Final Report | November 2013

Corridor Study and Feasibility Analysis

Rourke Bridge, Wood Street, Westford Street, and Drum Hill Road

PREPARED FOR

Northern Middlesex Council of Governments

PREPARED BY

Vanasse Hangen Brustlin, Inc.

IN ASSOCIATION WITH

TEC, Inc.
Regina Villa Associates

Vanasse Hangen Brustlin, Inc.

Corridor Study and Feasibility Analysis

Rourke Bridge, Wood Street, Westford Street, & Drum Hill Road

Lowell, Chelmsford, Dracut, & Tyngsborough

Prepared for **NMCOG / Northern Middlesex Council of Governments**

In association with **MassDOT / Massachusetts Department of Transportation**

Prepared by ***VHB*/Vanasse Hangen Brustlin, Inc.**

In association with **TEC, Inc.**

Regina Villa Associates

November 2013

Acknowledgements

Special acknowledgment is given to the following individuals who participated on the Technical Working Group and the Study Advisory Committee:

- Adam Baacke, Assistant City Manager/ Department of Planning and Development Director, City of Lowell
- Rick Barry, Trinity EMS
- Amy Carroll, Trinity EMS
- John Casey, Trinity EMS
- Lisa DeMeo, City Engineer, City of Lowell
- Eric Eby, Traffic Engineer, City of Lowell
- Jay Finnegan, Town of Chelmsford
- Gerard Frechette, Planning Board, City of Lowell
- Debbie Friedl, Acting Superintendent, Lowell Police Department
- Michael Gilleberto, Town Administrator, Town of Tyngsborough
- John Gleason, Engineer, City of Lowell
- Joe Greene, Permanent Building Committee, Town of Chelmsford
- Kevin Grondin, Business Representative, Town of Chelmsford
- Mark Hamel, Engineer, Town of Dracut
- Heather Hannon, MassDOT Planning
- Justin Howard, Transportation Program Manager, NMCOG
- Stephen Jahnle, Engineer, Town of Chelmsford
- Marty Lorrey, City Councilor, City of Lowell
- Nina Nazarian, Assistant Town Administrator, Tyngsborough
- Joe Onorato, MassDOT, District 4 Office
- Mark Pease, Planning Board, Town of Dracut
- Karen Pearson, MassDOT Planning
- Pat Wojtas, Board of Selectmen, Town of Chelmsford
- Beverly Woods, Executive Director, Northern Middlesex Council of Governments
- George Zaharoolis, Planning Board, Town of Chelmsford

Recognition is also given to Congresswoman Niki Tsongas, State Senator Eileen Donoghue, State Senator Barry Finegold, State Senator Michael Barrett, Representative Thomas Golden, Representative Kevin Murphy, Representative David Nangle, Representative James Arciero, and Representative Corey Atkins for their input, support and participation.

Table of Contents

List of Tables

List of Figures

List of Figures

List of Figures

Executive Summary

The Rourke Bridge, Wood Street, Westford Street, and Drum Hill Road Corridor and Feasibility Study is a partnership between the Northern Middlesex Council of Governments (NMCOG), the Massachusetts Department of Transportation (MassDOT) and the communities of Lowell, Chelmsford, Dracut, and Tyngsborough. It is a comprehensive state-sponsored study of the Rourke Bridge and the transportation network which serves it. The main focus of the study is two-fold: to determine whether replacing the Rourke Bridge with a permanent structure is feasible (including whether the existing location is the most suitable) and to develop a series of recommendations that will improve overall mobility for residents, businesses and visitors. The recommendations should enhance economic opportunities along transportation corridors, improve mobility for all roadway users (pedestrians, bicycles, vehicles, etc.), and improve multimodal connections between neighborhoods and community centers. The study recommendations focus on improving the movement of people and goods through the study area, recognizing that not all existing traffic congestion issues can be eliminated entirely.

The study examined and analyzed mobility under existing conditions and under year 2035 conditions. Immediate-term, short-term, and long-term recommendations have been developed using both quantitative information from analyses and also qualitative feedback provided by working committees and the public. In some cases, municipalities involved in the overall study process have been proactive in starting to address identified issues and implement study recommendations. The study includes the development of a process for ongoing coordination of operations and management of the region's multimodal system, including continuous review and implementation of improvement strategies. Through the analysis, the recommendations incorporate sustainable growth principles, economic development opportunities, evolving land uses, preservation needs, the potential for multimodal expansion and multimodal connectivity to enhance safer and more efficient access for the movement of people and goods from the present through 2035.

This report is organized into six chapters that generally correspond to the major work tasks. Highlights from each chapter are discussed below.

ES.1 Chapter 1: Study Process and Framework

Chapter 1 outlines the project purpose and need, study goals and objectives, and the evaluation criteria developed to test the feasibility of alternatives. The chapter also highlights the public participation plan established for the project and each outreach meeting held throughout the course of the study.

ES.2 Chapter 2: Existing Conditions

Chapter 2 describes the existing (2012) environmental, transportation, and structural conditions in the immediate vicinity of the Rourke Bridge and throughout the study area. The chapter includes a detailed explanation of the origin-destination patterns of vehicles using the Rourke Bridge.

ES.3 Chapter 3: Future Conditions

Chapter 3 describes the methodology used to forecast 2035 traffic volumes for study area roadways and intersections. This chapter includes an analysis of how increased traffic volume will affect roadway operations and how structural elements can be expected to deteriorate or be maintained through the 2035 design year.

ES.4 Chapter 4: Alternatives Development

Chapter 4 outlines the alternatives developed for study through the public outreach process. The chapter identifies which alternatives were considered, but dismissed prior to detailed analysis and which were carried forward for technical assessment.

The analysis of existing and future transportation conditions in the study area identified areas of the transportation network that require improvements. A range of transportation improvements were identified through Technical Working Group (TWG) and Study Advisory Committee (SAC) vetting and extensive public outreach throughout the study. The range of alternatives identified included:

- Rourke Bridge alternatives;
- Roadway and intersection capacity enhancements;
- Transportation system management strategies;
- Transportation demand management strategies;
- Transit system enhancements; and
- Bicycle/pedestrian enhancements.

For each sub-section listed above, a “fatal flaw” analysis was completed to determine which components could be feasible solutions to congestion issues and multi-modal deficiencies in the study area. The project goals were used as an abbreviated list of criteria against which to measure the alternatives. Any alternative showing merit was retained for consideration and subject to a more detailed technical analysis in order to determine the transportation benefit versus the associated impacts to the environment, economic development in the area, and other factors.

Table ES-1 summarizes the Rourke Bridge alternatives considered and the findings discussed in detail in Chapter 4.

Table ES-1 Rourke Bridge Alternatives – Initial Screening Results

Retained for Further Consideration	Discarded from Further Consideration	Comments
	No-Build Alternative: Remove Existing Bridge	Impacts to regional mobility and emergency access Use for comparison with Build alternatives
	Alternative 1: Maintain Existing Alignment (2-lane)	Inadequate improvements to regional mobility and emergency access
Alternative 2: Maintain Existing Alignment (4-lane)		Retain for further study
	Alternative 3: Eastern Bypass Alignment (4-lane)	Impacts to recreational land
Alternative 4: Western Bypass Alignment (4-lane)		Retain for further study
Alternative 5: Western Bypass Alignment with Grade-Separation (4-lane)		Retain for further study
Alternative 6: Skewed Bypass Alignment (4-lane)		Retain for further study
Alternative 7: Western Relocation Alignment - Vinal Square (4-lane)		Retain for further study
	Alternative 8: Eastern Relocation Alignment (4-lane)	Impacts to State-owned protected and recreational open space
	Alternative 9: Rourke Bridge plus New Crossing	Construction and maintenance costs

ES.5 Chapter 5: Alternatives Analysis

Chapter 5 presents a detailed evaluation of each alternative carried forward for technical analysis, including the five bridge alternatives chosen for detailed analysis and a series of non-bridge related improvements.

The main focus of the alternatives analysis was the feasibility of constructing a permanent Rourke Bridge. As shown in Table ES-1, the following five alternatives were retained for detailed study; four in the immediate vicinity of the existing temporary bridge structure:

- Alternative 2: Maintain Existing Alignment (4-lane)
- Alternative 4: Western Bypass Alignment (4-lane)
- Alternative 5: Western Bypass Alignment with Grade-Separation (4-lane)
- Alternative 6: Skewed Bypass Alignment (4-lane)
- Alternative 7: Western Relocation Alignment - Vinal Square (4-lane)

For each alternative, the project team reviewed the effects on transportation mobility (demand, regional impacts, operations, emergency vehicle access, safety, and multimodal benefits), structural (bridge length, span arrangement, property impacts, and constructability issues), environmental justice, economic development, environmental resources, lasting benefits, and community support. Preliminary order of magnitude cost estimates were also developed for each alternative and range from approximately $54.5 million (Alternative 2) to $82.4 million (Alternative 5).

The technical analysis determined that the four alternatives located in the immediate vicinity of the existing structure (Alternative 2, Alternative 4, Alternative 5, and Alternative 6) show only minor differences in transportation benefit or potential project impacts. Since there is no discernible difference in technical merits or impacts at this stage of study, all four alternatives could be subject to the National Environmental Policy Act (NEPA), which would be the next stage of the project. It should be noted that the Lowell City Council has reviewed the alternatives and has voted to discard Alternative 5 based on potential economic development impacts to the currently vacant drive-in movie parcel on the north side of the river. Although Alternative 5 is being eliminated from further consideration at this stage, it is possible that a NEPA review of this alternative would require a full assessment at a later date.

A fifth alternative, known as Alternative 7, relocates the permanent structure about one mile to the northwest. This alternative would connect Vinal Square in Chelmsford to Wedgewood Circle in Lowell. Compared to other alternatives considered, this alternative would have significant impacts to the environmental resources in the study area. As discussed in Chapter 5, environmental impacts are five-fold for some resources when compared to the other alternatives. Additionally, the relocation of the bridge to this location would require the complete reconstruction of Vinal Square and a substantial loss of traffic on Drum Hill Road, Westford Street, and Wood Street, which could contribute to further economic decline along the roadway corridor. As such, Alternative 7 was also eliminated from further consideration.

It should be noted that the alternatives considered are the best representation of alignments that increase transportation mobility while decreasing impacts to the environment and community. Numerous other roadway alignments were considered and the ones chosen can be altered or relocated slightly without change to the level of impact.

In addition to the Rourke Bridge alternatives, a series of non-bridge related improvements were also evaluated:

- **Roadway and Intersection Capacity Enhancements:** Two roadway and intersection capacity improvements were developed that seek to enhance the capacity of the study area transportation network.
  - **Wood Street/Drum Hill Road Widening** - This improvement considered widening of the Wood Street/Westford Street/Drum Hill Road corridor from the Rourke Bridge to Drum Hill Square. The alternative was ultimately discarded from further consideration due to limited regional transportation benefits and significant commercial property impacts. However, the feasibility of widening the Drum Hill Road section of the corridor (south of Parkhurst Road or Technology Drive) could be considered further if commercial parking can be reconfigured to accommodate need.
  - **Geometric Improvements -** This improvement considered localized geometric improvements to study area intersections aimed at improving operations. After a preliminary review of the existing right-of-way and an operational assessment, the addition or lengthening of turn lanes at three locations are recommended: Riverside Street at University Avenue; Riverside Street at VFW Highway; and Westford Street at Wood Street.
- **Transportation System Management (TSM) Strategies** – The six improvements discussed below seek to improve the management and operation of existing transportation facilities within the study area.
  - **Signalization** – The signalization of eight unsignalized study area intersections were evaluated. Based on the warrant and operational analyses, installation of traffic signals at the following three intersections is recommended: VFW Highway at Riverside Street; Westford Street at Stedman Street; and Westford Street at Technology Drive. Four additional locations should be periodically monitored by the appropriate

municipality or MassDOT to determine if/when conditions change such that a traffic signal becomes a viable improvement option.

- **Signal Optimization** – To improve capacity, traffic signal timing adjustments are recommended at three intersections: Pawtucket Street at School Street; Pawtucket Boulevard at Rourke Bridge; and Princeton Boulevard at North Road.
- **Signal Coordination** – This improvement investigated the coordination of traffic signals along several study area corridors to improve traffic progression and reduce overall delay. Based on operational analysis, it is recommended that coordination across the O'Donnell (School Street) Bridge be implemented as a short-term improvement. Coordination along the Drum Hill Road corridor from Technology Drive to Drum Hill Square will require a more detailed data collection effort to understand the effects of turning traffic at every driveway along the corridor. Coordination across the University Avenue Bridge is being considered as part of the University Avenue Bridge replacement project, coordinated through the City of Lowell.
- **Address Signal Issues** – This improvement considers addressing issues noted during field inventories of the study area signalized intersections associated with 2009 Manual on Uniform Traffic Control Devices (MUTCD) issues/violations; defective and/or broken equipment; Americans with Disabilities Act (ADA) non-compliance issues; and other issues (i.e. poor pavement condition, faded markings, "yellow traps", etc.). A complete list of issues by intersection is included in the Report Appendix. It should be noted that both the City of Lowell and Town of Chelmsford have been proactive in addressing some of the noted deficiencies at intersections under their respective jurisdiction.
- **Access Management –** At this time, it is recommended that access management be pursued for the Drum Hill Road corridor from Drum Hill Square to Parkhurst Road; and for the Middlesex Street corridor from Wood Street/Rourke Bridge to Pawtucket Street. Modifications to the Market Basket supermarket plaza access are not recommended at this time.
- **Overhead Signage –** Installation of overhead lane indication signage at the following complex study area intersections should be considered: Mammoth Road/School Street at Varnum Avenue/Riverside Street; Middlesex Street at Rourke Bridge/Wood Street; Westford Street at Wood Street; and VFW Highway at Riverside Street (signalization recommended as part of this study).

➤ **Transportation Demand Management (TDM) Strategies** – For many regions, strategies to encourage a shift from single-occupant vehicle (SOV) trips to non-SOV modes are organized and implemented by a regional Transportation Management Association/ Organization (TMA/TMO). The study area is not currently served by a TMA and this study recommends that the feasibility of creating a TMA for the region be further investigated.

- **Transit System Enhancements** – These improvements focus on increasing transit utilization and reducing reliance on the automobile.
    - **Transit Improvements** – Recommendations include improving pedestrian access to existing transit routes; and, if the LRTA financial situation improves, enhancing high volume LRTA bus stop facilities and providing transit access between Lowell General Hospital and the Drum Hill Road corridor.
    - **Support New Hampshire Commuter Rail Extension** – This study recommends that as improvements to study area roadways and intersections advance, they support access to this station wherever feasible.
- **Bicycle/Pedestrian Enhancements –** These improvements focus on improving pedestrian and bicycle mobility throughout the study area.
    - **Improved Bicycle Mobility** – All bridge alternatives include bicycle lanes in both directions. Additionally, potential bike lanes, bike shoulders, or shared lanes ("sharrows") along major study area corridors were identified to improve bicycle mobility in the region.
    - **Improved Pedestrian Mobility at Intersections** - This improvement includes intersection enhancements to address pedestrian mobility at study area intersections, including addressing ADA non-compliance issues and installation of pedestrian accommodations at signalized intersections that are currently lacking.
    - **Improved Pedestrian Mobility along Roadways** - This improvement includes the installation of new sidewalks/sidewalk upgrades aimed at improving mobility and eliminating gaps in the network along key routes.

ES.6 Chapter 6: Management and Operations Plan

Chapter 6 presents an action plan for the study recommendations. The recommended improvement projects identified by this study can be classified into the following two categories: Major Infrastructure Project (Rourke Bridge replacement) and Transportation Systems Management and Operations (TSM&O) Projects.

The replacement of the existing Rourke Bridge is classified as a Major Infrastructure Project and will require significantly more time and resources to proceed from inception to implementation than other improvements discussed in this study. The steps and permits needed to progress this project through the environmental review process, as established by Federal and State agencies, is outlined in Chapter 6. To ensure that the project is advancing and developing properly, this study recommends that *a Rourke Bridge Replacement Committee be formed*.

As with the Major Infrastructure Project, a successful TSM&O plan relies on collaboration and coordination across the traditional and organizational boundaries. This study recommends the development of two Regional Concepts for Transportation Operations (RCTO) that focus on different operations functions or services: Intersection and Corridor Management (Signal Improvements, Capacity Enhancement); and Multimodal Enhancements (Bike and Pedestrian).

Table ES-2 begins to establish timeframes for implementation and potential jurisdictional participants associated with the TSM&O recommendations of this study.

Table ES-2 TSM&O Recommendations - Implementation Timeframe and Commitment Matrix

	Cost	Implementation Timeframe			Potential Facilitating Organizations							Notes
		Immediate (<5 years)	Mid-term (5-10 years)	Long-term (10+ years)	MassDOT	NHDOT/ MBTA	LRTA	NMCOG	City of Lowell	Town of Chelmsford	Other Study Area Communities	
Geometric Improvements: University Avenue at Riverside Street	$1,000	✓			X				X			Improvement may be accomplished within the existing right-of-way.
Geometric Improvements & Signalization: VFW Highway at Riverside Street	$280,00		✓		X				X			Geometric improvement may require box widening. Conceptual cost estimate for traffic signal includes emergency vehicle pre-emption.
Geometric Improvements: Westford Street at Wood Street	$3,500	✓							X			Improvement may be accomplished within the existing right-of-way.
Signalization: Westford Street at Stedman Street	$210,000		✓						X			Conceptual cost estimate for traffic signal includes emergency vehicle pre-emption.
Signal Optimization: Pawtucket Boulevard at Rourke Bridge	$5,000	✓							X			Based on existing traffic volumes, optimization plans can be implemented as soon as possible at this intersection.
Signal Optimization: Princeton Street at North Road	$5,000	✓			X					X		Based on existing traffic volumes, optimization plans can be implemented as soon as possible at this intersection.
Signalization: Westford Street at Technology Drive **Signal Coordination & Optimization:** Drum Hill Road Intersections	$615,000		✓		X				X	X		Conceptual cost estimate for traffic signal at Westford Street at Technology Drive includes emergency vehicle pre-emption ($220,000). Conceptual cost estimate for signal coordination assumes hardwire (copper) interconnection to maintain consistency with Drum Hill Square system; costs may be reduced with GPS interconnection ($405,000).
Signal Coordination & Optimization: School Street Bridge Intersections	$16,000	✓			X				X			Conceptual cost estimate assumes GPS interconnection and the replacement of one traffic signal controller.
Address Signal Issues	Varies	✓	✓	✓	X				X	X	X	See Report Appendix for detailed summary of signal issues, jurisdiction, recommended implementation timeframe, and conceptual cost estimates.
Access Management: Drum Hill Road Corridor	TBD		✓				X	X		X		Improvements will need to be coordinated with private property owners.
Access Management: Middlesex Street Corridor	TBD		✓				X	X	X			Improvements will need to be coordinated with private property owners.
Overhead Signage	Varies	✓			X				X	X	X	Conceptual cost estimate varies depending on location (minimum cost of $100 for an R3-5 sign panel). Signage installation on existing mast arm assembly or span wire would require an evaluation of the equipment's loading capabilities.
Transit Improvements	TBD		✓	✓	X		X	X	X	X		Based on rising operating costs, coupled with decreased ridership over the past ten years on the LRTA and reduced state assistance, it is unlikely that these improvements would be able to be advanced at this time. They should be considered as potential improvements if the LRTA financial situation changes.
Support New Hampshire Commuter Rail Extension	n/a	✓	✓	✓		X	X	X		X		
Improved Bicycle Mobility	Varies	✓	✓	✓	X			X	X	X		Prioritize corridors for bicycle accommodation and conduct more detailed review of parking regulations/usage.
Improved Pedestrian Mobility at Intersections	Varies	✓	✓	✓	X			X	X	X		Prioritize intersection improvements. Many issues could be addressed with low-cost improvements; others require a longer-term approach.
Improved Pedestrian Mobility along Roadways	Varies	✓	✓	✓	X		X	X	X	X		Prioritize corridors for pedestrian accommodation; concentrate resources on improving pedestrian mobility along roadways with existing transit routes.

This page intentionally left blank

1

Study Process and Framework

This chapter describes the process and framework for this study – outlining the goals and objectives along with the mechanics of how these goals and objectives were achieved through the study process. Arguably the most crucial element of the study process was the public outreach plan. The public outreach plan is the Study Team's approach to sharing information and ideas with the general public throughout the study to ensure an open, transparent, and collaborative process.

The principal goal of the study is two-fold: (1) to fully analyze existing and future traffic conditions within the study area, and (2) to examine the feasibility of replacing the temporary Rourke Bridge over the Merrimack River with a permanent structure.

1.1 Introduction

The Rourke Bridge, Wood Street, Westford Street, and Drum Hill Road Corridor and Feasibility Study is a partnership between the Northern Middlesex Council of Governments (NMCOG), the Massachusetts Department of Transportation (MassDOT), and the communities of Lowell, Chelmsford, Dracut, and Tyngsborough. It is a comprehensive state-sponsored study of the Rourke Bridge and the transportation network which serves it. The main focus of the study is two-fold: to determine whether replacing the Rourke Bridge with a permanent structure is feasible (including whether the existing location is the most suitable) and to develop a series of recommendations that will improve overall mobility for residents, businesses and visitors. The recommendations should enhance economic opportunities along transportation corridors, improve mobility for all roadway users (pedestrians, bicycles, vehicles, etc.), and improve multimodal connections between neighborhoods and community centers. The study recommendations focus on improving the movement of people and goods through the study area, recognizing that not all existing traffic congestion issues can be eliminated entirely.

The study examined and analyzed mobility under existing conditions and under year 2035 conditions. Immediate-term, short-term, and long-term recommendations have been developed using both quantitative information from analyses and also qualitative feedback provided by working committees and the public. In some cases, municipalities involved in the overall study process have been proactive in starting to address identified issues and implement study recommendations. The study includes the development of a process for ongoing coordination of operations and management of the region's multimodal system, including continuous review and implementation of improvement strategies. Through the analysis, the recommendations incorporate sustainable growth principles, economic development opportunities, evolving land uses, preservation needs, the potential for multimodal expansion and multimodal connectivity to enhance safer and more efficient access for the movement of people and goods from the present through 2035.

Public outreach has been an integral component of the study. The study has been guided by two volunteer groups – a Technical Working Group (TWG) and a Study Advisory Committee (SAC). Invited members include local municipal representatives, state and federal agency representatives, local advocacy groups, and individuals representing business, the environment, traditionally underserved populations, and transportation interests. The members of the Working Group and Advisory Committee and all meeting notes are included in the Report Appendix of this report.

Over the course of the project, Technical Working Group members, (regular attendees represented NMCOG, MassDOT, and three of the four study communities) met eight times to discuss the methodology, data, analysis, and findings of the project. As technical members, they were given an unprecedented level of detail for which they provided feedback and suggested changes. Once working group comments were addressed and any changes were incorporated, project staff met with the SAC five times to provide an overview of project status. The SAC included TWG members and additional municipal officials, elected officials, business leaders, and residents. Comments from both meetings were incorporated into the presentations provided to the public. Five public meetings were held.

This report documents all phases of the work effort for this study. It is organized as follows:

- Chapter 1 – Study Process and Framework
- Chapter 2 – Existing Conditions
- Chapter 3 – Future Conditions
- Chapter 4 – Alternatives
- Chapter 5 – Recommendations

1.2 Study Process

A comprehensive corridor study and feasibility analysis involves a well-defined structure and process. The planning effort is organized into six tasks:

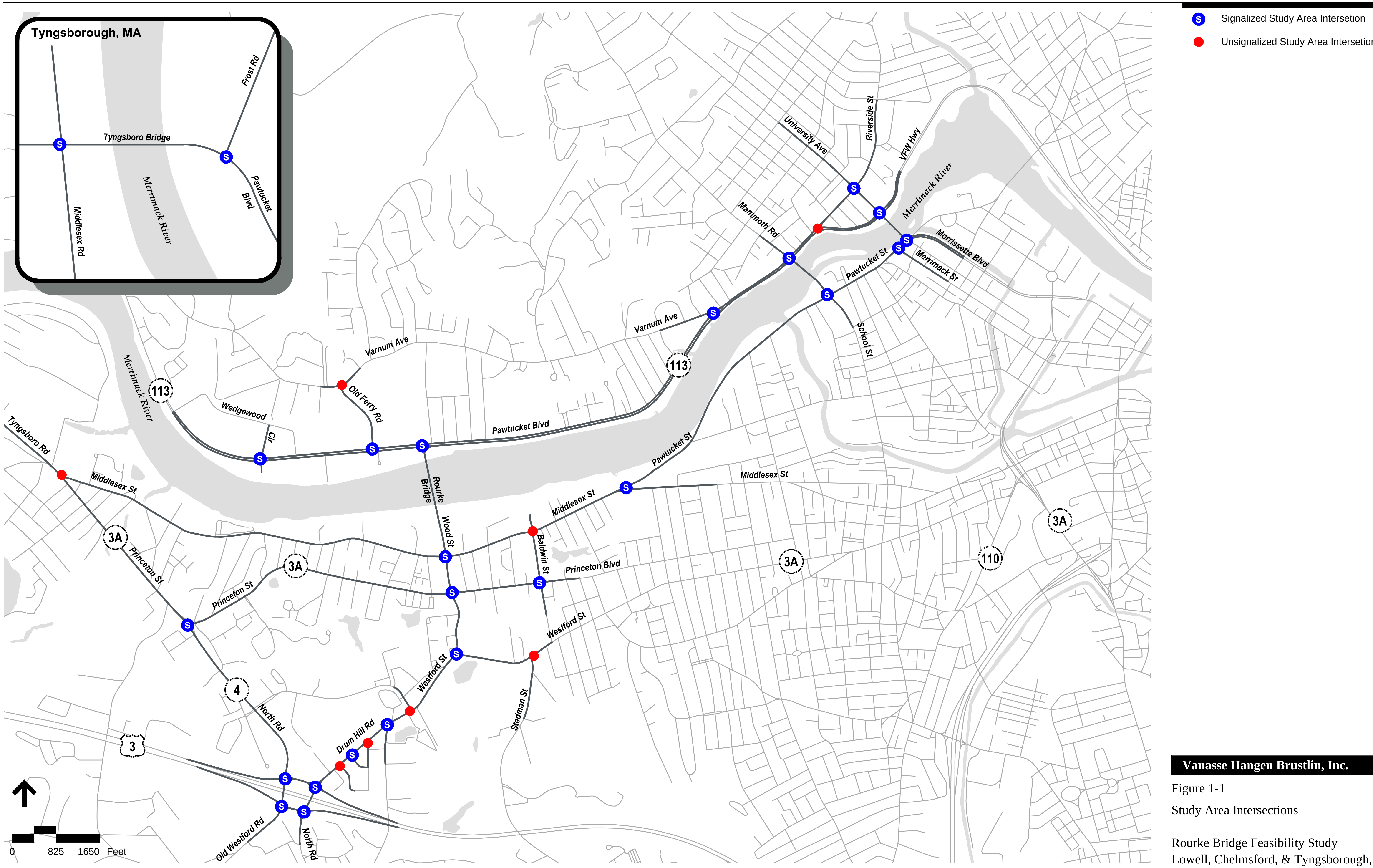
- Task 1: Framework – Develop the framework for the study, including goals, objectives, study area, evaluation criteria, and the public outreach plan.
- Task 2: Issues Evaluation – Evaluate existing and anticipated future conditions for the study area, including traffic congestion, safety, environmental issues, community effects, economic development, land use, pedestrians, bicyclists, and transit.
- Task 3: Alternatives Development – Identify a range of potential alternatives for a first level screening, encompassing bridge alternatives, roadway and intersection capacity improvements, transportation system and demand management strategies, and transit, pedestrian, and bicycle enhancements.
- Task 4: Alternatives Analysis – Analyze potential alternatives based on the established evaluation criteria in the areas of transportation, engineering feasibility, environmental impact, and cost considerations.
- Task 5: Recommendations – Develop a coordinated set of short- and long-term recommendations that contain specific, complementary transportation improvements and a proposed preferred alignment for a permanent structure to replace the temporary Rourke Bridge.
- Task 6: Preparation of Draft and Final Reports – Prepare draft and final Corridor Study and Feasibility Analysis report that documents the findings of Tasks 1 to 5.

A Public Outreach Plan was integrated throughout the six tasks. Opinions of the Technical Working Group, Study Advisory Committee, and public were solicited throughout the process.

1.3 Study Area

The first step in the study framework development involved defining the study area. The study area, depicted in Figure 1-1, extends from the University Avenue Bridge in the east to the Tyngsborough Bridge to the west and includes 33 intersections along the following major corridors:

- Pawtucket Boulevard;
- Wood Street/Westford Street/Drum Hill Road;
- Middlesex Street; and
- Princeton Boulevard.



Vanasse Hangen Brustlin, Inc.

Figure 1-1

Study Area Intersections

Rourke Bridge Feasibility Study
Lowell, Chelmsford, & Tyngsborough, MA

The study area boundary was determined with input from the Working Group and Advisory Committee. The four municipalities within the study area include Lowell, Chelmsford, Dracut, and Tyngsborough.

The key intersections, transit services, and pedestrian/bicycle networks within the study area were evaluated. Once the study area was defined, the next step in the study framework development involved refining the study goals, objectives, and evaluation criteria.

1.4 Study Goals, Objectives, Evaluation Criteria

During the study's initial months, preliminary goals, objectives, and evaluation criteria were developed and refined in conjunction with the Working Group and Advisory Committee. Goals define the general intentions and purposes for conducting the study based on the issues that have to be addressed. Objectives describe ways that the goals could be accomplished. The evaluation criteria are used to qualitatively and quantitatively measure how well each alternative meets the stated goal and objectives.

Through coordination with the Working Group and Advisory Committee, the following goals for the project were developed:

- Improve overall mobility and traffic flow throughout the area: including river crossings, key arterials, significant local streets, and key intersections;
- Improve safety for all modes of transportation;
- Improve accessibility and connectivity for all modes of transportation;
- Identify the optimal location and cost efficient structure type for a permanent Rourke Bridge;
- Meet transportation goals while supporting economic development and improving quality of life for area communities;
- Meet transportation goals while minimizing impacts to the environment;
- Develop a range of short- and long-term multimodal recommendations that consider lasting benefits to 2035;
- Build consensus through an open and inclusive process; and
- Develop recommendations that target demonstrated needs.

Table 1-1 summarizes the objectives and evaluation criteria related to each specific goal.

