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Appendix B: Engineering Considerations


B.1 Geometric Deficiencies of the Existing I-93/I-95 Interchange

The existing I-93/I-95 Interchange was designed and constructed as a full cloverleaf grade separated interchange. The left-turning movements are served by loop ramps while the right-turning movements are accommodated by direct at-grade ramps. This configuration allows each interchanging movement an independent ramp but also generates weaving maneuvers that occur in the area adjacent to the through lanes. When the weaving volume in a particular weaving section is greater than 1000 vehicles per hour, the operation of the interchange is severely impacted.

In addition to the overall deficient configuration of the interchange, there are other geometrical components that do not meet applicable design standards. The I-93/I-95 Interchange is located in close proximity to the Washington Street Interchange to the west and the Route 28 Interchange to the east. These create additional substandard weaving sections along I-95 in the immediate vicinity of the I-93/I-95 Interchange. The direct at-grade ramps serving right turn movements lack appropriate acceleration and deceleration lengths for vehicles to safely change speeds as needed. Lastly, the direct ramp from I-93 SB to I-95 SB contains a broken back arrangement of curves – two curves in the same direction separated by a short tangent. This creates a truck rollover hazard as most drivers subconsciously expect successive curves in opposite directions, not in the same direction like the alignment of this ramp.

I-93/I-95 INTERCHANGE STUDY EXISTING RAMP CONFIGURATIONS

RAMP / DESCRIPTION	DIRECTION	RADIUS	SPEED	ACCEL LANE	DECEL LANE
<u>I-93 NORTH</u>					
Ramp H	SE (OUTER)	I-93 NB to I-95 NB (Exiting) 500 feet	40 mph		220 feet
Ramp C	SE (INNER)	I-95 NB to I-93 NB (Entering) 180 feet	25 mph		
Ramp B	NE (INNER)	I-93 NB to I-95 SB (Exiting) 180 feet *	25 mph	Accel / Decel WEAVE	620 feet
Ramp G	NE (OUTER)	I-95 SB to I-93 NB (Entering) 430 feet	35 mph	500 feet	
<u>I-93 SOUTH</u>					
Ramp F	NW (OUTER)	I-93 SB to I-95 SB (Exiting) 520 feet	40 mph		200 feet
Ramp A	NW (INNER)	I-95 SB to I-93 SB (Entering) 240 feet	25 mph		
Ramp D	SW (INNER)	I-93 SB to I-95 NB (Exiting) 180 feet *	25 mph	Accel / Decel WEAVE	650 feet
Ramp E	SW (OUTER)	I-95 NB to I-93 SB (Entering) 430 feet	35 mph	450 feet	

 = Existing Design Does NOT Meet Current Design Standards
 * = Truck Roll Over Warning Sign (Posted 20 mph)

I-93/I-95 INTERCHANGE STUDY EXISTING RAMP CONFIGURATIONS

RAMP / DESCRIPTION	DIRECTION	RADIUS	SPEED	ACCEL LANE	DECEL LANE
<u>I-95 NORTH</u>					
Ramp E	SW (OUTER)	I-95 NB to I-93 SB (Exiting)	30 mph	320 feet	Accel / Decel WEAVE 1,300 feet
Ramp D	SW (INNER)	I-93 SB to I-95 NB (Entering)	25 mph	180 feet	Accel / Decel WEAVE 750 feet
Ramp C	SE (INNER)	I-95 NB to I-93 NB (Exiting)	30 mph	320 feet	Lane Drop over 600 feet
Ramp H	SE (OUTER)	I-93 NB to I-95 NB (Entering)	25 mph	240 feet	Accel / Decel WEAVE 1,650 feet
<u>I-95 SOUTH</u>					
Ramp G	NE (OUTER)	I-95 SB to I-93 NB (Exiting)	30 mph	320 feet	220 feet *
Ramp B	NE (INNER)	I-93 NB to I-95 SB (Entering)	25 mph	180 feet	Accel / Decel WEAVE 800 feet
Ramp A	NW (INNER)	I-95 SB to I-93 SB (Exiting)	30 mph	320 feet	
Ramp F	NW (OUTER)	I-93 SB to I-95 SB (Entering)	25 mph	240 feet	450 feet **

