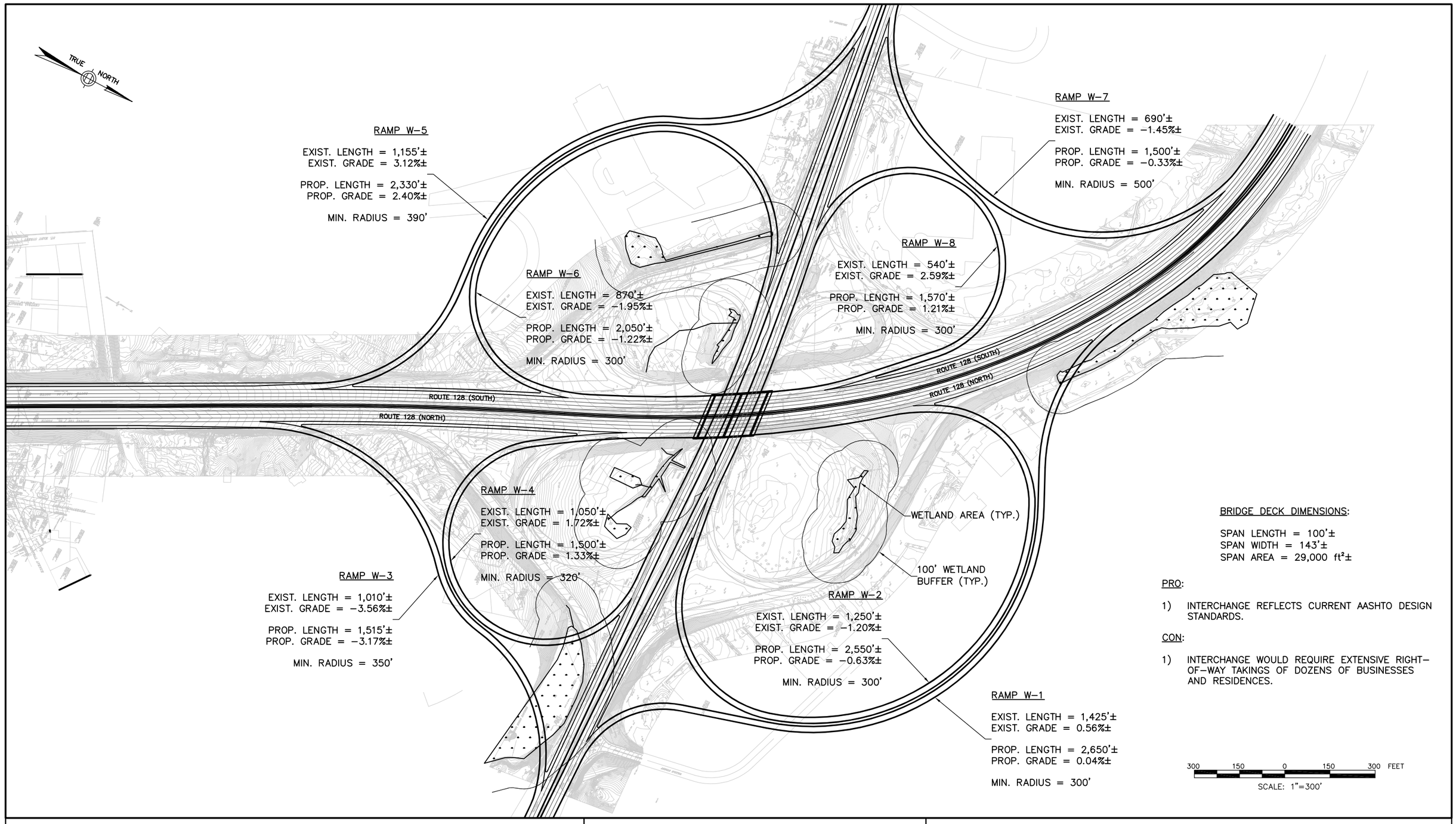
Build Alternative 3 – Diverging Diamond Interchange

Build Alternative 3 was developed as a Diverging Diamond interchange. All ramps would be reconfigured to meet current AASHTO standards. With this geometry, the eastbound and westbound travel movements along Route 9 would cross at a signalized intersection west of I-95/Route 128 and again at a signalized intersection east of I-95/Route 128.

Under this scenario, the left turn movements of a conventional diamond interchange are converted to free flowing or merge movements by crossing the two directions of travel along Route 9. Right turn movements entering ramps are free-flow and right turn movements exiting ramps are under yield condition. The Route 9 traffic reverses direction at two signalized intersections; one to the east of Route 128 and one to the west of Route 128. The signalized intersections do not have left turn movements, allowing the signals to operate in two phases; one phase for eastbound traffic and one phase for westbound traffic.

Figure 19 shows the proposed interchange design concept for this alternative.

With the removal of the loop ramps connecting Route 9 to I-95/Route 128, the existing weave conditions along mainline I-95/Route 128 would be eliminated in both the northbound and southbound directions of travel. This would eliminate any accidents expected to occur as a result of the weave conditions, which could include, among others, rear-end and side-swipe accidents. In addition, the existing safety condition occurring as a result of the weaving maneuver performed by the southbound-to-westbound traffic and the westbound traffic along Route 9 would be eliminated with the signalization of the southbound off-ramp traffic. However, a new weave condition would be introduced between the northbound-to-westbound traffic and the westbound-to-southbound traffic on Route 9 westbound. On Route 9 eastbound, a new weave condition would be introduced between the southbound-to-eastbound traffic and the eastbound-to-northbound traffic. Therefore, while this alternative eliminates the weave sections on Route 128 which may be contributing to the high occurrence of accidents, it creates weave sections along Route 9 that effectively retain the existing weave areas. The diverging diamond is also a newer type of interchange configuration that has not been used in this region. It is expected that significant driver education efforts would be needed for drivers to understand the new roadway configuration.