Table 1-1 Study Specific Goals, Objectives, and Evaluation Criteria

GOAL/OBJECTIVES	EVALUATION CRITERIA
Goal: Improve mobility and traffic flow	
▪ Decrease congestion and reduce delays ▪ Improve system reliability ▪ Minimize local street impacts and identify opportunities to relieve impacts of cut through traffic ▪ Improve emergency vehicle and first responder mobility	▪ Average speeds ▪ Delays/Level of service ▪ Travel time improvements ▪ Traffic demand by functional classification ▪ Origin-destination pairings ▪ Vehicle-hours traveled (VHT) ▪ Vehicle-miles traveled (VMT)
Goal: Improve safety	
▪ Identify, eliminate, or mitigate locations and situations that pose hazards ▪ Ensure that the transportation infrastructure meets current safe design standards ▪ Identify structurally deficient infrastructure	▪ 3-year crash data analysis ▪ High crash corridors/locations (vehicles, bikes, pedestrians) ▪ Geometric design review ▪ AASHTO/NBIS bridge ratings
Goal: Improve accessibility and connectivity for all modes	
▪ Explore ways to reduce auto dependency ▪ Seek ways to improve existing public transportation services ▪ Improve coordination of existing transit services ▪ Explore options for improved bike and pedestrian movement	▪ Transit travel time improvements ▪ Transit service/schedule enhancements ▪ Mode share ▪ Feasibility for expanding ridesharing ▪ Quality of pedestrian/bicycle accommodations
Goal: Identify the optimal location and most effective structure type for a permanent Rourke Bridge	
▪ Identify a location for a permanent bridge that minimizes impacts to surrounding development and environmental resources ▪ Determine a proposed structure type that is cost effective for the given span and waterway characteristics ▪ Design the structure to provide a service life of at least 75 years ▪ Design a structure that provides redundancy and is easy to inspect and maintain ▪ Explore options that maximize the pedestrian experience on the structure	▪ Origin-destination pairs for existing Rourke Bridge trips ▪ Permanent and temporary impacts to abutting land and waterway ▪ Construction costs not only associated with materials, but also construction duration ▪ Constructability ▪ Bridge openness for sight distance ▪ Structure depth and clearances
Goal: Meet transportation goals while supporting economic development and improving quality of life	
▪ Support existing and projected economic development ▪ Minimize negative economic effects to tax bases, and seek opportunities to enhance local and regional economic activity where possible ▪ Maintain reasonable business access or balance access with congestion reduction in key corridors ▪ Improve access and connectivity between priority business centers, major employment centers, and the regional highway system	▪ Impacts to businesses (access improvements, VMT, increased jobs in region) ▪ Tax base impacts (effects on jobs and employment) ▪ Impacts to residential/ schools/community facilities ▪ Qualitative indirect effects on adjacent minority and disadvantaged populations (environmental justice) ▪ Access to vacant and underutilized sites ▪ Reduce travel time, improve wayfinding, enhance system performance reliability

Table 1-1 (continued) Study Specific Goals, Objectives, and Evaluation Criteria

GOAL/OBJECTIVES	EVALUATION CRITERIA
Goal: Meet transportation goals while minimizing impacts to the environment	
▪ Support smart growth, anti-sprawl initiatives ▪ Avoid/minimize/mitigate impacts to the natural environment ▪ Reduce cut through traffic	▪ Impacts to natural environment (wetland/habitat/open space/historic areas/conservation areas/others) ▪ Traffic volume changes on local streets; VMT/VHT by functional classification ▪ Estimated reduction of greenhouse gas emissions and air toxics
Goal: Develop a range of multi-modal recommendations that have lasting benefits to 2035	
▪ Identify solutions that include both short-term and long-term actions to improve traffic flow, safety and efficiency ▪ Identify solutions that are cost-effective in the context of state transportation planning ▪ Identify solutions that comply with MAP-21 and incorporate sustainable growth principles ▪ Identify solutions that meet criteria for federal funding ▪ Identify next steps necessary for advancing priority projects forward	▪ Improved level of service, reduced VMT/VHT to 2035 ▪ Mode share, trip distribution by roadway functional classification ▪ Preliminary costs ▪ SAFETEA-LU compliance and sustainable growth compatibility ▪ Federal agency funding assessment
Goal: Encourage consensus through an open and inclusive process	
▪ Document and consider the input of the Working Group, Advisory Committee, and the public ▪ Attempt to reach reasonable consensus on study recommendations ▪ Keep adjacent communities and the public informed throughout the study ▪ Provide opportunities for public comment throughout the study ▪ Encourage feedback from traditionally underserved populations	▪ Develop and implement Public Outreach Plan ▪ Develop study website for public access ▪ Ensure transparency by posting study documents on the website (including meeting notes) ▪ Form a diverse Advisory Committee for the study ▪ Encourage consensus
Goal: Develop recommendations that target demonstrated needs	
▪ Quantify or qualify the needs – such as safety, traffic flow, reliability – as clearly as possible ▪ Provide justification for any additional recommended actions over and above what analyses show is necessary	▪ Documentation of analyses and recommendations throughout the study (Task 1 through Task 6)

After defining the study area and developing the goals, objectives, and evaluation criteria, the next step in the study framework development involved developing and refining a Public Outreach Plan to ensure that the study process would be transparent and that the recommendations would be thoroughly reviewed.

1.5 Public Outreach Plan

Public outreach and involvement were key components of each study task. As discussed in the introduction, an extensive Public Outreach Plan was implemented to ensure an open, transparent, and collaborative study process. The Public Outreach Plan included public informational meetings, Working Group and Advisory Committee meetings; all occurring at key decision making points to engage the public and stakeholders and provide a forum to solicit opinions and feedback. Meeting materials and summaries from each of the public informational meetings are included in the Report Appendix.

To further ensure constant information exchange, a study website was established to highlight study information including scope, study area, schedule, progress, and contacts for more information.

The study website (http://www.rourkebridgestudy.com/) served as an additional means for public and stakeholder comments. All meeting notes, presentation materials, and study reports were posted on the study website. Table 1-2 summarizes the overall study outreach program.

The project team worked with a number of community resources to ensure that the public process could be as inclusive as possible. The study website included landing pages in Spanish and Khmer, two non-English languages spoken predominantly throughout the area. All public meeting notices were published in multiple locations and included sentences in Spanish and Khmer saying the materials are important and should be translated. The extensive TWG and SAC convened for the project also verbally spread the word about public meetings. All meetings were held in locations accessible by people with disabilities and audio/visual aids known as Computer Aided Real Time transcription (CART) were made available upon request. The CART system was requested at three of the public meetings to allow for a hearing impaired resident to participate in the process.

Table 1-2 Study Outreach Program

Meeting	Date	Topics
Working Group Meeting 1	March 14, 2012	Study kick-off; review study area, goals/objectives, evaluation criteria, and public participation plan; Advisory Committee membership
Working Group Meeting 2	June 6, 2012	Update goals/objectives, evaluation criteria; review existing conditions evaluations (structural, transportation, safety, demographics); public involvement plan review; future conditions discussions
Advisory Committee Meeting 1	July 10, 2012	Study kick-off; goals/objectives, evaluation criteria, and public participation plan; review existing conditions evaluations (structural, transportation, safety, demographics)
Public Informational Meeting 1	July 17, 2012	Study kick-off; goals/objectives, evaluation criteria, and public participation plan; review existing conditions evaluations (structural, transportation, safety, demographics)
Working Group Meeting 3	October 2, 2012	2035 Baseline condition development and operations; alternatives groupings; Rourke Bridge alternatives testing
Advisory Committee Meeting 2	October 10, 2012	2035 Baseline condition development and operations; alternatives groupings; Rourke Bridge alternatives testing
Public Informational Meeting 2	November 8, 2012	2035 Baseline condition development and operations; alternatives groupings; Rourke Bridge alternatives testing; open house
Working Group Meeting 4	December 6, 2012	Local intersection improvements; summary of MUTCD, ADA, and safety issues
Advisory Committee Meeting 3	January 14, 2013	Local intersection improvements; summary of MUTCD, ADA, and safety issues
Public Informational Meeting 3	January 24, 2013	Local intersection improvements; summary of MUTCD, ADA, and safety issues
Working Group Meeting 5	February 21, 2013	Discussion of second level screening for Rourke Bridge Alternatives 2, 4,5, and 6
Working Group Meeting 6	February 28, 2013	Discussion of second level screening for Rourke Bridge Alternative 7 (Vinal Square alignment); discussion of pedestrian and bicycle alternatives
Advisory Committee Meeting 4	March 13, 2013	Discussion of second level screening for Rourke Bridge Alternatives 2, 4, 5, 6, and 7
Public Informational Meeting 4	March 21, 2013	Discussion of second level screening for Rourke Bridge Alternatives 2, 4, 5, 6, and 7
Working Group Meeting 7	April 16, 2013	Overview of recommendations and discussion of next steps
Advisory Committee Meeting 5	April 18, 2013	Overview of recommendations and discussion of next steps
Lowell City Council Meeting	May 7, 2013	Discussion of second level screening for Rourke Bridge Alternatives 2, 4, 5, 6, and 7
Public Informational Meeting 5	September 30, 2013	Review of draft final report, study recommendations, and project wrap-up
Joint Working Group/ Advisory Committee Meeting	October 29, 2013	Discussion of public comments, and project wrap-up.

2

Existing Conditions (2012)

This chapter provides an assessment of Existing Conditions within the study area. Sections of this chapter present demographics, environmental resources, land use and economic development, a multimodal transportation assessment, and a summary of the transportation infrastructure deficiencies and needs as of late spring 2012.

2.1 Demographics – Population and Employment

This section provides an overview of the relevant transportation-related demographics for the study area. Key demographic data such as population and employment are directly relevant to transportation demands and are the primary parameters used in travel demand forecasting models.

Estimated population and employment levels for the study area communities for year 2010 are summarized in Table 2-1.

Table 2-1 Study Area Population and Employment

City/Town	2010 U.S. Census Bureau Population (# residents)	2010 Average Employment (# jobs)
Lowell	106,519	33,668
Chelmsford	33,802	21,414
Dracut	29,457	4,910
Tyngsborough	11,292	4,227

Sources: U.S. Census Data; Massachusetts Department of Labor and Workforce Development.
Note: Population and employment levels are shown for the entire city/town.

Based on 2010 U.S. Census data, Lowell is by far the most populated community in the study area with 106,519 residents. Lowell is followed by Chelmsford (33,802 residents), Dracut (29,457 residents) and Tyngsborough (11,292 residents).

Massachusetts Department of Labor and Workforce Development statistics show that Lowell has the greatest employment base of the study area communities at 33,668 jobs. Lowell is followed by Chelmsford (21,414 jobs), Dracut (4,910 jobs), and Tyngsborough (4,227 jobs).

Population and employment statistics are important to quantify because they directly affect typical daily travel demands. Since the majority of trips begin from home or from work, journey-to-work data from the U.S. Census is helpful to quantify the interaction between population and employment with respect to travel demands.

2.2 Journey-to-Work and Mode Share

This section provides an overview of journey-to-work and mode share data for the study area. The data discussed below provides important information regarding both commuting patterns and modal preference that are useful in travel demand modeling and forecasting.

Journey-to-Work

Journey-to-work data from the 2000 U.S. Census is used to show the key origin and destination trip patterns. The journey-to-work data provide a wealth of information on commuting patterns and trends and is useful in travel demand modeling and forecasting.

Table 2-2 summarizes the daily work trips that occur for residents in the study area communities, showing total work trips, work trips within the study area, and work trips that are internal (within the city/town).

Table 2-2 Daily Work Trip Generation FROM the Study Area (Home Based)

		STUDY AREA TRIPS Trips Ending in Study Area		LOCAL TRIPS
Origin (Home)	Total Trips	# trips	%	% of Trips with Same City/Town
Lowell	46,760	19,980	43%	32%
Chelmsford	17,930	5,880	33%	21%
Dracut	15,040	6,130	41%	15%
Tyngsborough	5,860	2,360	40%	12%
Total	**85,590**	**34,240**	**40%**	**40%**

Sources: 2000 U.S. Census Data. Trips represent all modes of travel.

The key home-based commuting trends from the study area are as follows:

- A total of 85,590 daily work trips originate in the study area communities. Of these 34,240 work trips, or 40 percent, are internal to the study area.
- By far, Lowell had the highest work trip generation (46,760 trips) of the four study area towns.
- The highest percent of internal work trips (within the community) also occurred in Lowell (32 percent).

To understand regional commuting patterns, the number of study area residents who work in Boston was also evaluated. Based on the 2000 Census data, between 3 and 5 percent of study area residents commute to Boston.

Table 2-3 summarizes the daily work trips that enter the study area, showing total work trips, work trips originating within the study area, and work trips that are internal (within the city/town).

Table 2-3 Daily Work Trip Generation TO the Study Area (Work Based)

Destination (Work)	Total Trips	STUDY AREA TRIPS: Trips Originating in Study Area		LOCAL TRIPS
		# trips	%	%of Trips with Same City/Town
Lowell	37,600	20,290	54%	40%
Chelmsford	21,740	8,750	40%	18%
Dracut	5,550	3,430	62%	41%
Tyngsborough	3,890	1,870	48%	18%
Total	**68,780**	**34,340**	**50%**	**50%**

Sources: 2000 U.S. Census Data. Trips represent all modes of travel.

From Table 2-3, key work-based commuting trends to the study area are as follows:

- A total of 68,780 daily work trips are destined for the study area communities. The number of work trips entering the study area is approximately 20 percent less than the number of work trips originating from the study area, indicating that the available workforce outweighs the number of jobs in the study area.
- The communities with the highest work trip generation were Lowell (37,600 trips) and Chelmsford (21,740 trips).
- The highest percent of internal work trips (within the community) occurred in Dracut (41 percent).

To understand regional commuting patterns, the number of employees who live in Boston and commute to the study area was also evaluated. Based on the 2000 Census data, between 2 and 3 percent of study area workers commute to the study area from Boston.

These journey-to-work trip characteristics are important fundamental considerations for modeling existing and forecasted conditions using the travel demand model.

Mode Share

Understanding how people get to and from work in the study area is an important initial step in the evaluation of the transportation system deficiencies and needs. An evaluation of mode choice using the US Census helps measure auto-dependency.

Table 2-4 summarizes the mode share for people who live in the study area communities from the 2000 Census. Much like other communities throughout the US, there is a strong reliance on the automobile and very low transit use within the study area.

Table 2-4 Mode Choice for Study Area Residents (Home Based)

Mode	Lowell Residents	Chelmsford Residents	Dracut Residents	Tyngsborough Residents	Total Study Area Residents
Single-Occupant Automobile	74%	88%	88%	89%	80%
Multiple-Occupant Automobile	16%	6%	8%	7%	12%
Transit	3%	2%	1%	0%	2%
Bicycle/Walk	5%	1%	1%	1%	3%
Work at Home	1%	3%	2%	2%	2%
Other	1%	0%	0%	0%	1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Source: US Census, 2000, Census Transportation Planning Package, Part 1 – CT, MA, RI, May 2004.

Approximately 92 percent of study area residents drive to work – either alone or as part of a carpool. Very few study area residents rely on transit for their commute to and from work. The percentage of transit commuters for each study area community was less than or equal to 3 percent. Telecommuters, or residents who regularly work from home, account for 1 to 3 percent of total commuters.

The percentage of residents who walk or bike to work is the highest in Lowell at 5 percent – due in part to the denser, urban nature of Lowell when compared to other study area communities. By comparison, less than 1 percent of residents walk or bike to work in the other towns.

Mode share estimates are currently available for home-based trips from the 2006-2010 American Community Survey (ACS)[1]. A review of this data indicates that 2010 estimated mode share percentages are comparable to the 2000 Census data presented above. It should be noted that the 2010 ACS data provides estimates based on a sample of the overall population. As such, there are margins of error associated with the data ranging from 3 to 5 percent overall for each study area community, while margins of error are much higher for individual modes. The 2010 ACS data is included in the Technical Appendix for comparison purposes only.

Table 2-5 summarizes mode share for people employed in the study area from the 2000 Census. Much like other communities and throughout the US, there is a strong reliance on the automobile and very low transit use.

▼

[1] U.S. Census Bureau, 2006-2010 American Community Survey

Table 2-5 Mode Choice for Study Area Workers (Work Based)

Mode	Lowell Workers	Chelmsford Workers	Dracut Workers	Tyngsborough Workers	Total Study Area Workers
Single-Occupant Automobile	80%	84%	79%	82%	82%
Multiple-Occupant Automobile	10%	9%	11%	11%	10%
Transit	2%	2%	1%	2%	2%
Bicycle/Walk	6%	2%	3%	1%	3%
Work at Home	1%	2%	5%	4%	2%
Other	1%	1%	1%	0%	1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Source: US Census, 2000, Census Transportation Planning Package, Part 2 – CT, MA, ME, NH, RI, VT August 2004.

Approximately 92 percent of study area workers drive to work – either alone or as part of a carpool. Very few study area workers (between 1 and 2 percent) rely on transit for their commute to work. Telecommuters, or employees who regularly work from home, account for 1 to 5 percent of total commuters.

The percentage of workers who walk or bike to work is the highest in Lowell at 6 percent. This is compared to a much lower walk/bike mode share of 2 percent in Chelmsford, 3 percent in Dracut, and 1 percent in Tyngsborough.

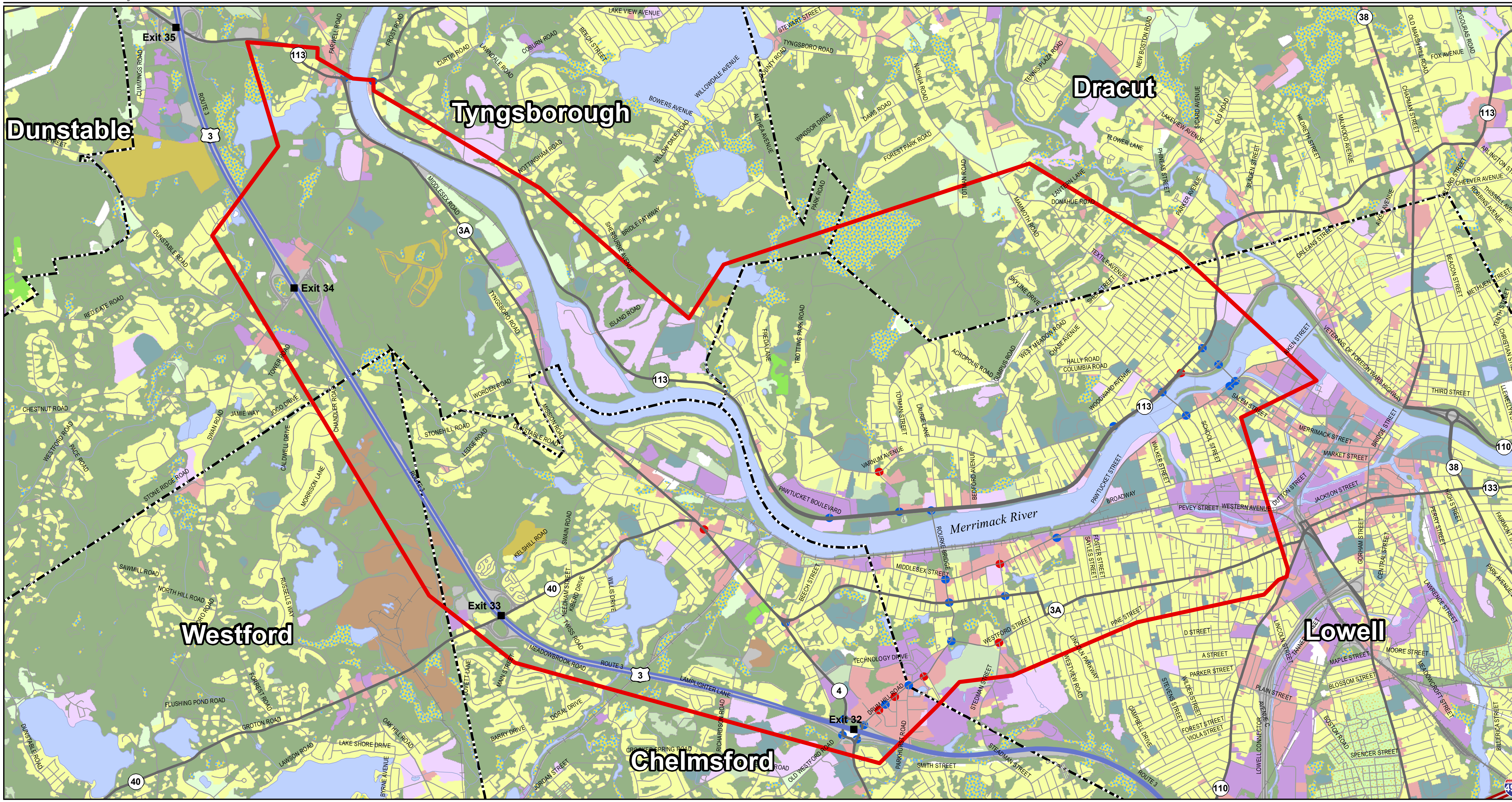
2.3 Land Use

The Rourke Bridge study area contains various land uses. Using MassGIS information, the following land uses were identified and are illustrated in Figure 2-1:

- Crop Lands & Pastures
- Forest
- Non-Forested Wetlands
- Mining
- Open Land
- Generic Recreation
- Residential
- Commercial
- Industrial
- Cemetery
- Urban Open Space
- Transportation Uses
- Waste Disposal
- Wooded Perennial Lands

While each community has specific zoning in place to guide development and land use decisions, knowing the current land use helps to understand the context for any proposed changes to the roadway network.

\\mawatr\ts\11906.00\GIS\Project\LandUse.mxd



Source: VHB 2012, MassGIS 2005 & 2010

Vanasse Hangen Brustlin, Inc.

- Study Area
- Signalized Study Area Intersection
- Unsignalized Study Area Intersection
- Town Boundaries

Land Use

- Cemetery
- Commercial
- Crop Land and Pasture
- Forest
- Generic Recreation
- Industrial
- Mining
- Non-Forested Wetland
- Open Land
- Residential
- Transportation
- Urban Open
- Waste Disposal
- Woody Perennial

Rourke Bridge
Land Use

Figure 2-1
May 2013

N

0 2,500 5,000 10,000 Feet

2.4 Environmental, Social, and Economic Assessment

The Study Area supports a variety of environmental, social, and economic features that have been considered in the planning of the replacement of the Rourke Bridge. Environmentally sensitive areas, historic resources, protected species habitat and open space and parkland and other constraints are all present within the Study Area. Understanding these constraints and potential impacts is critical in assessing the feasibility of the Project.

2.4.1 Environmental Resources

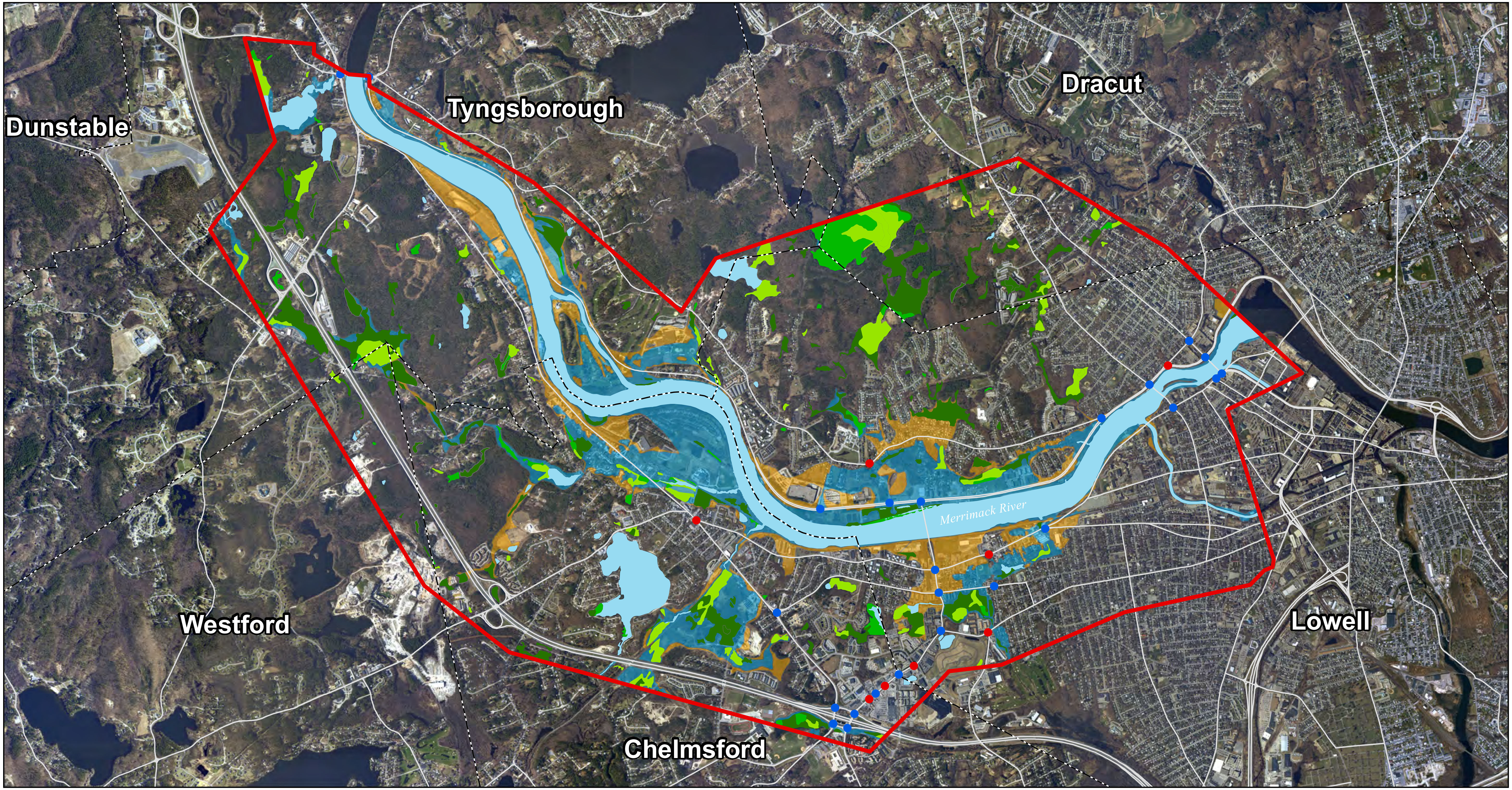
Environmental resources in the Study Area include wetlands, wildlife habitat, and protected species habitat. These resources are not only important to the environmental health of the area but also create constraints that are subject to a number of state and federal laws. In the vicinity of the Study Area, the most prominent environmental feature is the Merrimack River. This large river system extends from the White Mountains in New Hampshire, 100 miles north of the Study Area to the Atlantic Ocean 30 miles east of the Study Area. Associated with the Merrimack River are vegetated wetlands along the sides of the river, tributary streams, wildlife habitats, and wooded banks.

Initial environmental resource mapping for the corridor study and feasibility analysis was developed primarily using Massachusetts Geographic Information System (MassGIS) data (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/ layerlist.html), which is a part of the Executive Office of Energy and Environmental Affairs (EOEEA). In addition to using MassGIS data, additional information was obtained from the City of Lowell (http://www.lowellma.gov/services/gis) and Town of Chelmsford GIS (http://host.appgeo.com/ChelmsfordMA/) databases. Once mapping was prepared from the GIS data, field investigations were then conducted by environmental scientists with Vanasse Hangen Brustlin, Inc., to further refine resource area boundaries within the vicinity of potential bridge alignments. Resource area mapping included review of wetlands and waterways, floodplains, Bio Map, Living Waters, wildlife and protected species habitat, water resources, and hazmat disposal and release sites.

Wetlands and Waterways

Wetland and waterways resource systems in the Study Area include the Merrimack River, wooded swamps, shrub dominated swamps, emergent marshes, wet meadows, and streams, ponds, floodplain and floodways. Identified resource areas are depicted in Figure 2-2. The Merrimack River is the predominate wetland feature in the Study Area. The river has well defined banks and is 500 to 900 feet wide. Water level in the river is controlled by the Pawtucket Dam, approximately 7,800 feet downstream of the existing Rourke Bridge. Vegetated wetlands are present along the northern side of the Merrimack River although development has altered the extent of wetlands that remain. Wetlands extend to the base of the embankment for Pawtucket Boulevard on the north side. No

\\mawatr\ts\11906.00\GIS\Project\WetlandResources.mxd



Source: VHB 2012, MassGIS 1997, 2005 & 2009

Vanasse Hangen Brustlin, Inc.

Study Area
Signalized Study Area Intersection
Unsignalized Study Area Intersection
Town Boundaries

DEP Wetlands
Open Water
Marsh
Shrub-Scrub
Forested

FEMA Floodplain
100-Year Floodplain
500-Year Floodplain

Rourke Bridge
Wetland Resources

Figure 2-2
March 2013

N

0 2,500 5,000 10,000 Feet

vegetated wetlands are along the southern side of the river likely due to former development. Tracks of the Pan Am Railroad closely follow the southern bank of the river.

The Study Area extends approximately 1 mile west of the existing Rourke Bridge, where Stoney Brook and Deep Brook enter the Merrimack River on the south side. Extensive vegetated wetlands are associated with these tributaries. The north side of the Merrimack River opposite Stone and Deep Brooks is partially wooded and does not support vegetated wetlands. The Lowell Water Treatment pumping station is also on the northern bank of the river at the end of Wedgewood Circle.

Wetland resources in the Study Area are subject to regulation by the Massachusetts Wetlands Protection Act (WPA) and include Bordering Vegetated Wetland (BVW), Bank, Land Under Water Bodies and Waterways (LUWW), Bordering Land Subject to Flooding (BLSF), Isolated Land Subject to Flooding (ILSF), and Riverfront Area. The WPA establishes a 100-foot buffer zone from the limit of BVW and bank, associated with these wetland systems. Additionally, the WPA establishes a 200-foot Riverfront Area from the limit of the mean annual high water line (MAHWL) of perennial streams and rivers. Riverfront area is reduced to 25 feet in cities or towns that have been designated as densely developed areas, such as the City of Lowell. Riverfront Area remains at 200 feet in Chelmsford. The wetland and water resources are also subject to federal jurisdiction pursuant to the Clean Water Act. Any alteration or loss of wetlands or waters will require review and approval from the Lowell Conservation Commission, the Massachusetts Department of Environmental Protection and the U.S. Army Corps of Engineers.

