

Prepared For:



Bow Concord I-93
Improvements Project

Bow and Concord, NH

Technical Feasibility Report



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1 Project Description

The New Hampshire Department of Transportation (NHDOT) and the Federal Highway Administration (FHWA) have prepared an Environmental Assessment/Draft Section 4(f) Evaluation (EA/4(f)) for proposed improvements to the Interstate Route 93 (I-93) corridor between the Town of Bow and the City of Concord, Merrimack County, New Hampshire. The basic purpose of the I-93 Bow-Concord project is to improve transportation efficiency and reduce safety problems within this approximately 4.5-mile segment of highway.

I-93 is the principal north-south arterial highway within New Hampshire and is part of the National System of Interstate and Defense Highways. I-93 extends a total distance of 132 miles within New Hampshire, from the Massachusetts border to the northern Vermont border. The proposed project covers a distance of approximately 4.5 miles from south of the I-93/Interstate Route 89 (I-89) Interchange in Bow to just north of the I-93/Interstate Route 393 (I-393) Interchange (Exit 15) in Concord. The segment of I-93 from Manchester to Exit 14 is also part of the Central Turnpike, commonly known as the F.E. Everett Turnpike. The project also extends along I-89 from its terminus with Route 3A (Bow Junction) approximately 4,700 feet to the west. Along I-393 the project extends from just west of the bridge over the Merrimack River to the Route 202/North Main Street intersection, a distance of approximately 4,600 feet. Refer to **Figure 1 Study Area Overview** that depicts the study area and the project limits.

A description of I-93 within the project limits is included in the Existing Roadway Conditions section. There are seven existing interchanges within the project limits. A description of each, from south to north, is also discussed in the Existing Roadway Conditions section.

2 Purpose of Report

The purpose of this Technical Feasibility Report (TFR) is to demonstrate that the proposed modifications of the Preferred Alternative for the Bow-Concord I-93 Improvements project “will not have a significant negative impact on the safety and operations of the Interstate System” per the FHWA *Policy on Access to the Interstate System* (Policy) dated May 22, 2017. There are access modifications proposed for several of the interchanges. A detailed description of the proposed improvements at each interchange is provided later in this report along with a discussion of its safety, operational, and engineering acceptability, as emphasized in the Policy.

The Existing Roadway Conditions section will outline the geometric and operational deficiencies that exist at the various project interchanges. The Proposed Modifications section will focus on how the proposed modifications would address these deficiencies. The geometric deficiencies were identified by comparing the existing geometry against the standards set forth in the NHDOT *Highway Design Manual, A Policy on Geometric Design of Highways and Streets* from the American Association of State Highway and Transportation Officials (AASHTO) commonly referred to as the “Green Book”, and *A Policy on Design Standards Interstate System* from AASHTO (January 2005).

The operational deficiencies will reference the procedures for estimating the operating conditions of a roadway from the *Highway Capacity Manual, 6th Edition* (HCM). The basis for the HCM procedures is level-of-service (LOS), a quantitative measure describing the operating conditions as perceived by motorists driving in a traffic stream.

The HCM divides freeway facilities into three types of segments:

1. Basic – sections with no ramps
2. Merge or Diverge – 1,500-foot sections within either an on-ramp or an off-ramp
3. Weaving – sections with an on-ramp followed within 3,000 feet or less by an off-ramp.

Freeway LOS for all three segment types is based on vehicle density per lane, which is calculated by dividing the number of vehicles by the number of lanes and the average speed of those vehicles. There are six levels of service (LOS A to F) defined by the flow of traffic. **Table 1** shows the LOS Criteria for each segment type.

Table 1: LOS Criteria for Freeway Segments

LOS	Characteristics	Density (Passenger cars per mile per lane)		
		Basic	Weaving	Merge/Diverge
A	Free-flow operations	≤ 11	0-10	≤ 10
B	Reasonably free-flow	> 11-18	> 10-20	> 10-20
C	Speeds near free-flow	> 18-26	> 20-28	> 20-28
D	Speeds decline	> 26-35	> 28-35	> 28-35
E	Operation at capacity	> 35-45	> 35-43	> 35
F	Breakdown/Unstable flow	Demand Exceeds Capacity OR Density > 45	> 43, OR Demand Exceeds Capacity	Demand Exceeds Capacity

Freeway segments with LOS A to LOS C are considered acceptable. LOS D is generally considered acceptable during peak periods as the cost to make improvements to meet LOS C are typically unjustifiable. LOS E and LOS F are generally considered unacceptable with improvements necessary to provide an acceptable level of service.

2.1 Traffic Modeling

I-93 through Bow and Concord is a regionally significant corridor. Traffic data has been collected from both within the corridor and from outside the corridor. In cooperation with the Central New Hampshire Regional Planning Commission (CNHRPC), a regional model has been developed for the Central NH Region using the TransCAD software. The Regional Model includes the 20 communities that comprise the Central NH Region and

the Town of Weare, which is part of the Southern NH region. The model was calibrated using traffic and land use data to emulate actual traffic conditions in the region. The Base Year for the Regional Model is 2014. Future land use, employment and housing data was used to develop the Design Year 2035 model.

To appropriately evaluate the complex roadway network that comprises the I-93 corridor, a Microsimulation Model has also been developed for the project using the TransModeler software. The Microsimulation Model is a more detailed model of the corridor that provides more accurate information on the interaction of traffic between and within the interchanges. Information from the Regional Model is used to generate traffic entering and exiting the Microsimulation Model boundary. The operational results presented in this report were all generated by the Microsimulation Model.

3 Existing Roadway Conditions

Interstate 93 (I-93) within the project limits is a four-lane divided urban principal arterial highway, a major roadway whose primary purpose is to move high volumes of traffic, with limited access provided only at the interchanges. An additional lane exists southbound from Exit 12 and extends south of I-89. South of the project limits, I-93 is a six-lane divided urban arterial highway. The posted speed limit within the project area is 55 miles per hour (mph). The design speed within the project limits varies but exceeds 60 mph in most cases.

This 4.5-mile segment serves approximately 75,000 vehicles per day with peak summer travel at over 85,000 vehicles per day. See **Figure 2** for a map indicating the current annual average daily traffic (AADT) on each project segment. There are significant backups on I-93 during summer months and especially during holidays or special events. The traffic backups on northbound I-93 during peak periods can stretch as far south as the Hooksett Toll Plaza, a distance of about seven miles from I-89. The traffic backup on southbound I-93 during peak periods can stretch as far north as Exit 17, a distance of about five miles from the Merrimack River. See **Figure 3** for a map of the morning and afternoon peak hour volumes for the project Base Year 2014. See **Figure 4** for a Typical Section that includes existing I-93 within the project limits.

There are seven existing interchanges within the project limits, each is described in detail in the following sections.

3.1 I-89 Exit 1

Exit 1 on I-89 is a full access (four access points) partial cloverleaf interchange with all ramps located on the west side of South Street and Logging Hill Road in order to provide separation with the ramps from the I-93/I-89 Interchange. There is only ¼ mile between Exit 1 and I-93. See **Figure 5** for the existing conditions of I-89 Exit 1.

The close proximity of the two interchanges results in short weaving sections for both northbound and southbound I-89 traffic between the two interchanges. AASHTO

describes weaving as “highway segments where the pattern of traffic entering and leaving at contiguous points of access results in vehicle paths crossing each other”.

In particular, the southbound weave that involves traffic entering from Exit 1 and I-89 traffic exiting to southbound I-93 has long been a concern for those traveling in Bow. The distance between the entrance and exit ramps is approximately 440 feet, which is less than the AASHTO recommended 2,000 feet. This weave is made worse by the high speeds that are driven by traffic on southbound I-89. The grade of I-89 in the area is about 3% downhill and keeping traffic at or below the 40-mph speed limit has been unsuccessful. Reduced speed warning signs were installed several years ago but speeds continue to be well above the speed limit. The limited sight distance for those entering at Exit 1 along with the yield condition contributes to the poor operations as this entering traffic is traveling at speeds much lower than the traffic it is weaving with on I-89. This weave currently operates at a level of service (LOS) E/D (AM Peak Period/PM Peak Period) that projects to LOS F/E by 2035. The difficulty accessing I-89 at Exit 1 causes diversion to local streets as described by many Bow residents.

The northbound I-89 weave between I-93 and Exit 1 currently has an LOS B/E that by 2035 is projected to be LOS F/E. There is a substantial increase in morning peak hour traffic on the southbound I-93 to northbound I-89 ramp as a result of projected growth along the I-89 corridor that results in the dramatic reduction in LOS between 2014 and 2035. The distance between the entrance and exit ramps is approximately 500 feet, which is less than the AASHTO recommended 2,000 feet. Speed is not as critical an issue for this weave as traffic on I-89 is starting from a stopped condition at the Route 3A/Hall Street intersection.

3.2 I-93/I-89 Interchange

The I-93/I-89 Interchange is a modified trumpet interchange where I-89 ends at I-93. There are direct and loop ramps connecting the two Interstate routes. These four ramps constitute eight interstate access points. In addition, the extension of I-89 connects directly to NH Route 3A via a signalized at-grade intersection. There is only 1,200 feet between the I-93/I-89 Interchange and I-89 Exit 1. The AASHTO recommended spacing between interchanges in urban settings is one mile (5,280 feet). See **Figure 6** for the existing conditions of the I-93/I-89 Interchange.

There is a short weave within the I-93/I-89 Interchange between the two loop ramps on I-93 northbound. A collector-distributor (C-D) Road services this weaving section. This weave currently has a LOS E/E that projects to LOS F/F by 2035. The distance between the entrance and exit ramps is approximately 400 feet, which is less than the recommended 1,600 feet for this location by AASHTO. AASHTO standards allow a shorter weave distance on C-D Roads than on highway mainlines. These ramps have high volumes of traffic as they accommodate traffic moving between the two interstates.

3.3 I-93 Exit 12

Exit 12 is a full access partial cloverleaf interchange, but it has two sets of exit ramps from I-93 connecting to South Main Street (NH Route 3A). Therefore, there are six access points for Exit 12 as follows:

- Northbound exit to Route 3A south
- Northbound exit to Route 3A north
- Northbound entrance from Route 3A
- Southbound exit to Route 3A north
- Southbound exit to Route 3A south
- Southbound entrance from Route 3A

Three of the exit ramps at Exit 12 have deficient deceleration distances, both of the southbound exit ramps and the northbound exit ramp to northbound Route 3A. The spacing between the I-93/I-89 Interchange and Exit 12 is about 2/3-mile, less than the AASHTO recommended spacing of one mile. See **Figure 7** for the existing conditions of Exit 12.

3.4 I-93 Exit 13

Exit 13 is a full access (four access points) single point urban interchange (SPUI) with access to Water and Manchester Streets (US Route 3) in Concord. A SPUI terminates the ramps at a single point where a single traffic signal controls most of the movements within the intersection. A reconstruction of Exit 13 was completed in 2003 that anticipated a 6-lane I-93. Therefore, the interchange does not require reconstruction to accommodate this project's proposed widening.

One deficiency identified for Exit 13 concerns the northbound exit ramp. During AM peak periods, traffic backs up daily onto I-93 from the intersection of Manchester Street (Route 3). The cause of the backup is the high volume of traffic that makes a right turn onto Manchester Street. This movement is controlled by a stop sign and additionally the limited sight distance requires each turning vehicle to wait to make the turn. See **Figure 8** for the existing conditions of Exit 13.

3.5 I-93 Exit 14

Exit 14 is a full access (four access points) diamond interchange providing access to Loudon Road (NH Route 9). North of Exit 14 is Exit 15, only 2,800 feet away. See **Figure 9** for the existing conditions of Exit 14/15. The spacing between Exit 14 and Exit 15 is about 1/2-mile, less than the AASHTO recommended spacing of one mile. The minimal distance between Exits 14 and 15 results in deficient weaves on I-93 for both southbound and northbound directions. AASHTO recommends 2,000 feet between entrance and exit ramps for this ramp condition. The existing southbound weave is 380 feet long and the existing northbound weave is 370 feet long. The southbound weave along I-93 between Exits 14 and 15 operates at unacceptable levels. The current LOS F/D projects to LOS F/E by 2035. The northbound weave along I-93 between Exits 14 and 15 operates at unacceptable levels where the current LOS C/E is anticipated to be LOS C/F by 2035.

3.6 I-93 Exit 15

Exit 15 is a full cloverleaf interchange that includes four loop ramps and four directional ramps connecting I-93 and I-393. These eight ramps total 12 interstate access points. There are four short weave sections within the interchange, two for I-93 and two for I-393. These weaves are problematic because of the high volume of traffic using the ramps and because the weaves occur on the mainline. The weave distances are below those recommended by AASHTO, however, AASHTO treats cloverleaf interchanges differently than other weave conditions. See **Figure 9** for the existing conditions of Exit 14/15.

The weaves within Exit 15 along I-93 operate at unacceptable levels while those along I-393 operate at acceptable levels. The I-93 southbound weave within Exit 15 currently operates at LOS F/E that is anticipated to deteriorate to a LOS F/F by 2035. The northbound I-93 weave within Exit 15 currently operates at LOS C/E that is anticipated to remain LOS C/E by 2035.

3.7 I-393 Exit 1

Exit 1 of I-393 is a full access (four access points) partial cloverleaf with all ramps on the west side of College Drive because of its close proximity to the Merrimack River. The spacing between Exit 1 on I-393 and Exit 15 is about 2,500 feet, less than the AASHTO recommended spacing of one mile (5,290 feet). This close proximity results in deficient weaves on I-393 for both eastbound and westbound directions. AASHTO recommends 2,000 feet between entrance and exit ramps for this ramp condition. The existing eastbound weave is 540 feet long and the existing westbound weave is 600 feet long. However, the LOS for these two weaves, LOS B/B eastbound and LOS B/B westbound, is acceptable due to the relatively low volume of ramp traffic using I-393 Exit 1. See **Figure 10** for the existing conditions of I-393 Exit 1.