Edwards and Kelcey HDR A Joint Venture

Full Cloverleaf - Current AASHTO Standards

Drawn by: KPM
Scale: 1" = 300'
Date: April 7, 2010

I-95/I-93 (Route 128) Transportation Improvement Project (Bridge-V)
I-95 (Route 128) over Route 9
Wellesley, MA

Figure 17

TRUE NORTH

RAMP W–5

EXIST. LENGTH = 1,155'±
EXIST. GRADE = 3.29%±

PROP. LENGTH = 1,100'±
PROP. GRADE = 3.09%±

MIN. RADIUS = 240'

RAMP W–7

EXIST. LENGTH = 630'±
EXIST. GRADE = –1.27%±

PROP. LENGTH = 730'±
PROP. GRADE = –0.82%±

MIN. RADIUS = 300'

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

RAMP W–3

EXIST. LENGTH = 1,010'±
EXIST. GRADE = –3.37%±

PROP. LENGTH = 840'±
PROP. GRADE = –4.17%±

MIN. RADIUS = 300'

100' WETLAND BUFFER (TYP.)

WETLAND AREA (TYP.)

RAMP W–1

EXIST. LENGTH = 1,380'±
EXIST. GRADE = 0.51%±

PROP. LENGTH = 1,280'±
PROP. GRADE = 0.55%±

MIN. RADIUS = 250'

BRIDGE DECK DIMENSIONS:

SPAN LENGTH = 100'±
SPAN WIDTH = 143'±
SPAN AREA = 29,000 ft²±

PRO:

1) ALL LOOP RAMPS ELIMINATED.
2) IMPROVED GEOMETRY FOR ALL REMAINING RAMPS.

CON:

1) THREE SIGNALIZED INTERSECTIONS IN CLOSE PROXIMITY ALONG ROUTE 9 MAINLINE.
2) LIMITED FUTURE CAPACITY W/O SIGNIFICANT CAPITAL EXPENSE.

200 100 0 100 200 FEET

SCALE: 1"=200'

Edwards and Kelcey HDR A Joint Venture

Proposed Full Diamond Option

Drawn by: KPM
Scale: 1" = 200'
Date: April 7, 2010

I-95/I-93 (Route 128) Transportation Improvement Project (Bridge-V)
I-95 (Route 128) over Route 9
Wellesley, MA

Figure 18

TRUE NORTH

RAMP W–5

EXIST. LENGTH = 1,155'±
EXIST. GRADE = 3.29%±

PROP. LENGTH = 1,110'±
PROP. GRADE = 3.06%±

MIN. RADIUS = 240'

RAMP W–7

EXIST. LENGTH = 630'±
EXIST. GRADE = –1.27%±

PROP. LENGTH = 770'±
PROP. GRADE = –0.65%±

MIN. RADIUS = 300'

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

RAMP W–3

EXIST. LENGTH = 1,010'±
EXIST. GRADE = –3.37%±

PROP. LENGTH = 870'±
PROP. GRADE = –4.14%±

MIN. RADIUS = 200'

RAMP W–1

EXIST. LENGTH = 1,380'±
EXIST. GRADE = 0.51%±

PROP. LENGTH = 1,320'±
PROP. GRADE = 0.53%±

MIN. RADIUS = 150'

BRIDGE DECK DIMENSIONS:

SPAN LENGTH = 100'±
SPAN WIDTH = 143'±
SPAN AREA = 29,000 ft²±

PRO:

1) ALL RAMP TURNING MOVEMENTS ARE FREE MOVEMENTS.
2) NO QUEUEING ON OFF–RAMPS IS REQUIRED.
3) ALL LOOP RAMPS ELIMINATED.
4) IMPROVED GEOMETRY FOR ALL REMAINING RAMPS.

CON:

1) ROUTE 9 MAINLINE CROSSES OVER ITSELF TWICE.
2) ROUTE 9 TRAFFIC DRIVING ON THE LEFT WILL BE CONFUSING TO SOME, THOUGH THE CENTER PIER OF THE STRUCTURE WILL MITIGATE THIS BY BLOCKING THE VIEW OF THE OPPOSITE SIDE.

200 100 0 100 200 FEET

SCALE: 1"=200'

Edwards and Kelcey HDR A Joint Venture

Proposed Diverging Diamond Option

Drawn by: KPM
Scale: 1" = 200'
Date: March 19, 2010

I-95/I-93 (Route 128) Transportation Improvement Project (Bridge-V)
I-95 (Route 128) over Route 9
Wellesley, MA

Figure 19

Build Alternative 4 – Single Point Urban Interchange

Build Alternative 4 was developed as a Single Point Urban interchange. All ramps would be reconfigured to meet current AASHTO standards. With this geometry, all left turns and the Route 9 through movements would converge at a single signalized intersection on Route 9. Dual left turn lanes are provided on Route 9 and on the exiting ramps. The signal operates in three phases. Route 9 traffic turning right onto a ramp runs as free-flow and the ramp traffic turning right onto Route 9 runs under yield conditions. Figure 20 shows the proposed interchange design concept for this alternative.