Floodplain

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) identify the 100-year floodplain with a base flood elevation at Elev. 100 feet in the Study Area (Figure 2-2). The floodplain follows the banks of the Merrimack River on the southern side, but extends well beyond the banks and across Pawtucket Boulevard on the north side at the existing Rourke Bridge. West of the bridge on the south side of the river, elevated banks contain the floodplain until the Stoney and Deep Brook confluences. The FEMA designated floodplain back up these streams from the river. The 100-year floodplain is regulated by the WPA as Bordering Land Subject to Flooding.

Bio Map and Living Waters

Natural Communities, Supporting Natural Landscapes, Core Habitat and Living Waters data layer from MassGIS was reviewed for the Study Area. The only area of Bio Map significance was the Lowell-Dracut-Tyngborough State Forest, approximately 4,000 feet north of the Study Area. The State Forest is separated from the Study Area by dense residential development. No Living Waters were noted in the vicinity of the Study Area.

Water Resources

Wellhead protection areas (Zone II) are important for protecting water quality in recharge areas that support public water supplies. Certain land uses may be prohibited or restricted in Zone IIs and aquifer areas and stormwater management measures are more stringent. Based on mapping maintained by MassGIS there are no Zone IIs in the Study Area however, a high and medium yield aquifer underlies the Merrimack River in the Study Area. Figure 2-3 depicts the water resources within the Study Area.

Wildlife and Protected Species Habitat

The Natural Heritage and Endangered Species Program (NHESP), part of the Massachusetts Division of Fisheries and Wildlife is responsible for the conservation and protection of endangered, threatened, and species of special concern. Rare species are important for biodiversity and represent elements of an ecological system that are unique or few in number. Rare species are protected by both federal and state laws and include both plants and animals and their critical habitats.

According to the most recently published edition of the Massachusetts Natural Heritage Atlas[2] (October 2008), Priority Habitat of Rare Species, Estimated Habitat of Rare Wildlife, and Certified Vernal Pools occur within the Study Area, as shown on the attached Figure 2-4. Coordination with the NHESP has determined the state-listed protected species identified in Table 2-6 are present along the Merrimack River (Priority Habitat 1321, Estimated Habitat 65):

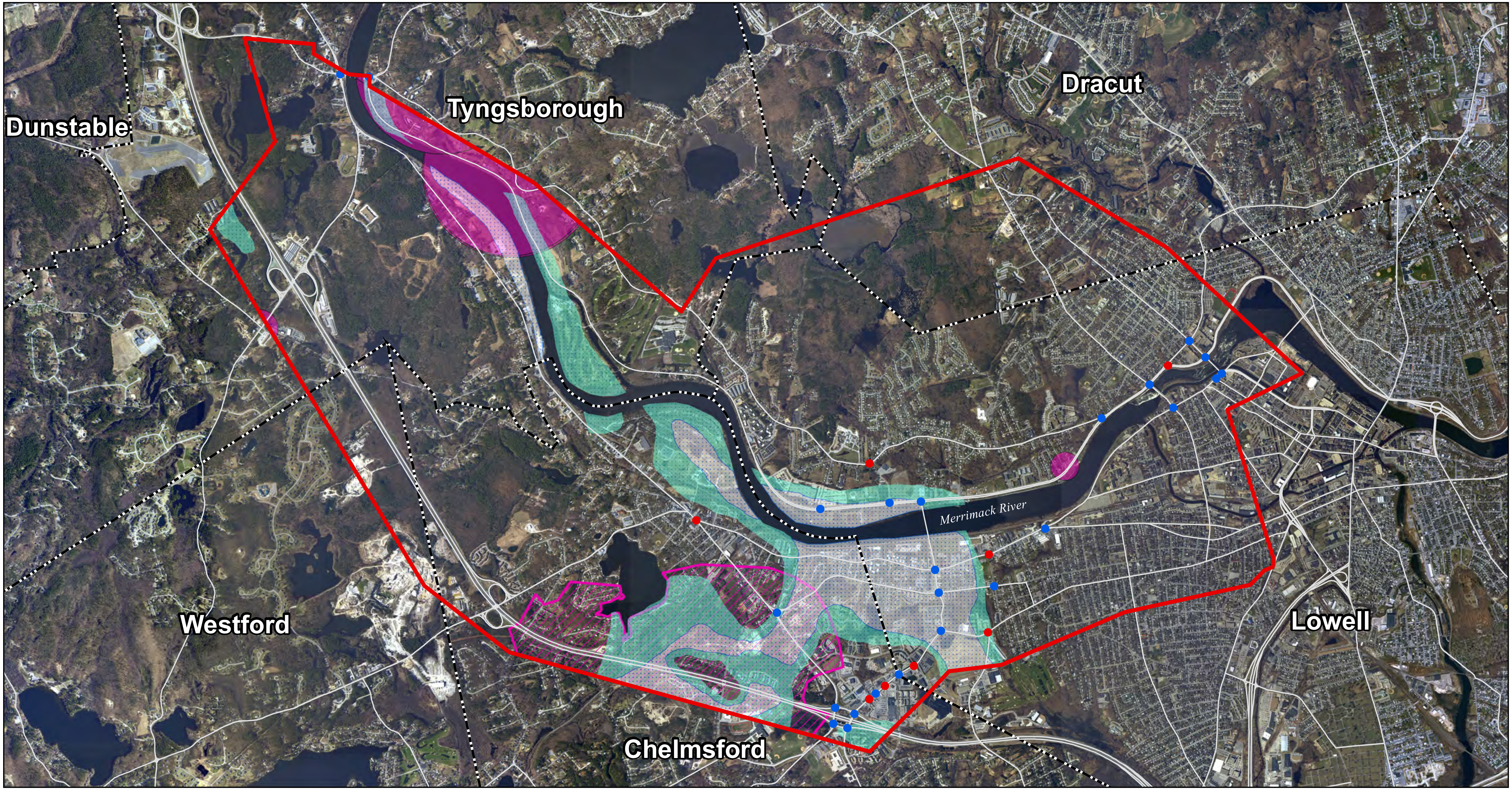
Table 2-6 State-listed Protected Species

Common Name	Scientific Name	Type	Status
Bald Eagle	Haliaeetus leucocephalus	Bird	Threatened
Cobra Clubtail	Gomphus vastus	Dragonfly	Special Concern
Umber Shadowdragon	Neurocordulia obsoleta	Dragonfly	Special Concern
Riverine Clubtail	Stylurus amnicola	Dragonfly	Endangered
Arrow Clubtail	Stylurus spiniceps	Dragonfly	Not listed as of 2/27/2012

Mapping maintained by MassGIS also indicates the presence of two potential vernal pools within the Study Area. These areas have not been inspected to determine their ability to provide successful amphibian breeding habitat, but are shown to identify the potential location of breeding habitats. Should future alternatives impact these potential locations, additional inspections will be required.

[2] NHESP, 2008. *Massachusetts Natural Heritage Atlas.* 13th Edition.

\\mawatr\ts\11906.00\GIS\Project\WetlandResources.mxd



Source: VHB 2012, MassGIS 2005, 2010 & 2012

Vanasse Hangen Brustlin, Inc.

Study Area
Signalized Study Area Intersection
Unsignalized Study Area Intersection
Town Boundaries

Outstanding Resource Water
Approved Wellhead Protection Area
Interim Wellhead Protection Area
Aquifers
High-Yield
Medium-Yield

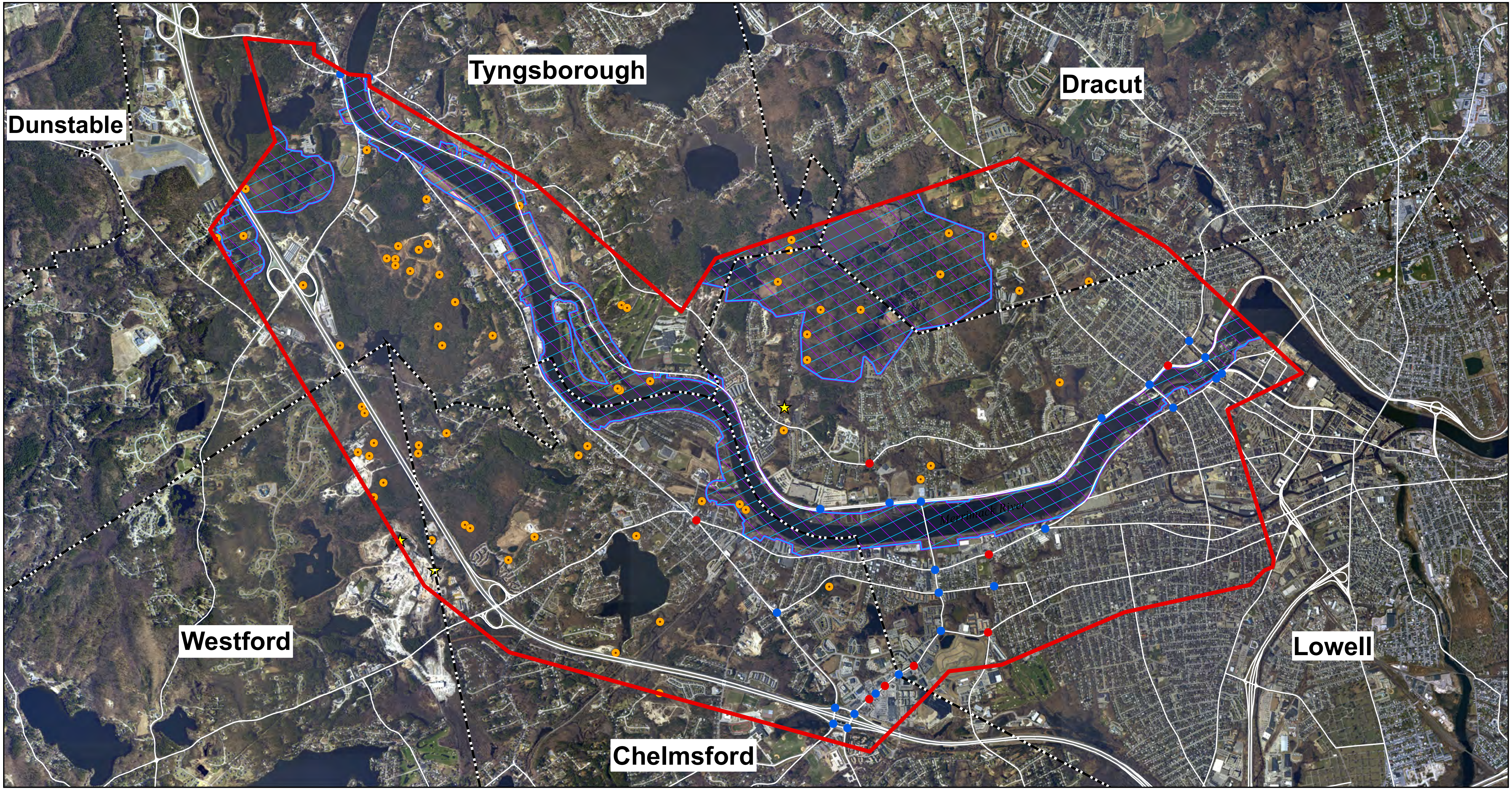
Rourke Bridge
Water Resources

Figure 2-3
March 2013

N

0 2,500 5,000 10,000 Feet

\\mawatr\ts\11906.00\GIS\Project\Wildlife.mxd



Source: VHB 2012, MassGIS 2005, & NHESP 2008

Vanasse Hangen Brustlin, Inc.

Study Area
Signalized Study Area Intersection
Unsignalized Study Area Intersection
Town Boundaries

Natural Heritage & Endangered Species Program Data
Priority Habitat of Rare Species
Estimated Habitat of Rare Wildlife
Certified Vernal Pool
Potential Vernal Pool

Rourke Bridge
Wildlife Areas

Figure 2-4
March 2013

N

0 2,500 5,000 10,000 Feet

2.4.2 Social and Economic Considerations

Cultural resource mapping for the corridor study and feasibility analysis was developed using MassGIS data. Cultural resources examined within the Study Area included historic resources, protected recreational and open space, and Areas of Critical Environmental Concern. Locations impacted by releases of oil or hazardous materials also affect constructability and work safety issues.

Historic Resources

Federal policy set forth in the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470 et seq.) includes preserving "the historical and cultural foundations of the Nation" and preserving irreplaceable examples important to our national heritage to maintain "cultural, educational, aesthetic, inspirational, economic, and energy benefits."

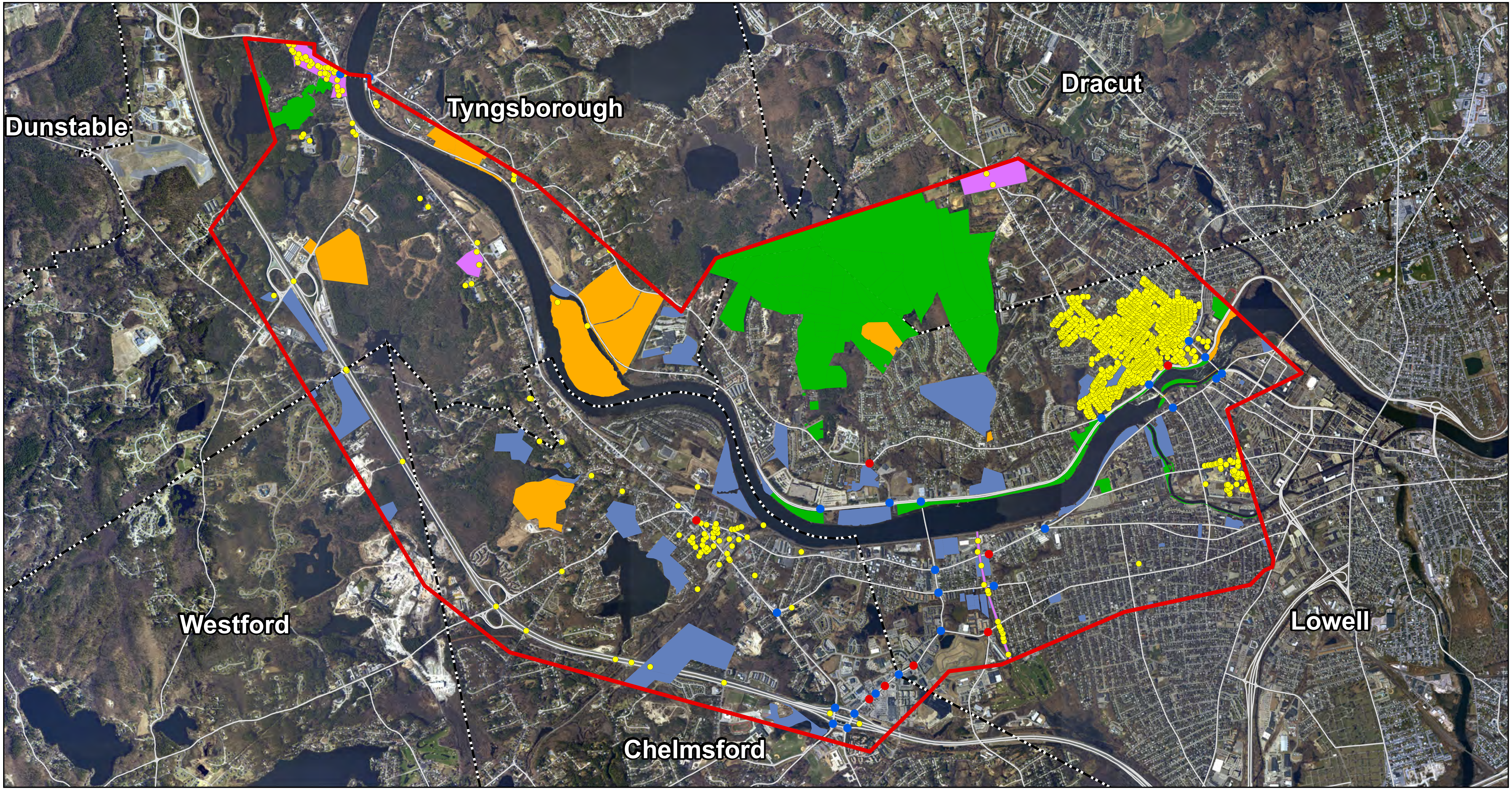
Data maintained by MassGIS displays historic resources generated from the Massachusetts Cultural Resource Information System (MACRIS). Resources included in the data layers consist of inventory points containing locations of buildings, burial grounds, structures and objects, including statues, monuments, and walls, and inventory areas, consisting of historic areas and districts. Historic resources in the vicinity of the project include the oldest house in Lowell on Wood Street along the approach to the Rourke Bridge. Figure 2-5 indicates the presence of approximately 1,200 inventory points and four inventory areas within the Study Area.

Any project alignment that has the potential to impact a cultural resource will need additional research during the permitting process to determine the exact nature of these historical resources, as well as the possible outcomes of any direct or indirect impact.

Protected Parkland and Open Space

MassGIS maintains an inventory of parcels of land that are designated recreational and open spaces. These parcels can be either publicly or privately owned and include parklands, conservation land, recreational areas, town forests, agricultural land, aquifer protection land, watershed protection land, forest land, and cemeteries. Publicly owned open space may be protected through Section 4(f) of the Department of Transportation Act or Section 6(f) of the Land and Water Conservation Fund Act. Any impacts to Section 4(f) or 6(f) land, as a result of a potential alignment, will require an evaluation of impact and will need to identify avoidance and minimization measures. Some public lands are also protected by the Commonwealth's Article 97 also requiring avoidance and minimization for any takings. Figure 2-5 depicts the recreational and/or open space parcels within the Study Area.

\\mawatr\ts\11906.00\GIS\Project\CulturalResources.mxd



Source: VHB 2012, MassGIS 2005, 2012, & 2013

Vanasse Hangen Brustlin, Inc.

Study Area
Signalized Study Area Intersection
Unsignalized Study Area Intersection
Town Boundaries
Areas of Critical Environmental Concern

Protected and Recreational Open Space
Municipal
Private
State Owned
Ownership Unknown

Massachusetts Historical Areas
State Registered Historic Places
State Registered Historic Sites

Rourke Bridge
Cultural Resources

Figure 2-5
March 2013

N

0 2,500 5,000 10,000 Feet

Areas of Critical Environmental Concern

Areas of Critical Environmental Concern (ACEC) are places that receive special recognition because of the quality, uniqueness, and significance of their natural and cultural resources. According to mapping maintained by MassGIS, no ACECs exist within the Study Area, as documented in Figure 2-5.

Oil and Hazardous Materials

The Massachusetts Department of Environmental Protection (MassDEP) Bureau of Waste Site Cleanup (BWSC) online database was reviewed to identify any release sites or generators in the Project Study Area. A total of 11 state listed disposal sites were identified in the vicinity the Study Area in Lowell and Chelmsford, Massachusetts. The presence of a disposal site indicates that a release of oil and/or hazardous materials (OHM) has occurred and/or been reported to MassDEP. Approximate locations of the disposal sites as mapped in the online MassDEP database are depicted on Figure 2-6. The results of the OHM review are included in the Technical Appendix.

2.4.3 Regulatory Significance

Potential impacts to the environmental or social constraints associated with this Project have regulatory implications. Several regulatory reviews and permits will be needed to allow the Project to proceed.

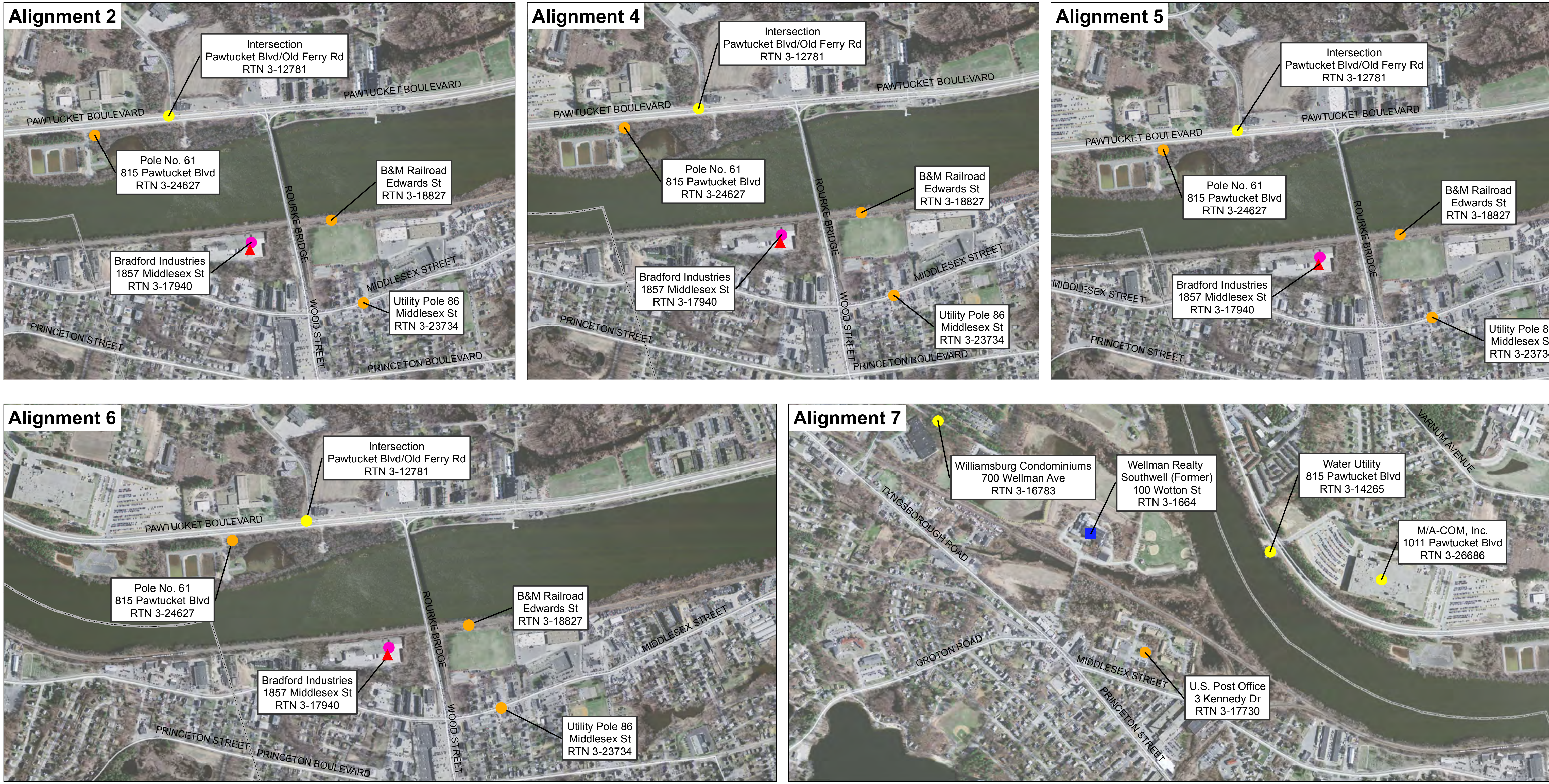
National Environmental Policy Act

Since federal funding is likely to be used for the construction of this project, compliance with the federal National Environmental Policy Act (NEPA) will be required. This will warrant the preparation of an Environmental Assessment (EA) and possibly an Environmental Impact Statement (EIS). Provided the Project impacts are found to be acceptable and appropriate and mitigation is provided, a Finding of No Significant Impact (FONSI) will be needed from the lead federal agency (Federal Highway Administration) to allow the Project to proceed.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) regulates alterations to wetlands pursuant to Section 404 of the Clean Water Act and work in navigable waters pursuant to Section 10 of the Rivers and Harbors Act. The Merrimack River is a federally navigable waterway in Massachusetts. Bridge construction in the water and adjacent wetlands will require a Section 10/404 permit from the USACE.

\\vhb\proj\Wat-TS\11906.00\GIS\Project\OHM Figure 2 March 2013.mxd



Source: USGS 2008 Aerial Imagery; www.mass.gov/dep

Note: Disposal site associated with RTN 3-26862 not mapped due to missing information.

N

0 500 1,000 2,000 Feet

Vanasse Hangen Brustlin, Inc.

MassDEP Disposal Sites
- ▲ AUL
- ● B-2 ROA
- ● A-2 ROA
- ● A-1 RAO
- ■ LSPNFA

Rourke Bridge
Oil and Hazardous Material Disposal Sites

Figure 2-6
March 2013

U.S. Coast Guard

As noted above, the Merrimack River is a federally navigable waterway. Establishment of a new bridge across a navigable waterway will require a Section 9 Bridge Permit from the U.S. Coast Guard (USCG). Through the Bridge Permit, the USCE will ensure the navigability of the Merrimack River (vertical and horizontal clearances) is preserved for the benefit of the public.

Massachusetts Environmental Policy Act

The replacement of the Rourke Bridge across the Merrimack River will exceed several review thresholds of the Massachusetts Environmental Policy Act (MEPA). Documentation will require the filing of an Environmental Notification Form (ENF) with the MEPA Office and may require an Environmental Impact Report (EIR) for review by the Secretary of Energy and Environmental Affairs.

State and Local Wetlands Programs

Wetlands resources are protected by several state and local regulatory programs. A number of wetland resource areas exist within the vicinity of the Study Area, which are protected by these regulatory programs. These programs include:

- The Massachusetts Wetlands Protection Act (WPA), MGL Chapter 131, Section 40 and its implementing regulations, 310 CMR 10.00;
- Water Quality Certification pursuant to Section 401 of the Clean Water Act (CWA) and its implementing regulations, 314 CMR 9.00;
- Massachusetts Waterways Program (310 CMR 9.00)
- Lowell Wetlands Ordinance; and
- Chelmsford Wetlands Protection Bylaw.

Depending on the final project design and impacts to wetland resources, these permitting programs will apply to the Project and will require issuance of permits for construction.

Protected Species

The Massachusetts Endangered Species Act (MESA) requires coordination with the Natural Heritage and Endangered Species Program (NHESP) to determine if the Project constitutes a "take" of a protected species. If the NHESP determines the Project represents a take of a protected species, a Conservation and Management Permit will be needed from NHESP pursuant to MESA. There are several protected species found within and adjacent to the Merrimack River in the Project area.

Historic

Since there will be state participation in the construction of this Project, a Chapter 254 review of potential impacts to historic and archaeological resources will be required. In addition, since a federal U.S. Army Corps of Engineers permit will be needed, a Section 106 review of impacts to historic and archaeological resources will also be needed. Review of the Project also will need to be coordinated with the State Historic Preservation Officer (SHPO).

Parkland and Open Space

Article 97 of the State Constitution protects public lands taken for wildlife conservation, open space protection, parks and historic sites and districts. Change of use of these areas requires a 2/3 vote from the state legislature and requires replacement of the area taken. Several parcels of state or local parkland are in the vicinity of the Project and any alignment that requires use of these lands will require release through the Article 97 process.

Environmental Justice

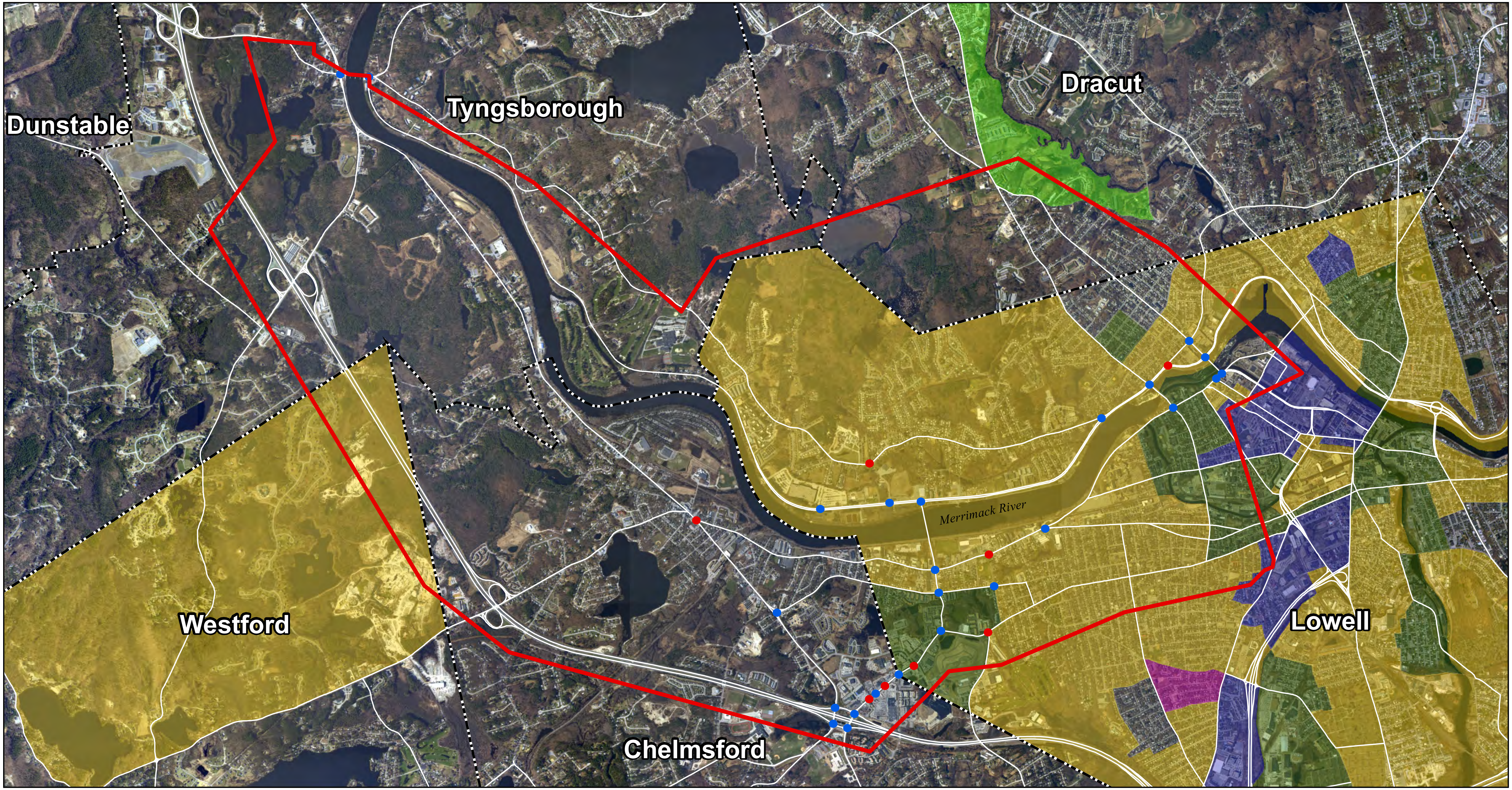
The Executive Order 12898, "Federal Action to Address Environmental Justice in Minority Populations and Low-Income Populations," also known as the Environmental Justice Movement, was set in place to address environmental injustices in communities across the country. The Environmental Justice Movement aids with the development, implementation, and enforcement of environmental policies and pro-active programs that help ensure minority and low-income communities have an equitable distribution of environmental benefits. This helps alleviate environmental hazards, such as industrial pollutants, and creates clean, healthy environments for the communities to enjoy[3].