3.8 Adjacent Interchanges

The first adjacent interchanges on the three project interstates are described below. There is only one adjacent interchange for I-89 and I-393 as these both terminate at I-93. See **Figure 11** for the existing condition of these four interchanges.

- I-93 South: Exit 11 is the next interchange on I-93 south of the project. Exit 11 is a partial cloverleaf/diamond interchange 7 miles south of the I-93/I-89 Interchange and is located at the Hooksett Toll Plaza. I-93 is six lanes wide adjacent to Exit 11 with current peak hour ramp traffic ranging between 100 and 300 vehicles per hour (vph). There are no impacts or effects anticipated by the project because I-93 has sufficient capacity in this area and no diversion of traffic is anticipated as a result of the proposed modifications.
- I-93 North: Exit 16 is the next interchange on I-93 north of the project. Exit 16 is also a partial cloverleaf/diamond interchange. It is 1 ½ miles north of Exit 15. I-93 is four lanes wide at Exit 16 with current peak hour ramp traffic ranging between

100 and 450 vph. No discernable impacts or effects are anticipated by the project as minimal diversion of traffic is anticipated as a result of the proposed modifications.

- I-89 North: Exit 2 is the next interchange on I-89 north of the project. Exit 2 is a partial cloverleaf/diamond interchange with stop control at each ramp junction with NH Route 13 (Clinton Street). It is 2 miles north of Exit 1. I-89 is four lanes wide at Exit 2 with projected peak hour ramp traffic ranging between 110 and 585 vph. There are backups that occur along the exit ramps during peak periods. A separate project, currently scheduled for fiscal year 2023, will evaluate the ramp junctions. However, no impacts or effects are anticipated by the 13742 project as no diversion of traffic is anticipated as a result of the proposed modifications.
- I-393 East: Exit 2 is the next interchange on I-393 east of the project. Exit 2 is a partial cloverleaf with stop control at the westbound ramp junction and a signal at the eastbound ramp junction with NH Route 132 (East Side Drive). It is 1 mile east of Exit 1. I-393 is four lanes wide at Exit 2 with projected peak hour ramp traffic ranging between 90 and 860 vph. Minor traffic impacts are anticipated by the project as some diversion of traffic is anticipated due to the elimination of the northbound entrance ramp at Exit 14. The diverted traffic would use the westbound loop entrance ramp at Exit 2 that has a yield controlled right turn. The additional traffic would be expected to add no more than 5% to the volume, which can be accommodated at Exit 2.

4 Proposed Modifications

The traffic projections developed for the project indicate that traffic volumes will increase and by the 2035 design year I-93 through Bow and Downtown Concord will require six traffic lanes, three in each direction, to accommodate this future traffic demand. See **Figure 12** for the No Build projected design year (2035) peak hour volumes in the project area. As specified in AASHTO, there are two main criteria used to evaluate the need for auxiliary lanes: the operation of the ramp merges and diverges and the spacing between successive entrance and exit ramps. As a result of this evaluation, it was determined that auxiliary lanes are warranted between interchanges for all segments of I-93, both northbound and southbound. See **Figure 4** that includes a Typical Section of the proposed I-93.

4.1 I-89 Exit 1

Concept K developed for the I-89 Area proposes modifications to I-89 Exit 1 and the I-93/I-89 Interchange. For I-89 Exit 1, the four access points with I-89 would be retained in their current location as seen on **Figure 13**. The proposed modifications address the weaving issues that exist between I-89 Exit 1 and I-93, but also effect the access between I-89 Exit 1 and Routes 3A.

For the northbound entrance ramp and exit ramp at I-89 Exit 1 the access is the same between I-89 and South Street. However, the access from Route 3A to I-89 would be modified with a new road connecting Route 3A and South Street. The new road would eliminate the weave that presently exists between I-93 and Exit 1.

For the two southbound ramps, a new flyover ramp is proposed between I-89 Exit 1 and the I-93/I-89 Interchange. While the configuration with the flyover ramp is different, the access does not change. The entrance ramp would pass under the flyover ramp but the access to I-89 and both directions of I-93 would be retained. The flyover ramp would eliminate the weave that presently exists between Exit 1 and I-93. Access to Route 3A would also be affected. The Route 3A traffic has three options; I-89 Exit 1 and the new connecting road, the two loop ramps at the I-93/I-89 Interchange, or I-93 Exit 12.

4.2 I-93/I-89 Interchange

Concept K also retains the eight access points at the I-93/I-89 Interchange, but proposes a new directional ramp for northbound I-93 to northbound I-89 traffic. The new ramp provides the same access, but the traffic would no longer utilize the existing C-D Road. The weaving section on the C-D Road would remain, but there would be far less traffic using the weave. See **Figure 13** for a plan of Concept K.

The connection of northbound I-93 to South Street traffic would be retained but would utilize the new road connecting Route 3A and South Street. This new connection also provides access to Route 3A from northbound I-93 that does not presently exist. The direct access that presently exists between Bow Junction (Route 3A/Hall Street/I-89 Extension) and I-89 would no longer exist with the proposed project. This traffic would use either I-89 Exit 1 and the new connecting road or Exit 12.

4.3 I-93 Exit 12

Concept F for Exit 12 proposes to retain the partial cloverleaf configuration, but would eliminate one exit ramp in each direction. While the access points would be reduced from six to four, access to both directions of Route 3A from both directions of I-93 are retained. The result is that all traffic accessing Route 3A would meet at two distinct intersections. Concept F proposes hybrid roundabouts for the two ramp intersections. See **Figure 14** for a plan of Concept F at Exit 12.

4.4 I-93 Exit 13

Concept B for Exit 13 has no proposed access modifications. The only proposed modification would be the northbound exit ramp would be widened to include two signalized right turn lanes onto southbound Route 3. See **Figure 15** for a plan of Concept B at Exit 13.

4.5 I-93 Exit 14

Concept F2 developed for the Exit 14/15 Area proposes modifications to Exit 14 and 15 but no modifications to I-393 Exit 1. For Exit 14, the four access points would be reduced to three access points as the northbound entrance ramp would be eliminated. Eliminating this ramp would allow the alignment of I-93 to be shifted east to avoid impacts to two historic properties, an electrical substation, an active railroad (also historic), a shopping plaza, and allows access to Stickney Avenue to remain. Access to Stickney Avenue is important as this is the primary access to I-93 for the Bus Terminal and a future rail station. Traffic exiting Stickney Avenue would be diverted to several other access points to northbound I-93, as described in detail in Section 6.5. Because the traffic would be diverted to several routes, no capacity issues are anticipated as a result of the diversion. See **Figure 16** for a plan of Concept F2 at Exit 14/15.

The elimination of the northbound entrance ramp also eliminates the deficient northbound weave between Exits 14 and 15. For the deficient southbound weave between Exits 14 and 15, a C-D Road is proposed as part of the project. The C-D Road benefits the weaving because the weaving traffic is traveling at slower speeds and there is no interference with I-93 traffic.

Several concepts were developed for Exit 14 that retained the northbound entrance ramp. Each of these impacted the two historic properties, Stickney Avenue, an electrical substation, an active railroad, and a shopping plaza mentioned above. The property and utility relocation costs for these impacts alone is estimated at approximately \$20M with impacts to three historic properties.

4.6 I-93 Exit 15

Concept F2 also retains the 12 access points at Exit 15, but proposes a cloverstack configuration to replace the existing full cloverleaf as seen on **Figure 16**. The proposed cloverstack would eliminate two of the loop ramps and replace them with directional ramps. By eliminating two of the loop ramps at Exit 15, four weave sections would be eliminated.

4.7 I-393 Exit 1

Concept F2 has no proposed access modifications for I-393 Exit 1. There are no geometric modifications proposed for this interchange.

5 Safety Considerations

Along I-93 within the project limits there are two primary safety concerns: congestion and the close proximity of interchanges. The proposed widening of I-93 is expected to address congestion related safety issues. The access to I-93 afforded by the various interchanges and the effect of the proposed interchange modifications on this access are however more relevant to the purpose of this report. The safety factors associated with the proposed modifications to access are detailed in the following sections for each interchange. It should be noted, however, that the proposed improvements to I-93 are expected to improve the safety of accessing I-93 by including auxiliary lanes between adjacent interchanges along I-93. Crash Modification Factors (CMF) are used to measure the safety effectiveness of a proposed geometric modification. For weaving sections, a CMF of between 0.76 and 0.80 can be expected when auxiliary lanes are provided between entrance and exit ramps. This represents at least a 20% reduction in crashes when auxiliary lanes are provided.

5.1 I-89 Exit 1

The primary safety concerns on I-89 at Exit 1 are the two weaving sections between Exit 1 and I-93. **Figure 17** depicts the crash history at the I-89 Area for the ten-year period from January 2007 to December 2016. In the vicinity of Exit 1, clusters of crashes are present in the two weaving sections. The proposed modifications for the area would eliminate the weaving between the two interchanges, thereby eliminating this safety concern. Wider shoulders and modern ramp geometry are also expected to improve safety at Exit 1. There is no CMF for eliminating a weave, but the reduction in crashes would be expected to be greater than the 20% for providing an auxiliary lane.

5.2 I-93/I-89 Interchange

The primary safety concern at the I-93/I-89 Interchange is the weaving section on the C-D Road that handles northbound I-93 traffic. **Figure 17** depicts the crash history at the I-89 Area for the ten-year period from January 2007 to December 2016. In the vicinity of the I-93/I-89 Interchange, a cluster of crashes are present on the C-D Road weaving section. The proposed modifications for the interchange would significantly reduce the number of vehicles weaving, thereby reducing the number of potential crashes. Since the most significant independent variable affecting crash frequency is traffic volume, it could be stated the reduction is expected to be proportional to the reduction of weaving traffic. The proposed project is expected to reduce the volume of traffic exiting the weave by about 80% during the AM peak period and about 90% during the PM peak period.

There are also clusters of crashes near the I-93 merge and diverge areas of the interchange ramps. The widening of I-93 would be expected to reduce these crashes as there will be less congestion at the merge and diverge points.

5.3 I-93 Exit 12

The primary safety concern at Exit 12 is the deficient deceleration at several of the exit ramps. However, the crash history for the Exit 12 Area depicted on **Figure 18**, for the ten-year period from January 2007 to December 2016, does not indicate high numbers of crashes as a result of the deficiencies. Regardless, a reduction in crashes is expected as a result of providing longer deceleration lanes appropriate for the design speed. A CMF of about 0.60 (40% reduction) can be expected when a deceleration distance is increased as proposed.

There are clusters of crashes on I-93 near Exit 12 that appear to be the result of geometry and congestion. The crashes occur approaching two sharp horizontal curves on I-93 that often experience congestion during peak periods. The crash data indicates approximately 2/3 of the crashes occur with low severity, which suggests they are at lower speeds during congested periods. The widening of I-93 would be expected to reduce these crashes as there will be less congestion.

5.4 I-93 Exit 13

Figure 19 depicts the crash history at the Exit 13 Area for the ten-year period from January 2007 to December 2016. There are no clusters of crashes at Exit 13, however, there are crashes shown on the northbound exit ramp where traffic backups occur. For a five-year period (2009 to 2013) there were at least 7 rear-end crashes on the exit ramp, which is indicative of a ramp that experiences backups. The proposed widening of this ramp would be expected to reduce these crashes as the backups would be reduced.

5.5 I-93 Exit 14

A primary safety concern at Exit 14 are the weaving sections on I-93 between Exit 14 and Exit 15. **Figure 20** depicts the crash history at the Exit 14/15 Area for the ten-year period from January 2007 to December 2016. There are clusters of crashes between Exits 14 and 15 where the two weave sections exist. The proposed elimination of the exit 14 northbound entrance ramp would eliminate the northbound weave between Exit 14 and 15, thereby eliminating this safety concern. A greater than 20% reduction would be expected as stated above for I-89 Exit 1.

The proposed modifications also propose a C-D Road between Exit 14 and 15 for southbound traffic. This weave section would continue to have a short length, however, the C-D Road would have a lower design speed and operating speeds, as well as fewer vehicle conflict points, therefore, a reduction in crashes would be expected.

There are also clusters of crashes along Loudon Road within the project limits. The proposed elimination of one signalized intersection (the northbound entrance ramp), as well as implementation of standard lane widths and shoulders is expected to reduce these crashes. A CMF of about 0.75 can be expected when 10-foot lanes are widened to 11-foot lanes, a reduction of about 25%.

5.6 I-93 Exit 15

The primary safety concern at Exit 15 are the four weaving sections that exist within the cloverleaf interchange. **Figure 20** depicts the crash history at Exit 15 for the ten-year period from January 2007 to December 2016. At Exit 15 there are clusters of crashes present on each weaving section. The proposed modifications for the interchange would eliminate all four weaving sections, thereby eliminating this safety concern. A greater than 20% reduction would be expected as stated above.

5.7 I-393 Exit 1

Also refer to **Figure 20** for the crash history of the I-393 Exit 1. The two weaving sections between I-93 Exit 15 and I-393 Exit 1 along eastbound and westbound I-393 would continue to have short weaving lengths with the proposed project, however, there are no clusters of crashes indicated for them. The low volume of traffic on the Exit 1 ramps and the auxiliary lanes that exist within both weaving sections help to limit the numbers of crashes.

6 Operational Considerations

As mentioned above in the Safety discussion, the inclusion of auxiliary lanes between each interchange along I-93 is expected to improve the safety for those accessing the highway. Auxiliary lanes would also improve the operations between the interchanges, which benefits those accessing the highway. **Table 2** below shows a comparison of the diverge, merge and weave sections along I-93 between the Future No Build (See **Figure 12**) and the Proposed Project. **Figure 21** shows the projected design year (2035) peak hour volumes for the Preferred Alternative. The shaded values indicate those segments with unacceptable levels of service (LOS E or F). The term Not Applicable (N/A) applies to the elimination of a weaving segment or ramp. This comparison illustrates the improved operations that the proposed project would provide.