With the removal of the loop ramps connecting Route 9 to I-95/Route 128, the existing weave conditions along mainline I-95/Route 128 would be eliminated in both the northbound and southbound directions of travel. Further, the weave conditions along Route 9 in both the eastbound and westbound directions of travel would also be eliminated with the proposed interchange configuration. This would eliminate any accidents expected to occur as a result of the weave conditions, which could include, among others, rear-end and side-swipe accidents. In addition, although the southbound-to-westbound right-turn movement would continue to be performed under free-flow control, the existing safety condition occurring as a result of the weaving maneuver performed by the southbound-to-westbound traffic and the westbound traffic along Route 9 would be eliminated given the relocation of the ramp. The southbound-to-westbound right-turn lane would transition into a westbound through travel lane along Route 9 with the proposed interchange configuration. Safety conditions for this Build alternative would be expected to be improved when compared to No Build conditions.

Build Alternative 5 – Partial Cloverleaf Interchange

Build Alternative 5 was developed as a Partial Cloverleaf interchange. With this geometry, the ramps in the northeast and southwest quadrants will remain. In the northwest quadrant, the loop ramps carrying traffic from Route 9 westbound to I-95 southbound will be removed and this movement will be served via Ramp W-6 on the opposite side of Route 9. Similarly, the loop ramp in the southeast quadrant will be removed and the movement from Route 9 eastbound to I-95 northbound will be served via Ramp W-1 on the opposite side of Route 9.

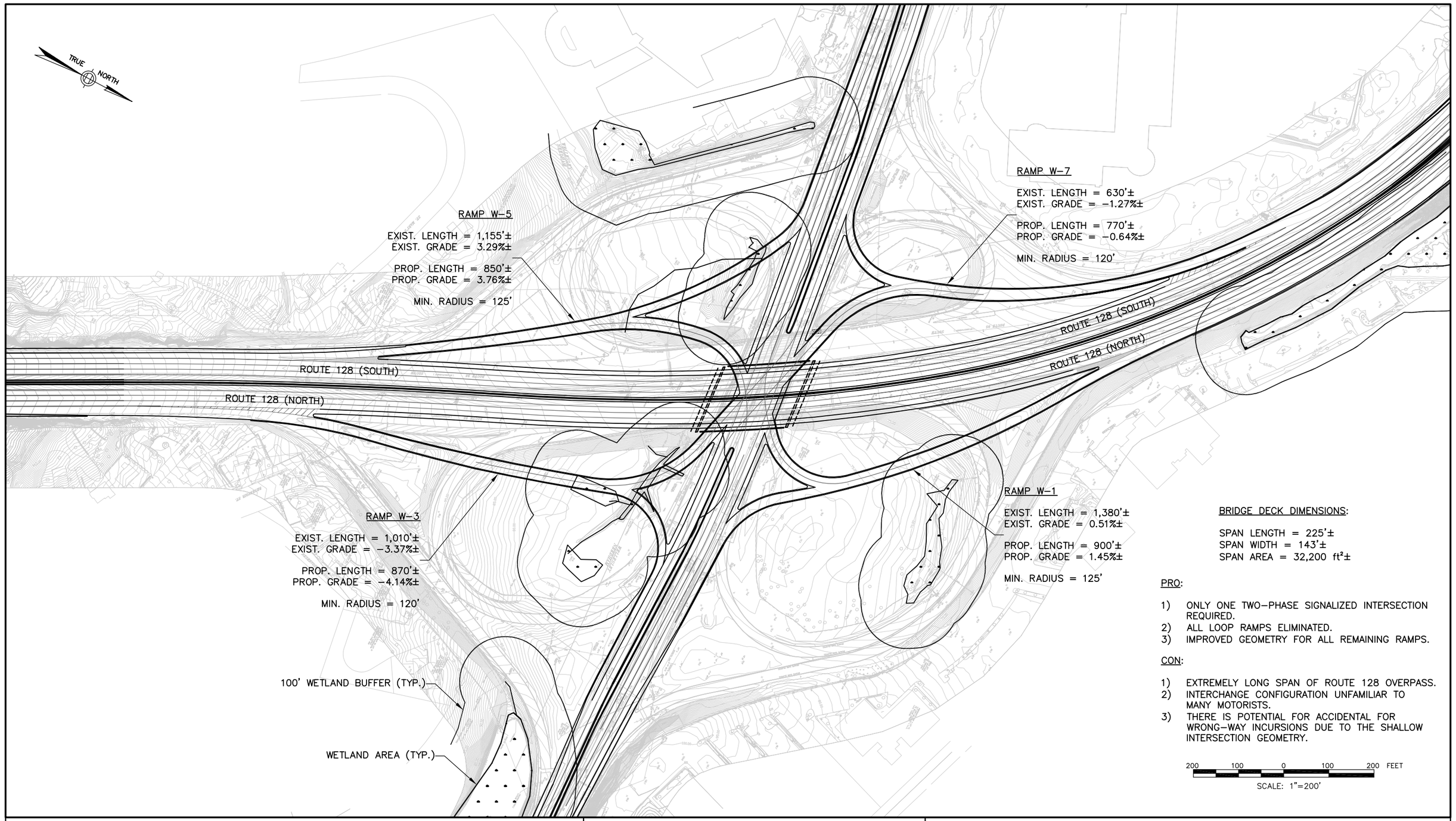
The eastbound to northbound movement that was made via Ramp W-4 under existing conditions will now be served via a left turn from Route 9 eastbound onto Ramp W-1. The westbound to southbound movement that was made via Ramp W-8 under existing conditions will now be made via a left turn from Route 9 onto Ramp W-5.

The new ramp in the northeast quadrant will intersect Route 9 opposite of Ramp W-5. The four-legged intersection will be signal controlled with dual left turn lanes on Route 9. To the east of I-95/Route 128, the intersection of Route 9 and Ramp W-1 will also be signalized with dual left turn lanes on Route 9. These signals will operate in coordination with the Route 9/Sun Life/Harvard Pilgrim intersection.