Figure 2-7 displays the Environmental Justice 2010 population criteria by block group using the 2010 census data[4]. The Environmental Justice block groups include minority, low-income, and English isolated (second language) communities. The figure also provides an outline of the project's study area with the studied roadways and

▼

[3] http://www.mass.gov/eea/docs/eea/ej/ej-policy-english.pdf
[4] http://maps.massgis.state.ma.us/map_ol/ej.php

\\vhb\proj\Wat-TS\11906.00\GIS\Project\EnvironmentalJustice.mxd



Source: VHB 2012, MassGIS 2005 & 2010

Environmental Justice 2010 Populations
EJ Criteria, by Block Group

- Study Area
- Signalized Study Area Intersection
- Unsignalized Study Area Intersection
- Town Boundaries

- Minority
- Income
- Minority and Income
- Minority and English Isolation
- Minority, Income and English Isolation

N

0 2,500 5,000 10,000 Feet

Vanasse Hangen Brustlin, Inc.

Rourke Bridge
Environmental Justice

Figure 2-7
March 2013

intersections highlighted. The majority of the study area (9 out of 30 intersections) and the Rourke Bridge fall under an Environmental Justice block group, therefore the Executive Order 12898 pertains to this project. The suggested bridge alternatives and intersection improvements cannot disproportionally, adversely affect these block group areas and an Environmental Justice screening is included in the alternatives analysis presented in Chapter 5.

2.4.4 Summary

Environmental resources, environmentally sensitive areas, historic inventories, and protected recreation and open spaces are shown in the attached set of Figures 2-2 through 2-7, and will serve as a guide during the development of bridge alignment alternatives to avoid or minimize impacts to environmental, social and cultural resources.

2.5 Transportation Assessment

This section describes and assesses the existing transportation conditions within the study area, including traffic volumes, traffic patterns, capacity, operations, safety, pedestrian and bicycle concerns, and public transportation.

2.5.1 Existing Traffic Demands

Looking at how vehicle traffic fluctuates over a typical weekday provides insight into when peak periods occur and the intensity of traffic. Automatic traffic recorder (ATR) data were obtained for a typical weekday to quantify hourly fluctuations. Table 2-7 summarizes the traffic volumes on key roads in the study area. Figure 2-8 depicts this ATR data for the Rourke Bridge. In addition, turning movement counts (TMCs) were collected at key intersections to quantify vehicle, pedestrian, and bicycle demands. Weekday morning and evening peak hour turning movement volumes are illustrated in Figure 2-9 and Figure 2-10 , respectively. Traffic volume data is included in the Technical Appendix.

The Rourke Bridge carries approximately 27,000 vehicles per day (vpd) and Westford Street carries approximately 25,000 vpd. The majority of traffic on the Rourke Bridge/Westford Street corridor travels southbound in the morning and northbound in the evening – indicative of the commuter patterns towards Route 3.

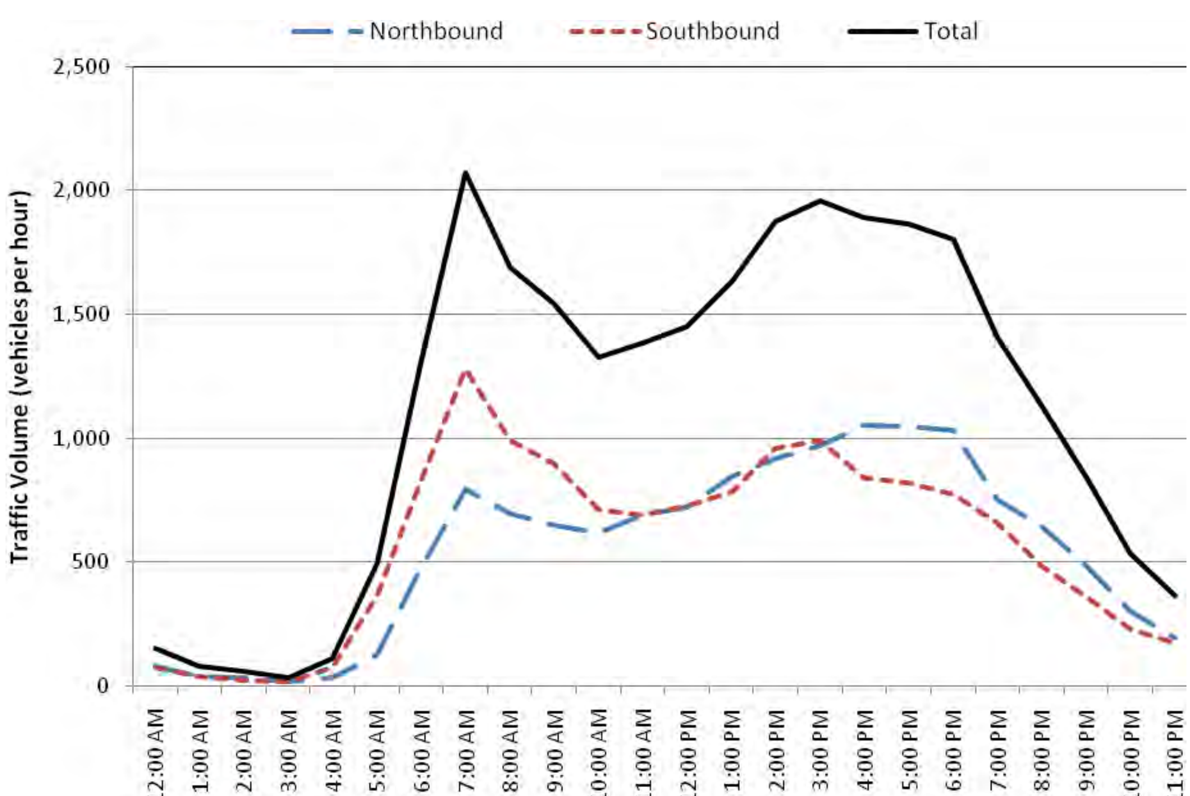
Major east-west roadways such as Pawtucket Boulevard, Middlesex Street, and Princeton Boulevard carry approximately 12,900 vpd, 12,700 vpd, and 6,200 vpd respectively.

Table 2-7 Study Area Traffic Volumes

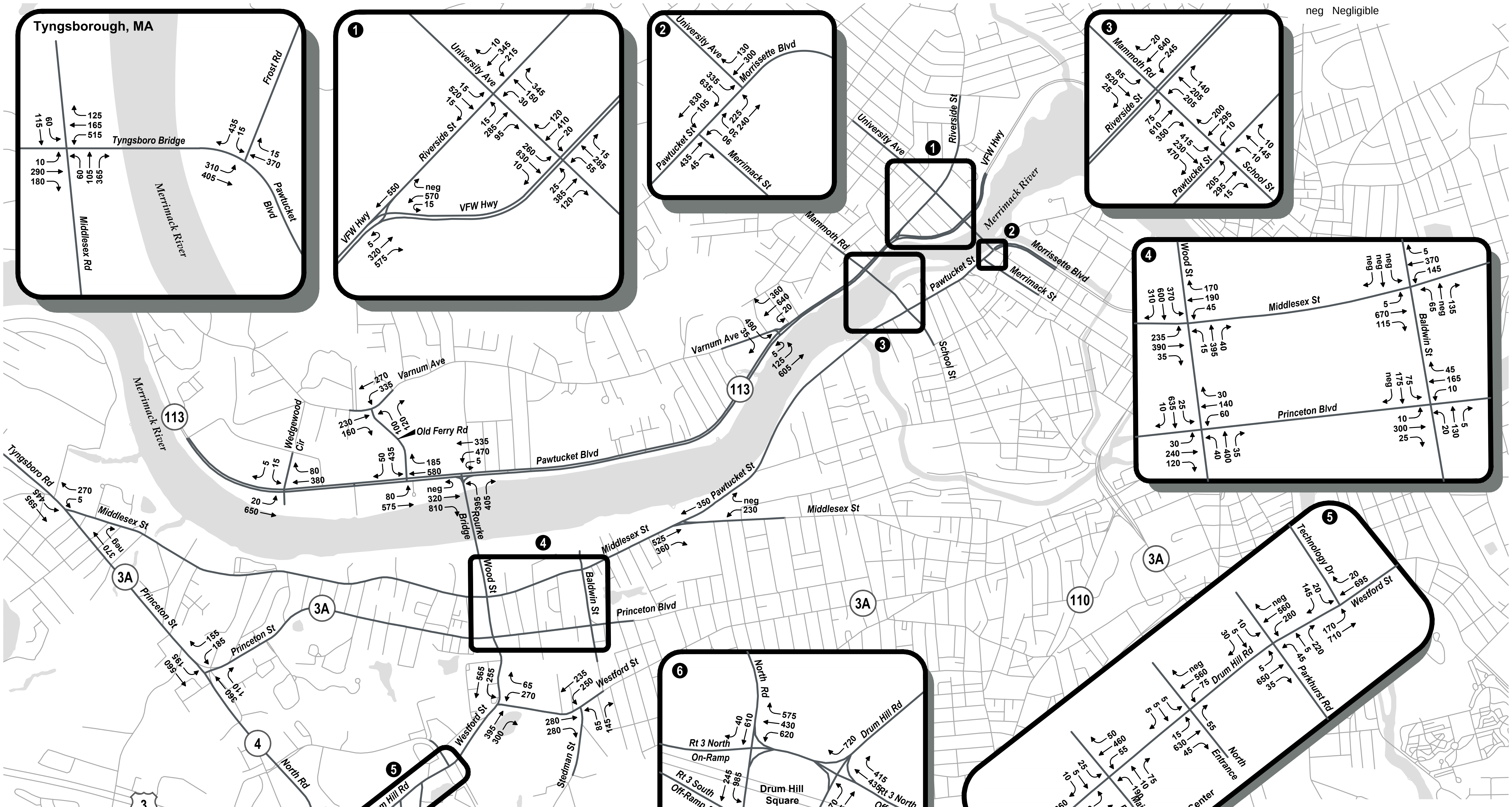
Location	Weekday [1] Daily	Weekday Morning Peak Hour Volume [2]	K Factor [3]	Dir. Dist. [4]	Weekday Evening Peak Hour Volume	K Factor	Dir. Dist.
Rourke Bridge between Pawtucket Blvd and Middlesex St	27,000	2,080	7.7%	61% SB	1,965	7.3%	51% NB
Westford St south of Carl St	25,000	1,345	5.4%	51% SB	1,785	7.1%	52% NB
Pawtucket Blvd west of Old Ferry Rd	12,900	1,190	9.3%	55% EB	960	7.4%	52% EB
Middlesex St west of Thorncliff Ave	12,700	1,005	7.9%	51% EB	940	7.4%	51% WB
Princeton St west of Corey St	6,200	415	6.7%	59% EB	580	9.3%	55% EB

Source: Vanasse Hangen Brustlin, Inc. Based on automatic traffic recorder (ATR) counts conducted in April 2012.
1 average daily traffic (ADT) volume expressed in vehicles per day
2 peak period traffic volumes expressed in vehicles per hour
3 percent of daily traffic that occurs during the peak period
4 directional distribution of peak period traffic

Figure 2-8 Weekday Traffic Fluctuations on the Rourke Bridge



Source: Vanasse Hangen Brustlin, Inc. Based on automatic traffic recorder (ATR) counts conducted in April 2012.

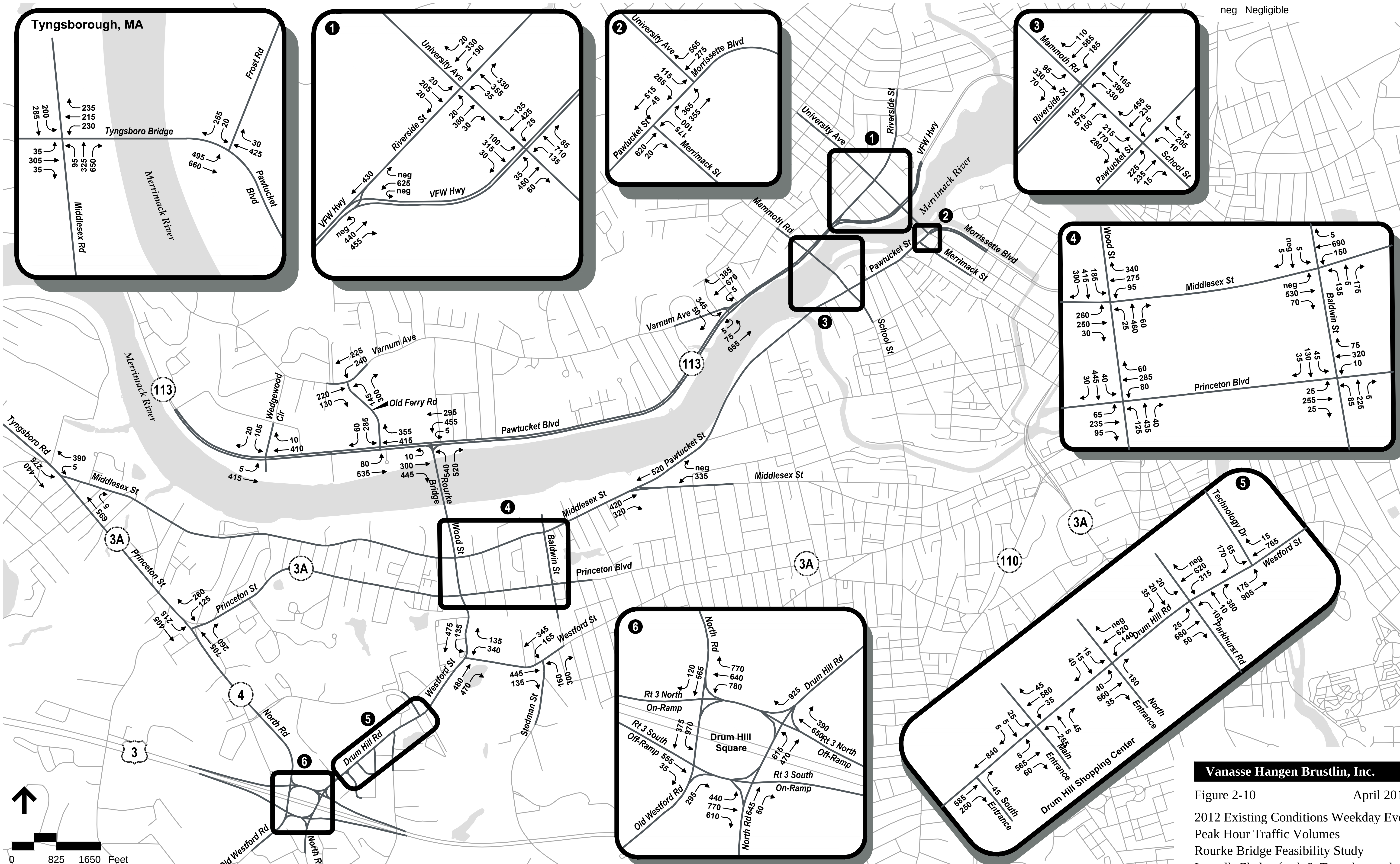


Vanasse Hangen Brustlin, Inc.

Figure 2-9 April 2012

2012 Existing Conditions Weekday Morning Peak Hour Traffic Volumes
Rourke Bridge Feasibility Study
Lowell, Chelmsford, &Tyngsborough, MA

neg Negligible



Vanasse Hangen Brustlin, Inc.

Figure 2-10 April 2012

2012 Existing Conditions Weekday Evening Peak Hour Traffic Volumes

Rourke Bridge Feasibility Study

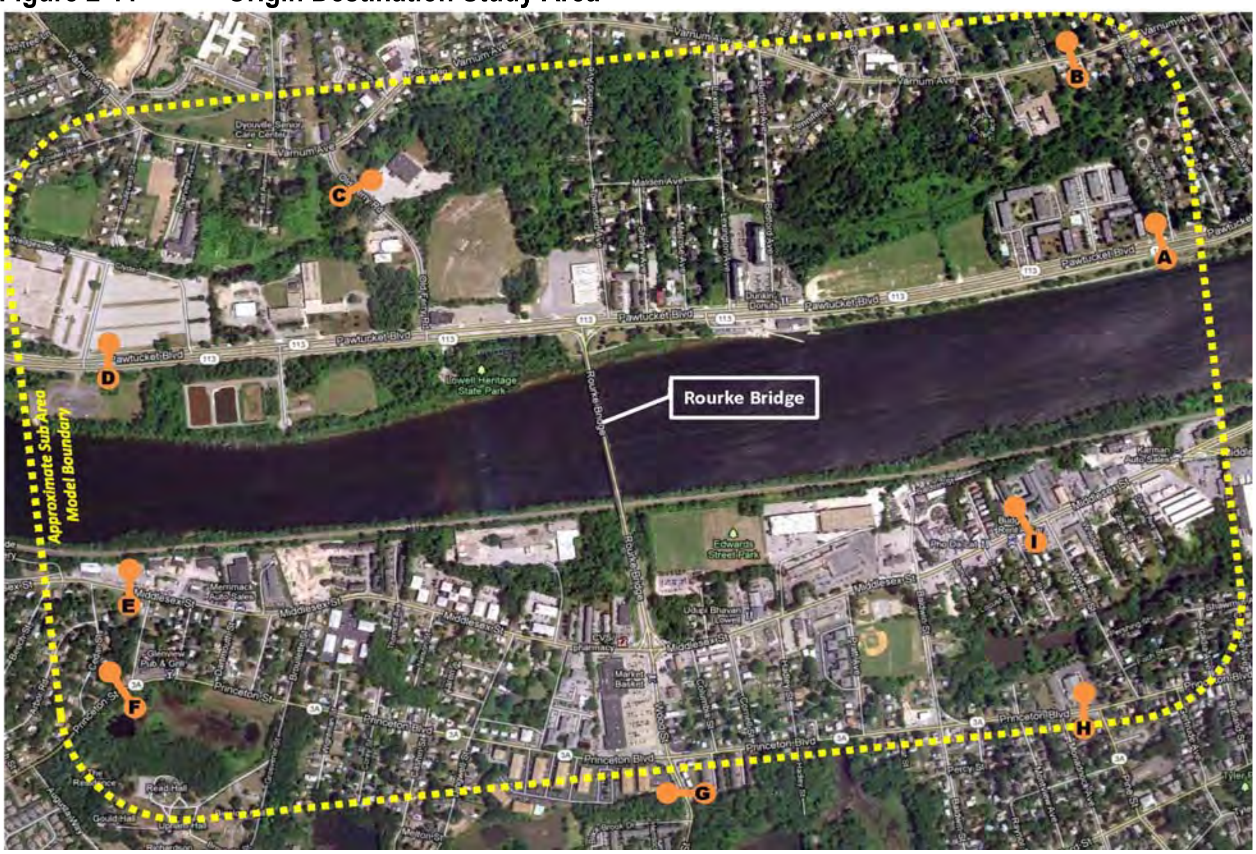
Lowell, Chelmsford, & Tyngsborough, MA

2.5.2 Rourke Bridge Origin-Destination Study

To gain an understanding of the trip patterns across the Rourke Bridge, an origin-destination (O-D) license plate survey was conducted in April 2012. The results of the O-D survey will help guide the process of identifying and recommending bridge alignment alternatives and other roadway improvements. Because traffic conditions are strongly influenced by school-related traffic, the license plate O-D surveys were conducted while all colleges, high schools, and elementary schools in the study area were on a regular schedule.

License plate data was collected during the morning (7:00 – 9:00 AM) and evening (4:00 – 6:00 PM) peak periods, concurrent with the Rourke Bridge ATR discussed previously. There were two technicians stationed along each of nine corridors that provide access to the Rourke Bridge with each technician collecting data in one direction. These stations created a cordon in an attempt to capture the vast majority of Rourke Bridge trips, as depicted in Figure 2-11. The technicians recorded the last four characters of the license plates for each vehicle into hand-held voice recorders.

Figure 2-11 Origin Destination Study Area



To analyze the travel patterns of vehicles over the Rourke Bridge, license plate data from all of the stations were matched. A match consisted of vehicles with the same license plate characteristics entering the cordon area at one location and exiting the area at a second location. A complete match of the license plate characters was required and any data that did not satisfy this requirement was excluded. Matches were summarized for all 72 possible travel routes within the study area and are included in the Technical Appendix. It should be noted that these total matches include both trips using the Rourke Bridge and trips not using the bridge.

A more detailed analysis was conducted for trips over the Rourke Bridge to help guide the alternatives development process, in particular establishing a permanent Rourke Bridge alignment. Matches entering the study area on one side of the bridge and exiting the study area on the opposite side of the bridge were assumed to be a Rourke Bridge trip. Table 2-8 below summarizes the percent of total northbound Rourke Bridge trips by origin and destination. Similarly, Table 2-9 summarizes the percent of total southbound Rourke Bridge trips by origin and destination.

Table 2-8 Northbound Rourke Bridge Trip Patterns

Origin	AM % (PM %)	Destination	AM % (PM %)
Location E: Middlesex Street west	25% (20%)	Location A: Pawtucket Blvd east	50% (45%)
Location F: Princeton Street west	5% (5%)	Location B: Varnum Avenue east	10% (5%)
Location G: Wood Street south	45% (45%)	Location C: Old Ferry Road north	20% (35%)
Location H: Princeton Street east	10% (10%)	Location D: Pawtucket Blvd west	20% (15%)
Location I: Middlesex Street east	15% (20%)		

Source: Vanasse Hangen Brustlin, Inc. Based on data collected in April 2012. See Figure 2-11 for location identification.

Table 2-9 Southbound Rourke Bridge Trip Patterns

Origin	AM % (PM %)	Destination	AM % (PM %)
Location A: Pawtucket Blvd east	40% (50%)	Location E: Middlesex Street west	15% (20%)
Location B: Varnum Avenue east	5% (5%)	Location F: Princeton Street west	5% (5%)
Location C: Old Ferry Road north	30% (20%)	Location G: Wood Street south	50% (45%)
Location D: Pawtucket Blvd west	25% (25%)	Location H: Princeton Street east	15% (10%)
		Location I: Middlesex Street east	15% (20%)

Source: Vanasse Hangen Brustlin, Inc. Based on data collected in April 2012. See Figure 2-11 for location identification.

As shown, approximately 45 percent of northbound Rourke Bridge trips entered the study area on the Wood Street corridor (Location G) during both the morning and evening peak periods. Similarly, 50 percent of southbound Rourke Bridge trips in the morning peak period and 45 percent of southbound Rourke Bridge trips in the evening peak period are destined for Wood Street southbound (Location G). These patterns are not surprising given that the Wood Street corridor provides direct access to Route 3; however, the patterns also suggest that the bridge is in an optimal location from an O-D perspective.

North of the bridge, 40 percent of morning trips and 50 percent of evening trips enter the study area as a westbound trip on Pawtucket Boulevard (Location A), turn left, and travel southbound over the Rourke Bridge. In the northbound direction, 50 percent of morning trips and 45 percent of evening trips cross the bridge, turn right, and exit the study area as a Pawtucket Boulevard eastbound trip (Location A).

2.5.3 VMT and VHT

MassDOT Planning maintains the Massachusetts Statewide Travel Demand Model (the "model"), a travel demand model used to forecast traffic conditions. In addition to estimating the volume of traffic on a particular roadway, the model is used to estimate expected changes in vehicle-miles traveled (VMT) and vehicle-hours traveled (VHT). VMT is an indicator of trip lengths for all trips within the study area. One vehicle traveling one mile constitutes one vehicle-mile. Adding the vehicle-miles traveled for every trip that occurs results in an estimate of total VMT for the area. VHT is an indicator of trip times. Similar to VMT, one vehicle traveling one hour constitutes one vehicle-hour. VHT for the study area is the sum of the vehicle-hours traveled for every trip. VMT and VHT are important factors that are used to evaluate the effectiveness of alternatives in meeting regional mobility and efficiency goals for vehicular travel. VMT and VHT are also indicators of potential air quality benefits, such as reductions in greenhouse gas emissions, associated with improvements.

Table 2-10 summarizes the VMT and VHT for the study area from the statewide model for 2010 conditions. The VMT and VHT are provided for each roadway functional classification to show how much traffic is carried on higher speed, higher classified roadways.

The majority of the study area's vehicle trips are on principal arterials such as Route 3, the Drum Hill Road/Westford Street/Wood Street corridor, and the study area bridges. Roadways such as Varnum Avenue and North Road, classified as minor arterials, carry the next highest share of the study area traffic, followed by collector roadways such as Old Ferry Road.

Table 2-10 2010 VMT and VHT Summary

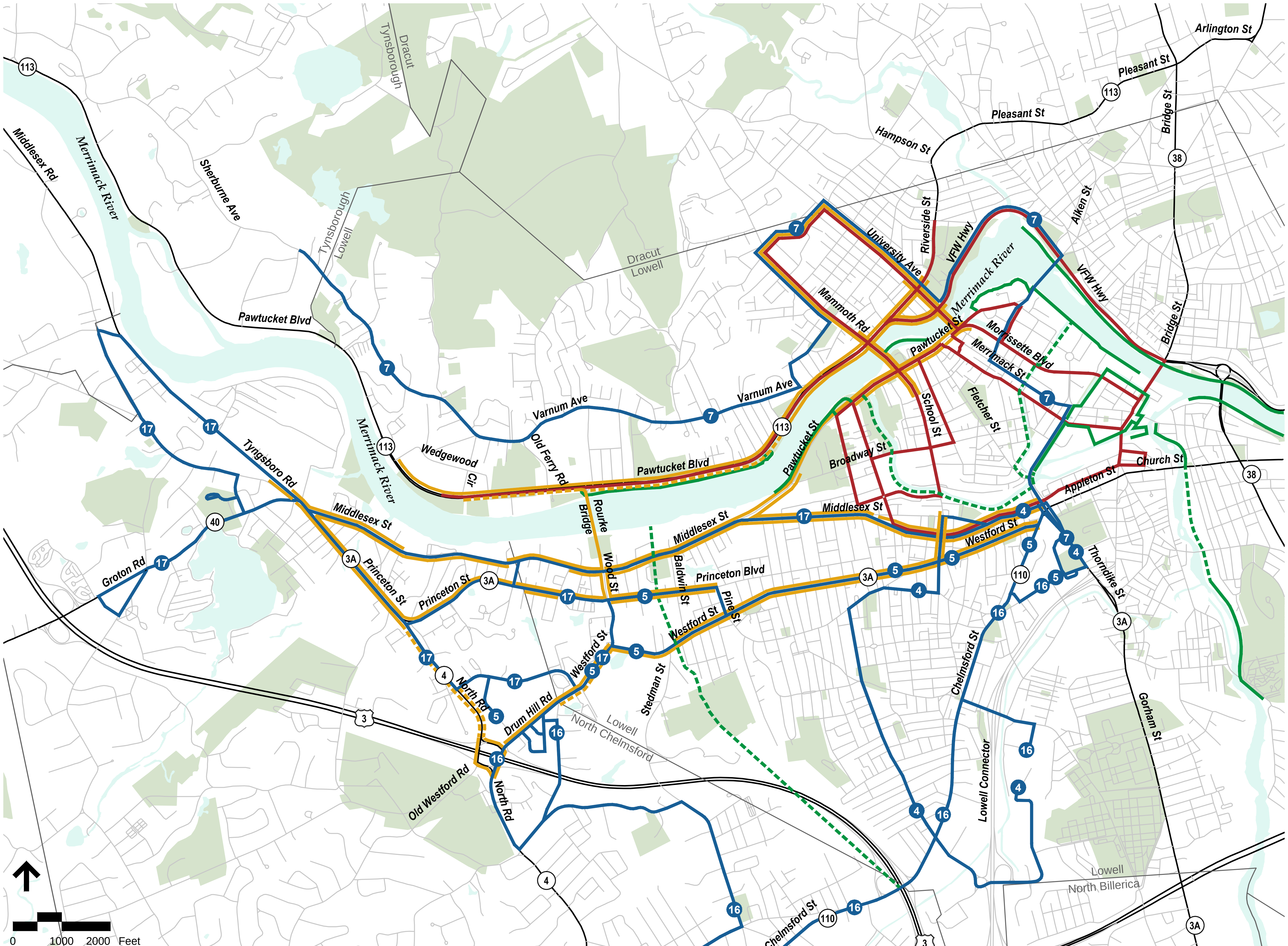
Functional Classification	VMT [1]	VHT [2]
Principal Arterials	973,387 (66%)	22,548 (55%)
Minor Arterials	404,909 (28%)	14,936 (37%)
Collectors	80,080 (5%)	2,860 (7%)
Local Roads	18,532 (1%)	589 (1%)
TOTAL	1,476,908 (100%)	40,932 (100%)

Source: Massachusetts Statewide Model for 2010.
Note: Not all local roadways are accounted for in the model.
1 Vehicle-miles traveled per day
2 Vehicle-hours traveled per day

2.5.4 Pedestrian and Bicycle Facilities

Pedestrian and bicycle facilities were evaluated for the major corridors in the study area and are illustrated in Figure 2-12. These include Pawtucket Boulevard, Rourke Bridge, Wood Street/Westford Street/Drum Hill Road, Middlesex Street/Pawtucket Street, and Princeton Street/Princeton Boulevard/Route 3A. Bicycle facilities, including bike paths, bike lanes, shared use lanes, and signage, are not found along the major corridors within

\\vhb\proj\Wat-TS\11906.00\graphics\FIGURES\Transit.dwg



Vanasse Hangen Brustlin, Inc.

Figure 2-12

Pedestrian Facilities along Major Corridors and Transit Services

Rourke Bridge Feasibility Study

Lowell, Chelmsford, & Tyngsborough, MA

the study area. Along the major corridors, sidewalks or paths on at least one side of the road are present almost everywhere. However, the condition of the sidewalks and paths in the study area ranges from good to poor, as described below. A complete inventory of pedestrian and bicycle facilities along major study area corridors is included in the Technical Appendix.