A comparison of the diverge, merge and weave sections along I-89 and I-393 between the Future No Build and the Proposed Project are found on **Table 3** and **Table 4**, respectively. The comparison for I-89 (Table 3) illustrates the improved operations that the proposed project would provide by eliminating many of the elements that contribute to the existing operational issues. The new flyover ramp and CD Road eliminate the weaving that currently occurs between I-93 and I-89 Exit 1.

The comparison for I-393 (Table 4) illustrates the improved operations that the proposed project would provide by eliminating the weaving that currently occurs along I-393 at Exit 15.

Table 2: I-93 Mainline Operations Comparison

I-93 Segment	Direction	Type	LOS (AM/PM)	
			Projected 2035	
			No Build	Proposed
Exit 15 Off ramp	Southbound	Diverge	F/C	C/B
Exit 15 Weave	Southbound	Weaving	F/E	N/A
Between Exit 14 & 15	Southbound	Weaving	F/D	B/B
Exit 14 On Ramp	Southbound	Merge	D/E	B/B
Exit 13 Off ramp	Southbound	Diverge	D/E	B/B
Exit 13 On ramp	Southbound	Merge	D/F	B/C
Exit 12 Off ramp N	Southbound	Diverge	D/F	N/A
Exit 12 Off ramp S	Southbound	Diverge	D/F	B/C
Exit 12 On ramp	Southbound	Merge	B/C	B/C
I-89 On ramp	Southbound	Merge	B/B	B/C
I-89 Off ramp	Northbound	Diverge	D/C	C/D
I-93/I-89 Weave	Northbound	CD Weaving	F/F	D/C
I-89 On ramp	Northbound	Merge	F/F	C/C
Exit 12 Off ramp S	Northbound	Diverge	F/F	N/A
Exit 12 Off ramp N	Northbound	Diverge	F/F	C/C
Exit 12 On ramp	Northbound	Merge	F/F	C/C
Exit 13 Off ramp	Northbound	Diverge	F/F	C/C
Exit 13 On ramp	Northbound	Merge	F/F	B/C
Exit 14 Off ramp	Northbound	Diverge	F/F	B/C
Between Exit 14 & 15	Northbound	Weaving	B/E	N/A
Exit 15 Weave	Northbound	Weaving	B/E	N/A
Exit 15 On ramp	Northbound	Merge	B/D	B/E

Table 3: I-89 Mainline Operations Comparison

I-89 Segment	Direction	Type	LOS (AM/PM)	
			Projected 2035	
			No Build	Proposed
North of Exit 1	Southbound	Basic	F/D	D/C
Exit 1 Off ramp	Southbound	Diverge	F/D	D/C
Between Exit 1 Ramps	Southbound	Basic	F/E	N/A
Between Exit 1 & I-93	Southbound	Weaving	F/E	N/A
CD Road between Exit 1 & I-93	Southbound	Basic	N/A	E/D
I-93 NB Off ramp	Southbound	Diverge	F/C	N/A
Exit 1/I-93 NB On ramp	Southbound	Merge	N/A	D/C
I-93 NB On ramp	Northbound	Merge	B/B	N/A
Between Exit 1 & I-93	Northbound	Weaving	B/E	N/A
I-89 between Exit 1 & I-93	Northbound	Basic	N/A	A/A
Between Exit 1 Ramps	Northbound	Basic	B/C	B/D
Exit 1 Off ramp	Northbound	Diverge	N/A	B/B
Exit 1 On ramp	Northbound	Merge	B/C	B/D
CD Road On Ramp	Northbound	Merge	N/A	B/C

Table 4: I-393 Mainline Operations Comparison

I-393 Segment	Direction	Type	LOS (AM/PM)	
			Projected 2035	
			No Build	Proposed
At I-93 Exit 15	Eastbound	Weaving	A/B	N/A
SB I-93 On Ramp	Eastbound	Merge	N/A	A/B
Between I-93 and Exit 1	Eastbound	Weaving	A/C	B/C
Between Exit 1 Ramps	Eastbound	Basic	B/C	B/C
Exit 1 On ramp	Eastbound	Merge	B/D	B/D
East of Exit 1	Eastbound	Basic	B/D	B/D
East of Exit 1	Westbound	Basic	E/D	E/D
Exit 1 Off ramp	Westbound	Diverge	D/C	D/C
Between Exit 1 Ramps	Westbound	Basic	E/C	E/C
Between I-93 and Exit 1	Westbound	Weaving	C/C	C/C
At I-93 Exit 15	Westbound	Weaving	D/C	N/A
NB I-93 On Ramp	Westbound	Merge	N/A	B/A

The operational considerations associated with the proposed interchange modifications are highlighted below.

6.1 I-89 Exit 1

The proposed modifications at Exit 1 are focused on addressing the weaving issues that exist between Exit 1 and I-93. **Table 5** below compares the weaving operations of the proposed project to the No Build. The proposed modifications eliminate the weaves while maintaining the access.

Table 5: I-89 Exit 1 Weaving Comparison

Segment	Level of Service (LOS)			
	Projected 2035			
	No Build		Proposed	
	AM	PM	AM	PM
I-89 Northbound between Exit 1 and I-93	B	E	N/A	N/A
I-89 Southbound between Exit 1 and I-93	F	E	N/A	N/A

The new directional ramp at the proposed I-93/I-89 Interchange for northbound I-93 to northbound I-89 traffic eliminates the direct I-89 extension to Bow Junction (Route 3A/Hall Street/I-89 Extension). This traffic can still access Bow Junction, but only by using I-89 Exit 1, the I-93/I-89 Interchange loop ramps, or Exit 12 on I-93. The additional traffic on South Street and Logging Hill Road require that both Exit 1 intersections are signalized. **Table 6** below presents the intersection operations for the proposed I-89 Exit 1 ramp intersections.

Table 6: I-89 Exit 1 Intersection Operations

Project Area	Intersection	Type	Projected 2035	
			Overall Delay (Seconds) (AM/PM)	LOS (AM/PM)
I-89 Exit 1	Logging Hill Road/I-89 Exit 1 Southbound Ramps	Signal	19/14	B/B
	South Street/I-89 Exit 1 Northbound Ramps	Signal	13/20	B/C

6.2 I-93/I-89 Interchange

The proposed modifications at the I-93/I-89 Interchange are focused on addressing the weaving issue that exists on the northbound C-D Road within the interchange. **Table 7** below compares the weaving operations of the proposed project to the No Build.

Table 7: I-93/I-89 Interchange Weaving Comparison

Segment	Level of Service (LOS)			
	Projected 2035			
	No Build		Proposed	
	AM	PM	AM	PM
I-93 Northbound CD Road connecting to I-89	F	F	D	C

The proposed project is expected to reduce the volume of traffic exiting the weave by about 80% during the AM peak period and about 90% during the PM peak period. The resulting LOS would be acceptable while maintaining the access between I-93 and I-89. Also, the existing loop ramp would be converted to a local ramp that terminates at the new connection between Route 3A and South Street. This provides access to Route 3A from I-93 that currently does not exist.

6.3 I-93 Exit 12

The proposed modifications at Exit 12 are focused on addressing the deficient deceleration that exists on three of the existing exit ramps. By eliminating two of the exit ramps, one in each direction of I-93, the remaining exit ramps can be designed with appropriate deceleration distances. The two ramp intersections are proposed to include hybrid roundabouts to access Route 3A. **Table 8** below presents the intersection operations for Exit 12 Concept F.

Table 8: Exit 12 Intersection Operations

Project Area	Intersection	Type	Projected 2035			
			Overall Delay (Seconds) (AM/PM)		LOS (AM/PM)	
			No Build	Proposed	No Build	Proposed
Exit 12	I-93 Exit 12 Northbound Ramps/NH 3A	Stop & Yield/ Roundabout	6/6	11/12	A/A	B/B
	I-93 Exit 12 Southbound Ramps/NH 3A	Stop & Yield/ Roundabout	6/8	12/14	A/A	B/B

The roundabouts effectively process the traffic accessing Route 3A. Full access is therefore maintained at Exit 12.

6.4 I-93 Exit 13

The proposed modifications at Exit 13 are focused on eliminating the queue along the northbound exit ramp that currently backs up onto I-93. Providing two right turn lanes and placing the right turn on signal control would prevent the queue from backing onto I-93. The proposed project would maintain the full access at Exit 13.

The signalized single point intersection at Exit 13 that provides access to US Route 3 would remain with the proposed project. **Table 9** below presents the intersection operations for Exit 13.

Table 9: Exit 13 Intersection Operations

Project Area	Intersection	Type	Projected 2035			
			Overall Delay (Seconds) (AM/PM)		LOS (AM/PM)	
			No Build	Proposed	No Build	Proposed
Exit 13	I-93 Exit 13 SPU/US 3	Signal	123/100	44/51	F/F	D/D
	I-93 Exit 13 Southbound Ramp/US 3/Hall Street	Signal	20/30	21/32	C/C	C/C

The improved LOS for the SPUI intersection for the proposed is attributed to the significant reduction in delay on the northbound exit ramp. This delay is reduced during the AM peak period from 326 seconds for the No Build to 48 seconds for the proposed.

6.5 I-93 Exit 14

The modifications at Exit 14 propose retaining its diamond configuration for three of the ramps, however, the northbound entrance ramp would be eliminated. The projected (2035) peak hour traffic demand on this ramp is 110 vehicles per hour (vph) during the morning peak period and 281 vph during the afternoon peak period. The volumes are evenly split with about 50% coming from both Westbound and Eastbound Loudon Road. The traffic model predicts this traffic would divert to several other routes to access I-93. Those travelers who originate on the west side of I-93 would divert to I-393 via North Main Street, the new connection from Stickney Avenue, or the proposed Storrs Street Extension (to be constructed by the City of Concord). Those travelers who originate on the east side of I-93 would divert to I-393 via Fort Eddy Road or East Side Drive. Once these travelers are on I-393, they would access I-93 through Exit 15.

The dispersion of the relatively low existing northbound entrance ramp traffic to the various routes described above means no one route receives all of the traffic. **Table 10** below outlines the various intersections that would experience increased traffic as a result of the ramp elimination. The proposed layout of each intersection would be optimized to accommodate the additional traffic. All but the North Main Street/I-393 Extension/Boutin Street Intersection would operate at acceptable levels. However, the LOS of that intersection improves to LOS C/E compared to the No Build with LOS B/F.

Table 10: Exit 14 Entrance Ramp Closure Intersection Operations

Project Area	Intersection	Type	Projected 2035			
			Overall Delay (Seconds) (AM/PM)		LOS (AM/PM)	
			No Build	Proposed	No Build	Proposed
Exit 14	Loudon Road/Northbound Exit Ramp/Fort Eddy Road	Signal	299/209	30/46	F/F	C/D
	Loudon Road/Northbound Entrance Ramp	Signal	33/22	N/A	C/C	N/A
	Loudon Road/Stickney Avenue/Bridge Street	Signal	13/25	5/11	B/C	A/B
Exit 15	North Main Street/I-393 Extension/Boutin Street	Signal	19/127	22/67	B/F	C/E
	South Commercial Street/US 202 Eastbound	Signal	6/32	10/39	A/C	A/D
I-393 Exit 1	Westbound Ramps/College Park Drive (Eastbound Approach)	Stop	9/12	10/12	A/B	A/B
	Eastbound Ramps/Fort Eddy Road	Signal	13/17	13/16	B/B	B/B

The proposed modifications to the ramps at Exit 14 also benefits the operation of the Loudon Road corridor. The elimination of the northbound entrance ramp eliminates one of these intersections, which allows for more storage and fewer conflicts. The delay is significantly reduced as compared to the No Build. **Table 11** below presents a comparison of the intersection operations along Loudon Road between the No Build and proposed project.

Table 11: Loudon Road Intersection Operations

Project Area	Intersection	Type	Projected 2035			
			Overall Delay (Seconds) (AM/PM)		LOS (AM/PM)	
			No Build	Proposed	No Build	Proposed
Loudon Road	Loudon Road/Northbound Exit Ramp/Fort Eddy Road	Signal	299/209	30/46	F/F	C/D
	Loudon Road/Southbound Ramps	Signal	55/26	21/17	D/C	C/B
	Loudon Road/Stickney Avenue/Bridge Street	Signal	13/25	5/11	B/C	A/B

Access to I-93 in Concord is currently well signed. The signage would need to be revised to direct those destined for northbound I-93 to I-393 and then I-93. These signs would need to extend further radially from I-93 to divert to the best route. Traffic on Loudon Road east of Hazen Drive/Airport Road would be directed to East Side Drive that provides access via I-393 Exit 2. Traffic in Downtown Concord would be directed to I-393 via North Main Street.

The proposed modifications at Exit 14/15 address the weaving issues that exist between Exit 14 and I5. **Table 12** below compares the weaving operations of the proposed project to the No Build. The proposed modifications eliminate the northbound weave and improve the southbound weave to an acceptable LOS.

Table 12: Exit 14/15 Weaving Comparison

I-93 Segment	Direction	Type	LOS (AM/PM)	
			Projected 2035	
			No Build	Proposed
Between Exit 14 & 15	Southbound	Weaving	F/D	B/B
Between Exit 14 & 15	Northbound	Weaving	B/E	N/A

6.6 I-93 Exit 15

The proposed modifications at Exit 15 are focused on addressing the weaving issues that exist at this full cloverleaf interchange. The proposed cloverstack configuration replaces two of the loop ramps with directional ramps thereby eliminating the four weaving sections within Exit 15. The new configuration retains full access at Exit 15. **Table 13** below compares the weaving operations of the proposed to the No Build.