Traffic entering Ramps W-1 and W-5 via right turns will continue to operate as free flow. Traffic exiting Ramp W-3 via a right turn will operate under yield conditions. Traffic exits Ramp W-7 via two right turn lanes. There is not adequate length along Route 9 prior to the adjacent signalized intersection to allow the dual right-turn lanes to merge onto Route 9. Therefore, the right turn lanes will be signal controlled.

Figure 21 shows the proposed interchange design concept for this alternative.

With the removal of the eastbound-to-northbound and the westbound-to-southbound loop ramps connecting Route 9 to I-95/Route 128, the existing weave conditions along mainline I-95/Route 128 would be removed in both the northbound and southbound directions of travel. Further, the weave conditions along Route 9 in both the eastbound and westbound directions of travel would also be removed with the proposed interchange configuration. This would eliminate any accidents expected to occur as a result of the weave conditions, which could include, among others, rear-end and side-swipe accidents. In addition, the existing safety concerns occurring as a result of the weaving maneuver performed by the southbound-to-westbound traffic and the westbound traffic along Route 9 would be eliminated with the signalization of the southbound off-ramp traffic. Therefore, safety conditions for this Build alternative would be expected to be improved when compared to No Build conditions.



BRIDGE DECK DIMENSIONS:

SPAN LENGTH = 225'±
SPAN WIDTH = 143'±
SPAN AREA = 32,200 ft²±

PRO:

1) ONLY ONE TWO–PHASE SIGNALIZED INTERSECTION REQUIRED.
2) ALL LOOP RAMPS ELIMINATED.
3) IMPROVED GEOMETRY FOR ALL REMAINING RAMPS.

CON:

1) EXTREMELY LONG SPAN OF ROUTE 128 OVERPASS.
2) INTERCHANGE CONFIGURATION UNFAMILIAR TO MANY MOTORISTS.
3) THERE IS POTENTIAL FOR ACCIDENTAL FOR WRONG–WAY INCURSIONS DUE TO THE SHALLOW INTERSECTION GEOMETRY.

200 100 0 100 200 FEET
SCALE: 1"=200'

Edwards and Kelcey HDR A Joint Venture

Proposed Single Point Urban Interchange Option

Drawn by: KPM
Scale: 1" = 200'
Date: April 7, 2010

I-95/I-93 (Route 128) Transportation Improvement Project (Bridge-V)
I-95 (Route 128) over Route 9
Wellesley, MA

Figure 20

TRUE NORTH

RAMP W–5

EXIST. LENGTH = 1,155'±
EXIST. GRADE = 3.29%±

PROP. LENGTH = 1,070'±
PROP. GRADE = 3.27%±

MIN. RADIUS = 240'

RAMP W–6

EXIST. LENGTH = 425'±
EXIST. GRADE = –2.59%±

PROP. LENGTH = 500'±
PROP. GRADE = –4.00%±

MIN. RADIUS = 160'

RAMP W–7

EXIST. LENGTH = 630'±
EXIST. GRADE = –1.27%±

PROP. LENGTH = 640'±
PROP. GRADE = –0.94%±

MIN. RADIUS = 500'

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

RAMP W–2

EXIST. LENGTH = 840'±
EXIST. GRADE = –1.67%±

PROP. LENGTH = 870'±
PROP. GRADE = –1.72%±

MIN. RADIUS = 180'

RAMP W–3

EXIST. LENGTH = 1,010'±
EXIST. GRADE = –3.37%±

PROP. LENGTH = 1,040'±
PROP. GRADE = –3.65%±

MIN. RADIUS = 500'

100' WETLAND BUFFER (TYP.)

WETLAND AREA (TYP.)

RAMP W–1

EXIST. LENGTH = 1,380'±
EXIST. GRADE = 0.51%±

PROP. LENGTH = 1,325'±
PROP. GRADE = 0.53%±

MIN. RADIUS = 240'

BRIDGE DECK DIMENSIONS:

SPAN LENGTH = 100'±
SPAN WIDTH = 143'±
SPAN AREA = 29,400 ft²±

PRO:

1) LOOP RAMPS (W–4 AND W–8) ELIMINATED.
2) IMPROVED GEOMETRY FOR RAMPS W–3 AND W–7.
3) ELIMINATES WEAVE AREAS ON I–95/ROUTE 128 AND ROUTE 9.

CON:

1) SUPERELEVATION ISSUES FOR RAMP W–2.
2) LIMITED FUTURE CAPACITY W/O SIGNIFICANT CAPITAL EXPENSE.
3) SIGNIFICANT RETAINING WALL CONSTRUCTION ALONG RAMPS W–1 AND W–5 TO KEEP LIMIT OF SLOPE WITHIN ROW.

200 100 0 100 200 FEET

SCALE: 1"=200'

Edwards and Kelcey HDR A Joint Venture

Proposed Partial Cloverleaf Option

Drawn by: KPM
Scale: 1" = 200'
Date: April 7, 2010

I-95/I-93 (Route 128) Transportation Improvement Project (Bridge-V)
I-95 (Route 128) over Route 9
Wellesley, MA

Figure 21

Preferred Alternative – Partial Cloverleaf Interchange

The results of the intersection and ramp capacity analyses for the proposed alternatives and the No Build Alternative were compared and evaluated.

The Build alternatives offer safety improvements as they eliminate the inadequate weaves on Route 128 and eliminate some of the weave maneuvers on Route 9. Under the Build alternatives, the ramps are projected to operate at poor levels of service due to the over-capacity peak hour conditions of I-95/Route 128. Build Alternative 1 would likely provide the best traffic operations relative to capacity given that all the ramps operate under free-flow condition. However, the construction of the ramps to AASHTO standards renders the project infeasible given its impacts to the abutting properties. A comparison of the analyses for the practical alternatives revealed that the Partial Cloverleaf Alternative would provide significant improvement in vehicle delays and, therefore, in levels of service, when compared to the other Build alternatives and when compared to the No Build Alternative.