Pawtucket Boulevard

Continuous sidewalks are present along the majority of Pawtucket Boulevard within the study area. On the westbound side, a sidewalk is present at the intersection of Riverside Street and University Avenue, at the eastern edge of the study area. The sidewalk continues along Riverside Street/Pawtucket Boulevard to just east of the unsignalized intersection of Pawtucket Boulevard and Wedgewood Circle. The majority of the sidewalk is in good condition. On the eastbound side of Pawtucket Boulevard, an informal, worn pedestrian path ("cow path") begins at the Boat Ramp Parking Lot across from the signalized intersection of Pawtucket Boulevard and Wedgewood Circle. The cow path continues to the intersection of Pawtucket Boulevard and the Rourke Bridge, where it turns into a sidewalk to cross the bridge. A section of the sidewalk branches off and goes under the Rourke Bridge to the Vandenburg Esplanade. A cow path begins on the eastern side of the intersection right next to the road, while the Vandenburg Esplanade sidewalk continues along the water. A sidewalk begins at the end of the Vandenburg Esplanade and continues to the intersection of University Avenue and Riverside Street, at the edge of the study area.

Rourke Bridge

The Rourke Bridge provides a sidewalk along the southbound side of the bridge. A sidewalk begins at the corner of Pawtucket Boulevard and the Rourke Bridge and continues up to the bridge at which point an enclosed pedestrian path is located next to the bridge. A sidewalk begins again where the enclosed pathway ends and continues to the intersection of Middlesex Street and Wood Street/Rourke Bridge, where crosswalks are provided on all sides of the intersection.

Wood Street/Westford Street/Drum Hill Road

The Wood Street/Westford Street/Drum Hill Road corridor begins at the southern side of the Rourke Bridge and ends at Drum Hill Square. Along the southbound side a sidewalk starts at the intersection of Middlesex Street and Wood Street/Rourke Bridge and continues through the intersection of Wood Street and Princeton Boulevard to Black Brook Drive. After crossing Black Brook Drive, a cow path begins and continues to the intersection of Wood Street and Westford Street. A sidewalk begins again at the intersection of Wood Street and Westford Street and continues to Drum Hill Square. Along the northbound side of the corridor, there is no sidewalk present from Drum Hill Square to Parkhurst Road. A cow path, containing many obstacles such as large rocks, bollards and telephone poles, begins at the intersection of Drum Hill Road and Parkhurst

Road and continues to the intersection of Wood Street and Westford Street. After crossing Westford Street, no sidewalk is present. A sidewalk begins again at Black Brook Drive and continues through the intersection of Wood Street and Princeton Boulevard to the intersection of Middlesex Street and Wood Street/Rourke Bridge.

Middlesex Street/Pawtucket Street

Along the westbound side of Middlesex Street, a sidewalk is present from the intersection of Father Morissette Boulevard/Pawtucket Street and University Avenue, at the eastern edge of the study area, to the intersection of Middlesex Street and the Rourke Bridge. The sidewalk continues from the Rourke Bridge to Thorncliff Avenue; however there are some small segments where the sidewalk changes to a cow path along this stretch. A segment of sidewalk is present in front of Millview Estates. The sidewalk begins again at Highland Avenue and continues to Quigley Avenue, where there is a break until Edwards Avenue. It then continues from Edwards Avenue through the intersection of Middlesex Street and Tyngsboro Road. Along the eastbound side of the Middlesex Street, a sidewalk is present from the intersection of Middlesex Street and Tyngsboro Road and continues to Amherst Street. A cow path runs from Amherst Street to Dingwell Street, where a sidewalk begins again. The sidewalk continues until just after Broadway Street where there is a break in front of the UMass Lowell Campus. The sidewalk begins again east of the campus and continues to Father Morissette Boulevard at the edge of the study area. Land use along the westbound side consists of mostly residential, with commercial sections from the Rourke Bridge to Middlesex Street. Land uses along Middlesex Street eastbound consist primarily of residential, with a commercial section from the Rourke Bridge to just before Broadway where the UMass Lowell Campus is located. The speed limit along Middlesex Street is 30 mph.

Princeton Street/Princeton Boulevard/Route 3A

Along the westbound side of Princeton Street/Princeton Boulevard/Route 3A, a sidewalk is present at the intersection of Princeton Boulevard and Baldwin Street and continues through the intersection of Princeton Street/Route 3A and North Road, where Route 3A turns right. The sidewalk continues along Princeton Street/Route 3A through the intersection of Princeton Street and Middlesex Street/Tyngsboro Road. Along the eastbound side of Princeton Street/Princeton Boulevard/Route 3A, a sidewalk is present at the intersection of Princeton Street and Middlesex Street/Tyngsboro Road and continues to the intersection of Princeton Street/Route 3A and North Road, at which point Princeton Street/Route 3A turns left. No sidewalk is present along Princeton Street at the intersection. A sidewalk begins again at Wightman Street and ends at Dingwell Street. A cow path begins just east of the intersection of Princeton Boulevard and Wood Street. A sidewalk begins at the intersection of Princeton Boulevard and Wood Street and continues through the intersection of Princeton Boulevard and Baldwin Street.

2.5.5 Transit Facilities

There are three transit services that operate in the study area. They include; the Lowell Regional Transit Authority (LRTA), UMass Lowell Shuttle Service, and the MBTA Commuter Rail. Figure 2-12 summarizes the transit services in the study area; transit route and service details are included in the Technical Appendix.

Lowell Regional Transit Authority

The Lowell Regional Transit Authority (LRTA) operates five bus lines within the study area. These include Route 4, Route 5, Route 7, Route 16, and Route 17. The LRTA does not have fixed bus stops and in order to board a bus, the rider must be along the bus route flag the bus from the correct side of the road. The LRTA provides service Monday through Saturday and all buses depart from and return to the Kennedy Center at Gallagher Intermodal Transportation Center in downtown Lowell.

According to the MassDOT website[5], the LRTA carried approximately 1.4 million passengers system wide in 2010, of which 93 percent used local bus service and 7 percent used paratransit. Ridership on fixed-route buses has declined by 21 percent from 2001, due in large part to service cuts in 2002. Conversely, operating costs have increased by approximately 32 percent since 2001, an average of 3 percent per year.

The following provides a summary of the five LTRA bus routes that operate within the study area:

- Route 4, "Shaw/Stevens," provides service between The Kennedy Center and the Veteran's Administration Clinic, with a stop at Lowell Catholic High School, and operates along Middlesex Street within the study area. Service runs from 5:55 AM to 6:30 PM on weekdays with approximate 30-minute peak headways and is combined with Route 3, "South Lowell," on Saturdays, running from 8:00 AM to 4:25 PM with approximate two-hour peak headways.
- Route 5, "Westford Street," provides service between The Kennedy Center and Walmart in the Drum Hill Shopping Center in Chelmsford. The route operates along Westford Street, Princeton Boulevard, Wood Street, Drum Hill Road, and Technology Drive within the study area. Service runs from 5:50 AM to 7:10 PM on weekdays with approximate 30-minute peak headways and from 8:10 AM to 6:10 PM on Saturdays with approximate one-hour peak headways.
- Route 7, "Pawtucketville," provides service between The Kennedy Center and Greater Lowell Technical High School. The route operates on Varnum Avenue in the study area with a stop at Lowell General Hospital. Service runs from 5:50 AM to 7:35 PM on weekdays with approximate 30-minute peak headways and from 7:45 AM to 5:50 PM on Saturdays with approximate one-hour peak headways.

▼

[5] https://www.massdot.state.ma.us/planning/Main/CurrentStudies/BeyondBostonTransitStudy/LRTAProfile.aspx#section5

- Route 16, "Chelmsford Center," provides service between The Kennedy Center and Walmart in the Drum Hill Shopping Center, with a stop at the Radisson Hotel in Chelmsford. The route operates along Drum Hill Road through Drum Hill Square and along Parkhurst Road within the study area. Service runs from 6:00 AM to 7:45 PM on weekdays (with variable headways) and from 8:20 AM to 5:40 PM on Saturdays, with approximate 80-minute peak headways.
- Route 17, "North Chelmsford," provides service between The Kennedy Center and Triangle Store, with a stop at Lowell General Hospital's Chelmsford campus on Technology Drive. The route operates along Middlesex Street, Princeton Boulevard, Wood Street/Westford Street/Drum Hill Road, Technology Drive, North Road, and Tyngsboro Road within the study area. Service runs from 6:00 AM to 6:35 PM on weekdays with approximate 30-minute peak headways and from 7:50 AM to 4:50 PM on Saturdays with approximate 90-minute peak headways.

UMass Lowell Shuttle Service

UMass Lowell provides multiple shuttles, serving the UMass Lowell population, that run between their North, South, and East Campuses. Service is provided on weekdays, when the university is open, from 7:00 AM to 6:00 PM. These shuttles have set origin and destination points, however the route taken between the two is up to the driver's discretion based on prevailing traffic conditions. Routes are also limited by the location of bridges across the Merrimack River and their respective weight restrictions.

MBTA Commuter Rail

The Lowell Line on the Commuter Rail operates on weekdays from 5:35 AM to 10:35 PM for inbound travel, and from 5:45 AM to 12:10 AM for outbound travel. Trains run approximately every 45 minutes during peak hours and approximately every hour all other times. On weekends, inbound trains operate from 7:00 AM to 9:00 PM, and outbound trains operate from 8:00 AM to 11:30 PM. Trains run approximately every 2 hours on weekends. All trains run between North Station, Boston and Gallagher Terminal, Lowell, with seven stops in between. The commuter rail is accessible via a transfer from any LRTA bus line at The Kennedy Center located in Gallagher Terminal.

2.5.6 Safety

To identify potential vehicle crash trends and/or roadway deficiencies in the project study area, the most current vehicle crash data for the study area intersections was obtained from MassDOT for the years 2007 to 2010. Crash data is included in the Technical Appendix.

Crash rates are calculated based on the number of crashes at an intersection and the volume of traffic traveling through that intersection on a daily basis. Rates that exceed MassDOT's average for crashes at an intersection in the district in which the town or city is located (District 4) could indicate safety or geometric issues for a particular intersection. The latest published crash rate by MassDOT in District 4 is 0.78 for signalized intersection and 0.59 for unsignalized intersections. These rates imply that, on average, 0.78 crashes occurred per million vehicles entering signalized intersections throughout District 4, and 0.59 crashes occurred per million vehicles entering unsignalized intersections in the District. Crash rate calculations are included in the Technical Appendix. It should be noted that the location for some crashes cannot be precisely determined from the database. These locations typically involve interchange and rotary intersections. Additionally, some crashes may have occurred but were either not reported or not included in the database, and therefore not considered. A summary of the study intersections' vehicle crash history is presented in Table 2-11.

It should be noted that the intersection of Frost Road at Pawtucket Boulevard in Tyngsborough is currently under construction (2011 to present). The project includes relocating Pawtucket Boulevard to the east and creating a three-legged intersection with Frost Road. Since the most recent crash data available is prior to the start of construction, the crash data shown in the table for this location is a combination of crashes from Frost Road at Pawtucket Boulevard and Frost Road at Sherburne Avenue.

As shown in Table 2-11, calculated crash rates for 20 study area intersections are equal to or greater than the MassDOT District 4 average crash rate values. This means that only 11 intersections in the study area operate as safely as – or safer than – other similar intersections in the same district. Furthermore, a total of 26 non-motorist (bike, pedestrian) crashes occurred at 12 intersections in the study area. Review of the accident data indicates that the intersections of Middlesex Street at Wood Street/Rourke Bridge, and Riverside Street/Varnum Avenue at Mammoth Road/School Street, with total crashes of 161 and 157 respectively, have the highest number of accidents from the years 2007 through 2010. Overall, the majority of crashes were angle and rear-end collisions that occurred under dry conditions.

This page intentionally left blank

Table 2-11 Vehicular Crash Summary [2007-2010]

	University Avenue at:			Riverside Street at:		Pawtucket Street at:		Pawtucket Blvd at:				Varnum Avenue at:	Middlesex Street at:			Princeton Blvd at:		Princeton Street at:	
	Riverside Street	VFW Highway	Father Morissette Blvd	VFW Highway	Varnum Avenue at Mammoth Road/School Street	Merrimack Street	School Street	Varnum Avenue	Rourke Bridge	Old Ferry Road	Wedgewood Circle	Old Ferry Road	Pawtucket Street	Baldwin Street	Wood Street/Rourke Bridge	Baldwin Street	Wood Street	North Road	Middlesex Street/Tyngsboro Street
Currently Signalized?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No
MassDOT ACR	0.78	0.78	0.78	0.59	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.59	0.78	0.59	0.78	0.78	0.78	0.78	0.59
MassDOT CCR	2.02	1.09	1.04	0.73	3.11	1.22	2.26	0.84	1.35	0.71	0.26	0.59	0.96	1.19	3.69	1.71	1.67	0.88	0.31
Exceeds?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Year																			
2007	12	15	8	2	31	6	24	11	11	5	0	4	6	5	29	7	12	4	4
2008	16	7	11	5	52	9	20	8	16	5	1	4	6	10	53	10	16	6	3
2009	20	9	8	8	35	7	18	6	16	6	3	3	8	9	36	8	10	8	1
2010	15	12	6	8	39	7	13	5	12	4	0	1	5	10	43	9	14	10	1
Total	63	43	33	23	157	29	75	30	55	20	4	12	25	34	161	34	52	28	9
Collision Type																			
Angle	27	13	10	7	71	15	21	5	11	3	0	3	8	22	62	22	19	12	2
Head-on	2	2	3	0	7	1	2	2	0	0	0	1	0	0	5	0	1	4	0
Rear-end	12	17	8	11	33	10	33	9	25	8	0	3	12	8	69	8	25	9	4
Rear-to-rear	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Sideswipe	15	5	5	0	8	1	10	0	7	2	2	0	1	1	15	3	4	1	1
Single-vehicle crash	4	4	6	4	10	2	5	10	5	4	2	1	3	1	5	1	1	1	2
Unknown	3	2	1	1	28	0	3	4	7	3	0	4	1	2	5	0	2	1	0
Total	63	43	33	23	157	29	75	30	55	20	4	12	25	34	161	34	52	28	9
Severity																			
Fatality	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0
Injury	18	11	3	6	42	6	19	7	15	7	0	3	6	8	32	5	10	7	2
Property-related	36	28	26	16	103	22	51	18	37	12	2	6	16	20	110	25	36	20	7
Unknown	9	4	4	1	12	1	4	5	3	1	1	3	2	6	18	4	6	1	0
Total	63	43	33	23	157	29	75	30	55	20	4	12	25	34	161	34	52	28	9
Time of day																			
Weekday, 7:00 AM - 9:00 AM	5	6	3	1	20	5	10	4	4	3	0	1	5	3	16	2	8	4	0
Weekday, 4:00 PM - 6:00 PM	6	5	4	1	16	10	7	7	7	5	1	3	1	9	35	10	8	8	3
Saturday, 11:00 AM - 2:00 PM	1	0	1	1	6	0	2	0	2	1	0	1	1	3	12	3	1	1	0
Weekday, other time	30	27	19	15	81	9	34	14	29	7	3	6	14	19	79	9	29	11	4
Weekend, other time	21	5	6	5	34	5	22	5	13	4	0	1	4	0	19	10	6	4	2
Total	63	43	33	23	157	29	75	30	55	20	4	12	25	34	161	34	52	28	9
Pavement Conditions																			
Dry	42	29	23	16	114	20	50	18	39	13	3	9	17	26	114	29	35	19	8
Wet	18	7	7	5	26	7	17	8	9	4	1	0	6	7	39	5	10	5	0
Snow	1	1	1	2	3	0	4	2	1	1	0	1	1	0	3	0	1	2	1
Ice/Slush	0	3	0	0	3	1	0	2	0	1	0	0	1	0	2	0	3	1	0
Sand/Mud/Dirt/Oil/Gravel	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Unknown	2	3	1	0	11	1	4	0	5	1	0	2	0	1	3	0	3	1	0
Total	63	43	33	23	157	29	75	30	55	20	4	12	25	34	161	34	52	28	9
Non Motorist (Bike, Pedestrian)																			
Total	3	5	1	1	6	0	2	0	0	1	2	0	1	1	2	1	0	0	0

ACR average crash rate
CCR calculated crash rate
Source: MassDOT vehicle crash data

Table 2-11 (cont'd) Vehicular Crash Summary [2007-2010]

	Westford Street at:			Drum Hill Road at:				Drum Hill Square at:					Frost Road at:	
	Wood Street	Stedman Street	Technology Drive	Parkhurst Road	Drum Hill Shopping Center - north	Drum Hill Shopping Center - main	Drum Hill Shopping Center - south	Drum Hill Road	North Road - south	Old Westford Road	North Road - north	Drum Hill Square [a]	Middlesex Road/Kendall Road	Pawtucket Blvd/Sherburne Avenue [b]
Currently Signalized?	Yes	No	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	n/a	Yes	Yes
MassDOT ACR	0.78	0.59	0.59	0.78	0.59	0.78	0.59	0.78	0.78	0.78	0.78	n/a	0.78	0.78
MassDOT CCR	1.06	1.39	0.80	0.53	0.34	0.68	0.35	0.53	0.44	0.39	0.33	n/a	0.92	n/a
Exceeds?	Yes	Yes	Yes	No	No	No	No	No	No	No	No	n/a	Yes	n/a
Year														
2007	7	13	6	3	4	4	3	3	3	3	2	5	9	11
2008	10	5	10	5	1	4	4	9	7	3	5	26	8	5
2009	6	12	5	7	2	2	3	9	4	4	4	17	10	3
2010	12	5	5	3	1	6	0	5	4	4	4	21	12	11
Total	35	35	26	18	8	16	10	26	18	14	15	69	39	30
Collision Type														
Angle	10	22	11	8	3	7	5	8	6	5	9	25	7	9
Head-on	1	0	1	1	0	0	0	0	0	0	0	1	3	3
Rear-end	14	8	9	5	5	2	3	14	5	6	4	23	23	11
Rear-to-rear	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Sideswipe	3	0	4	2	0	5	1	3	3	2	1	4	5	3
Single-vehicle crash	7	5	1	1	0	1	0	0	4	1	1	9	1	2
Unknown	0	0	0	1	0	1	1	0	0	0	0	6	0	2
Total	35	35	26	18	8	16	10	26	18	14	15	69	39	30
Severity														
Fatality	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Injury	8	14	9	3	3	2	3	6	5	7	6	19	5	8
Property-related	25	17	14	12	5	14	7	18	10	5	5	47	34	21
Unknown	2	4	3	3	0	0	0	2	3	2	4	3	0	1
Total	35	35	26	18	8	16	10	26	18	14	15	69	39	30
Time of day														
Weekday, 7:00 AM - 9:00 AM	4	5	1	3	1	1	2	4	4	1	1	8	7	3
Weekday, 4:00 PM - 6:00 PM	6	5	6	5	1	2	2	3	0	0	0	5	7	4
Saturday, 11:00 AM - 2:00 PM	3	2	0	0	0	1	0	0	0	1	1	3	1	0
Weekday, other time	13	16	15	5	3	7	3	13	10	8	10	37	17	17
Weekend, other time	9	7	4	5	3	5	3	6	4	4	3	16	7	6
Total	35	35	26	18	8	16	10	26	18	14	15	69	39	30
Pavement Conditions														
Dry	23	19	15	12	6	10	8	22	8	10	12	52	28	19
Wet	10	14	8	4	2	3	1	4	7	4	3	12	6	8
Snow	1	0	1	1	0	1	1	0	0	0	0	1	3	0
Ice/Slush	1	2	2	0	0	1	0	0	1	0	0	3	1	2
Sand/Mud/Dirt/Oil/Gravel	0	0	0	1	0	1	0	0	2	0	0	1	1	1
Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	35	35	26	18	8	16	10	26	18	14	15	69	39	30
Non Motorist (Bike, Pedestrian)														
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ACR average crash rate
CCR calculated crash rate
Source: MassDOT vehicle crash data
n/a crash rate cannot be calculated since specific (rotary) locations of the crashes are not available
[a] exact rotary locations are not specified
[b] intersection is under construction 2011 – present; data includes crashes at the intersections of Pawtucket Blvd at Frost Rd and Frost Rd at Sherburne Ave, which are currently being relocated

In addition to the MassDOT crash data, detailed crash records were evaluated for the Highway Safety Improvement Program (HSIP) eligible locations (described in detail below) in Lowell from January 2010 to May 2012 (the most recent data available at the time of the evaluation). Individual crash records were reviewed and collision diagrams were developed and are included in the Technical Appendix. The diagrams helped to determine if crash patterns or tendencies emerged that could be linked to physical roadway conditions or signal operations. The results of this evaluation indicate the following potential patterns:

- **Middlesex Street at Wood Street/Rourke Bridge** – The northbound departure leg of this intersection saw three rear-end/side swipe crashes that could be a result of unclear pavement markings that do not delineate the two-lane to one-lane taper.
- **University Avenue at VFW Highway** – Three pedestrian/bicycle crashes occurred at this location.
- **Middlesex Street at Baldwin Street** – Northbound left-turn collisions with eastbound through vehicles could indicate a sight distance issue for this maneuver.

In addition to the specific patterns discussed above, rear-end crashes on one or more approaches could indicate the need to review yellow clearance intervals at the following intersections:

- University Avenue at Riverside Street
- University Avenue at VFW Highway
- Pawtucket Boulevard at Rourke Bridge
- Princeton Boulevard at Wood Street
- Pawtucket Boulevard at Varnum Avenue

MassDOT 2009 Top Crash Locations Report

MassDOT published a *2009 Top Crash Locations Report* in August of 2011, ranking the Top 200 Intersection Locations based on crash data from the years 2007 through 2009. In order to determine an intersection's ranking, MassDOT created a comprehensive method to locate crash clusters. This method uses a 25 meter search distance to locate adjacent crashes, and then merges the areas together to create a crash cluster. The clusters are then named based on the first and second highest functional classification roadways within the cluster and ranked by the number of Equivalent Property Damage Only (EPDO) crashes; where fatal crashes are weighted by 10, injury crashes are weighted by 5 and property damage only and non-reported crashes are weighted by 1. Therefore, each cluster can contain multiple intersections or segments of roadway located near the main intersection. Table 2-12 displays the four intersections in the study area included on the list.

Table 2-12 2007-2009 Statewide Top 200 Intersection Crash List

Rank	Town	Intersection
1	Lowell	VFW Highway/Riverside Street/Varnum Avenue at Mammoth Road/School Street
9	Lowell	Middlesex Street at Wood Street/Rourke Bridge
128	Lowell	Pawtucket Street at School Street
142	Lowell	Riverside Street at University Avenue

Source: MassDOT *2009 Top Crash Locations Report*; August 2011.

Highway Safety Improvement Program (HSIP)

The Federal Highway Administration requires all states to publish an annual "5-Percent Report" which identifies not less than 5 percent of locations exhibiting the most severe safety needs. The report must also include potential remedies, estimated costs, and any problems inhibiting implementation. The "5 Percent Report" along with a Strategic Highway Safety Plan (SHSP), an annual report to the Secretary of Transportation and the development of a crash data base that can perform an analysis, allow the identified locations to be eligible for Highway Safety Improvement Program (HSIP) funding. MassDOT uses the same methodology as the *2009 Top Crash Locations Report* to identify the top 5 percent of locations. Table 2-13 shows the locations within the study area that are included on the HSIP crash cluster list and their respective Equivalent Property Damage Only (EPDO) ranking.

Table 2-13 2009 HSIP Crash Clusters

EPDO Range	Town	Location
150-300	Lowell	VFW Highway/Riverside Street/Varnum Avenue at Mammoth Road/School Street
	Lowell	Middlesex Street at Wood Street/Rourke Bridge
50-150	Lowell	Riverside Street at University Avenue
	Lowell	University Avenue at VFW Highway
	Lowell	Pawtucket Street at School Street
	Lowell	Pawtucket Blvd at Rourke Bridge/Townsend Avenue
	Lowell	Princeton Blvd at Wood Street
	Lowell	Westford Street at Stedman Street
	Lowell	Westford Street at Technology Drive
	Chelmsford	Drum Hill Road at Drum Hill Shopping Center - north
>50	Lowell	Pawtucket Blvd at Varnum Avenue
	Lowell	Middlesex Street at Baldwin Street
	Chelmsford	Drum Hill Square eastern side, between Route 3 NB Off Ramp and Route 3 SB On Ramp

Source: MassDOT. <http://services.massdot.state.ma.us/maptemplate/topcrashlocations/ >

Road Safety Audit (RSA)

The Federal Highway Administration (FHWA) defines a Road Safety Audit (RSA) as "*the formal safety examination of an existing or future road or intersection by an independent, multidisciplinary team*". The purpose of an RSA is to identify elements of a roadway or intersection that may present safety concerns and possible opportunities to mitigate these issues for all roadway users. Within the study area, an RSA was conducted in June 2010 by MassDOT at the intersection of Varnum Avenue (Route 113)/Riverside Street at Mammoth Road/School Street in Lowell to identify potential short-term improvements. This RSA is included in the Technical Appendix.

The RSA discussed a series of issues at the intersection which may present safety concerns. Among others, these issues include significant traffic congestion, faded pavement markings, substandard pedestrian accommodations, limited signal head visibility, sight distance issues, and lack of emergency vehicle preemption. Recommended improvements include signal timing/phasing adjustments, signage and pavement marking updates/installation, landscape maintenance, pedestrian signal equipment and replacement and wheelchair ramp realignment, and emergency vehicle preemption. To date, none of these improvements have been completed[6].

2.5.7 Traffic Operations

Understanding the relationship between the supply and demand on a roadway is a fundamental consideration in evaluating how well a transportation facility safely and efficiently accommodates the traveling public. Methods from the 2000 Highway Capacity Manual (HCM)[7] were used to evaluate how the intersections accommodate the traffic demands under existing conditions.

The methods used to conduct this Existing Condition traffic operations assessment followed standard traffic engineering industry practices. The study area and key intersections for the analysis were established at the outset. These locations were shown previously in Figure 1-1.

Peak hour traffic volume data were obtained at the key intersections in April 2012 or were obtained from other recently completed studies in the area. Field reviews were conducted in April and May 2012 to visually observe weekday peak hour traffic operations and to inventory geometry and physical conditions. Annual and monthly historical traffic data for roadways in the area were reviewed to ensure that the data was not collected during a historically low month for the traffic demand.

Inventories of the signalized intersections within the study area were completed in April 2012. Data from this effort was used to calibrate the capacity analysis presented in this section. Additionally, if present, the following issues were noted:

- 2009 Manual on Uniform Traffic Control Devices (MUTCD) issues/violations;
- Defective and/or broken equipment;
- Americans with Disabilities Act (ADA) non-compliance issues; and
- Other issues (i.e. poor pavement condition, faded markings, "yellow traps", etc.).

A complete summary of the issues identified at each of the signalized intersections within the study area is included in the Report Appendix. Recommendations for addressing these issues are included in Chapter 4 – Alternatives.

The term "Level of Service" (LOS) is used to denote the different operating conditions that occur under select traffic volume loads. It is a qualitative measure that considers a number of factors including traffic demands, roadway geometry, speed, signal operations, travel delay, and freedom to maneuver. The level of service designation is an index ranging from A to F, with LOS A representing the best

▼

6 Note: Throughout the study process, several of these recommendations have been implemented.
7 *2000 Highway Capacity Manual*; Transportation Research Board Special Report 209; Washington, D.C.; 2000.

operating conditions and LOS F representing the worst operating conditions. Typically, LOS D (as defined in the HCM) is considered to be the acceptable limit and LOS E or F conditions are typically considered unacceptable. The level of service ratings are based on delay for signalized and unsignalized intersections.

The computer software program, SYNCHRO 7.0, was used for the LOS evaluation of signalized and unsignalized intersections. This modeling software is widely used by traffic engineering professionals and is consistent with procedures in the HCM. Levels-of-service analyses were conducted for the 2012 Existing Conditions for the signalized and unsignalized study area intersections.

Signalized Intersections

The capacity analysis results for the key signalized intersections in the study area are presented in Table 2-14 and are included in the Technical Appendix. For each of the signalized intersections, the table summarizes the delay and level-of-service for the intersection as a whole.