Table 13: Exit 15 Weaving Comparison

Segment	Level of Service (LOS)			
	Projected 2035			
	No Build		Concept F2	
	AM	PM	AM	PM
I-93 Northbound at Exit 15	B	E	N/A	N/A
I-93 Southbound at Exit 15	F	E	N/A	N/A
I-393 Westbound at Exit 15	D	C	N/A	N/A
I-393 Eastbound at Exit 15	A	B	N/A	N/A

6.7 I-393 Exit 1

There are no proposed modifications at I-393 Exit 1 or the weaving sections between it and Exit 15. The weaves currently operate at acceptable levels and as shown below in **Table 14**, perform well into the future.

Table 14: I-393 Exit 1 Weaving Comparison

Segment	Level of Service (LOS)			
	Projected 2035			
	No Build		Concept F2	
	AM	PM	AM	PM
I-393 Westbound between Exit 15 and Exit 1	C	C	C	C
I-393 Eastbound between Exit 15 and Exit 1	A	C	B	C

7 Engineering Acceptability

The access modifications proposed by the Bow Concord I-93 Improvements Project would address existing operational and safety issues while maintaining all interstate access except for one ramp. That one point of access, the northbound entrance ramp at Exit 14, is removed in order to avoid impacts to two historic properties, Stickney Avenue, an electrical substation, an active railroad, and a shopping plaza. It also provides operational benefits by eliminating a weaving section on I-93 and eliminating a signalized intersection on Loudon Road. The projected peak hour traffic on this ramp is less than 300 vehicles per hour.

There is a reduction of total access points at Exit 12 from 6 to 4, however, the same access to the interstate is retained.

The overall project maintains a high level of interstate access especially considering that the 4.5 mile I-93 corridor has seven full access interchanges including two system interchanges.

8 Summary

Table 15 below summarizes the access point modifications proposed by the project.

Table 15: Access Point Summary

Interchange	Existing Access Points	Proposed Access Points	Description of Modification
I-89 Exit 1	4	4	Access maintained but new ramps and roadways to eliminate problem weaving sections.
I-93/I-89	8	8	Northbound 93 to northbound I-89 converted from a loop to a direct connection. New access to Route 3A from northbound I-93.
I-93 Exit 12	6	4	Retain as a partial cloverleaf interchange except with only one exit ramp in each direction.
I-93 Exit 13	4	4	Retain interchange except widen the northbound exit ramp.
I-93 Exit 14	4	3	Retain diamond interchange except eliminate the northbound entrance ramp.
I-93 Exit 15	12	12	Convert from cloverleaf to cloverstack configuration. Two loops are converted to direct connections.
I-393 Exit 1	4	4	No Changes.

See **Figure 22** for a composite plan of the Preferred Alternative.

APPENDIX A - FIGURES

Figure 1	Study Area Overview
Figure 2	Annual Average Daily Traffic Volumes
Figure 3	Base Year 2014 Peak Hour Traffic Volumes
Figure 4	I-93 Typical Sections
Figure 5	I-89 Exit 1 Existing Conditions
Figure 6	I-93/I-89 Interchange Existing Conditions
Figure 7	Exit 12 Existing Conditions
Figure 8	Exit 13 Existing Conditions
Figure 9	Exit 14/15 Existing Conditions
Figure 10	I-393 Exit 1 Existing Conditions
Figure 11	Adjacent Interchanges
Figure 12	No Build Year 2035 Peak Hour Traffic Volumes
Figure 13	I-89 Area Concept K
Figure 14	Exit 12 Concept F
Figure 15	Exit 13 Concept B
Figure 16	Exit 14/15 Concept F2
Figure 17	Crash History for the I-89 Area
Figure 18	Crash History for the Exit 12 Area
Figure 19	Crash History for the Exit 13 Area
Figure 20	Crash History for the Exit 14/15 Area
Figure 21	Preferred Alternative Year 2035 Peak Hour Traffic Volumes
Figure 22	Preferred Alternative