Given the results of the analyses, the preferred interchange configuration for the proposed reconstruction of the interchange of Route 9 and I-95/Route 128 is Build Alternative 5 – Partial Cloverleaf. The preferred Alternative is graphically depicted in Figure 22.

Design Exceptions

With the selected alternative for the Route 9 interchange configuration, there are a series of exceptions to design standards and requirements from AASHTO and MassDOT. These design exceptions are required in order to implement the proposed design alternative. The design exceptions are listed and described in a memo from HDR Engineering and can be found in Appendix R. Such exceptions include vertical clearances, distance between successive ramps, and ramp curve radii and lengths.

TRUE NORTH

RAMP W–5

EXIST. LENGTH = 1,155'±
EXIST. GRADE = 3.29%±

PROP. LENGTH = 1,070'±
PROP. GRADE = 3.27%±

MIN. RADIUS = 240'

RAMP W–6

EXIST. LENGTH = 425'±
EXIST. GRADE = –2.59%±

PROP. LENGTH = 500'±
PROP. GRADE = –4.00%±

MIN. RADIUS = 160'

RAMP W–7

EXIST. LENGTH = 630'±
EXIST. GRADE = –1.27%±

PROP. LENGTH = 640'±
PROP. GRADE = –0.94%±

MIN. RADIUS = 500'

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

ROUTE 128 (SOUTH)

ROUTE 128 (NORTH)

RAMP W–2

EXIST. LENGTH = 840'±
EXIST. GRADE = –1.67%±

PROP. LENGTH = 870'±
PROP. GRADE = –1.72%±

MIN. RADIUS = 180'

RAMP W–3

EXIST. LENGTH = 1,010'±
EXIST. GRADE = –3.37%±

PROP. LENGTH = 1,040'±
PROP. GRADE = –3.65%±

MIN. RADIUS = 500'

100' WETLAND BUFFER (TYP.)

WETLAND AREA (TYP.)

RAMP W–1

EXIST. LENGTH = 1,380'±
EXIST. GRADE = 0.51%±

PROP. LENGTH = 1,325'±
PROP. GRADE = 0.53%±

MIN. RADIUS = 240'

BRIDGE DECK DIMENSIONS:

SPAN LENGTH = 100'±
SPAN WIDTH = 143'±
SPAN AREA = 29,400 ft²±

PRO:

1) LOOP RAMPS (W–4 AND W–8) ELIMINATED.
2) IMPROVED GEOMETRY FOR RAMPS W–3 AND W–7.
3) ELIMINATES WEAVE AREAS ON I–95/ROUTE 128 AND ROUTE 9.

CON:

1) SUPERELEVATION ISSUES FOR RAMP W–2.
2) LIMITED FUTURE CAPACITY W/O SIGNIFICANT CAPITAL EXPENSE.
3) SIGNIFICANT RETAINING WALL CONSTRUCTION ALONG RAMPS W–1 AND W–5 TO KEEP LIMIT OF SLOPE WITHIN ROW.

200 100 0 100 200 FEET

SCALE: 1"=200'

Edwards and Kelcey HDR A Joint Venture

Proposed Partial Cloverleaf Option

Drawn by: KPM
Scale: 1" = 200'
Date: April 7, 2010

I-95/I-93 (Route 128) Transportation Improvement Project (Bridge-V)
I-95 (Route 128) over Route 9
Wellesley, MA

Figure 22

Future Traffic Volumes

No-Build

Figure 11 presents the morning and evening peak hour traffic flows for the No-Build condition for the year 2025 and Figure 14 depicts the morning and evening peak hour traffic volumes for the 2017 No-Build condition. These scenarios represent full growth in the study area without the improvements to I-95/Route 128 resulting from this project.

Build

Future traffic volumes along Route 9 and at the I-95/Route 128 interchange for this alternative were estimated based upon a reassignment of the future Full Cloverleaf volumes. The resulting 2017 Partial Cloverleaf Interchange traffic volumes along Route 9 and the I-95/Route 128 ramps are graphically depicted in Figure 15 for the morning and evening peak hours. The 2025 morning and evening peak hour traffic flows for the Build Condition are shown in Figure 12.

Future Analysis

Ramps

Table 24 displays the levels of service for the ramp merge and diverge movements during the morning peak hour for the 2025 no build and 2025 build scenarios. Table 25 presents the analysis results for the ramps for the evening peak hour for both the 2025 no build and build conditions. As shown in Table 24 and Table 25, for the 2025 no build condition all of the ramps in the Route 9 Interchange are expected to operate at LOS F during both the weekday morning and evening peak hours. With the partial cloverleaf alternative the two new ramps will operate at LOS E during the morning peak hours and LOS F during the afternoon peak hours. During the 2025 build scenario all maintained ramps will continue to operate at LOS F during both the weekday morning and evening peak hours, with two exceptions.

Two of the ramps were not analyzed utilizing HCS, since they are classified as lane additions/drops instead of merges and diverges. These ramps are located at the southern most part of the Route 9 Interchange, identified as Ramp W-5 and W-3. Traffic travels on Ramp W-5 from Route 9 eastbound to I-95/Route 128 southbound and results in an added lane in the southbound direction on I-95/Route 128. Ramp W-3 travels from I-95/Route 128 northbound to Route 9 eastbound and results in a dropped lane on I-95/Route 128 in the northbound direction. The HCS procedure does not adjust for mainline lane additions or lane drops at a ramp junction. Therefore, different analyses were completed to account for the mainline lane addition and drop.