As shown in Table 2-14, the following intersections operate at or over capacity during the morning and/or evening peak periods (LOS E/F conditions):

- University Avenue at Riverside Street
- University Avenue at VFW Highway
- University Avenue at Father Morissette Boulevard (Weekday Morning)
- Pawtucket Street at Merrimack Street (Weekday Morning)
- Mammoth Road/School Street at Varnum Avenue/Riverside Street (Weekday Morning)
- School Street at Pawtucket Street (Weekday Morning)
- Pawtucket Boulevard at Rourke Bridge (Weekday Morning)
- Wood Street/Rourke Bridge at Middlesex Street
- Wood Street at Princeton Boulevard (Weekday Evening)
- Princeton Street at North Road (Weekday Evening)
- Middlesex Road at Frost Road/Kendall Road

Table 2-14 Signalized Intersection Capacity Analysis Summary

Location	Period	2012 Existing Conditions v/c [1]	Delay [2]	LOS [3]
University Ave at Riverside St	Weekday Morning	1.15	114	F
	Weekday Evening	1.12	84	F
University Ave at VFW Hwy	Weekday Morning	1.12	64	E
	Weekday Evening	1.03	>120	F
University Ave at Father Morissette Blvd	Weekday Morning	0.74	>120	F
	Weekday Evening	0.52	15	B
Pawtucket St at Merrimack St	Weekday Morning	0.88	105	F
	Weekday Evening	0.73	27	C
Mammoth Rd/School St at Varnum Ave/Riverside St	Weekday Morning	1.10	77	E
	Weekday Evening	0.89	50	D
School St at Pawtucket St	Weekday Morning	0.93	71	E
	Weekday Evening	0.76	50	D
Pawtucket Blvd at Varnum Ave	Weekday Morning	0.56	19	B
	Weekday Evening	0.56	15	B
Middlesex St at Pawtucket St	Weekday Morning	0.59	12	B
	Weekday Evening	0.66	13	B
Pawtucket Blvd at Old Ferry Rd	Weekday Morning	0.75	24	C
	Weekday Evening	0.62	18	B
Pawtucket Blvd at Rourke Bridge	Weekday Morning	0.97	75	E
	Weekday Evening	0.90	55	D
Wood St/Rourke Bridge at Middlesex St	Weekday Morning	1.10	70	E
	Weekday Evening	>1.20	110	F
Wood St at Princeton Blvd	Weekday Morning	0.76	43	D
	Weekday Evening	0.90	57	E

Source: VHB, Inc. using Synchro 7 (Build 773, Rev 8) software.
Note: Shaded cells denote LOS E/F conditions.
1 volume to capacity ratio
2 average delay in seconds per vehicle
3 level of service

Table 2-14 (cont.) Signalized Intersection Capacity Analysis Summary

Location	Period	2012 Existing Conditions v/c [1]	Delay [2]	LOS [3]
Princeton Blvd at Baldwin St	Weekday Morning	0.48	13	B
	Weekday Evening	0.62	17	B
Westford St at Wood St	Weekday Morning	0.58	15	B
	Weekday Evening	0.73	21	C
Drum Hill Rd at Parkhurst Rd	Weekday Morning	0.77	32	C
	Weekday Evening	0.96	34	C
Drum Hill Rd at	Weekday Morning	0.76	25	C
Shopping Center main	Weekday Evening	0.75	27	C
Drum Hill Square at	Weekday Morning	0.69	27	C
Drum Hill Rd/North Rd	Weekday Evening	0.73	34	C
Drum Hill Square at	Weekday Morning	0.48	12	B
North Rd - south	Weekday Evening	0.52	12	B
Drum Hill Square at	Weekday Morning	0.71	29	C
Old Westford Rd	Weekday Evening	0.56	23	C
Drum Hill Square at	Weekday Morning	0.52	12	B
North Rd – north	Weekday Evening	0.73	19	B
Princeton St at North Rd	Weekday Morning	0.79	33	C
	Weekday Evening	0.89	62	E
Pawtucket Blvd at Wedgewood Cir	Weekday Morning	0.34	7	A
	Weekday Evening	0.37	13	B
Pawtucket Blvd at Frost Rd [4]	Weekday Morning	0.45	17	B
	Weekday Evening	0.62	16	B
Middlesex Rd at	Weekday Morning	1.05	77	E
Frost Rd/Kendall Rd	Weekday Evening	1.04	69	E

Source: VHB, Inc. using Synchro 7 (Build 773, Rev 8) software.
Note: Shaded cells denote LOS E/F conditions.
1 volume to capacity ratio
2 average delay in seconds per vehicle
3 level of service
4 Intersection is currently under construction

Unsignalized Intersections

Levels of service at the seven unsignalized intersections were analyzed under existing conditions and the results are summarized in Table 2-15 and are included in the Technical Appendix.

As shown in Table 2-15, seven of the eight unsignalized study area intersections operate at or over capacity (LOS E/F) during the morning and/or evening peak periods:

- VFW Highway at Riverside Street (Weekday Morning)
- Varnum Avenue at Old Ferry Rd
- Middlesex Street at Baldwin Street
- Westford Street at Stedman Street
- Westford Street at Technology Drive
- Drum Hill Road at Shopping Center North
- Middlesex Street at Princeton Street/Tyngsboro Street

Table 2-15 Unsignalized Intersection Capacity Analysis Summary

Location	Critical Movement	Peak Period	2012 Existing Conditions Dem [1]	v/c [2]	Del [3]	LOS [4]
VFW Hwy at Riverside St	SB L-R	Weekday Morning	555	1.13	100	F
		Weekday Evening	430	0.71	23	C
Varnum Ave at Old Ferry Rd	NB L-TH-R	Weekday Morning	220	>1.20	>120	F
		Weekday Evening	445	>1.20	>120	F
Middlesex St at Baldwin St	NB L-TH-R	Weekday Morning	200	>1.20	>120	F
		Weekday Evening	315	>1.20	>120	F
Westford St at Stedman St	NB L-R	Weekday Morning	240	0.75	41	E
		Weekday Evening	460	>1.20	>120	F
Westford St at Technology Dr	EB L-R	Weekday Morning	165	>1.20	>120	F
		Weekday Evening	235	>1.20	>120	F
Drum Hill Rd at Shopping Center north	EB L-TH-R	Weekday Morning	15	0.17	36	E
		Weekday Evening	70	0.66	75	F
Drum Hill Rd at Shopping Center south	WB L-R	Weekday Morning	10	0.09	23	C
		Weekday Evening	60	0.35	29	D
Middlesex St at Princeton Rd/Tyngsboro St	WB L-R	Weekday Morning	275	0.78	38	E
		Weekday Evening	395	1.14	>120	F

Source: VHB, Inc. using Synchro 7 (Build 773, Rev 8) software.
Note: Shaded cells denote LOS E/F conditions.
1 demand in vehicles per hour for unsignalized intersections; the demand applies to only the most critical street approach or lane group
2 volume-to-capacity ratio for the critical movement
3 delay of critical approach only, rounded to the nearest whole second
4 level of service
EB = Eastbound; WB = Westbound; NB = Northbound; SB = Southbound; R = right; TH = through; L= left

2.6 Structural Assessment

This section provides an overview of the existing Rourke Bridge Structure, detailing its structural conditions based on available data and confirmed through recent field investigative work, as well as a description and assessment of the health of the bridge infrastructure network within the project study area.

2.6.1 Rourke Bridge Overview

MassDOT Bridge No. L-15-088, is a 9-span bridge carrying the Wood Street Extension over the Boston and Maine (B&M) Railroad and Merrimack River in the City of Lowell. Known locally as the “Rourke Bridge,” MassDOT constructed the bridge in 1983, which is named after former Lowell Mayor Raymond Rourke and his son, State

Representative Tim Rourke. The bridge spans south to north over the B&M Railroad and the Merrimack River connecting the intersection of Wood Street and Middlesex Street to the south, and connecting Wood Street Extension to Pawtucket Boulevard on the north side of the River.

The bridge is a nine-span structure totaling nearly 1,100 feet. Of the 9 spans (viewed south to north), spans 1, 2 and 9 are over land, while the remaining six spans are over the Merrimack River. Specifically, span 2 is over the B&M Railroad (owned and maintained by Pan AM Railways), and span 9 is over a pedestrian path along the Department of Conservation and Recreation (DCR) parkland on the northern shore of the Merrimack River. Its geometry provides two travel lanes (one in each direction) with a curb to curb width of nearly 24 feet. There is also one sidewalk structure, outboard on the westerly side of the bridge. The sidewalk structure is enclosed and provides an accessible width of approximately 5 feet.

The bridge nomenclature presented in this study is consistent with MassDOT terminology and industry standard for bridge inspection. Specifically, the following structural elements will be discussed: Deck, Superstructure, Substructure, and Channel & Channel Protection.

<u>Deck</u>

The deck is the structural element on the bridge that constitutes the riding surface. As with the Rourke Bridge, the deck structure consists of prefabricated modular steel deck panels that have an epoxy coating applied to the riding surface to provide "anti-skid" resistance.

<u>Superstructure</u>

The superstructure (i.e., supports immediately beneath the deck that spans above the foundation elements) consists primarily of a steel through truss panel system. The proprietary name for the truss panel system is "ACROW," a modular type construction consisting of deck panels, transom beams, and truss panel elements. Eight of the nine spans consist of this structure type. The ninth (most northerly) span, is a cast in place reinforced concrete structural slab.

<u>Substructure</u>

The bridge's substructure, structural elements that support the bridge superstructure (i.e. foundation and supporting piers, piles, etc.), consist of concrete stems, concrete abutments, concrete capped pile bents with concrete pedestals, and steel piles that support the ACROW panel towers.

<u>Channel & Channel Protection</u>

The channel is typically evaluated for observed hydraulic performance and the possibility of local scouring at substructure units, embankment erosion, debris, excessive vegetation, as well as evaluating the condition of fender systems that protect the substructure units for impact damage. These elements are usually assessed and covered in a separate Routine Underwater inspection report.

2.6.2 Existing Structural Conditions

MassDOT is charged with performing a routine bridge inspection once every two years to characterize the existing conditions of structural elements (including deck, superstructure, and substructure) as well as commenting on features at the bridge approaches, and traffic safety features incorporated into the bridge. In addition to the routine bridge inspection, for those structures that span waterways, like the Rourke Bridge, MassDOT performs a routine underwater inspection report to assess the conditions of the substructure elements, as well as the channel and channel protection. The intent of the routine inspection is to track structural element conditions over time, thus allowing MassDOT to identify possible issues requiring repair or maintenance, or even replacement. Each of the elements are categorized as either "GOOD," "FAIR," "POOR," or "CRITICAL" where these classifications are based on a scale of 0 to 9 (with 0 scoring as a failed condition, and 9 scoring as an excellent condition). Routine inspections also provide the inspector with the option to recommend that a bridge be re-rated based on observed changes in structural conditions. The request to re-rate the bridge may yield results that would require the bridge to be "posted," i.e. weight restricted, due to its structural condition.

Based on the latest available information, (and subsequently confirmed via a site inspection in May 2012) the following ratings summarize the existing structural condition of the bridge elements in accordance with the MassDOT Routine Inspection and Routine Underwater Inspection coding system:

Structural Element	Rating	Description
Deck:	5	FAIR – All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
Superstructure:	6	SATISFACTORY – Structural elements show some minor deterioration.
Substructure:	6	SATISFACTORY – Structural elements show some minor deterioration.
Channel & Channel Protection	6	SATISFACTORY – Structural elements show some minor deterioration.

MassDOT prepared a bridge rating in 2002 to determine the safe load carrying capacity of the bridge. Each of the bridge's main load carrying superstructure elements is evaluated to determine its available load carrying capacity based on as-inspected (i.e., 2002) conditions. These capacities are compared to four design vehicles with varying axle loadings and configurations, the H20, the Type 3, the Type 3S2, and the HS20:

Design Vehicle	Total Vehicular Weight
H20	20 tons
Type 3	25 tons
Type 3S2	36 tons
HS20	36 tons

Based on the information provided in the 2002 rating report, the bridge currently satisfies all design vehicle loadings; however, MassDOT elected to post the bridge with a slight weight restriction, an option permitted to MassDOT as stated in NBIS Item 70 of the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*. The bridge is currently posted for 20, 25 and 28 tons for the H20, Type 3 and 3S2 truck loadings respectively.

In early May 2012, the study team was able to gain access to the underside of the bridge via a barge and man lift to verify the current conditions of the bridge. In general, the structure appears to be in a condition that is consistent with its age. Typically, in moderate salt exposure environments, galvanizing will typically last 15-20 years. As the Rourke Bridge is nearly 30 years old, it is evident that the galvanizing is nearing the end of its useful service life. The typical noted deficiencies are related to wear and tear, and structural vibrations that cause the connection elements to loosen over time. The following describes the current condition of each major structural element encompassing the study team's field observations along with the most recent MassDOT inspection report.

Deck

The condition of the bridge deck is currently classified as "FAIR." There are isolated areas of light to moderate rust on the underside of the modular deck panels (Figure 2-13). Several locations of the epoxy coated wearing surface of the deck are delaminated and/or missing due to normal vehicle wear (Figure 2-13). Many of these deck panels also have loose bolted connections, leaving a gap between the deck panel and the rubber bearing pad on top of the supporting transom. This gap results in loud clanking noises heard by motorists when travelling over the bridge. The rubber bearing pad installed on top of the transom beams was not part of the ACROW product line. It was installed during original construction to help with vehicular noise and overtime has worn/torn at several locations causing some of the deck panel movement. Figure 2-14 shows a typical loose deck panel with a broken rubber bearing pad between the deck panel and transom.

Figure 2-13 Typical Deck Panel Condition

Figure 2-14 Loose Deck Connection, Broken Neoprene

Superstructure

The overall condition of the superstructure is classified as "SATISFACTORY." Figures 2-15 and 2-16 show the typical conditions of the transoms and truss panels respectively. The galvanizing coating is beginning to fail in spot locations throughout the superstructure, however; there is very little to no section loss in any of the structural members as a result of the corrosion process. Figure 2-17 shows a typical spot failure of the galvanized coating on the bottom flange of a transom (north face of Transom T6, Span 7). The newly exposed steel has yet to experience any signs of delamination or section loss. Once the galvanized coating fails, the exposed steel will begin to corrode. Over time this unprotected steel will experience measurable section loss and begin to lose some of its load carrying capacity. Figure 2-18 shows another spot failure in the galvanized coating where delamination and minor section loss has begun to occur.

Due to structural vibrations over time, bolted connections throughout the superstructure have become loose, broken, or missing. A majority of these deficient connections occur between the transom ends and the ACROW truss panels. Figure 2-19 shows a sheared bolt at a transom to ACROW truss panel connection. The ACROW truss panels are connected together by connection pins with a retainer clip to prevent any movement of the pin. Several of these pins have become loose due to wear and have damaged or missing pin retainer clips.

Figure 2-15 Typical Transom Condition

Figure 2-16 Typical Truss Conditions

Figure 2-17 Typical Failure in Galvanized Coating

Figure 2-18 Beginning of Lamination/Section Loss

Figure 2-19 Sheared Bolt at the End of a Transom

Substructure

The condition of the substructure is categorized as "SATISFACTORY." The ACROW panel towers appear to have isolated areas of minor corrosion scattered throughout the towers (Figure 2-20). The tower bracing was installed with the legs of the steel channels facing upward allowing debris to be trapped within the bracing. Heavy corrosion and minor section loss has occurred at these bracing locations. The concrete pedestals supporting the ACROW panel towers show few minor problems (minor delamination and hairline vertical cracks) with the exception of the west pedestal at pier 3. Through verification of a concrete sounding test it was confirmed that multiple sides of this pedestal exhibit major delamination and spalling (Figure 2-21). The steel piles appear to have minor to moderate corrosion at or near the waterline (Figure 2-22). According to the 2009 routine underwater inspection report the minor to moderate corrosion continues throughout the piles to the mudline.

Figure 2-20 Typical Acrow Panel Tower

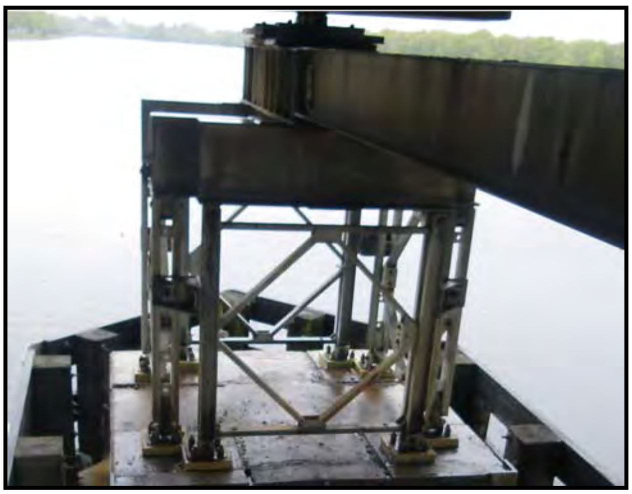


Figure 2-21 West Concrete Pedestal at Pier 3

Figure 2-22 Typical Steel Pile with Moderate Rusting

2.6.3 MassDOT Programmed Bridge Maintenance

One of the reasons for the bridge's extended use is directly associated with MassDOT's continuing effort in providing scheduled preventive maintenance and repairs to the bridge. The Study Team has interviewed representatives from MassDOT's District 4 Structures Maintenance group to gather the historical data surrounding the scope of repairs. The extent of the repairs has been associated with general upkeep and maintenance.

Specifically, within the past five years, MassDOT has invested nearly $4 million in bridge maintenance costs to continue to rehabilitate and maintain the structural integrity of the temporary bridge structure. In 2007, MassDOT invested approximately $3.5 million involving rehabilitation of the superstructure and a portion of the substructure. The work included but was not limited to:

- Replacing modular deck panels in spans 1 through 8 whose epoxy coating surface has worn away
- Replacing the asphalt wearing surface over the structural concrete slab on Span 9
- Replacing the existing expansion joints at both abutments
- Replacing modular deck panel connection pins that are damaged or loosened due to vehicular vibration
- Tightening loose bolts and replacing missing bolts that have loosened due to vehicular vibrations
- Cleaning debris off of abutment bridge seats and truss bottom chords
- Replacing broken and work utility clamps along the top of both trusses
- Cleaning debris off of abutment bridge seats
- Repairing damaged sidewalk walkway top plates and sidewalk approaches
- Performing concrete patch repairs to spalled substructure areas at abutments and piers

Most recently, MassDOT has used its Middlesex County Scheduled and Emergency repairs contract to provide additional bridge maintenance to the Rourke Bridge. The work was completed in the summer of 2012. The proposed work was in response to addressing some of the noted deficiencies in the 2010 Routine Inspection report. These repairs included:

- Replacing modular deck panels in spans 1 through 8 whose epoxy coating surface has worn away
- Replacing modular deck panel connection pins that are damaged or loosened due to vehicular vibration
- Tightening loose bolts and replacing missing bolts that have loosened throughout the superstructure due to vehicular vibrations
- Applying spray-applied galvanized coating to exposed steel surfaces

MassDOT conducted a routine inspection subsequent to the preventative maintenance completed in 2012. This Inspection Report has not been finalized and was not available to be incorporated into this study. The contents should be available to supplement environmental permitting work related to the new bridge.

2.6.4 Bridge Infrastructure Assessment within Project Study Area

The Study Team inventoried all of the structures within the project study area to categorize their conditions. There are 88 bridges within the study area. Bridges within the area are owned by either MassDOT, the municipalities of Lowell, Chelmsford, and Tyngsborough, or private entities, (i.e., canal owners, mill owners, etc.)

The inventory collects readily available data provided by MassDOT in the form of Structural Inventory & Appraisal (SI&A) Forms and the National Bridge Inventory Standard (NBIS) database.

It is important to understand the "health" of the existing infrastructure network and how short or long term improvements to this infrastructure will correlate to the planned 2035 conditions. As noted on MassDOT's Project Information database, some structures (such as the University Avenue Bridge over the Merrimack River) are currently under construction and several other bridges within the study area are planned for reconstruction within the next 5 to 10 years and currently in design.

The study team categorized the "health" of each structure in Figure 2-23 below consistent with the methodology that MassDOT would use to rate each bridge – a color coding system that indicates the structures capacity when compared to statutory design vehicular loads:

- Green – structure currently meets statutory load requirements
- Yellow – structure does not meet statutory loads, but has capacity > 6 tons
- Red – structural capacity does not meet statutory loads, capacity < 6 tons

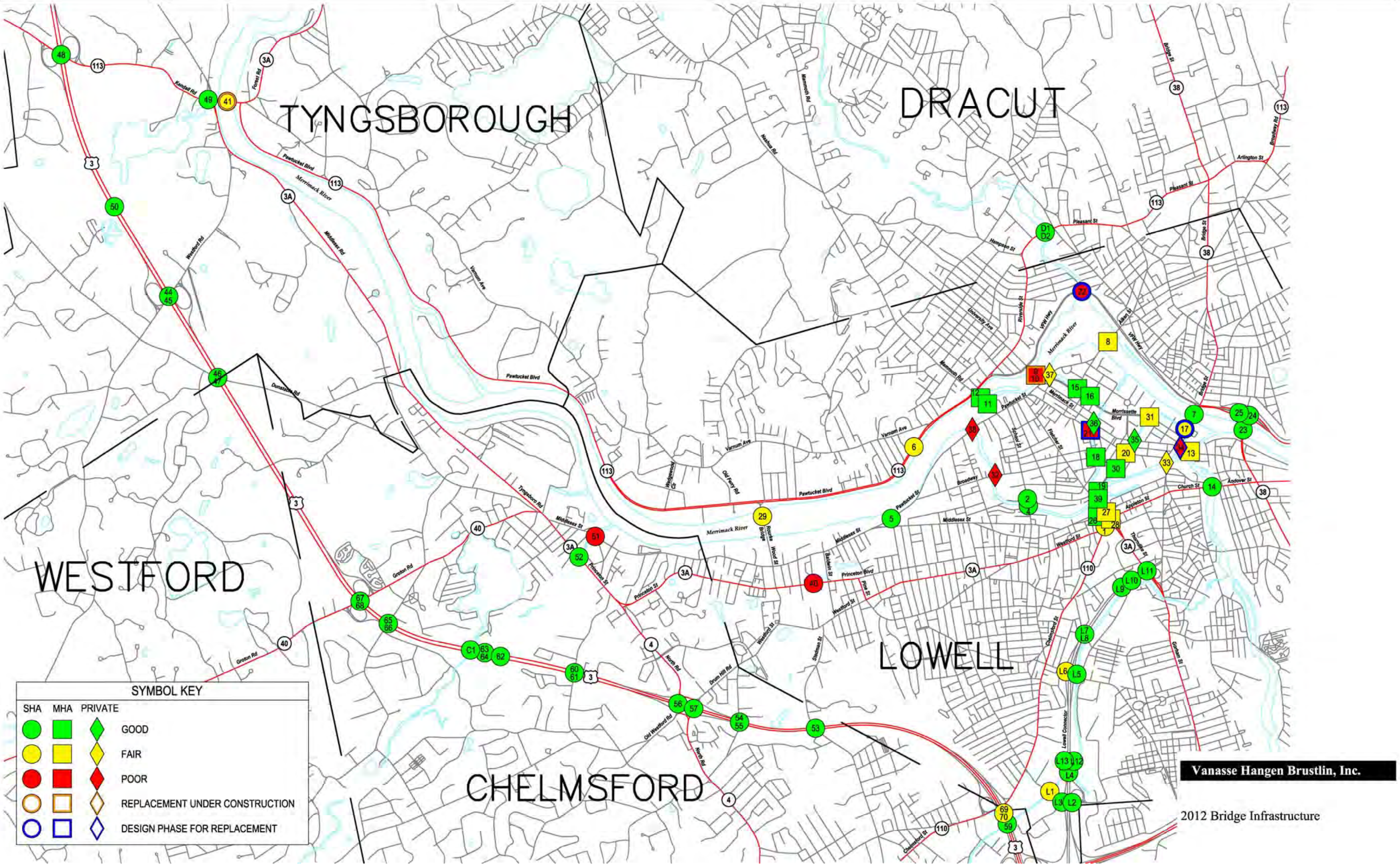
The figure also codes the structures by ownership and whether it is under reconstruction or currently in the design phase for reconstruction.

It is important to understand that Figure 2-23 is an illustration of the *current* condition of the existing infrastructure and will not accurately reflect the infrastructure's condition in 2035.

This page intentionally left blank

Figure 2-23 2012 Bridge Infrastructure Summary

T:\T0435\CAD\Structural\Prelim\T0435_Bridge Infrastructure - 2x.dwg



This page intentionally left blank

3

Future Conditions (2035)

This chapter provides an assessment of Future Conditions within the study area. The future conditions described in this chapter assume that the transportation improvements currently under construction or programmed have occurred. Programmed improvements include projects programmed on the Transportation Improvement Program (TIP) or currently being initiated by municipalities.

Sections of this chapter present the land use forecasts, planned infrastructure improvements, future traffic demand forecasts, and future traffic operations. Subsequent chapters present the range of alternatives considered, provide an evaluation of these alternatives, and packaged/phased recommendations to address the short, medium, and long-term transportation needs in the study area.

3.1 Land Use Forecasts

An important component of this study involved forecasting travel demands and land use changes through the year 2035. Doing so ensures that alternatives studied and that the recommended transportation infrastructure investments anticipate future needs and provide long-term benefits for the area.

Once existing traffic volumes have been quantified (as in Chapter 2), predicting changes in future traffic demand is best accomplished through understanding and mapping changes in land uses and demographics and inputting this information into a travel forecasting model. The demographics that have the most influence on the traffic forecast are changes in the number of households and employment. As an initial step, the sub-area model was reviewed to determine how future changes in households and employment had been accounted for. The TWG was also consulted to identify large-scale planned or permitted development projects that should be included in land use forecasts. The following projects were identified and have been accounted for in the sub-area model:

- Hamilton Canal District - Lowell
- University of Massachusetts Expansion – Lowell
- Lowell General Hospital Expansion – Lowell

- Lowell Collegiate Charter School - Lowell
- Tyngsborough Commons & Tyngsborough Technology Park - Tyngsborough
- Cornerstone Square - Westford
- Westford Technology Park West - Westford
- Princeton Westford Apartments- Westford

Land use forecast assumptions for each project identified above are included in the Technical Appendix.

Once the future scenario has been defined from the land use perspective, the next step in the study process involved layering of the planned roadway enhancements.

3.2 Planned Infrastructure Improvements

Section 3.1 defined the future scenario from a land use perspective. This section discusses the planned infrastructure enhancements from the TIP or local efforts and incorporates these plans into the future scenario. Doing so ensures that the study accounts for benefits from infrastructure investments that are already programmed and that future recommendations complement the programmed improvements to the extent possible.

In addition to the University Avenue Bridge project (reconstruction and realignment), which is included in the sub-area model and located immediately in the study area, the following planned infrastructure improvements have been incorporated in the sub-area model future condition:

- Interstate Capacity Enhancements
  - Lowell Junction & I-93 widening from new interchange to I-495
  - I-495 widening: Exits 33-35 and 37-40
  - I-93/I-95 interchange reconfiguration
  - NH I-93 widening: state line to I-293
- Other Improvements
  - Route 2/Crosby's Corner (grade separation)
  - Middlesex Turnpike widening/improvements
  - I-93 at Route 110/113 revised ramp configuration (Methuen Rotary)
  - Route 114 widening in North Andover
  - Route 110 widening in Carlisle and Chelmsford

Once the future scenario was fully defined in terms of land use changes and transportation infrastructure upgrades, the next step involved utilizing the Rourke Bridge sub-area travel demand model to quantify future travel demands. This is an important step that will help assess recommendations in terms of improved mobility, safety, and efficiency.

3.3 Travel Demand Forecasts

Sections 3.1 and 3.2 defined the future scenario in terms of land use changes and transportation infrastructure upgrades. This section quantifies travel demands associated with the scenario through the use of a regional travel demand model. The travel demand assessment is a critical step. The development of improvement alternatives hinges largely on travel demand benefits in terms of improved mobility, safety, and efficiency.

In a regional travel demand model, traffic volumes are forecast through the interaction of transportation demand and supply. This section translates the estimated land use changes into vehicle demands on the study area's roadway system.

3.3.1 Overview

MassDOT's Office of Transportation Planning maintains the Massachusetts Statewide Travel Demand Model (the "model"), a travel demand model used to forecast traffic conditions. One of the primary functions of this model is to comply with the air quality and congestion management requirements of the 1990 Clean Air Act Amendments and 1991 Intermodal Surface Transportation Efficiency Act. The model also likely complies with all subsequent transportation legislation but no specific updates related to legislation such as Moving Ahead for Progress in the 21st Century (MAP-21) have been made.

In a regional travel demand model, traffic volumes are forecasted through the interaction of supply and demand. The model consists of a series of points, or nodes, that represent locations of roadway intersections and other elements of the network. Connections between nodes are called links. Links represent highway segments and contain information such as speed and road capacity. Traffic Analysis Zones (TAZs) are defined to encompass areas of development that represent the demand, while the road network represents the supply.

In addition to estimating the volume of traffic on a particular roadway, the model is used to estimate expected changes in vehicle-miles traveled (VMT) and vehicle-hours traveled (VHT). VMT is an indicator of trip lengths for all trips within the study area. One vehicle traveling one mile constitutes one vehicle-mile. Adding the vehicle-miles traveled for every trip that occurs results in an estimate of total VMT for the area. VHT is an indicator of trip times. Similar to VMT, one vehicle traveling one hour constitutes one vehicle-hour. VHT for the study area is the sum of the vehicle-hours traveled for every trip. VMT and VHT are important factors that are used to evaluate the effectiveness of alternatives in meeting regional mobility and efficiency goals for vehicular travel. VMT and VHT are also indicators of potential air quality effects, such as reductions in greenhouse gas emissions, associated with improvements.

3.3.2 Methodology

The model was used to create a Rourke Bridge sub-area model to estimate future travel demand within the study area. The sub-area model was developed to be more detailed in that it contains a more detailed TAZ structure as well as more local roadways. The 58 zones within the study area were further broken down into 201 zones based on an aggregation of census blocks, the smallest census geographic unit.

The TAZ structure is critically important because each TAZ represents a demographic and employment load point on the network. Each TAZ produces and attracts person trips based on its land use. Information entered into the model for each zone (such as population, households, income, and employment) determines the number of trips produced and attracted to that zone. Households are the primary producer of trips, while employment sites are the primary trip attractors. The number of trips for different trip purposes (work, shopping, school, personal business, recreation, etc.) are based on each TAZ's land use composition (types of households and employment types). This process is referred to as trip generation and it is very important that land use information is accurate because it is the land uses that generate trips on the network.

The process of trip distribution determines where the trips end once they leave their traffic zones. For trip distribution, it is very important that the roadway and transit networks are appropriately coded in the model and that planned infrastructure upgrades are considered such that the model accurately reflects the accessibility of each TAZ. Trip distribution produces a matrix of origins and destinations between all zones for each trip purpose. This is done according to the "attractiveness" of a zone, based on its proximity to other zones and on the total number of trips by trip purpose generated in that zone. If all other factors are equal, zones that are closest to each other will have more trips flowing between them. The more trips a zone generates relative to all other zones, the greater the "pull" it will exert on all other zones in terms of attracting trips.

Trip assignment determines what route, or path, trips will take in going from zone to zone. It is here where the travel demand generated by the traffic zones interacts with the supply, provided by the regional transportation network. All trips from all zones are assigned along the network to all their destination zones. The equilibrium assignment procedure is used in this model. The equilibrium method essentially assumes that a person will continue to shift his path until there is no quicker path available. The time for each path is calculated based on capacity, congestion and speed on each link that makes up a path.

The final step is calibration of the model. Calibration refers to the adjusting of various model factors and components - and running the model again, until it replicates current travel patterns and traffic volumes at acceptable levels of accuracy. Frequent adjustments and subsequent model runs must be conducted many times before an accurate result is reached. The model was calibrated using observed traffic volume data and the results of the license plate origin-destination survey.

To arrive at future travel demands, the Study Team used the specific land use forecasts discussed with the TWG and estimated the number of households or jobs created by each land use. The additional households/jobs were then applied to the appropriate TAZ in the model. Additionally, background growth independent of specific development growth was allocated to each TAZ in the model based on existing land use patterns to remain consistent with statewide forecasts. The land use forecasts from the Nashua Regional Planning Commission's Model were reviewed to confirm that they were consistent with the MA model in areas of overlap.