Figure 1: Study Area Overview

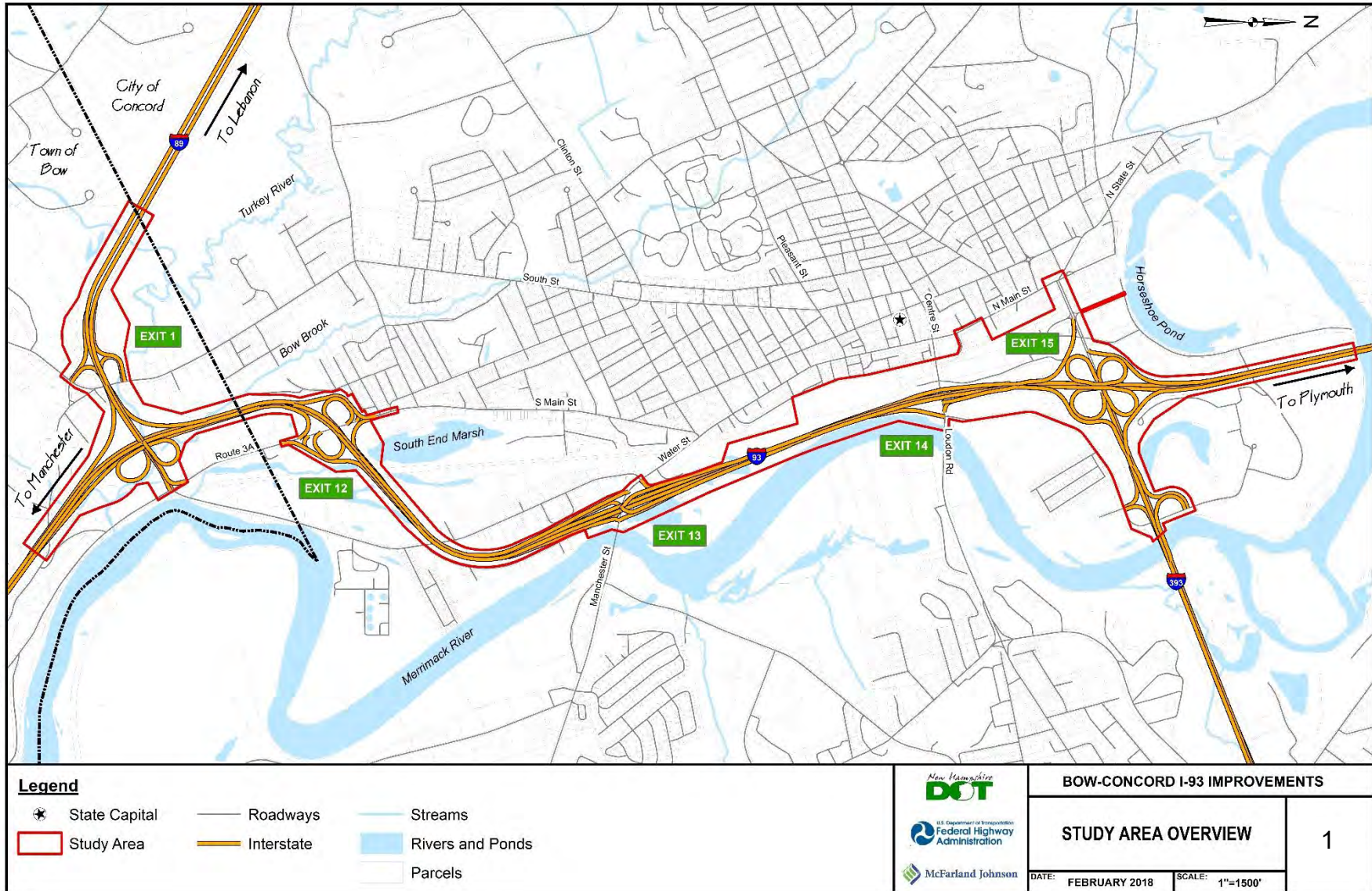


Figure 2: Current (2017) Project AADT

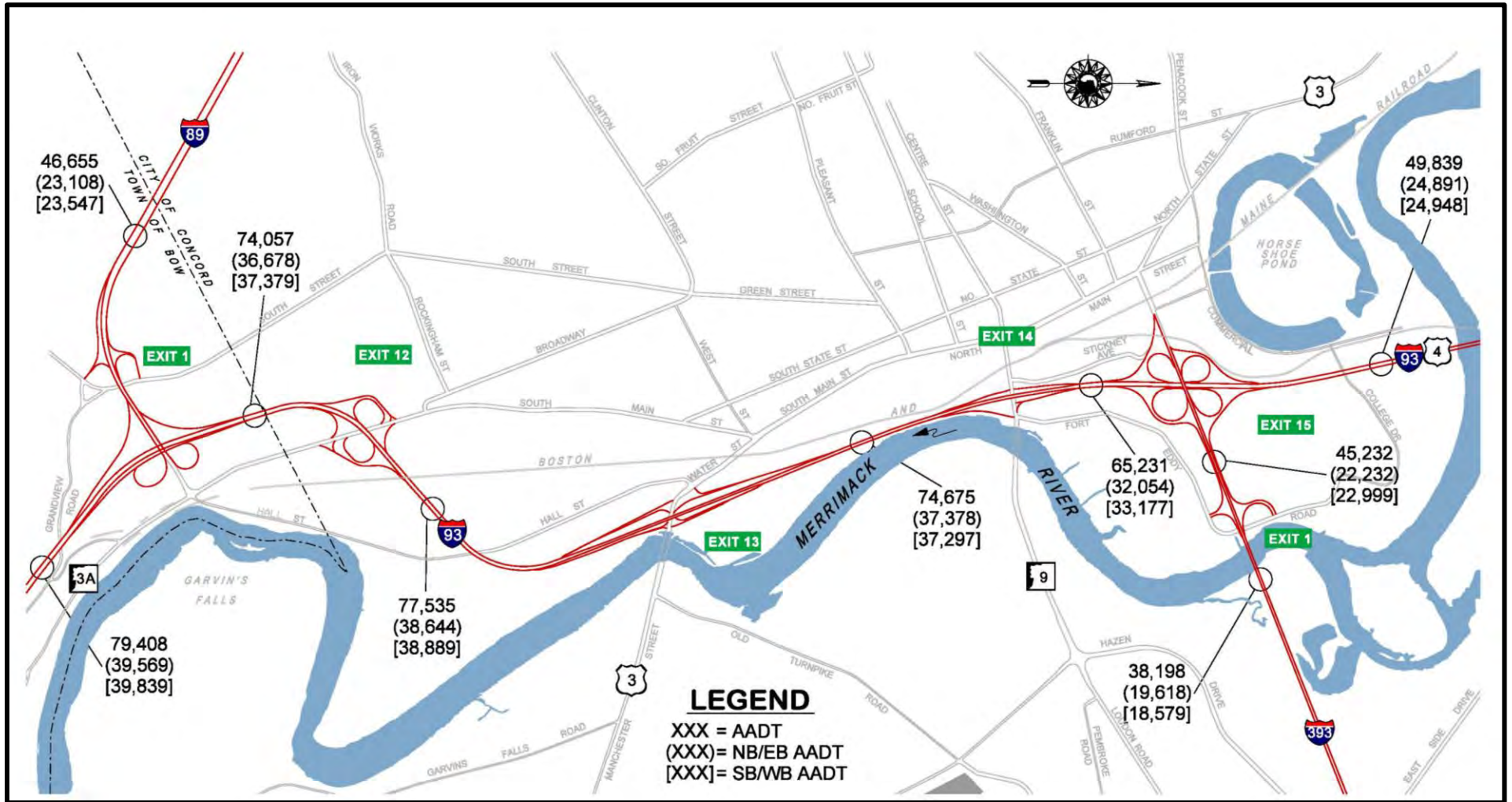


Figure 3: Base Year 2014 Peak Hour Traffic Volumes

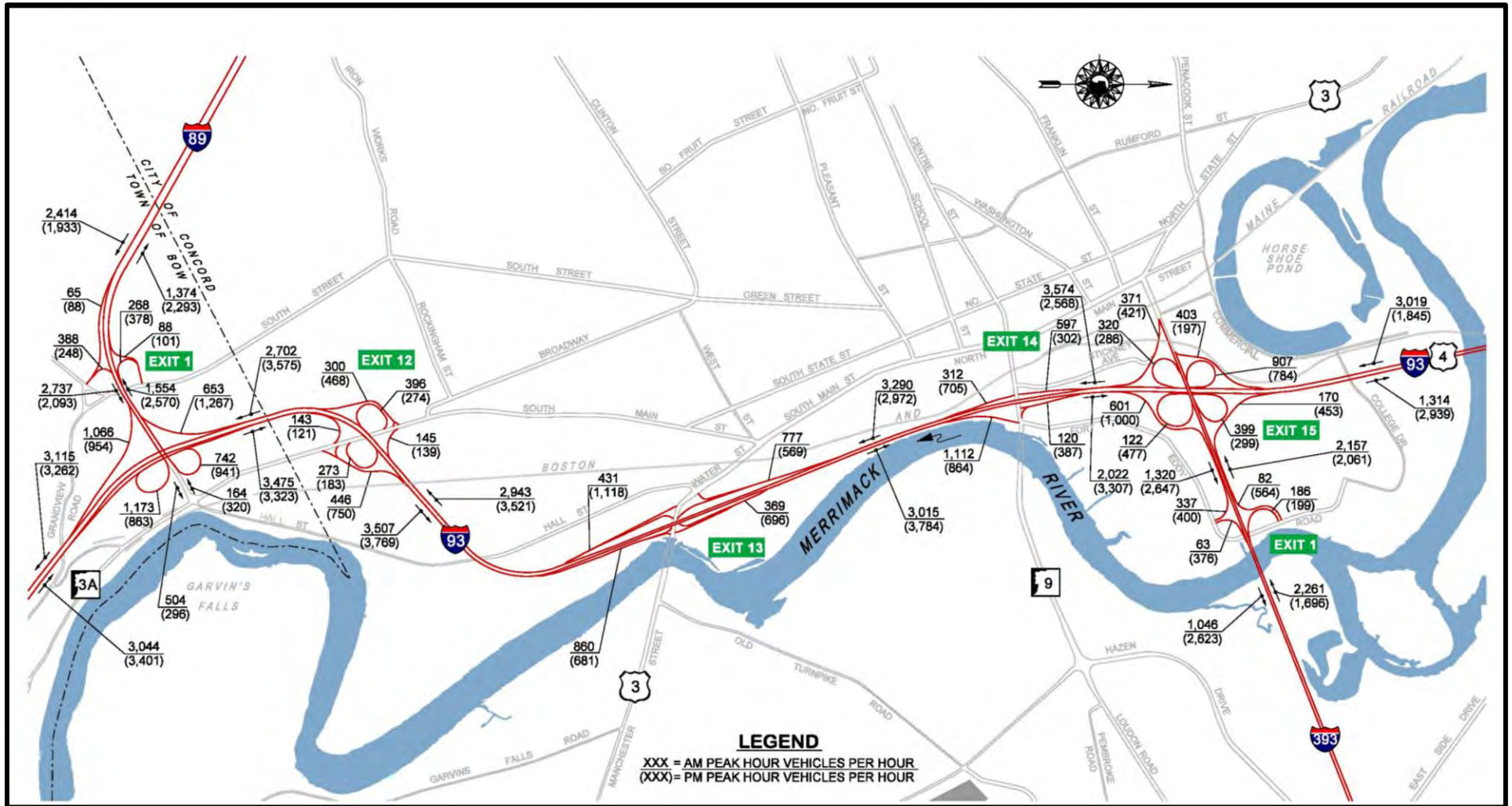


Figure 4: I-93 Typical Section

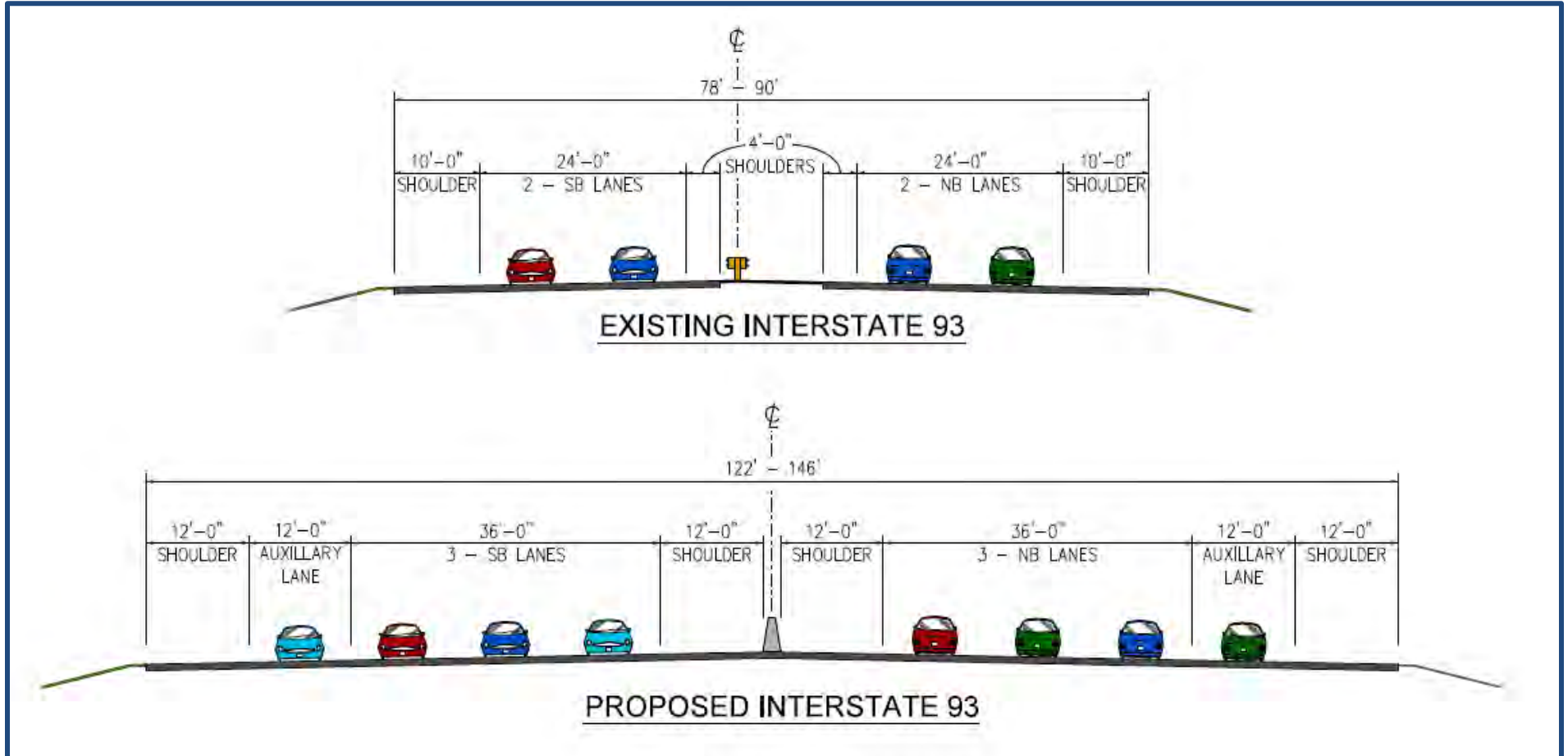


Figure 5: I-89 Exit 1 Existing Conditions

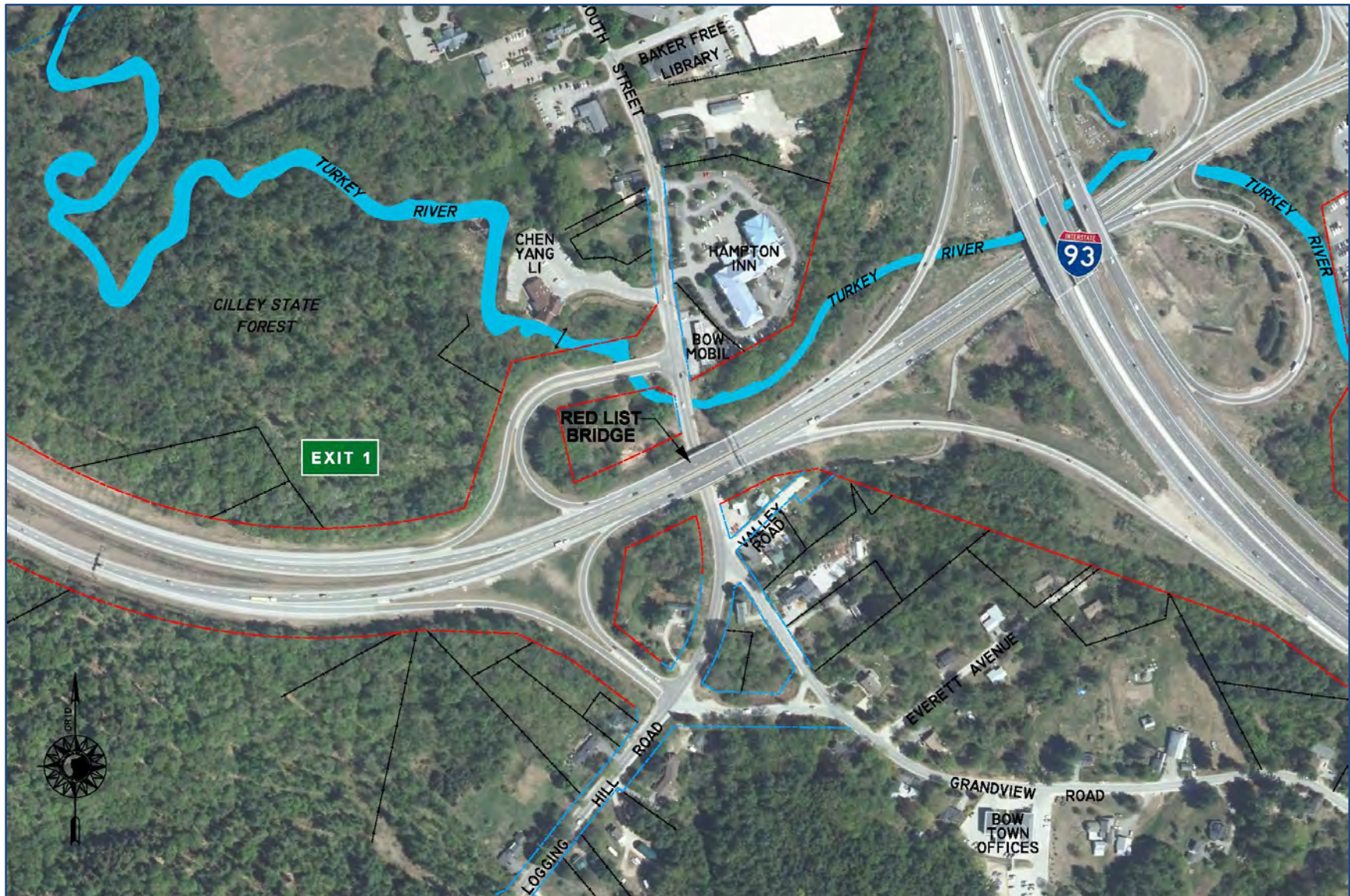