When dealing with ramps that either add a lane or drop a lane from the mainline, a ramp merge analysis does not provide the complete analysis. Instead these types of merges are considered lane additions. As indicated on page 25-9 of the HCM, it should be analyzed by comparing the capacities of each entering ramp lane and the departing freeway (Exhibit 25-7) to the peak demand flow. The downstream segment should simply be looked at as a basic freeway segment with an added lane or subtracted lane. In the case of the partial cloverleaf interchange alternative, the freeway segment will be analyzed as a weave segment, due to the proximity of the Highland Avenue interchange.

Ramp W-5 in the southbound direction results in an added lane to the mainline, resulting in a five lane cross-section downstream of the ramp. Using the data from Exhibit 25-7, the downstream capacity is approximately 2,400 passenger cars per hour (pc/h) per lane or 12,000 pc/h for the roadway. Demand during the morning peak hour is approximately 9,046 pc/h and the demand during the evening peak hour is approximately 10,040 pc/h. Using this methodology, sufficient capacity has been calculated downstream of the W-5 ramp for the demand during both the morning and evening peak hours. In addition to these calculations, the ramp was analyzed with HCS utilizing a 5 lane cross-section. Although this is not accurate depiction of how the ramp is configured, it does generate an approximate LOS for the ramp. Using this analysis, the ramp would operate at a LOS D for the morning peak period and at LOS C during the evening peak period.

This same logic can be applied to ramp W-3 in the northbound direction. This ramp is a dropped lane which results in a four lane cross-section north of the ramp. Using the data from Exhibit 25-7, the capacity upstream and downstream of the ramp is approximately 2400 pc/h per lane or 9,600 pc/h. Demand during the morning peak hour is approximately 8,918 pc/h and the demand during the evening peak hour is approximately 9,646 pc/h. Therefore, sufficient capacity has been calculated downstream of the W-3 ramp for the demand during the morning peak hour. During the afternoon peak hour, the downstream segment is just slightly over capacity as the demand flow is less than one percent higher than the capacity. Again, using HCS to approximate a LOS, the ramp would operate at a LOS E for both the morning and evening peak period

The 2025 Build Alternative 5 conditions ramp capacity analyses worksheets and calculations are included in Appendix K.

Table 24. Route 9 Ramp Levels of Service for 2025 Morning Peak Hour

	No Build		Build	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Route 9				
I-95/Route 128 NB to Route 9 EB	F	*	**	**
I-95/Route 128 NB to Route 9 WB	n/a	n/a	E	37.7
Route 9 WB to I-95/Route 128 NB	F	*	F	*
I-95/Route 128 SB to Route 9 WB	F	*	F	*
I-95/Route 128 SB to Route 9 EB	n/a	n/a	E	38.5
Route 9 EB to I-95/Route 128 SB	F	*	**	**

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

[*] Volume exceeds capacity. Density is not calculated.

[**] Ramp analysis not completed using HCS

Table 25. Route 9 Ramp Levels of Service for 2025 Evening Peak Hour

	No Build		Build	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Route 9				
I-95/Route 128 NB to Route 9 EB	F	*	**	**
I-95/Route 128 NB to Route 9 WB	n/a	n/a	F	*
Route 9 WB to I-95/Route 128 NB	F	*	F	*
I-95/Route 128 SB to Route 9 WB	F	*	F	*
I-95/Route 128 SB to Route 9 EB	n/a	n/a	F	*
Route 9 EB to I-95/Route 128 SB	F	*	**	**

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

[*] Volume exceeds capacity. Density is not calculated.

[**] Ramp analysis not completed using HCS

Weave Sections

Table 26 shows the summary of results from the capacity analysis of the weave sections in the study area for the morning and evening peak hours, respectively. For the 2025 no build conditions, the northbound weave section on I-95/Route 128 at the Route 9 interchange is expected to operate at LOS F during both the weekday morning and evening peak hours. For the 2025 no build scenarios, the I-95/Route 128 southbound weave section at the Route 9 interchange is expected to operate at LOS F during the morning and evening peak hour. The worksheets for the No Build capacity analysis for

the weave sections may be found in Appendix S. Note that the weave sections are eliminated under the build condition.

Table 26. 2025 No Build Weave Segment Levels of Service

	AM Peak Hour		PM Peak Hour	
	LOS[1]	Density[2]	LOS	Density
I-95/Route 128 at Route 9				
Northbound	F	74.6	F	84.6
Southbound	F	50.5	F	54.5

[1] Level-of-Service

[2] Density in passenger cars per mile per lane (pc/mi/ln)

Local Street Corridor Intersections

Previously, no permanent changes were proposed as part of this project for the Route 9 corridor as no change in traffic patterns or volumes would result from the Add-a-Lane project. The Route 9 corridor is included in this analysis as it will experience changes from the proposed construction staging for the I-95/Route 128 overpass. In order to reconstruct these bridges, it is proposed to remove the loop ramps entering onto I-95/Route 128, thereby eliminating the need for an acceleration lane on the bridge. The ramp modification would occur for both northbound and southbound entering traffic. To effect the elimination of the loop ramps entering onto I-95/Route 128, two new traffic signals would be required near the existing ramp termini on Route 9 to allow entering ramp traffic to turn left from Route 9 onto the ramps. Although this plan was originally meant to be temporary, as part of the construction, MassDOT expressed interest in maintaining the configuration permanently. As a result, further analysis and evaluation were conducted to evaluate the traffic operations of the corridor intersections of this alternative and is described below.