█ = Existing Design Does NOT Meet Current Design Standards

* = Preceded by Weave from Route 28 On-ramp (2,000 feet)

** = Followed by Weave to Washington Street Off-ramp (1,300 feet)

I-93/I-95 INTERCHANGE STUDY EXISTING RAMP CONFIGURATIONS

Assumptions:

Horizontal Curve - Design Speed (from page 830 - 2001 AASHTO)

Ramp Design Speed	(from page 830 - 2001 AASHTO)	IF Highway Design Speed =	55 mph	65 mph	70 mph
		Upper	48 mph	55 mph	60 mph
		Mid	40 mph	45 mph	50 mph
		Low	28 mph	30 mph	35 mph

Weave Lengths (from page 848 - 2001 AASHTO)
EN-EX Full fwy - not applicable for loop ramps 2000 ft

Accel Lane Lengths	(from page 851 - 2001 AASHTO)	Ramp speed	50	370 feet
hwy speed = 65			45	600 feet
			30	1120 feet

Decel Lane Lengths	(from page 855 - 2001 AASHTO)	Ramp speed	50	280 feet
hwy speed = 65			45	340 feet
			30	470 feet

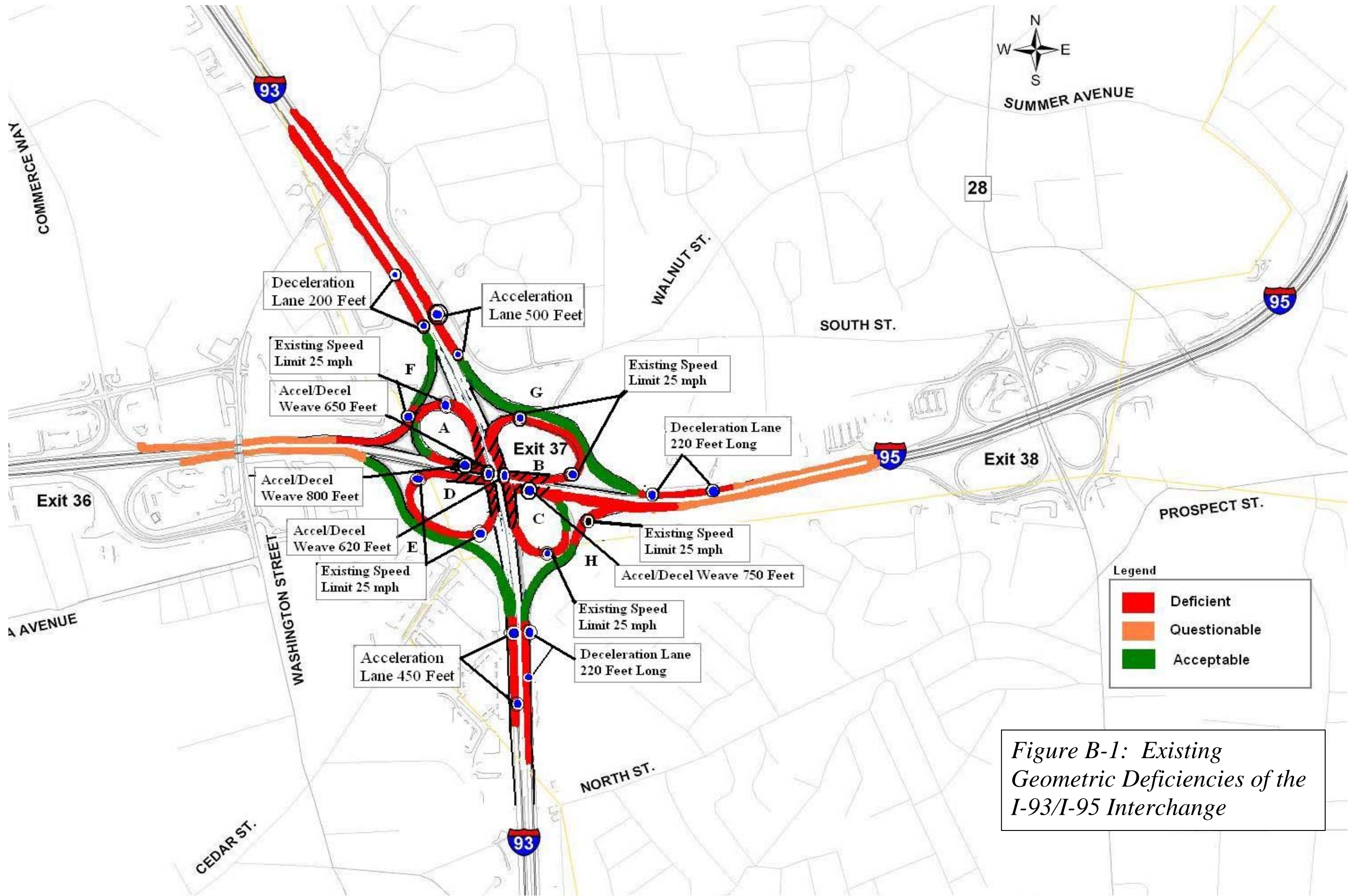


Figure B-1: Existing Geometric Deficiencies of the I-93/I-95 Interchange

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B.2 Design Criteria for Highway Improvements

The alternative development process adhered to the overall goals of the interchange study. These goals were to improve congestion and traffic operations, improve safety and minimize private property takings while taking into consideration any ideas or concerns from the public. To achieve these goals, a context sensitive design approach was used.

Geometric design of the alternatives was based on the 2004 *AASHTO Policy on Geometric Design of Highways and Streets* and the 2006 *MassHighway Project Development and Design Guide*. Due to the constraints imposed by the previously mentioned project goals, the designs do not meet all of the recommended design criteria for this type of project. However, the geometry of the alternatives was developed in the framework of context sensitive design as promoted by the new MHD Design Guide. This led to the creation of practical solutions that greatly improve the interchange while minimizing impact and disruption to the surrounding communities.

The greatest constraint for any geometrical improvement to the I-93/I-95 Interchange is the limited state right-of-way available. To minimize land takings, the horizontal layouts of the alternatives were confined to the limits of the right-of-way wherever possible. This resulted in the design speed of the I-93/I-95 Interchange ramps being controlled by the horizontal alignment. Design speeds range from 25 mph to 40 mph as limited by the radii of the horizontal curves and a 6% maximum superelevation. The vertical alignment of the ramps typically have design speeds 5mph to 15mph greater than the horizontal control as controlled by minimum K values of the vertical curves.