Figure 6: I-93/I-89 Interchange Existing Conditions

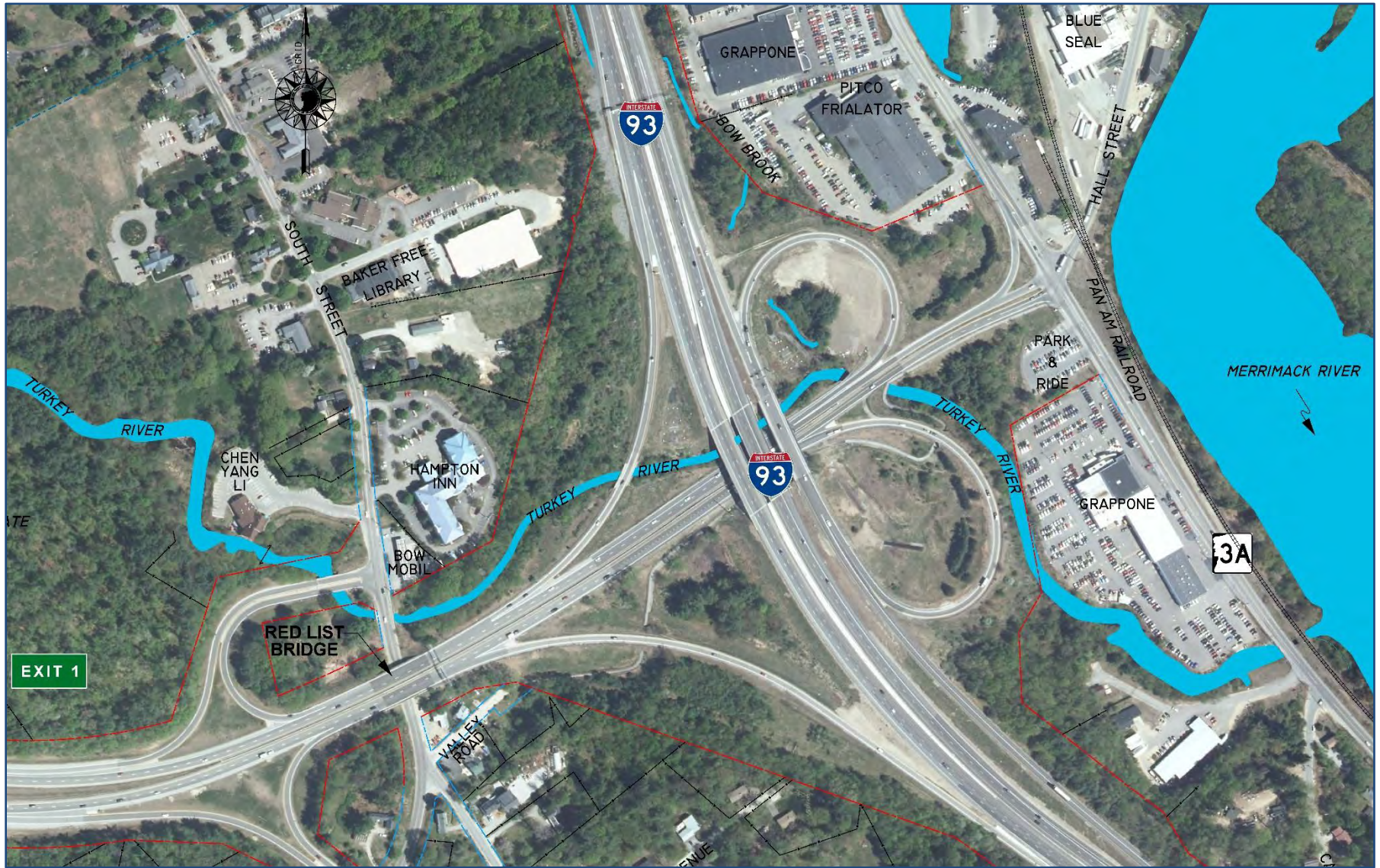


Figure 7: Exit 12 Existing Conditions

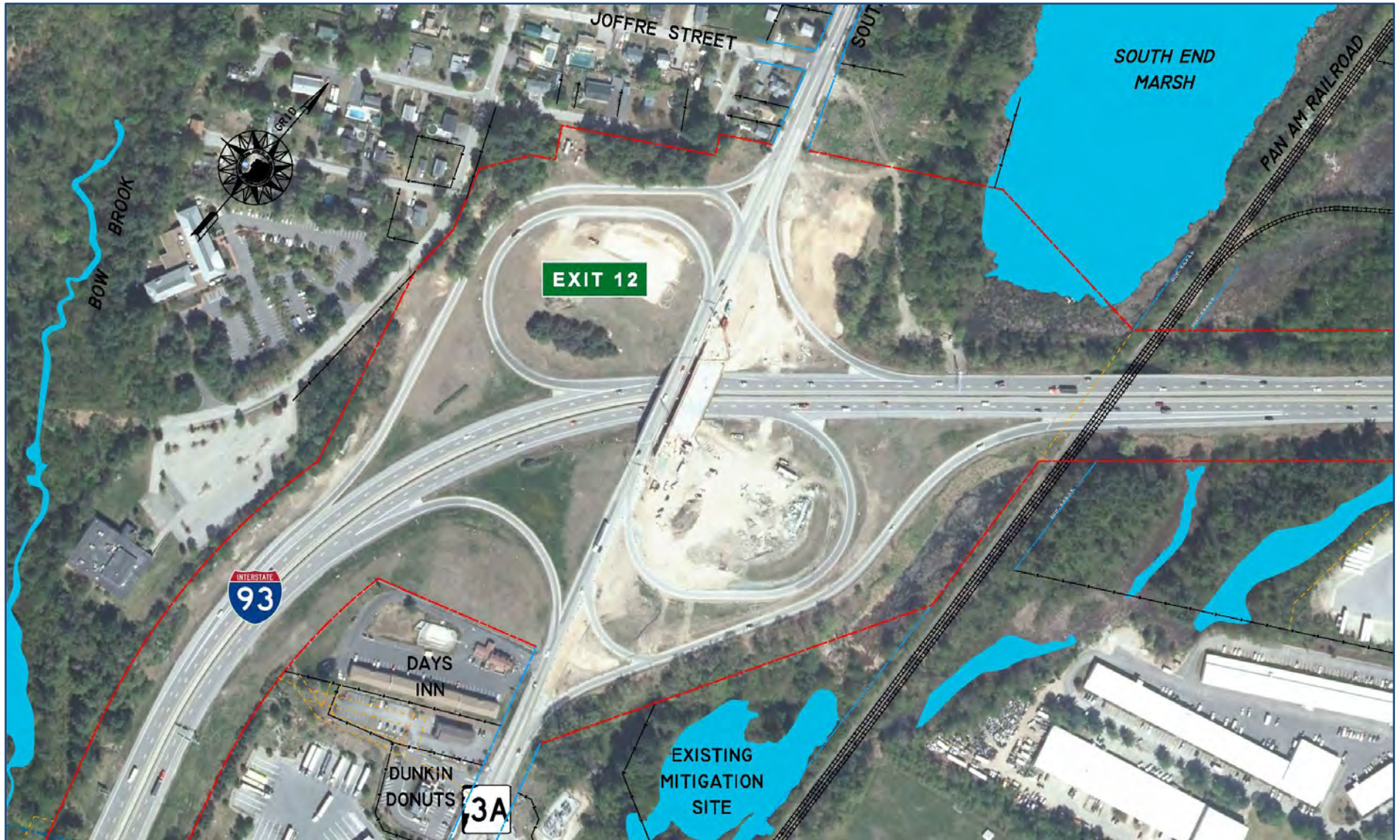


Figure 8: Exit 13 Existing Conditions

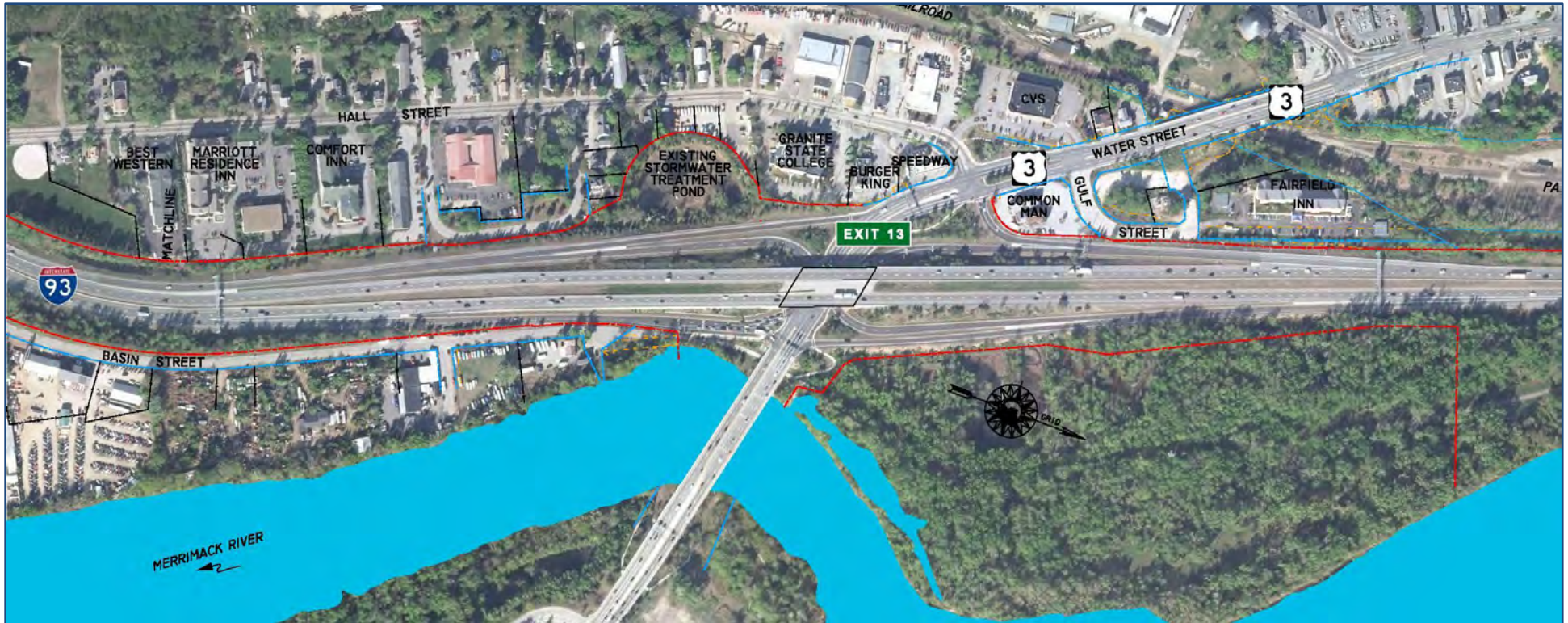


Figure 9: Exit 14/15 Existing Conditions



Figure 10: I-393 Exit 1 Existing Conditions



Figure 11: Adjacent Interchanges

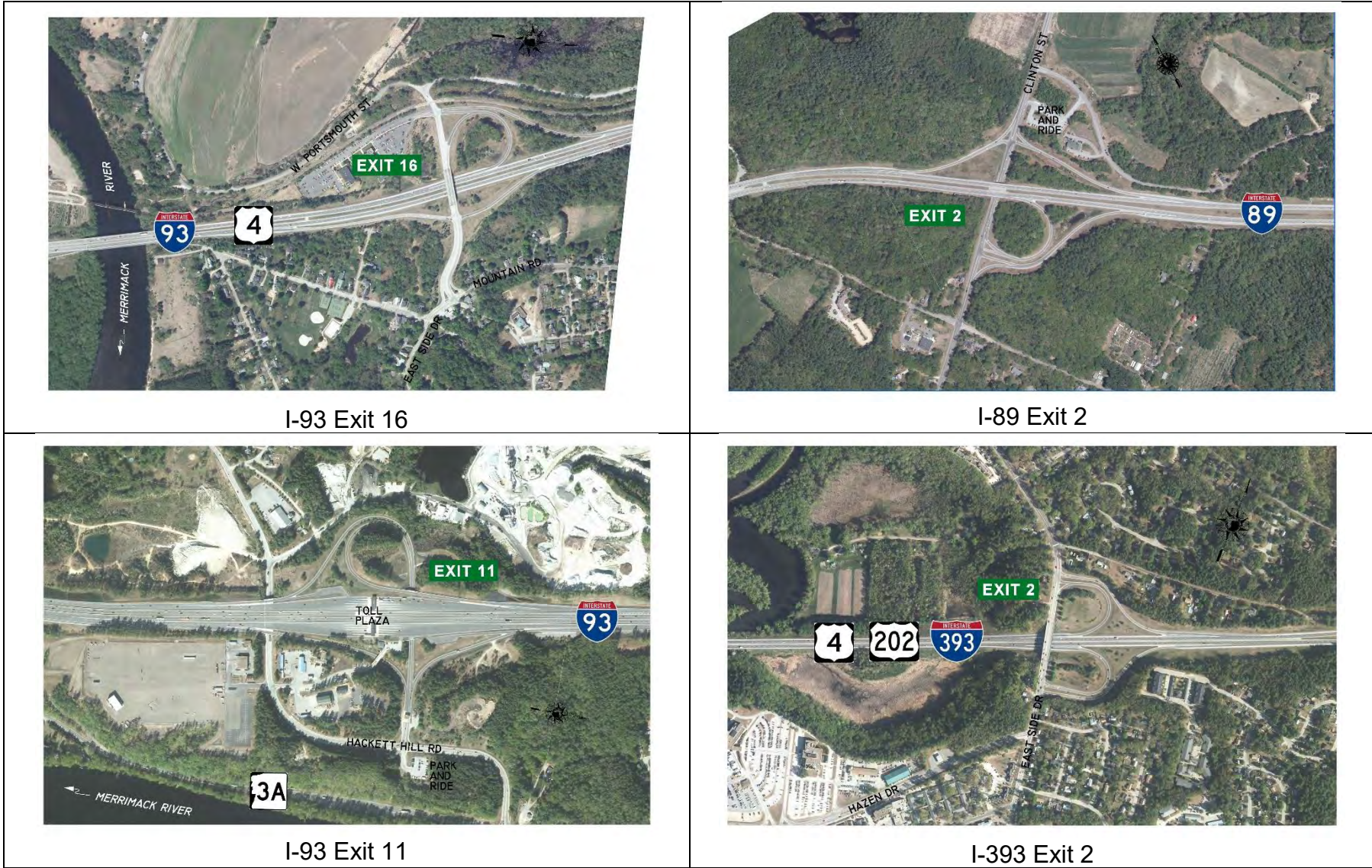