Table 27 is a summary of the expected traffic operations for the Route 9 ramp modifications for the existing morning and evening peak hours. As illustrated on this table, the traffic operates at LOS C for the Route 9 at Harvard Pilgrim/Sun Life driveway. The new signal at the southbound ramps to I-95/Route 128 would operate at LOS B during the morning peak hour and at LOS A during the evening peak hour. The new signal at the northbound ramps to I-95/Route 128 would operate at LOS A during the morning peak hour and at LOS C during the evening peak hour. Further, the traffic operates at an acceptable LOS for the Route 9 mainline traffic, thus minimizing traffic queues in the area. As the signals are constructed, fine tuning of the signal timings based on field conditions is recommended. The capacity analysis worksheets for the Route 9 ramp modifications intersection analysis for the existing morning and evening peak can be found in Appendix T.

Table 27. 2007 Existing Route 9 Ramp Modification Levels of Service

			Morning Peak Hour			Evening Peak Hour		
Intersection	**Movement**		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Route 9 at Sun Life/Harvard Pilgrim	EB	L	E	60.3	0.63	D	47.9	0.26
	EB	TR	D	35.4	0.97	C	22.1	0.68
	WB	L	E	56.2	0.57	D	52.9	0.13
	WB	T	B	17.2	0.50	C	24.1	0.94
	WB	R	A	4.3	0.43	A	3.5	0.09
	NB	LT	E	55.3	0.03	F	175.2	1.21
	NB	R	B	10.2	0.10	A	6.3	0.48
	SB	L	E	57.9	0.21	F	103.3	0.95
	SB	T	F	229.3	1.31	F	100.4	0.94
	SB	R	A	8.2	0.07	A	5.8	0.34
	Overall		*C*	*34.1*		*C*	*33.0*	
Route 9 at I-95/Route 128 SB Ramps	EB	T	C	23.3	0.83	A	6.0	0.55
	WB	L	C	28.6	0.76	D	36.2	0.78
	WB	T	A	0.3	0.40	A	0.6	0.62
	Overall		*B*	*15.7*		*A*	*7.7*	
Route 9 at I-95/Route 128 NB Ramps	EB	L	B	16.8	0.56	D	52.9	0.86
	EB	T	A	1.5	0.67	A	0.3	0.40
	WB	T	A	7.2	0.42	C	20.4	0.89
	Overall		*A*	*4.9*		*B*	*19.6*	

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

No Build

Intersection capacity analyses were performed for the intersection of Route 9 at Sun Life/Harvard Pilgrim. The 2017 No Build conditions intersection capacity analyses worksheets are included in Appendix U.

Build

Intersection capacity analyses were performed for 2017 Build Alternative 5 conditions at the intersection of Route 9 at Sun Life/Harvard Pilgrim and Route 9 at the proposed I-95/Route 128 ramps. The signals along Route 9 were coordinated to a 100-second cycle length for analyses purposes. The 2017 build conditions intersection capacity analyses worksheets are included in Appendix V. Results of the analyses are summarized in Table 28 and Table 29.

Table 28. Route 9 Levels of Service for 2017 Morning Peak Hour

Intersection	Movement		2017 No Build LOS[1]	2017 No Build Delay[2]	2017 No Build V/C[3]	2017 Build LOS	2017 Build Delay	2017 Build V/C
Route 9 at Sun Life/Harvard Pilgrim	EB	L	D	49.0	0.58	D	49.0	0.58
	EB	TR	C	25.5	0.92	C	25.5	0.92
	WB	L	F	145.8	1.09	F	126.5	1.09
	WB	T	C	22.3	0.72	B	15.8	0.72
	WB	R	A	5.3	0.47	A	2.2	0.47
	NB	LT	D	45.0	0.03	D	45.0	0.03
	NB	R	B	10.8	0.13	B	10.8	0.13
	SB	L	D	48.3	0.21	D	48.3	0.21
	SB	T	F	251.3	1.38	F	251.3	1.38
	SB	R	A	7.2	0.06	A	7.2	0.06
	Overall		*C*	33.1		C	30.2	
Route 9 at I-95 Southbound Ramps	EB	T	n/a	n/a	n/a	A	7.7	0.77
	EB	R	n/a	n/a	n/a	A	3.1	0.46
	WB	L	n/a	n/a	n/a	D	46.5	0.84
	WB	T	n/a	n/a	n/a	A	8.1	0.62
	SB	R	n/a	n/a	n/a	D	49.2	0.91
	Overall		***n/a***	n/a	n/a	B	16.4	
Route 9 at I-95 Northbound Ramps	EB	L	n/a	n/a	n/a	D	41.0	0.57
	EB	T	n/a	n/a	n/a	A	1.1	0.66
	WB	T	n/a	n/a	n/a	B	13.5	0.60
	Overall		***n/a***	n/a	n/a	B	10.0	

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

As seen in Table 28 and Table 29 the intersection of Route 9 at Sun Life/Harvard Pilgrim would be expected to continue to operate at an overall acceptable level of service during AM and PM peak hour conditions. However, delays would continue to be observed along the minor streets of the intersection. The intersection of Route 9 and I-95/Route 128 Northbound Ramps and the intersection of Route 9 and I-95/Route 128 Southbound Ramps would be expected to operate at an overall acceptable level of service B during both peak periods. Further, all movements would be expected to operate at an acceptable level of service during both peak periods. It is also worth noting that the future queues for the eastbound-to-northbound and the westbound-to-southbound left-turn movements would not be anticipated to exceed the available storage expected to be provided on Route 9.