The 40 mph design for major ramps is acceptable, though less than the 50 mph design speed that would be used in the absence of significant community constraints; discussions were initiated with MassHighway and FHWA regarding a design exception that would be requested during the preliminary design phase. It should be noted that the 40 mph ramp speeds are substantially superior to the low-speed ramps that are to be replaced or re-aligned. Two of the loop ramps from the existing interchange configuration cannot be replaced without major community takings, and these ramps, in the northeast and southwest quadrants, remain.

The design criteria and controls for each ramp of H3-OS and H3-US are shown on the following pages.

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-OS - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Ramp: Rt 128 NB to I-93 NB

Cross-section:

50-ft wide with three travel lanes from Rte 128 NB to ramp split I-93 NB / I-93 SB
38-ft wide-two travel lanes from ramp split tapering to 28-ft wide-one travel lane before merging with I-93 NB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent semi-directional ramp and available right-of-way.

Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 485-ft ==>> Design Speed 40 mph

Vertical Control:

Constraint: Vertical alignment restricted by clearance requirements and ramp tie-in to existing roadway.

Min K Crest Vertical Curve: 117.65 ==>> Design Speed 55 mph
Min K Sag Vertical Curve: 115.07 ==>> Design Speed 55 mph

Maximum Vertical Tangent Grade Up: 3.25%
Length of Maximum Vertical Tangent Grade Up: 1313-ft
Maximum Vertical Tangent Grade Down: 1.75%
Length of Maximum Vertical Tangent Grade Down: 677-ft

Vertical Clearance Provided: 25-ft road surface to road surface
Vertical Clearance Required: 16.5-ft
Depth of Bridge Superstructure Accomodated: 8.5-ft

Ramp Design Speed: 40 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-OS - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Ramp: Rt 128 SB to I-93 SB

Cross-section:

38-ft wide with two travel lanes from Rte 128 SB to ramp split I-93 NB / I-93 SB
38-ft wide-two travel lanes from ramp split tapering to 28-ft wide-one travel lane before merging with I-93 SB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent semi-directional ramp and available right-of-way.

Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 485-ft ==>> Design Speed 40 mph

Vertical Control:

Constraint: Vertical alignment restricted by clearance requirements and ramp tie-in to existing roadway.

Min K Crest Vertical Curve: 91.84 ==>> Design Speed 50 mph
Min K Sag Vertical Curve: 98.97 ==>> Design Speed 50 mph

Maximum Vertical Tangent Grade Up: 3.25%
Length of Maximum Vertical Tangent Grade Up: 518-ft
Maximum Vertical Tangent Grade Down: 3.75%
Length of Maximum Vertical Tangent Grade Down: 751-ft

Vertical Clearance Provided: 25-ft road surface to road surface
Vertical Clearance Required: 16.5-ft
Depth of Bridge Superstructure Accomodated: 8.5-ft

Ramp Design Speed: 40 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-OS - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Inner Loop Ramps

Ramp: I-93 NB to Rt 128 SB

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 180-ft ==>> Design Speed 25 mph

Ramp Design Speed: **25 mph**

Ramp: I-93 SB to Rt 128 NB

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 180-ft ==>> Design Speed 25 mph

Ramp Design Speed: **25 mph**

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-OS - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Washington Street Ramps

Ramp: Washington Street to Rte 128 CD Ramp NB

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 158 ==>> Design Speed 25 mph

Ramp Design Speed: 25 mph

Ramp: Washington Street to Rte 128 NB

Cross-section:
38-ft wide with two travel lanes from Rte 128 NB to ramp split I-93 NB / I-93 SB
22-ft wide with one travel lane from ramp split to I-93 SB

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 158-ft ==>> Design Speed 25 mph

Ramp Design Speed: 25 mph

Ramp: Rte 128 CD Ramp NB to Washington Street

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 350-ft ==>> Design Speed 35 mph

Ramp Design Speed: 35 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-OS - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Outer Connection Ramps

Ramp: Rt 128 SB to I-93 NB

Cross-section:

38-ft wide with two travel lanes from Rte 128 SB to ramp split I-93 NB / I-93 SB
22-ft wide with one travel lane from ramp split to I-93 NB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 400-ft ==>> Design Speed 35 mph

Ramp Design Speed: 35 mph

Ramp: Rt 128 NB to I-93 SB

Cross-section:

50-ft wide with three travel lanes from Rte 128 NB to ramp split I-93 NB / I-93 SB
38-ft wide with two travel lanes from ramp split to I-93 SB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 485-ft ==>> Design Speed 40 mph

Ramp Design Speed: 40 mph

Ramp: I-93 SB to Rt 128 SB

Cross-section:

22-ft wide with one travel lane

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 500-ft ==>> Design Speed 40 mph

Ramp Design Speed: 40 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-OS - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Outer Connection Ramps

Ramp: I-93 NB to Rt 128 NB

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 600-ft ==>> Design Speed 40 mph

Ramp Design Speed: **40 mph**

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-US - Eliminate Two Loop Ramps and Reconfigure Washington Street Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Ramp: Rt 128 NB to I-93 NB

Cross-section:

50-ft wide with two travel lanes from Rte 128 NB to ramp split I-93 NB / I-93 SB

38-ft wide-two travel lanes from ramp split tapering to 28-ft wide-one travel lane before merging with I-93 NB

Horizontal Control:

Constraint: Horizontal alignment restricted by available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 485-ft ==>> Design Speed 40 mph

Vertical Control:

Constraint: Vertical alignment restricted by clearance requirements and ramp tie-in to existing roadway.

Min K Crest Vertical Curve: 61.74 ==>> Design Speed 45 mph

Min K Sag Vertical Curve: 79.17 ==>> Design Speed 45 mph

Maximum Vertical Tangent Grade Up: 3.25%

Length of Maximum Vertical Tangent Grade Up: 1077-ft

Maximum Vertical Tangent Grade Down: 5.00%

Length of Maximum Vertical Tangent Grade Down: 19-ft

Vertical Clearance Provided: 25-ft road surface to road surface

Vertical Clearance Required: 16.5-ft

Depth of Bridge Superstructure Accomodated: 8.5-ft

Ramp Design Speed: 40 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-US - Eliminate Two Loop Ramps and Reconfigure Washington Street Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Ramp: Rt 128 SB to I-93 SB

Cross-section:

38-ft wide with two travel lanes from Rte 128 SB to ramp split I-93 NB / I-93 SB
38-ft wide with one travel lane from ramp split to I-93 SB

Horizontal Control:

Constraint: Horizontal alignment restricted by available right-of-way.

Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 485-ft ==>> Design Speed 40 mph

Vertical Control:

Constraint: Vertical alignment restricted by clearance requirements and ramp tie-in to existing roadway.

Min K Crest Vertical Curve: 84 ==>> Design Speed 50 mph
Min K Sag Vertical Curve: 79 ==>> Design Speed 45 mph

Maximum Vertical Tangent Grade Up: 3.00%
Length of Maximum Vertical Tangent Grade Up: 794-ft
Maximum Vertical Tanget Grade Down: 6.00%
Length of Maximum Vertical Tangent Grade Down: 290-ft

Vertical Clearance Provided: 25-ft road surface to road surface
Vertical Clearance Required: 16.5-ft
Depth of Bridge Superstructure Accomodated: 8.5-ft

Ramp Design Speed: 40 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-US - Eliminate Two Loop Ramps and Reconfigure Washington St. Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Washington Street Ramps

Ramp: Washington Street to Rte 128 CD Ramp NB

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 158 ==>> Design Speed 25 mph

Ramp Design Speed: 25 mph

Ramp: Washington Street to Rte 128 NB

Cross-section:
38-ft wide with two travel lanes from Rte 128 NB to ramp split I-93 NB / I-93 SB
22-ft wide with one travel lane from ramp split to I-93 SB

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 158-ft ==>> Design Speed 25 mph

Ramp Design Speed: 25 mph

Ramp: Rte 128 CD Ramp NB to Washington Street

Cross-section:
22-ft wide with one travel lane

Horizontal Control:
Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.
Rate of Superelevation (e): 6%
Minimum Radius of Curvature: 350-ft ==>> Design Speed 35 mph

Ramp Design Speed: 35 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-US - Eliminate Two Loop Ramps and Reconfigure Washington Street Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Inner Loop Ramps

Ramp: I-93 NB to Rt 128 SB

Cross-section:

22-ft wide with one travel lane from split to Rte 128 NB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 180-ft ==>> Design Speed 25 mph

Ramp Design Speed: 25 mph

Ramp: I-93 SB to Rt 128 SB

Cross-section:

22-ft wide with one travel lane from split to Rte 128 SB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 180-ft ==>> Design Speed 25 mph

Ramp Design Speed: 25 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-US - Eliminate Two Loop Ramps and Reconfigure Washington Street Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Outer Connection Ramps

Ramp: Rt 128 SB to I-93 NB

Cross-section:

38-ft wide with two travel lanes from Rte 128 SB to ramp split I-93 NB / I-93 SB
22-ft wide with one travel lane from ramp split to I-93 NB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 609-ft ==>> Design Speed 40 mph

Ramp Design Speed: 40 mph

Ramp: Rt 128 NB to I-93 SB

Cross-section:

50-ft wide with three travel lanes from Rte 128 NB to ramp split I-93 NB / I-93 SB
38-ft wide with two travel lanes from ramp split to I-93 SB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 485-ft ==>> Design Speed 40 mph

Ramp Design Speed: 40 mph

Ramp: I-93 SB to Rt 128 SB

Cross-section:

22-ft wide with one travel lane from split to Rte 128 SB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 500-ft ==>> Design Speed 40 mph

Ramp Design Speed: 40 mph

**I-93 - Rte 128
Interchange Study
Highway Geometric Design Controls**

**Alt H3-US - Eliminate Two Loop Ramps and Reconfigure Washington Street Ramps
Remove NW and SE Loop Ramps and Replace with Semi-directional Ramps**

Outer Connection Ramps

Ramp: **I-93 NB to Rt 128 NB**

Cross-section:

22-ft wide with one travel lane from split to Rte 128 NB

Horizontal Control:

Constraint: Horizontal alignment restricted by adjacent ramp and available right-of-way.

Rate of Superelevation (e): 6%

Minimum Radius of Curvature: 600-ft ==>> Design Speed 40 mph

Ramp Design Speed: **40 mph**