Figure 12: No Build Year 2035 Peak Hour Traffic Volumes

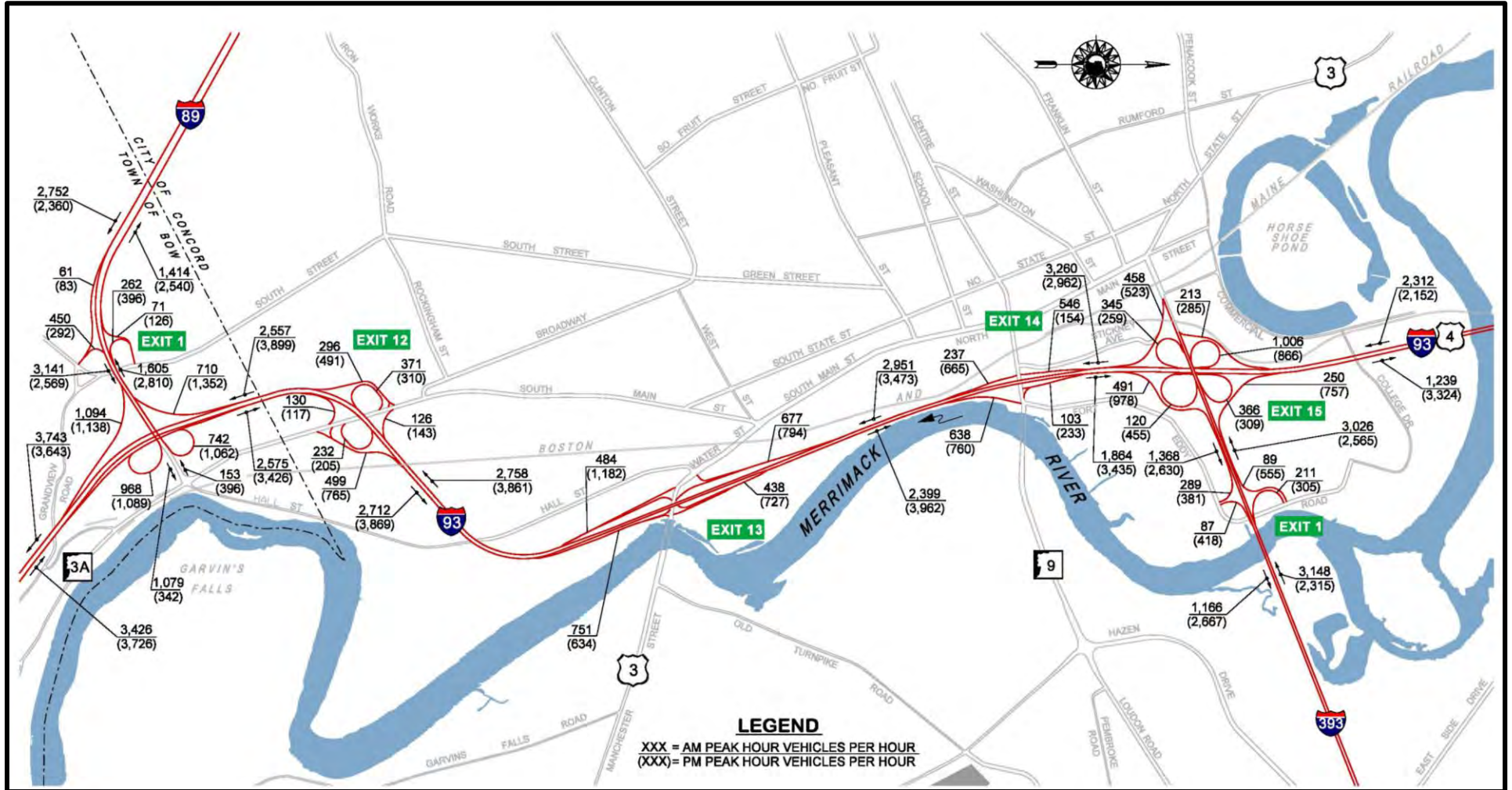


Figure 13: I-89 Area Concept K

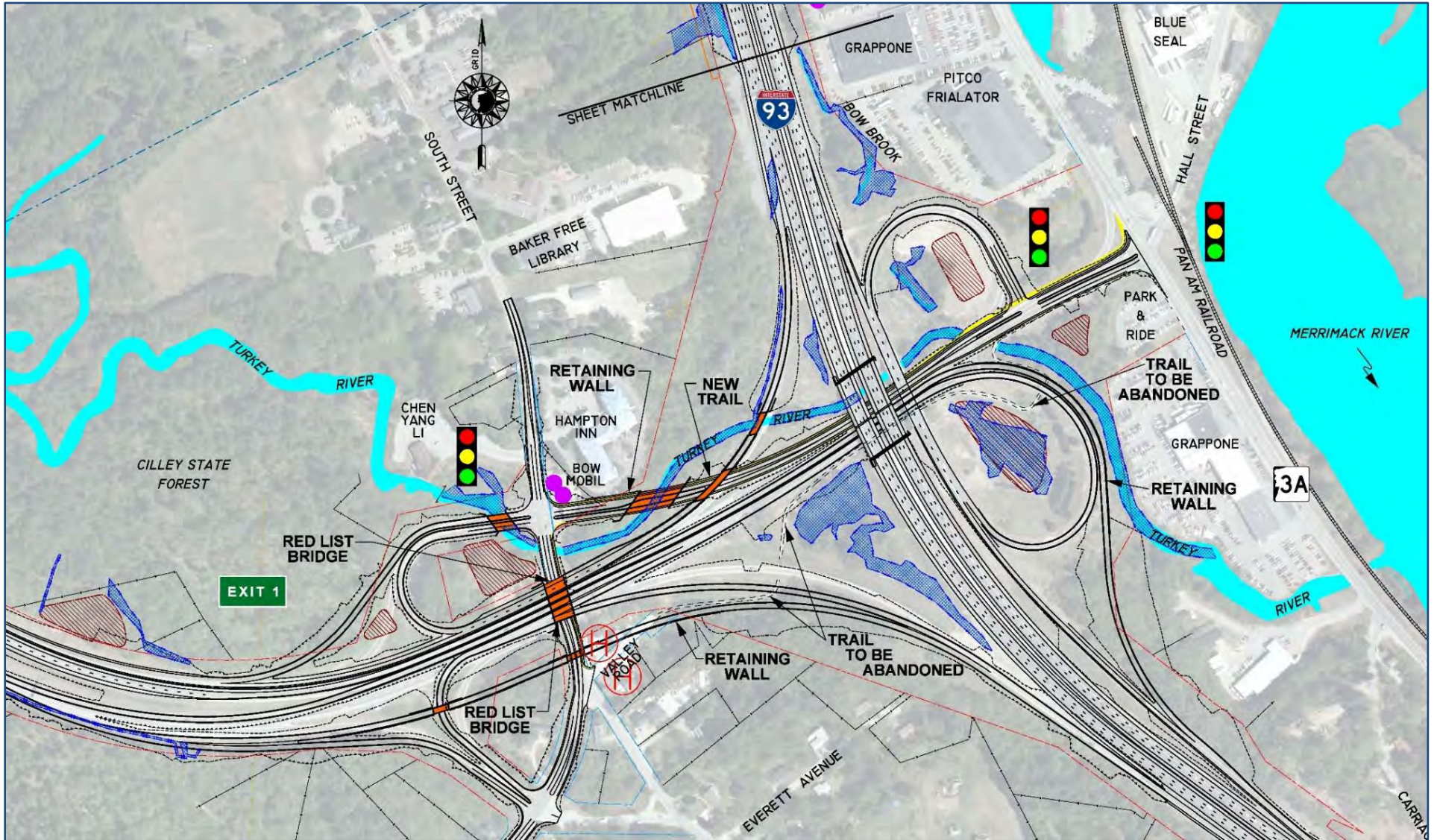


Figure 14: Exit 12 Area Concept F



Figure 15: Exit 13 Area Concept B

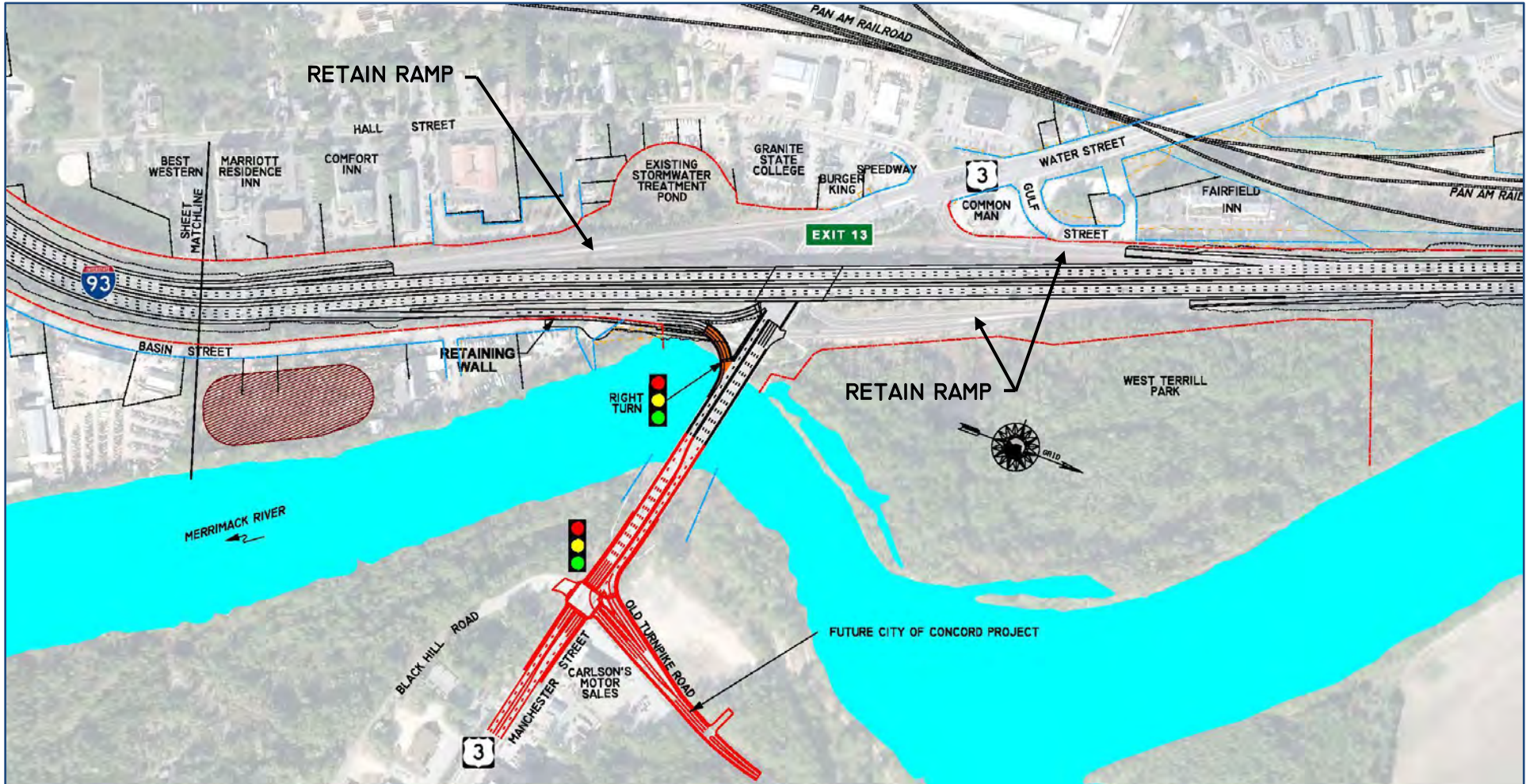


Figure 16: Exits 14/15 Concept F2

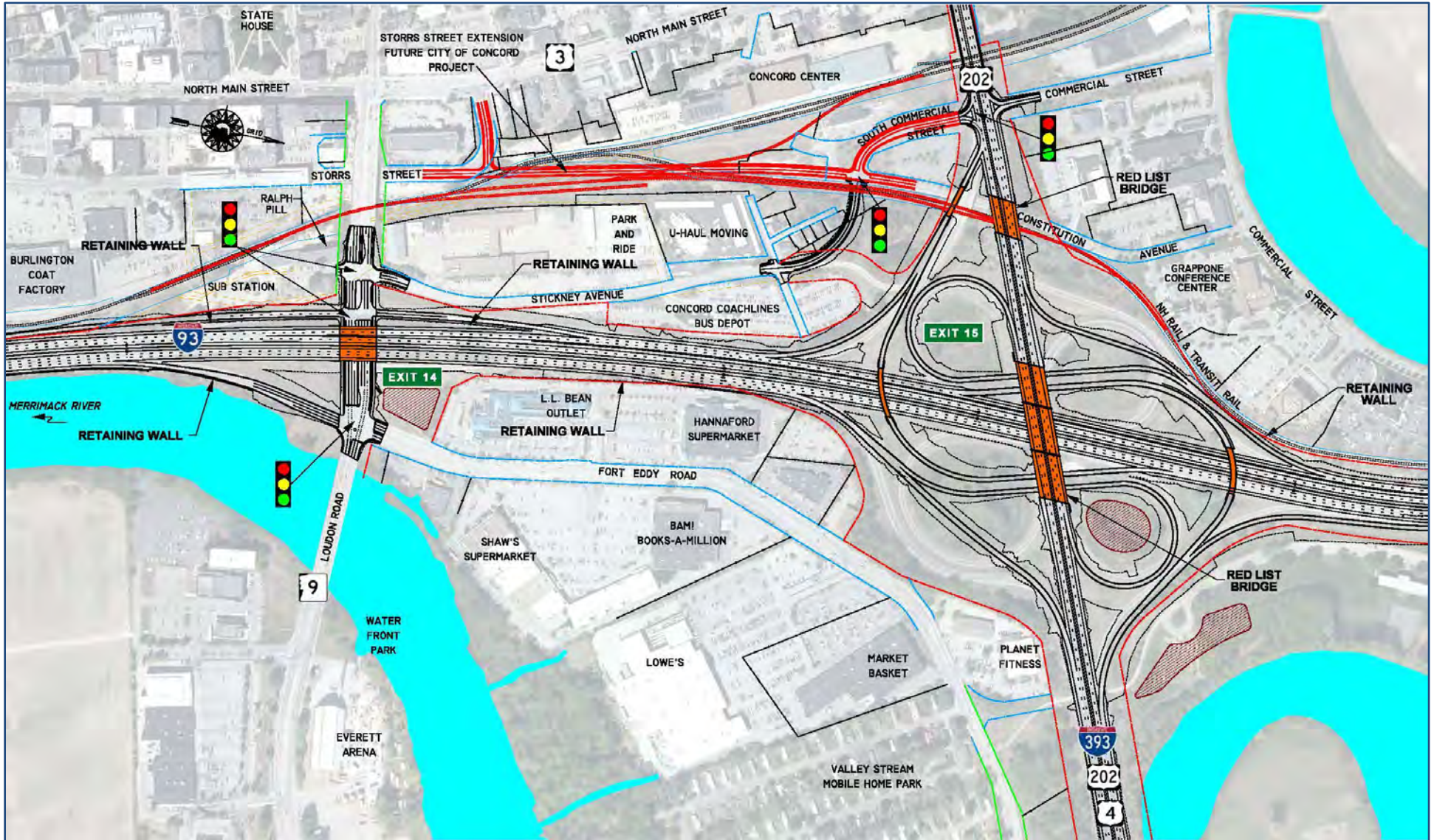


Figure 17: Crash History for the I-89 Area (2007 to 2016)