Table 29. Route 9 Levels of Service for 2017 Afternoon Peak Hour

Intersection	Movement		2017 No Build LOS[1]	2017 No Build Delay[2]	2017 No Build V/C[3]	2017 Build LOS	2017 Build Delay	2017 Build V/C
Route 9 at Sun Life/Harvard Pilgrim	EB	L	D	45.7	0.26	D	45.7	0.26
	EB	TR	C	23.6	0.82	C	23.6	0.82
	WB	L	D	45.1	0.13	C	26.4	0.13
	WB	T	C	25.6	0.84	B	18.3	0.84
	WB	R	A	7.8	0.09	A	6.1	0.09
	NB	LT	F	288.9	1.50	F	288.9	1.50
	NB	R	A	7.8	0.54	A	7.8	0.54
	SB	L	F	244.4	1.36	F	244.4	1.36
	SB	T	F	246.1	1.36	F	246.1	1.36
	SB	R	A	7.8	0.34	A	7.8	0.34
	Overall		*D*	47.1		*D*	*44.1*	
Route 9 at I-95 Southbound Ramps	EB	T	n/a	n/a	n/a	B	12.9	0.82
	EB	R	n/a	n/a	n/a	A	6.5	0.63
	WB	L	n/a	n/a	n/a	D	51.7	0.75
	WB	T	n/a	n/a	n/a	B	13.0	0.56
	SB	R	n/a	n/a	n/a	D	41.6	0.67
	Overall		*n/a*	*n/a*	*n/a*	*B*	*17.7*	
Route 9 at I-95 Northbound Ramps	EB	L	n/a	n/a	n/a	C	27.1	0.79
	EB	T	n/a	n/a	n/a	A	0.5	0.53
	WB	T	n/a	n/a	n/a	C	30.4	0.93
	Overall		*n/a*	*n/a*	*n/a*	*B*	*17.7*	

[1] Level-of-Service

[2] Average vehicle delay in seconds

[3] Volume to capacity ratio

The improved operations associated with this alternative are due to the fact that only one direction of Route 9 traffic and the left –turn onto the ramp are under signal control at each intersection. These signals are able to operate with an efficient two-phase configuration.

Conclusions

Overview of Preferred Plan

As documented in this report, the improvements from this project will provide an overall benefit for this sector of the I-95/Route 128 corridor. This project will result in four travel lanes and a full shoulder in each direction along I-95/Route 128. This cross section will provide an increase in the capacity of the mainline, primarily through improved merge and diverge operations. The elimination of travel on the shoulder will provide for a smoother traffic flow and safer environment by returning the shoulder/breakdown lane to its intended purpose during the eight hours it is currently used as a travel lane and by providing adequate merge and diverge areas. In addition, this project will result in a new interchange at Kendrick Street. The new interchange will provide more direct access to office and industrial parks to the east of I-95/Route 128 and will divert trips from the Highland Avenue interchange and the Great Plain Avenue interchange to the south. The interchange at Route 9 will also be reconfigured to eliminate the weave sections which currently exist due to the substandard existing cloverleaf interchange. After a thorough analysis of the available interchange alternatives, the redesigned interchange will be built as a partial cloverleaf interchange.

Operational Analyses and Findings

For this project, analyses were conducted for the freeways, ramps and local street systems. The freeways and ramps were analyzed using the CTPS 2025 travel forecasts and the local street network used a 2017 planning horizon. Both are consistent with MassDOT design guidelines.

The opening of a new interchange on Kendrick Street is the most dramatic improvement to the study area and in particular to the economic opportunities to the neighboring communities. This interchange will provide relief to the Highland Avenue corridor and Greendale Avenue and allow better access into the office/industrial area to the east. By allowing only turns to the east for exiting traffic at this interchange, with the exception of right turning vehicles off of the southbound off ramp, there is protection offered to residential uses to the west of the proposed interchange.

In order to open a new interchange at Kendrick Street and to reduce conflicts on the mainline, a C-D roadway was required to distribute traffic between Highland Avenue and Kendrick Street in an efficient and safe manner. This C-D Road is an integral component of the improvement scheme. A refinement to the C-D roadway was presented by the project team to separate the northbound I-95/Route 128 traffic exiting to Kendrick Street from the traffic exiting to the northbound C-D roadway by

constructing separate ramps. Construction of separate ramps for the Kendrick Street interchange and the C-D Road will provide acceptable operations on both ramps.

This FDR also analyzed the Highland Avenue and Kendrick Street corridors. In particular, the Kendrick Street corridor is essential to understand the traffic implications of the proposed interchange at Kendrick Street. The Highland Avenue corridor is also an important roadway that serves the industrial developments to the east of I-95/Route 128.

As shown in this document, the impacts to Kendrick Street can be accommodated with modest improvements to existing intersections including an additional lane in the eastbound direction between the proposed interchange and Third Avenue.

The Highland Avenue corridor will be somewhat improved under this project due to changed traffic patterns and additional improvements to this corridor that are currently being designed by the Town of Needham. The overall improvement scheme for the I-95/I-93 Transportation Improvement Project (Bridge V) will not be detrimental to Highland Avenue as traffic is afforded a more direct connection to many of the local traffic generators via the proposed Kendrick Street ramps. However, traffic operations along Highland Avenue will continue to be strained given plans to expand the New England Business Center and other growth potential in the immediate environs. The operations of Highland Avenue should be further assessed during the permitting for future development projects.

Another component of the project is for the temporary construction staging alterations to the Route 9 interchange to become part of the improvement scheme. The traffic operation with two signals on Route 9 eliminates a substandard weave length on the mainline of the freeway and eliminates the weaving sections on Route 9. This component of the project was not included as part of the original project, but has now been included due to the reconsidered scope and design.

Based on the findings in this FDR, it is concluded that this project will be beneficial to traffic operations and safety on I-95/Route 128, and in the neighboring communities.