3.3.3 Resulting Forecasts

Once the model was calibrated to current conditions, it was then used to forecast the 2035 Baseline scenario and to test alternatives that involve major changes in transportation infrastructure that alter traffic patterns. Based on the travel demand model projections, growth was obtained for the key roadways and intersections in the study area. Daily, weekday morning, and weekday evening travel demand model growth was reviewed and compared and it was determined that growth in the study area was projected to be relatively constant among the time periods for the key roadways and intersections. As such, a 0.6 percent annual growth rate was selected as appropriate for the study area and was applied to the 2012 Existing Conditions volumes to develop the 2035 Baseline Condition. This annual growth rate translates to approximately 14.8 percent total growth to 2035.

One noted exception to this characteristic study area growth rate was at the Tyngsborough Bridge study area intersections. Model projections indicated more aggressive growth in this area. Since the intersections are not immediately proximate to the rest of the study area, an annual growth rate of 1.0 percent (or total growth rate of 25.7 percent), was applied to the intersections on either side of the Tyngsborough Bridge to account for the projected increased growth.

These percentages were then applied to the existing morning and evening peak hour volumes to provide a reasonable projection of hourly volume adjustments. The resulting 2035 Baseline traffic volumes consider the existing and future traffic volumes within the project study area and provide a reasonable basis from which to begin to identify long-term transportation issues within the study area. Traffic volume networks representing the 2035 Baseline Condition for the weekday morning and weekday evening peak hours are provided in Figures 3-1 and 3-2, respectively.

VMT/VHT

Table 3-1 summarizes the VMT and VHT for the study area from the statewide model for 2010 conditions. The VMT and VHT are provided for each roadway functional classification to show how much traffic is carried on higher speed, higher classified roadways.

Table 3-1 2010 and 2035 VMT and VHT Summary

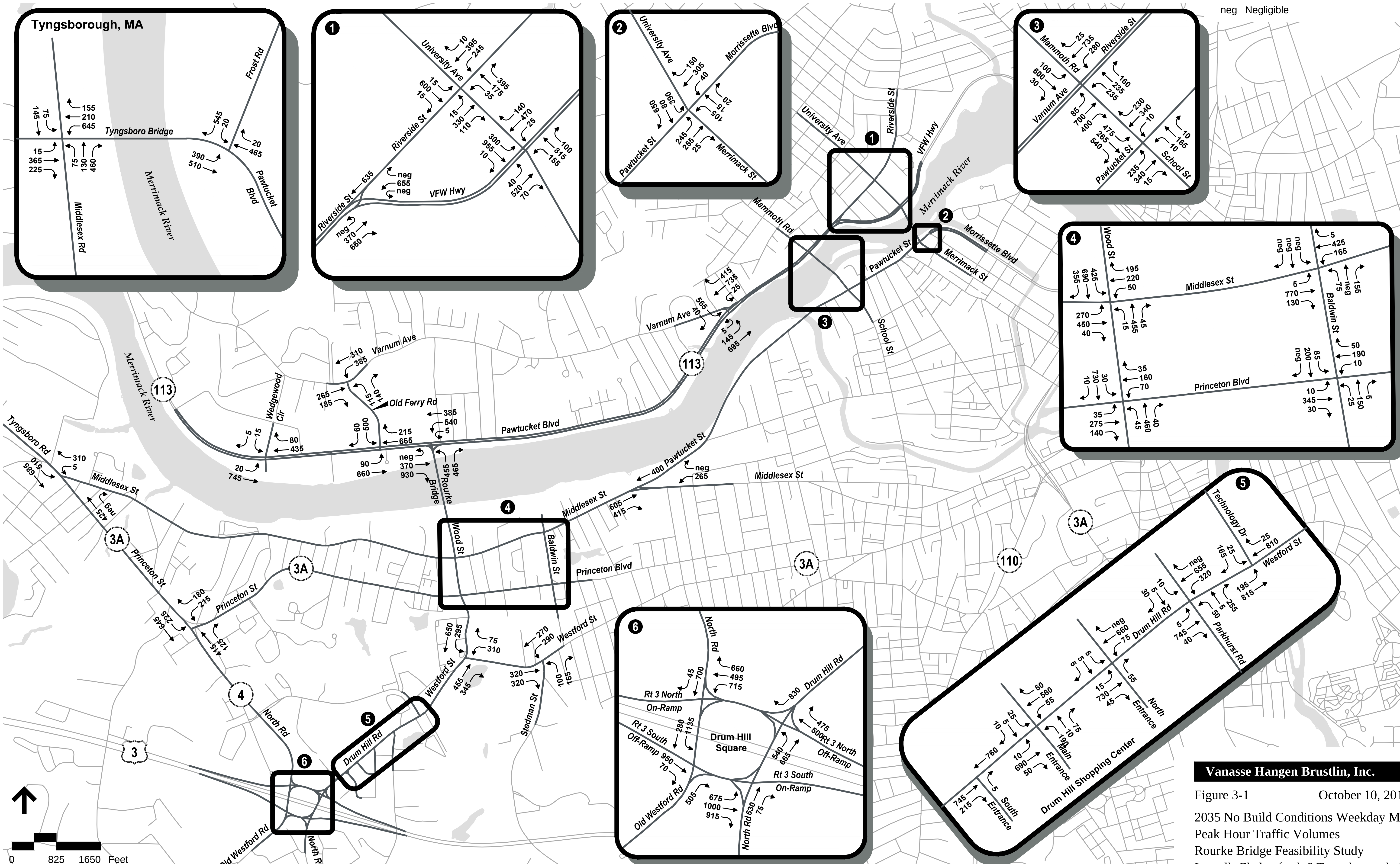
	VMT [1]		VHT [2]	
Roadway Functional Class Type	**2010 Existing**	**2035 Baseline**	**2010 Existing**	**2035 Baseline**
Principal Arterials	973,387	1,059,174	22,548	25,737
Minor Arterials	404,909	466,527	14,936	18,149
Collectors	80,080	94,090	2,860	3,403
Local Roads	18,532	23,536	589	775
TOTAL	**1,476,908**	**1,643,328**	**40,932**	**48,064**

Source: Massachusetts Statewide Model for 2010.
Note: Not all local roadways are accounted for in the model.
3 Vehicle-miles traveled per day
4 Vehicle-hours traveled per day

A comparison of the VMT and VHT results for the existing and future model conditions reveals the following notable trends:

- By far the majority of the traffic in the study area is carried on principal arterial roadways, such as Route 3, the Drum Hill Road/Westford Street/Wood Street corridor, and the study area bridges.
- The VMT in the study area is projected to grow by 11 percent from 2010 to 2035, primarily the result of more vehicle trips on the network and not necessarily longer trip lengths.
- The VHT in the study area is projected to grow by 17 percent from 2010 to 2035; the fact that VHT is increasing at a greater rate than VMT indicates more congestion on an increasingly strained transportation network.

The resulting 2035 Baseline model can be used to assess various alternatives and to project traffic volumes to be used in the roadway capacity analyses. Doing so will help validate whether or not the alternative that is proposed will yield long-term benefits. In addition to estimating the volume of traffic on a particular roadway, the model will be used to estimate expected changes in VMT and VHT to estimate improvements in air quality through reductions in greenhouse gas emissions.



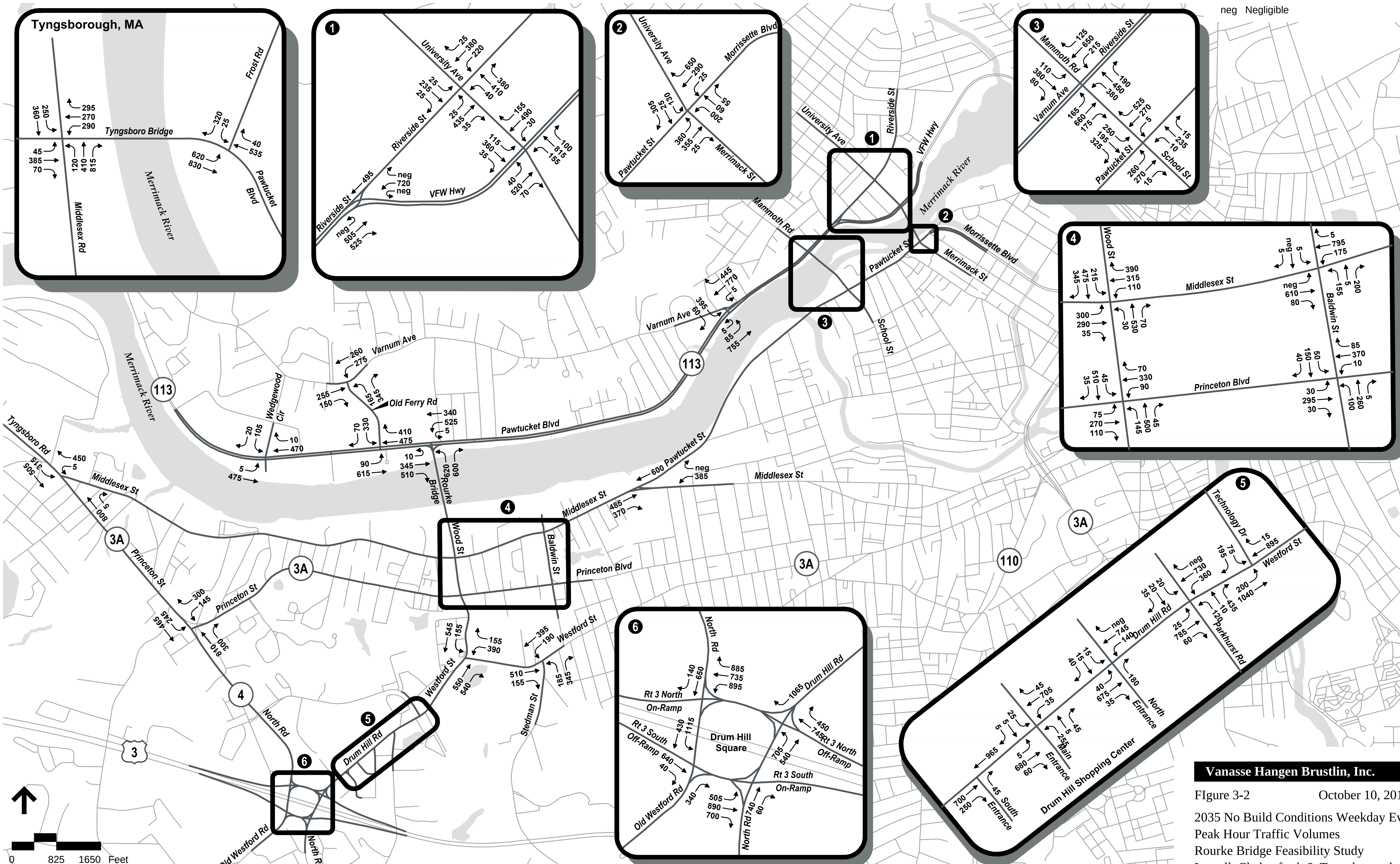
Vanasse Hangen Brustlin, Inc.

Figure 3-1 October 10, 2012

2035 No Build Conditions Weekday Morning Peak Hour Traffic Volumes
Rourke Bridge Feasibility Study
Lowell, Chelmsford, &Tyngsborough, MA

\\vhb\proj\Wat-TS\11906.00\graphics\FIGURES\Networks 2.dwg

neg Negligible



Vanasse Hangen Brustlin, Inc.

FIgure 3-2 October 10, 2012

2035 No Build Conditions Weekday Evening Peak Hour Traffic Volumes

Rourke Bridge Feasibility Study

Lowell, Chelmsford, & Tyngsborough, MA

3.4 2035 Baseline Traffic Operations

The next step in the study process was to evaluate the projected future operations of the study area roadway system and compare them to the existing conditions. The traffic analysis was conducted using the 2035 Baseline weekday morning and weekday evening peak hour traffic volumes and the future geometric design conditions as they currently are anticipated to exist at the study area intersections. These future conditions include the following improvements to study area intersections:

- Consolidate Pawtucket Street at University Avenue and Merrimack Street intersections and the full reconstruction of the University Avenue Bridge.
- Walgreens intersection improvements at Wood Street/Rourke Bridge at Middlesex Street:
  - Modify the Wood Street northbound geometry from a left-turn lane and a shared through/right-turn lane to two shared lanes;
  - Add a Middlesex Street westbound right-turn lane;
  - Repair vehicle detection; and
  - Optimize signal timings.
- Tyngsborough Bridge improvements at Middlesex Road at Frost Road/Kendall Road:
  - Add a Middlesex Road northbound through lane;
  - Add a Tyngsborough Bridge westbound left-turn lane; and
  - Optimize signal timings.

Capacity analysis results for the signalized and unsignalized intersections within the study area are summarized in Tables 3-2 and 3-3, respectively, and are included in the Technical Appendix. Key results of this analysis include:

- **Signalized Intersections –** Of the 11 intersections projected to operate at or over capacity in the morning and/or evening peak hours under 2012 conditions, 10 would continue to operate poorly under 2035 Baseline conditions. The intersection of Wood Street/Rourke Bridge at Middlesex Street is projected to improve to LOS D or better as a result of Walgreens mitigation. It should be noted that five of these intersections operate at LOS E/F during only one peak hour in 2012 and are now projected to operate at or over capacity during both peak hours in 2035. In addition, the intersection of Drum Hill Road at Parkhurst Road is projected to degrade to LOS E during the weekday evening peak hour in the future.

Table 3-2 Signalized Intersection Capacity Analysis Summary

		2012 Existing Conditions			2035 Baseline Conditions		
Location	Period	v/c [1]	Delay [2]	LOS [3]	v/c [1]	Delay [2]	LOS [3]
University Ave at Riverside St	Weekday Morning	1.15	114	F	>1.20	>120	F
	Weekday Evening	1.12	84	F	>1.20	>120	F
University Ave at VFW Hwy	Weekday Morning	1.12	64	E	>1.20	>120	F
	Weekday Evening	1.03	>120	F	>1.20	>120	F
University Ave at Father Morissette Blvd	Weekday Morning	0.74	>120	F	0.87	>120	F
	Weekday Evening	0.52	15	B	0.64	17	B
Pawtucket St at Merrimack St	Weekday Morning	0.88	105	F	1.02	>120	F
	Weekday Evening	0.73	27	C	0.86	39	D
Mammoth Rd/School St at Varnum Ave/Riverside St	Weekday Morning	1.10	77	E	>1.20	120	F
	Weekday Evening	0.89	50	D	1.12	81	F
School St at Pawtucket St	Weekday Morning	0.93	71	E	1.07	95	F
	Weekday Evening	0.76	50	D	0.89	60	E
Pawtucket Blvd at Varnum Ave	Weekday Morning	0.56	19	B	0.63	22	C
	Weekday Evening	0.56	15	B	0.56	16	B
Middlesex St at Pawtucket St	Weekday Morning	0.59	12	B	0.69	14	B
	Weekday Evening	0.66	13	B	0.76	16	B
Pawtucket Blvd at Old Ferry Rd	Weekday Morning	0.75	24	C	0.85	36	D
	Weekday Evening	0.62	18	B	0.70	21	C
Pawtucket Blvd at Rourke Bridge	Weekday Morning	0.97	75	E	1.17	>120	F
	Weekday Evening	0.90	55	D	1.04	102	F
Wood St/Rourke Bridge at Middlesex St	Weekday Morning	1.10	70	E	0.84	38	D
	Weekday Evening	>1.20	110	F	0.85	34	C
Wood St at Princeton Blvd	Weekday Morning	0.76	43	D	0.87	61	E
	Weekday Evening	0.90	57	E	1.04	78	E
Princeton Blvd at Baldwin St	Weekday Morning	0.48	13	B	0.55	15	B
	Weekday Evening	0.62	17	B	0.73	27	C
Westford St at Wood St	Weekday Morning	0.58	15	B	0.67	18	B
	Weekday Evening	0.73	21	C	0.83	29	C
Drum Hill Rd at Parkhurst Rd	Weekday Morning	0.77	32	C	0.89	50	D
	Weekday Evening	0.96	34	C	1.19	56	E
Drum Hill Rd at Shopping Center main	Weekday Morning	0.76	25	C	0.84	36	D
	Weekday Evening	0.75	27	C	0.84	40	D
Drum Hill Square at Drum Hill Rd/North Rd	Weekday Morning	0.69	27	C	0.85	39	D
	Weekday Evening	0.73	34	C	0.85	49	D

Source: VHB, Inc. using Synchro 7 (Build 773, Rev 8) software.
Note: Shaded cells denote LOS E/F conditions.
1 volume to capacity ratio
2 average delay in seconds per vehicle
3 level of service

Table 3-2 (cont.) Signalize Intersection Capacity Analysis Summary

Location	Period	2012 Existing Conditions			2035 Baseline Conditions		
		v/c [1]	Delay [2]	LOS [3]	v/c [1]	Delay [2]	LOS [3]
Drum Hill Square at North Rd – south	Weekday Morning	0.48	12	B	0.56	14	B
	Weekday Evening	0.52	12	B	0.60	14	B
Drum Hill Square at Old Westford Rd	Weekday Morning	0.71	29	C	0.82	32	C
	Weekday Evening	0.56	23	C	0.64	24	C
Drum Hill Square at North Rd – north	Weekday Morning	0.52	12	B	0.60	16	B
	Weekday Evening	0.73	19	B	0.85	42	D
Princeton St at North Rd	Weekday Morning	0.79	33	C	0.89	57	E
	Weekday Evening	0.89	62	E	1.05	92	F
Pawtucket Blvd at Wedgewood Cir	Weekday Morning	0.34	7	A	0.38	8	A
	Weekday Evening	0.37	13	B	0.41	13	B
Pawtucket Blvd at Frost Rd[4]	Weekday Morning	0.45	17	B	0.61	21	C
	Weekday Evening	0.62	16	B	0.83	29	C
Middlesex Rd at Frost Rd/Kendall Rd	Weekday Morning	1.05	77	E	>1.20	>120	F
	Weekday Evening	1.04	69	E	>1.20	>120	F

Source: VHB, Inc. using Synchro 7 (Build 773, Rev 8) software.
Note: Shaded cells denote LOS E/F conditions.
1 volume to capacity ratio
2 average delay in seconds per vehicle
3 level of service
4 Intersection is currently under construction

- **Unsignalized Intersections –** All 12 of the unsignalized intersections analyzed are forecasted to operate at or over capacity in the morning and/or evening peak hours.

Table 3-3 Unsignalized Intersection Capacity Analysis Summary

Location	Critical Movement	Peak Period	2012 Existing Conditions				2035 Baseline Conditions			
			Dem [1]	v/c [2]	Del [3]	LOS [4]	Dem [1]	v/c [2]	Del [3]	LOS [4]
VFW Hwy at Riverside St	SB L-R	Weekday Morning	555	1.13	100	F	640	>1.20	>120	F
		Weekday Evening	430	0.71	23	C	495	0.82	30	D
Varnum Ave at Old Ferry Rd	NB L-TH-R	Weekday Morning	220	>1.20	>120	F	255	>1.20	>120	F
		Weekday Evening	445	>1.20	>120	F	510	>1.20	>120	F
Middlesex St at Baldwin St	NB L-TH-R	Weekday Morning	200	>1.20	>120	F	230	>1.20	>120	F
		Weekday Evening	315	>1.20	>120	F	360	>1.20	Err	F
Westford St at Stedman St	NB L-R	Weekday Morning	240	0.75	41	E	265	>1.20	>120	F
		Weekday Evening	460	>1.20	>120	F	530	>1.20	>120	F
Westford St at Technology Dr	EB L-R	Weekday Morning	165	>1.20	>120	F	180	>1.20	Err	F
		Weekday Evening	235	>1.20	>120	F	270	>1.20	Err	F
Drum Hill Rd at Shopping Center north	EB L-TH-R	Weekday Morning	15	0.17	36	E	15	0.23	51	F
		Weekday Evening	70	0.66	75	F	70	0.93	>120	F
Drum Hill Rd at Shopping Center south	WB L-R	Weekday Morning	10	0.09	23	C	10	0.11	28	D
		Weekday Evening	60	0.35	29	D	60	0.54	55	F
Middlesex St at Princeton St/Tyngsboro Rd	WB L-R	Weekday Morning	275	0.78	38	E	315	1.13	>120	F
		Weekday Evening	395	1.14	>120	F	455	>1.20	>120	F

Source: VHB, Inc. using Synchro 7 (Build 773, Rev 8) software.
Note: Shaded cells denote LOS E/F conditions.
1 demand in vehicles per hour for unsignalized intersections; the demand applies to only the most critical street approach or lane group
2 volume-to-capacity ratio for the critical movement
3 delay of critical approach only, rounded to the nearest whole second
4 level of service
Err Error: Delay outside of calculable range.
EB = Eastbound; WB = Westbound; NB = Northbound; SB = Southbound; R = right; TH = through; L= left

3.5 Structural Assessment

The no-build alternative assumes that the existing structure would remain in place through year 2035. In addition to the previous issues identified with the no-build alternative such as insufficient lane widths, emergency access, and pedestrian safety, this approach requires continuous preventive maintenance and rehabilitation activities to maintain the bridges current posting.

As discussed in section 2.6.3 of the report, MassDOT has provided scheduled preventive maintenance and repairs to the temporary bridge including replacing deck panels, tightening loose bolts, cleaning debris, etc. The extent of these repairs thus far has been associated with general upkeep and maintenance and will continue throughout the desired life of the bridge. Using historical data from recent MassDOT maintenance work, this annual expense is estimated at approximately $30,000 (in 2013 dollars).

According to the Federal Highway Administration (FHWA), a routine inspection and underwater bridge inspection are required every 2 and 5 years respectively. These inspections will continue throughout the life of the bridge. Assuming the routine bridge inspection would be conducted over a 5-day period with a two-member inspection crew via barge access, the annual routine inspection cost was estimated at approximately $17,000 using 2013 dollars. Assuming the underwater inspection can be completed with a four-member dive crew in two days, the underwater inspection cost would be approximately $5,000 annually (in 2013 dollars).

The protective galvanizing coating on the structural steel, as stated in section 2.6.2, is nearing the end of its useful service life. The structural steel will need to be cleaned and a protective outer coating will need to be reapplied to prevent future section loss and subsequent bridge load carrying capacity reductions. Using various cost data such as MassDOT weighted bid prices, FHWA publications, and RS Means Cost Index, it was found that the cost to clean and reapply a protective outer coating to the structural steel below the roadway surface would be around $940,000. The protective coating will need to be reapplied subject to the chosen coatings service life. Based on the 15-20 year service life of typical galvanizing, it was assumed the protective coating would be applied twice by 2035.

As the bridge continues to age, the extent of the repairs required to maintain the structural integrity may extend beyond general upkeep and maintenance. Various bridge elements may eventually require more costly bridge rehabilitation if not properly addressed through ongoing preventive maintenance. For example, the existing steel piles currently experience minor to moderate corrosion. If not addressed over time, these steel piles will continue to degrade and will eventually require costly rehabilitation techniques such as installing supplemental piles to strengthen the existing pile bents. The required rehabilitation work will depend on the desired extended life of the existing bridge and a more detailed analysis of the life expectancy of the various bridge elements. In time the costs of preserving and/or rehabilitating the existing bridge may exceed the costs required for a total bridge replacement.

Furthermore, there may be the possibility of increased design vehicular loading requirements in the future that could make the existing structure seemingly more deficient when compared to its current weight restrictions and conditions.

Table 3-4 summarizes the cumulative bridge maintenance costs required to maintain the bridge until 2035. An inflation rate of 2.5 percent, determined by taking an average of U.S. inflation rates over the past 10 years, has been applied annually to the 2013 costs described above. As previously stated, following a more detailed analysis of the life expectancy of the various bridge elements, additional bridge rehabilitation costs may be required to maintain the bridge through 2035 and beyond. A breakdown of the costs summarized in the table can be found in the Report Appendix.

Table 3-4 Cumulative Maintenance Costs (2013-2035)

	2035 Costs
Bridge Inspection	$ 680,000
Programmatic Maintenance	$920,000
Clear and Paint Structural Steel	$2,300,000
TOTAL COSTS	**$3,900,000**

4

Alternatives Development

The analysis of existing and future transportation conditions in the study area identified areas of the transportation network that require improvements. A range of transportation improvements were identified through TWG and SAC vetting and extensive public outreach throughout the study. The range of alternatives identified included:

- Rourke Bridge alternatives;
- Roadway and intersection capacity enhancements;
- Transportation system management strategies;
- Transportation demand management strategies;
- Transit system enhancements; and
- Bicycle/pedestrian enhancements.

This chapter describes the alternatives that were identified as having the potential to address the transportation system issues and deficiencies and meet the goals and objectives of this study. This preliminary screening evaluation is the equivalent of a "fatal flaw" assessment that helped to discard recommendations that are either outside the scope of this study, do not address the goals or objectives, or deemed to be not realistic or feasible. Chapter 5 will present a more detailed evaluation of the screened alternatives from this section that warrant additional consideration. The detailed evaluation in Chapter 5 will help determine which alternatives are ultimately carried forward for future study and environmental analysis.

4.1 Previous Recommendations Considered

There have been many studies and recommendations for transportation-related improvements in the area over the years, including:

- Draft Environmental Impact Statement (DEIS), State Route 213, Chelmsford, Lowell, Dracut, Massachusetts Department of Public Works – 1975
  - Evaluation of permanent Rourke Bridge alternatives
  - Construction of a limited access roadway from the Rourke Bridge, through the Lowell-Dracut-Tyngsborough State Forest to Route 38 and Route 113 in Dracut

- DEIS/Report and Section 4(F) Evaluation, Merrimack River Bridge and Approach Roadways, Massachusetts Department of Public Works – 1985
  - Evaluation of permanent Rourke Bridge alternatives
  - Construction of a limited access roadway from the Rourke Bridge, through the Lowell-Dracut-Tyngsborough State Forest to Mammoth Road
- Drum Hill Master Plan – 2008
  - Upgrade/install sidewalks along Drum Hill Road
  - Access management along Drum Hill Road corridor
  - Signal timing optimization and coordination along Drum Hill Road
  - Install a traffic signal at Westford Street and Technology Drive with an exclusive northbound left-turn lane
- Pawtucketville Traffic Study 2000 and Pawtucketville Neighborhood Master Plan – 2006
  - Installation of neighborhood traffic calming measures
- City of Lowell Bicycle Network Improvements – 2012
  - Installation of bicycle lanes and/or shared lane markings along major corridors
- Vinal Square Traffic and Safety Study – 2012
  - Roadway and intersection improvements in Vinal Square
  - Enhancements to pedestrian and bicycle accommodations

These studies were reviewed prior to the development of new alternatives for this study. Many of these options were revisited, refined, and incorporated into the recommendations.

4.2 Rourke Bridge Alternatives

A total of 11 alternatives for replacing the temporary Rourke Bridge with a permanent structure were investigated and screened as part of this study, including the No-Build Alternative. The first ten alternatives (including the No-Build) are based on alignments established in working with the TWG and SAC throughout this study. The eleventh alternative is a review of all previous alignments considered in the 1975 and 1985 environmental permitting documents. It should be noted that all bridge alternatives include sidewalks and bicycle lanes in both directions. Improving emergency access across the river was also considered as part of each bridge alternative. Each bridge alternative, including the No-Build would also have environmental impacts associated with removing the existing bridge structure.

4.2.1 No-Build Alternative: Remove Existing Bridge

The No-Build Alternative would demolish the existing Rourke Bridge and not replace it. All traffic currently using the bridge would be accommodated at adjacent river crossings, such as the O'Donnell (School Street) and University Avenue Bridges, which are already over capacity.

The No-Build Alternative severely degrades access and mobility for emergency response vehicles.

The No-Build Alternative would have environmental impacts associated with work required to remove the structure.

- **Recommendation – Discard the No-Build Alternative from further consideration due to <u>impacts to regional mobility and emergency access.</u>**

While the No-Build Alternative was discarded from consideration, it will be used for comparison purposes with the Build Alternatives that are advanced for further study.

4.2.2 Alternative 1: Maintain Existing Alignment (2-lane)

Alternative 1 would maintain the alignment of the existing Rourke Bridge and construct a new 2-lane permanent structure with improved pedestrian and bicycle accommodations. The new bridge would maintain connections to Pawtucket Boulevard to the north and the Wood Street corridor to the south.

While this alternative would increase capacity for pedestrians and bicyclists crossing the river, it would not add capacity for vehicles. As such, Alternative 1 would not attract any additional trips to the Rourke Bridge from other river crossings such as the O'Donnell (School Street) and University Avenue Bridges and would not help alleviate congestion at those locations. Traffic operations under Alternative 1 throughout the region are projected to be similar to 2035 Baseline conditions.

Alternative 1 does not substantially improve access or mobility for emergency response vehicles. No additional travel lanes are proposed under this option and travel time across the bridge is projected to worsen over time as traffic volumes increase. It should be noted that the curb-to-curb width of the bridge would be wider than the existing structure due to the addition of bicycle lanes and may provide opportunities for emergency vehicles to by-pass vehicles queued on the bridge.

- **Recommendation – Discard Alternative 1 from further consideration due to <u>inadequate improvements to regional mobility and emergency access.</u>**

4.2.3 Alternative 2: Maintain Existing Alignment (4-lane)

Future traffic volume projections indicate a peak demand of approximately 2,250 vehicles per hour for the existing 2-lane bridge. Based on guidance in the HCM shown in Table 4-1, a 4-lane bridge is warranted to accommodate this projected demand.

Table 4-1 HCM Capacity Guidance

Number of Lanes (Both Directions)	Capacity (vph)
2-Lanes	1,700 vph
4-Lanes	3,300 vph
6-Lanes	4,900 vph

Source: *2000 Highway Capacity Manual*; Transportation Research Board Special Report 209; Washington, D.C.; 2000.
vph vehicles per hour

Alternative 2 would maintain the alignment of the existing Rourke Bridge and construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) with improved pedestrian and bicycle accommodations. As shown in Figure 4-1[8], the new bridge would maintain connections to Pawtucket Boulevard to the north and the Wood Street corridor to the south, with upgrades on the north side to accommodate the additional capacity of the bridge. On the south side of the bridge, capacity upgrades are difficult given land constraints and property impacts at the Middlesex Street/Wood Street intersection.

Figure 4-1 Alternative 2

The transportation mobility effects of this alternative were evaluated using the sub-area travel demand model developed for this study. Alternative 2 would attract approximately 300 weekday morning peak hour trips (an increase of 12 percent) and 150 weekday evening peak hour trips (an increase of 5 percent) to the Rourke Bridge. The majority of these trips would shift from the O'Donnell (School Street) Bridge, alleviating some of the congestion issues currently

▼

[8] Source aerial map images in Chapter 4 are from MassGIS, 2005.

experienced at this bridge. No additional regional impacts are anticipated as a result of this alternative.