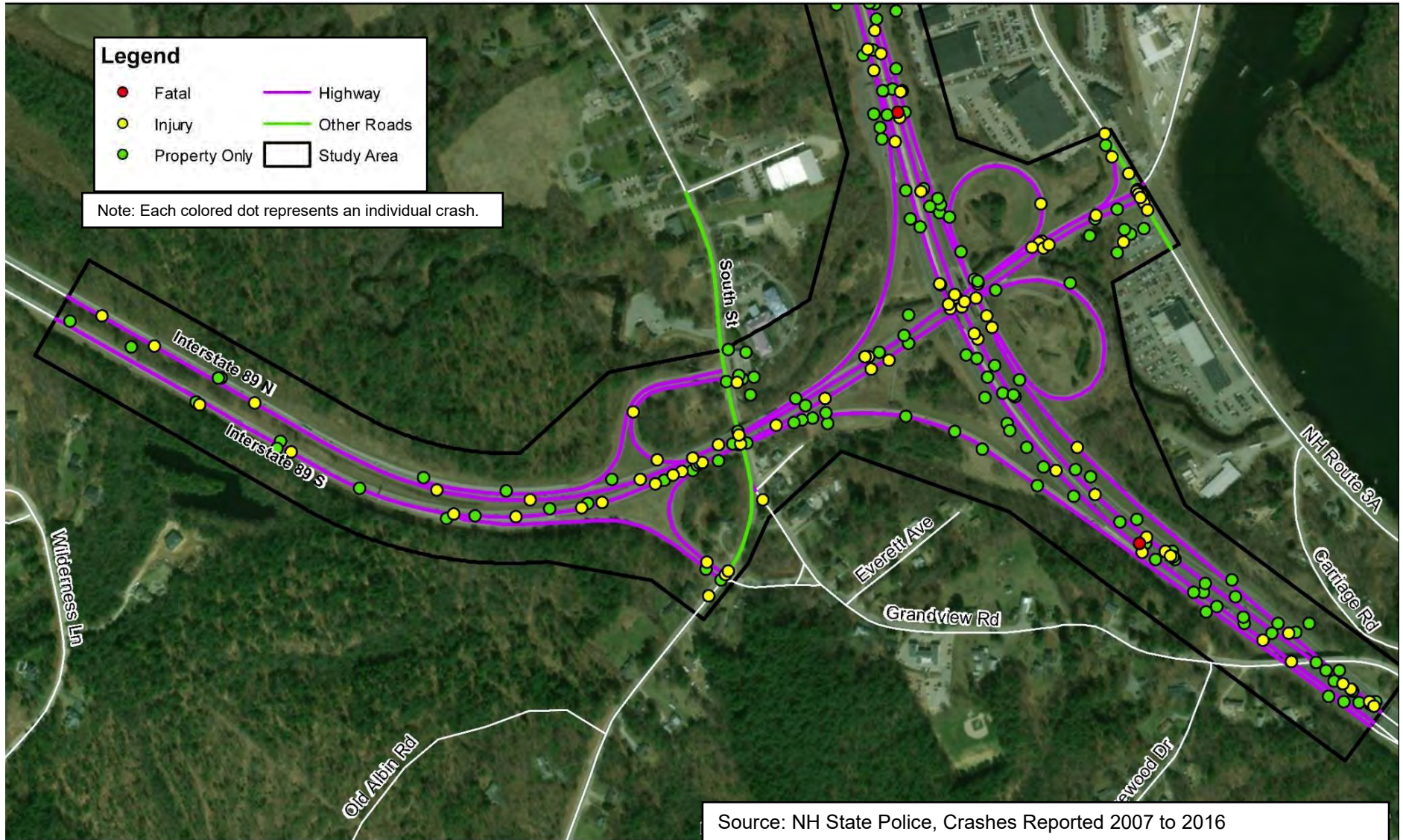


Figure 18: Crash History for the Exit 12 Area (2007 to 2016)

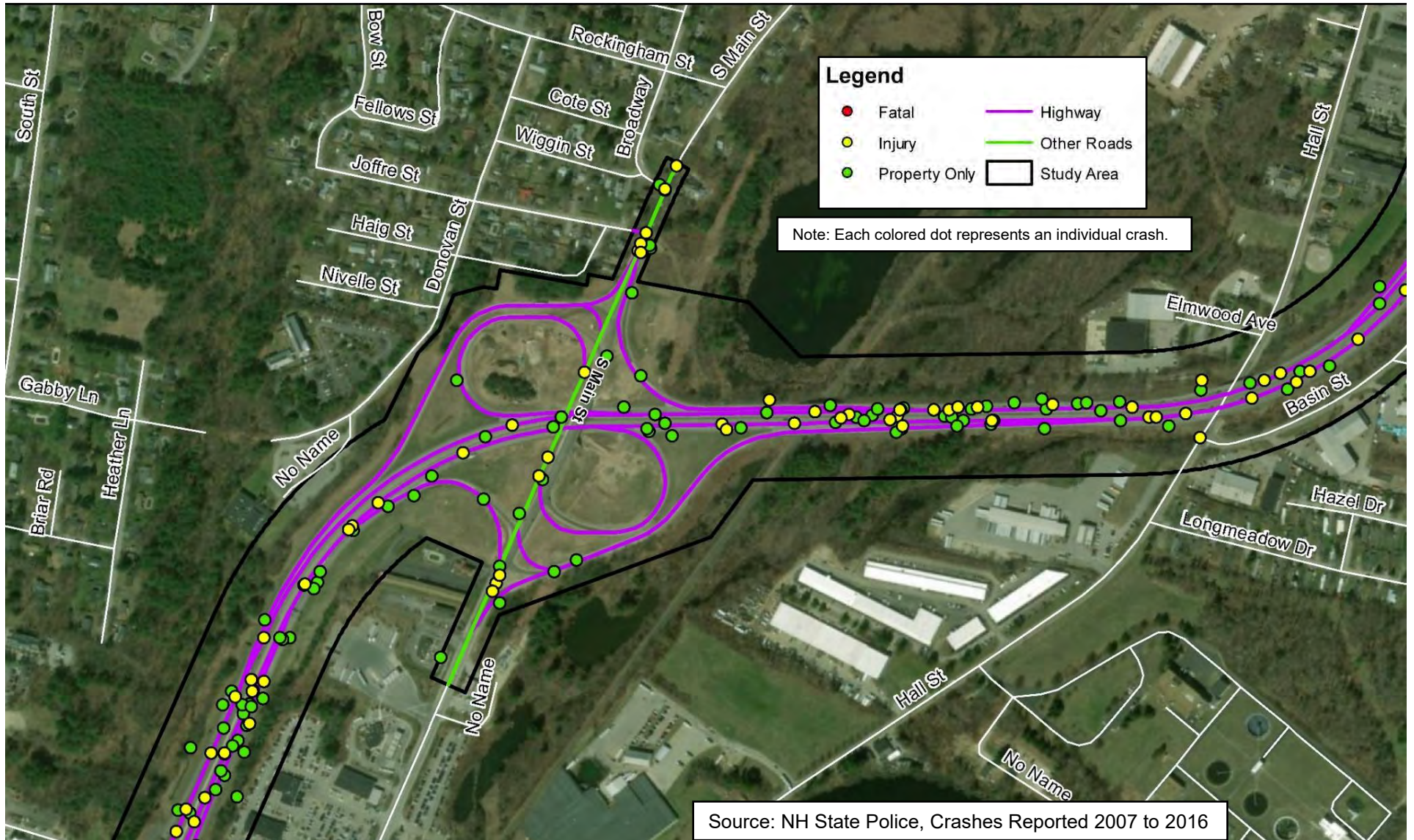


Figure 19: Crash History for the Exit 13 Area (2007 to 2016)

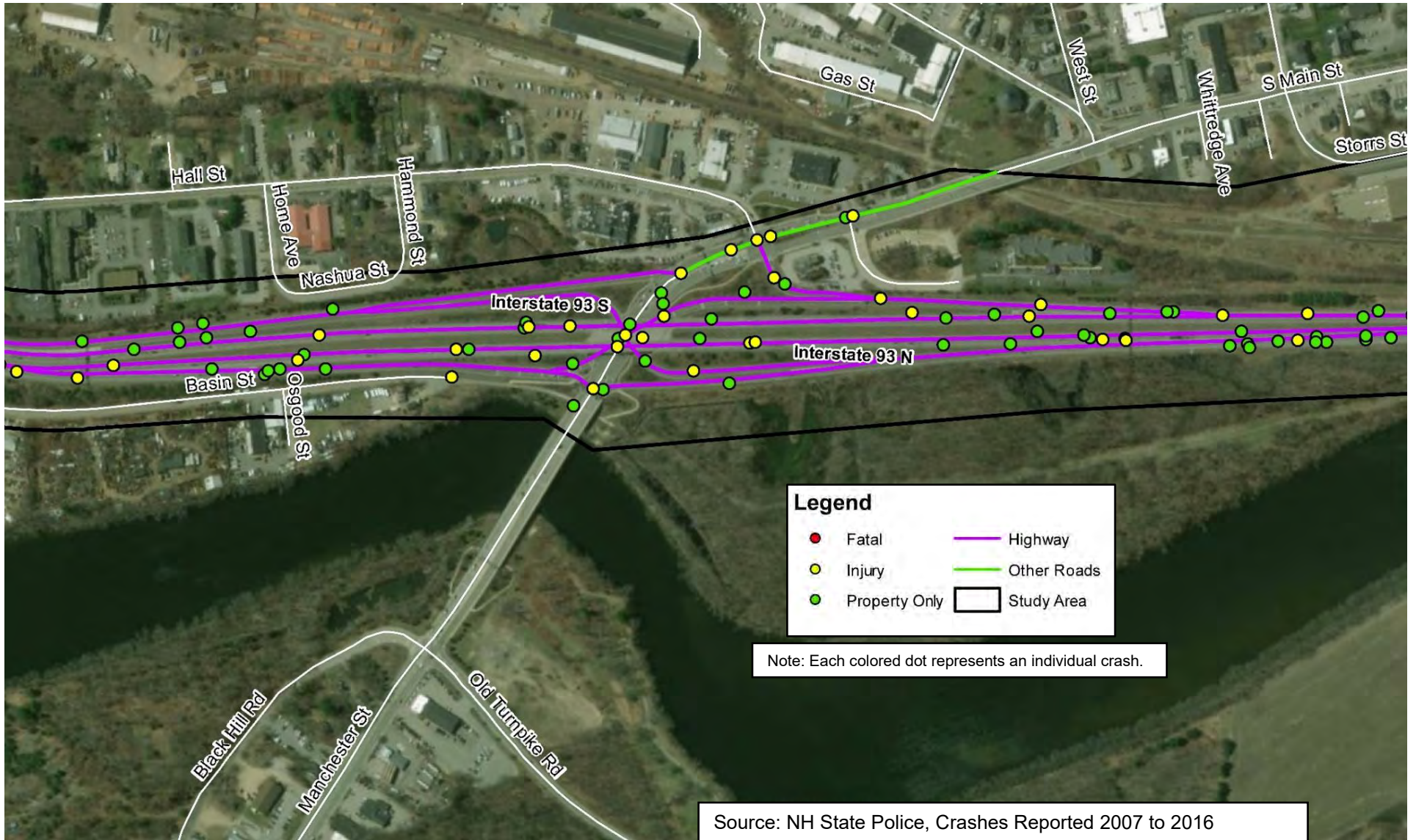


Figure 20: Crash History for the Exit 14/15 Area (2007 to 2016)

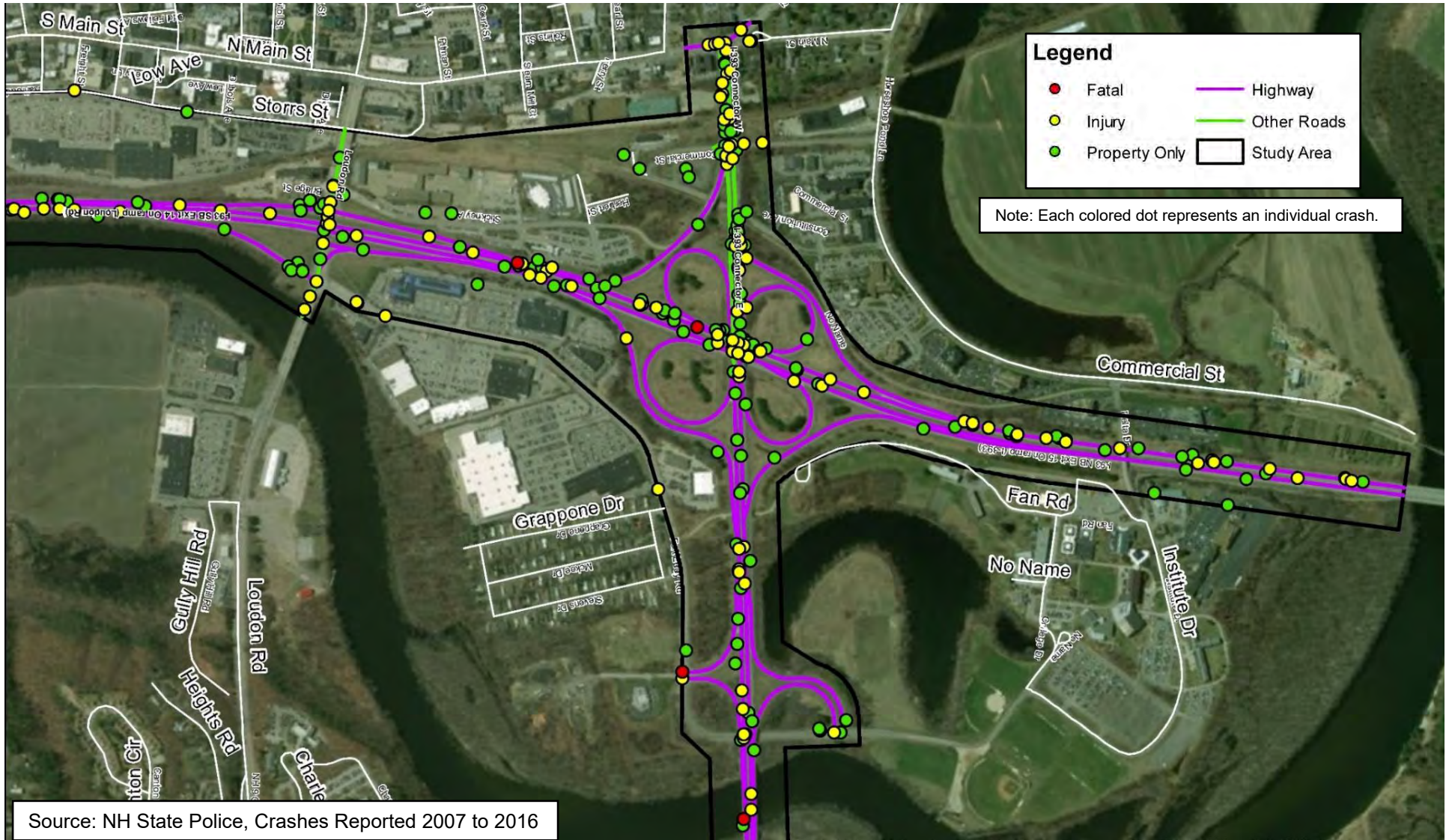


Figure 21: Preferred Alternative Year 2035 Peak Hour Traffic Volumes



Figure 22: Preferred Alternative