By providing additional travel lanes and reducing congestion, Alternative 2 improves access and mobility for emergency response vehicles.

Alternative 2 would require a phased construction approach in order to maintain travel on the existing Rourke Bridge through the duration of construction.

Alternative 2 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure.

- **Recommendation – Retain Alternative 2 for more detailed evaluation (See Chapter 5)**.

Based on the projected future demand, a 4 lane bridge would provide sufficient capacity to accommodate travel demands in 2035 and beyond. A 6-lane bridge was also considered to determine if the additional capacity that would be created would help address congestion issues in the region. The 6-lane bridge would also provide sufficient capacity beyond 2035 and possibly beyond the useful life of the structure. However, existing constraints on the Wood Street/Westford Street/Drum Hill Road corridor limit the number of travel lanes that can serve the bridge; therefore, additional travel lanes on the bridge would not be likely to alleviate congestion along the corridor. These factors, combined with a significant construction cost differential, eliminated the 6-lane option from further study.

4.2.4 Alternative 3: Eastern Bypass Alignment (4-lane)

Alternative 3 would construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) just east of the existing bridge with improved pedestrian and bicycle accommodations (see Figure 4-2). The new bridge would maintain connections to Pawtucket Boulevard to the north and the Wood Street corridor to the south, with upgrades to accommodate the additional capacity of the bridge.

Figure 4-2 Alternative 3

Alternative 3 would provide the same increased capacity as Alternative 2 and the slight relocation of the bridge to the east is not anticipated to influence trip making patterns. Therefore, the transportation mobility effects of Alternative 3 are the same as Alternative 2, described above.

By providing additional travel lanes and reducing congestion, Alternative 3 improves access and mobility for emergency response vehicles.

It would be feasible to construct Alternative 3 in one phase while maintaining travel on the existing Rourke Bridge through the duration of construction.

The preliminary evaluation of this potential location for the eastern alignment alternative indicates impacts to recreational land on both the north and the south sides of the river would be substantial.

- **Recommendation – Eliminate Alternative 3 from further consideration due to <u>impacts to recreational land.</u>**

4.2.5 Alternative 4: Western Bypass Alignment (4-lane)

As shown in Figure 4-3, Alternative 4 would construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) just west of the existing bridge with improved pedestrian and bicycle accommodations. The new bridge would maintain connections to Pawtucket Boulevard to the north and the Wood Street corridor to the south, with upgrades to accommodate the additional capacity of the bridge.

Figure 4-3 Alternative 4

Alternative 4 would provide the same increased capacity as Alternative 2 and the slight relocation of the bridge to the west is not anticipated to influence trip making patterns. Therefore, the transportation mobility effects of Alternative 4 are the same as Alternatives 2 and 3, described above.

By providing additional travel lanes and reducing congestion, Alternative 4 improves access and mobility for emergency response vehicles.

It would be feasible to construct Alternative 4 in one phase while maintaining travel on the existing Rourke Bridge through the duration of construction.

Alternative 4 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure.

> ➤ **Recommendation – Retain Alternative 4 for more detailed evaluation (See Chapter 5)**.

4.2.6 Alternative 5: Western Bypass Alignment with Grade-Separation (4-lane)

Figure 4-4 Alternative 5

As shown in Figure 4-4, Alternative 5 is a variation on Alternative 4 and would modify connections on the north side of the river. The new Rourke Bridge would travel over Pawtucket Boulevard and intersect Old Ferry Road at a signalized, at-grade, "T" intersection. "Right-on/right-off" connections from/to Pawtucket Boulevard to the bridge would be maintained via slip ramps. As under Alternative 4, Alternative 5 would consist of a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) just west of the existing bridge with improved pedestrian and bicycle accommodations. The new bridge would maintain the connection to the Wood Street corridor to the south.

Alternative 5 would provide the same increased capacity as Alternative 2 and the slight relocation of the bridge to the west is not anticipated to influence trip making patterns. While there would be localized traffic shifts associated with the grade-separation over Pawtucket Boulevard, the transportation mobility effects of Alternative 5 are the same as Alternatives 2, 3, and 4 described above.

By providing additional travel lanes and reducing congestion, Alternative 5 improves access and mobility for emergency response vehicles.

It would be feasible to construct Alternative 5 in one phase while maintaining travel on the existing Rourke Bridge through the duration of construction. It should be noted that construction of the slip ramps from/to Pawtucket Boulevard would require the demolition of the existing Rourke Bridge first. During this time, these movements would be temporarily re-routed to Old Ferry Road.

Alternative 5 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure.

> ➤ **Recommendation – Retain Alternative 5 for more detailed evaluation (See Chapter 5)**.

4.2.7 Alternative 6: Skewed Bypass Alignment (4-lane)

Figure 4-5 Alternative 6

Alternative 6 would construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) west of the existing bridge with improved pedestrian and bicycle accommodations. As shown in Figure 4-5, the new bridge would be skewed in a northwesterly direction, providing a northern connection along Pawtucket Boulevard opposite Old Ferry Road; the existing connection to the Wood Street corridor to the south would be maintained. Intersections on either side of the bridge would be upgraded to accommodate the additional capacity of the bridge.

Alternative 6 would provide the same increased capacity as Alternative 2 and the slight relocation of the bridge to the west is not anticipated to influence trip making patterns. Therefore, the transportation mobility effects of Alternative 6 are the same as Alternatives 2, 3, 4, and 5 described above. It should be noted that localized shifts in traffic at intersections on the north side of the bridge are anticipated, due to the revised alignment opposite Old Ferry Road.

By providing additional travel lanes and reducing congestion, Alternative 6 improves access and mobility for emergency response vehicles.

It would be feasible to construct Alternative 6 in one phase while maintaining travel on the existing Rourke Bridge through the duration of construction.

Alternative 6 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure.

> ➤ **Recommendation – Retain Alternative 6 for more detailed evaluation (See Chapter 5)**.

4.2.8 Alternative 7: Western Relocation (Vinal Square) Alignment (4-lane)

Alternative 7 would construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) with improved pedestrian and bicycle accommodations. As shown in Figure 4-6, the new bridge would be located approximately one-mile west of the current Rourke Bridge and would replace the existing structure. Under Alternative 7, the bridge would intersect Pawtucket Boulevard opposite Wedgewood Circle to the north and Vinal Square to the south. Intersections on either side would be upgraded to accommodate the bridge. Access to Route 3 would be provided along the Route 40/Groton Road and Route 4/North Road corridors.

Figure 4-6 Alternative 7

While Alternative 7 would provide the same increased capacity as the other widening alternatives, the relocation of the bridge one-mile to the west is anticipated to further influence regional trip making patterns. The transportation mobility effects of this alternative were evaluated using the sub-area travel demand model developed for this study and are as follows:

- Relocating the bridge to the west would result in between 5 and 15 percent fewer peak hour trips under Alternative 7 than the existing Rourke Bridge, indicating that the relocated bridge does not serve origin-destination needs as well as the existing bridge location;
- The bridge relocation would divert approximately 30 percent of existing Rourke Bridge peak hour trips to the O'Donnell (School Street) and University Avenue bridges (includes trips that cross the river twice);
- The volume of peak hour trips crossing the river twice[9] would more than double under Alternative 7, resulting in additional traffic on the O'Donnell (School Street) and University Avenue bridges;
- The bridge relocation would reduce traffic volumes along the Wood Street corridor; trips accessing Route 3 would utilize Route 4/North Road and, to a lesser extent, the Route 40/Groton Road.

While the capacity of the existing Rourke Bridge is limited, the location of the structure serves emergency response access needs for Lowell General Hospital and other medical facilities in the area. Relocating the bridge to the west degrades emergency vehicle access for these facilities.

It would be feasible to construct Alternative 7 in one phase while maintaining travel on the existing Rourke Bridge through the duration of construction.

Preliminary plans for the proposed 12-mile extension of an existing commuter rail line from Lowell to Nashua, New Hampshire consider a commuter rail station in Vinal Square, Chelmsford. Roadway connections to support Alternative 7 could impact the potential commuter rail station.

Alternative 7 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure.

- **Recommendation – Retain Alternative 7 for more detailed evaluation (See Chapter 5)**.

[9] Traffic crossing the river twice is projected to increase due to the relocation of the Rourke Bridge further west under Alternative 7. Vehicles would cross to the north side of the river, travel along Pawtucket Boulevard, then cross a second time to the south side of the river. This travel pattern avoids the congestion on east-west roadways along the south side of the river, but increases the volume of total river crossings.

4.2.9 Alternative 8: Eastern Relocation Alignment (4-lane)

Alternative 8 would construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) with improved pedestrian and bicycle accommodations. As shown in Figure 4-7, the new bridge would be located to the east, between the current Rourke Bridge and the O'Donnell (School Street) Bridge and would replace the existing structure. While there appear to be several locations on the south side of the river where a new bridge could be constructed, State-owned protected and recreational open space on the north side of the river precludes these sites from being feasible options.

Figure 4-7 Alternative 8

➤ **Recommendation – Eliminate Alternative 8 from further consideration due to <u>impacts to State-owned protected and recreational open space.</u>**

4.2.10 Alternative 9: Rourke Bridge plus New Crossing

Alternative 9 would construct a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) with improved pedestrian and bicycle accommodations. As shown in Figure 4-8, the existing Rourke Bridge would remain operational under this alternative and the new bridge would be an additional river crossing following the Vinal Square alignment discussed under Alternative 7.

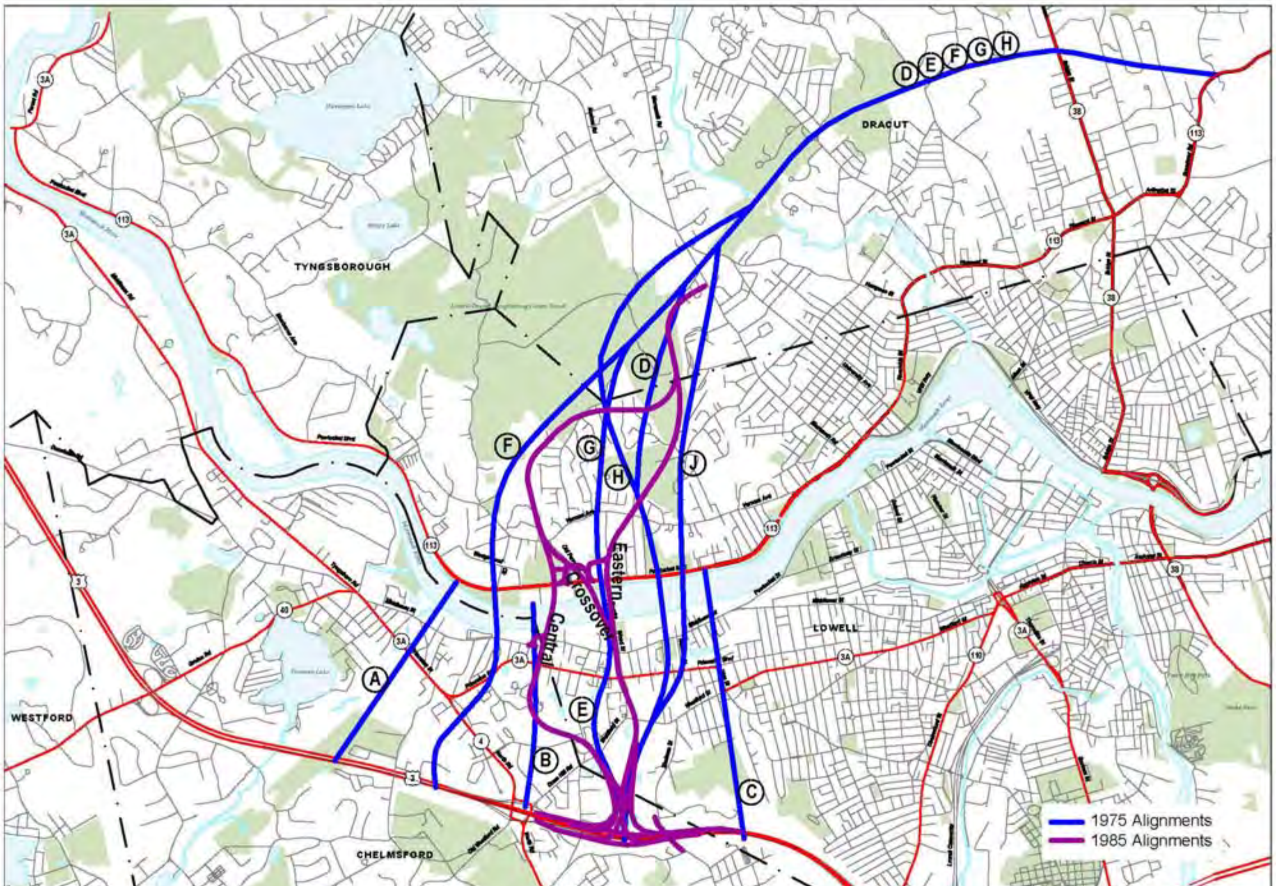
Figure 4-8 Alternative 9

Construction and maintenance costs of this alternative preclude it from further study. The origin-destination pattern of traffic flow across the river would also influence the amount of traffic using the new bridge. Many would remain on the existing Rourke Bridge, as the location of this bridge better serves travel needs. Further, it is very likely that the existing structure would still require replacement in the near future. The financial implications of constructing two new bridge structures in the relative near-term are significant.

- **Recommendation – Eliminate Alternative 9 from further consideration due to construction and maintenance costs.**

4.2.11 Previously Discarded Options

The Rourke Bridge options that were discarded prior to this study are presented graphically in Figure 4-9 and summarized in Table 4-2. Illustrations of these alignments on an aerial base can be found in the report appendix, where more specific property impacts can be assessed. Both the 1975 Draft Environmental Impact Statement (DEIS) and 1985 DEIS are included in the Technical Appendix for reference purposes.



Sources: Draft Environmental Impact Statement (DEIS), State Route 213, Chelmsford, Lowell, Dracut, Massachusetts Department of Public Works; 1975. Draft Environmental Impact Statement (DEIS)/Report and Section 4(F) Evaluation, Merrimack River Bridge and Approach Roadways, Massachusetts Department of Public Works; 1985.

Figure 4-9 Rourke Bridge Options Eliminated from Further Consideration

Table 4-2 Rourke Bridge Options Eliminated from Further Consideration

Option	Reason for Elimination
1975 Line A (1966 study): Previous western-most alignment; included new Route 3 interchange west of Drum Hill Square	Discarded in 1975 due to minimal traffic relief for other crossings & impacts to the industrial park north of river.
1975 Line B (1966 study): Lowell Water Department to Drum Hill Square	Discarded in 1975 due projected traffic volumes at the Drum Hill Square.
1975 Line C (1966 study): Previous eastern-most alignment; included new Route 3 interchange east of Drum Hill Square	Discarded in 1975 due to significant residential and recreational (Mount Pleasant Golf Course) impacts.
1975 Line D/G/H: Alignment east of current Rourke Bridge; included new Route 3 interchange east of Drum Hill Square and northern connection to Route 113	Line D was discarded in 1975 due to residential and commercial impacts and local opposition; Line G/H was discarded due to interchange spacing issues.
1975 Line E: Alignment just west of current Rourke Bridge; included new Route 3 interchange east of Drum Hill Square and northern connection to Route 113	Discarded in 1975 due to residential and commercial impacts and local opposition.
1975 Line F: Alignment west of current Rourke Bridge; included new Route 3 interchange west of Drum Hill Square and northern connection to Route 113	Discarded in 1975 due to residential and commercial impacts and local opposition.
1975 Line J: Variation of Line D/G/H; included new Route 3 interchange east of Drum Hill Square and northern connection to Route 113	Discarded in 1975 due to significant residential, commercial, 4F, and historic impacts
1985 Central Alignment:: Alignment west of current Rourke Bridge; included new Route 3 interchange east of Drum Hill Square and northern connection to Mammoth Road	No preferred alternative selected in 1985 study; Discarded due to interchange spacing issues.
1985 Crossover Alignment: Skewed alignment west of current Rourke Bridge; included new Route 3 interchange east of Drum Hill Square and northern connection to Mammoth Road	No preferred alternative selected in 1985 study; Discarded due to interchange spacing issues.
1985 Eastern Alignment: Current Rourke Bridge alignment; included new Route 3 interchange east of Drum Hill Square and northern connection to Mammoth Road	No preferred alternative selected in 1985 study; Discarded due to interchange spacing issues.

Sources: Draft Environmental Impact Statement (DEIS), State Route 213, Chelmsford, Lowell, Dracut, Massachusetts Department of Public Works; 1975; and Draft Environmental Impact Statement (DEIS)/Report and Section 4(F) Evaluation, Merrimack River Bridge and Approach Roadways, Massachusetts Department of Public Works; 1985.

Northern Connections

Alternatives from both the 1975 DEIS and 1985 DEIS considered limited access northern connections. From the 1975 DEIS, Lines D/G/H, Line E, Line F, and Line J included a limited access roadway from the Rourke Bridge, through the Lowell-Dracut-Tyngsborough State Forest to Route 38 and Route 113 in Dracut. All three 1985 alternatives included a similar, yet shorter, connection through the state forest which terminated at Mammoth Road. The intent of both connections was to provide an option to by-pass downtown Lowell to gain access to Route 3 and I-495 for commuters from the north.

The transportation mobility effects of a potential northern connection were evaluated using the sub-area travel demand model developed for this study. Modeling results indicate between 125 and 175 peak hour trips (in both directions) are projected to use the northern connection.

Construction of a northern connection would impact the state forest as well as numerous residential properties along its potential alignment. The small transportation benefit related to creation of the northern connection is substantially offset by impacts to the surrounding community.

- **Recommendation – Discard northern connection from further consideration and study due to minimal mobility benefits and significant impacts to recreational and residential properties.**

4.3 Roadway and Intersection Capacity Enhancements

Two alternatives were considered to enhance the capacity of the study area transportation network:

- Widen the Wood Street/Westford Street/Drum Hill Road corridor from 2-lanes to 4-lanes; and
- Consider intersection improvements to enhance capacity (as presented in Table 4-3 below).

Table 4-3 Potential Intersection Capacity Improvements

Intersection	Improvement
Riverside Street at University Avenue	Northbound University Avenue right-turn lane Westbound Riverside Street left-turn lane
University Avenue at VFW Highway	Second University Avenue southbound through lane
Riverside Street at VFW Highway	Eastbound Riverside Street left-turn lane
Wood Street at Princeton Boulevard	Second northbound and southbound Wood Street through lanes
Westford Street at Wood Street	Lengthen Westford Street northbound right-turn lane

4.4 Transportation System Management Strategies

The Transportation System Management (TSM) strategies discussed below seek to improve the management and operation of existing transportation facilities within the study area. These enhancements are intended to improve traffic flow, air quality, and the movement of vehicles and goods, as well as improve system accessibility and safety.

- Consider the signalization of eight study area unsignalized intersections projected to operate at LOS E/F under 2035 Baseline conditions (Figure 4-10)
- Optimize signal timings at nine study area intersections projected to operate at LOS E/F under 2035 Baseline conditions (Figure 4-10)
- Coordinate traffic signals along the following study area corridors to improve traffic progression and reduce overall delay (Figure 4-10):
  - Drum Hill Road corridor
  - University Avenue Bridge corridor
  - O'Donnell (School Street) Bridge corridor
  - University Avenue Bridge and O'Donnell (School Street) Bridge corridors
- Address signal issues noted during field inventories (complete list of issues by intersection included in Report Appendix) to address the following:
  - 2009 Manual on Uniform Traffic Control Devices (MUTCD) issues/violations;
  - Defective and/or broken equipment;
  - Americans with Disabilities Act (ADA) non-compliance issues; and
  - Other issues (i.e. poor pavement condition, faded markings, "yellow traps," etc.).
- Consider access management improvements at the following locations (refer to Section 5.3.5 for detailed discussion of access management improvements):
  - Drum Hill Road corridor
  - Middlesex Street corridor
  - Market Basket supermarket plaza
- Consider overhead lane indication signage at complex intersections

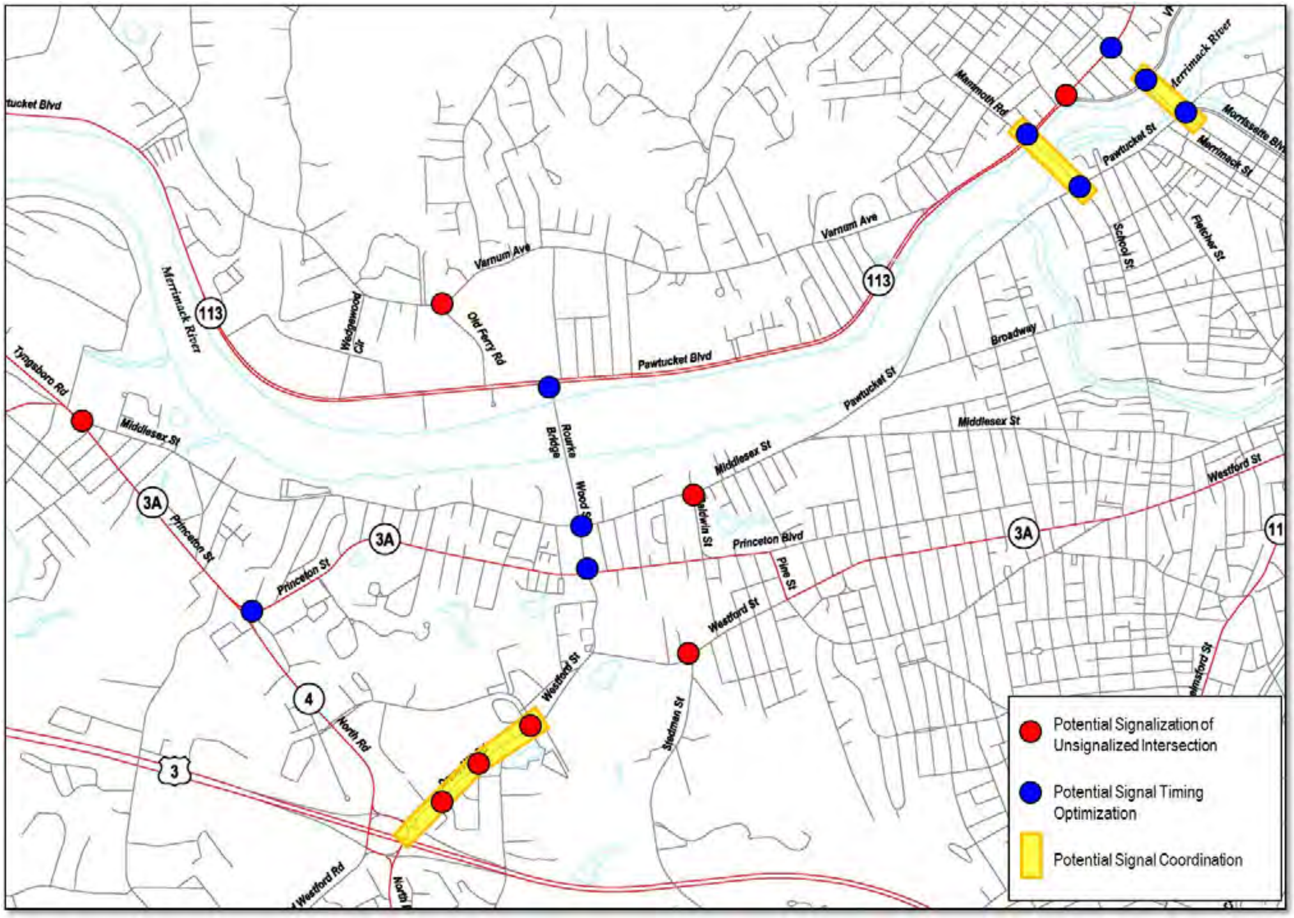


Figure 4-10 Potential Intersection Improvements

4.5 Transportation Demand Management Strategies

Transportation Demand Management (TDM) strategies seek to increase overall system efficiency by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes, or shifting auto trips out of peak periods. For many regions, TDM strategies are organized and implemented by a regional Transportation Management Association/Organization (TMA/TMO). The study area communities are not served by such an organization and investigation of the feasibility of creating a TMA for the region could be considered.

4.6 Transit System Enhancements

The transit alternatives focus on making transit options more attractive, available, and efficient with an overarching goal of increasing transit utilization and reducing reliance on the automobile. The following transit-related improvements were considered:

- Improve pedestrian access to existing transit routes along major study area corridors;
- Enhance the transit experience by improving bus stop facilities and operations;
- Consider providing LRTA bus service to the Lowell General Hospital from the Drum Hill Road corridor; and
- Support New Hampshire Commuter Rail Extension.

4.7 Bicycle/Pedestrian Enhancements

The alternatives in this section focus on addressing existing area mobility issues for pedestrians, and/or bicyclists at intersections and along corridors within the study area. Specific alternatives developed include:

- Provide bicycle accommodations on the new Rourke Bridge;
- Investigate the feasibility of installing bicycle lanes or shared lanes ("sharrows") along major study area corridors;
- Improve pedestrian accommodations at study area intersections; and
- Investigate the feasibility of installing or upgrading sidewalks along major study area corridors.

4.8 Structural Considerations and Assumptions

While structural considerations do not substantially factor into the outcome of the initial alternatives development/screening, the methodology and assumptions will contribute to the alternatives analysis discussed in Chapter 5. As such, it was important to develop the considerations and assumptions in concert with the alternatives. From a structural standpoint, the retained alternatives were compared and evaluated based on the following criteria:

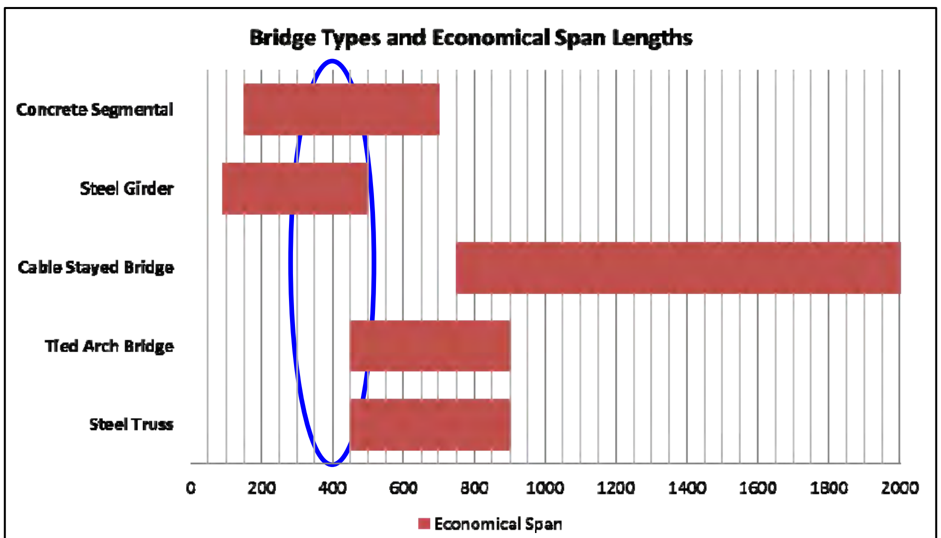
- A single economic structure type and span range
- Conceptual bridge costs
- Potential temporary & permanent impacts
- Constructability issues
- Pedestrian accommodation

The following describes the approach used by the Study Team to develop the evaluation criteria stated above.

4.8.1 Single Economic Structure Type and Span Range

There are many possibilities for structure types and span arrangements that could be used to span over the Merrimack River near the existing Rourke Bridge. The main goal of the structural portion of the study was to compare and evaluate the retained alternatives to one another and develop recommendations for preferred bridge alignments. Once a preferred alignment alternative has been finalized, a Bridge Type Selection Study would be required to determine the most feasible structure type and span arrangement. To develop comparative data including construction costs, potential impacts, and constructability issues, a single structure type and economical span range is presented herein.

The existing Rourke Bridge is comprised of spans of approximately 150 feet with 6 piers in the waterway. A span of 150 feet is relatively small for permanent bridges spanning over large waterways. Therefore, the Study Team presumed that the proposed bridge would have fewer piers in the waterway, resulting in bridge spans greater than 150 feet. Fewer piers would also improve the recreational experience and minimize permanent environmental impacts to the Merrimack River. Using a minimum span of 150 feet as a lower limit, the Study Team developed a list of several common bridge types found over large waterways similar to the Merrimack River. A summary of these bridge types showing their economical bridge span ranges can be found in Figure 4-11.



Sources: 1. Wright, PE, K. (2012). Steel Bridge Design Handbook: Selecting the Right Bridge Type. FHWA.
2. Madani, M. (2011). General Guidelines for the Preliminary Design for Segmental Concrete Box Girder Superstructure.
3. Chen, W., & Duan, L. (1999). Bridge Engineering Handbook. CRC Press.

Figure 4-11 Bridge Types and Economical Span Lengths

The Merrimack River around the existing Rourke Bridge has no significant features that must be bridged over such as existing wide channels, deep sections of the waterway or historically sensitive areas. Therefore, proposing very long spans requiring complex bridge types and erection techniques would be difficult to justify for the purposes of comparing the retained alternatives. By using additional criteria including ease of delivery, structure redundancy, and ease of inspection and maintenance, the Study Team selected a steel plate girder bridge type. As previously stated, a Bridge Type Selection Study would eventually be required to determine the preferred structure type for the Rourke Bridge replacement during the MassDOT design/development process. A steel plate girder bridge would be one of several viable candidates for a future Bridge Type Selection Study. Other bridge types that should be considered in the future study include but are not limited to steel box girder, segmental concrete box girder, steel truss, tied arch, and cable stayed bridges.

Even though large span steel plate girder bridges are becoming increasingly popular for river crossings, spans currently exceeding 500 feet are rarely built in the U.S. For this analysis, the Study Team presents a maximum span of 400 feet as a feasible upper limit. Figure 4-12 shows a rendering of a conceptual long span steel plate girder bridge with a maximum span of approximately 400 feet.

Source: Lake Champlain Bridge Project – Final Design Report. February 2010.

Figure 4-12 Continuous Steel Plate Girder Bridge

Certain geometric constraints were considered in determining the pier layout of the retained alternatives. The Study Team presumed that the proposed bridge would provide minimum vertical and horizontal navigation clearances that meet or exceed those that exist today. The two existing channels found on the existing 1983 bridge plans include a 100′ (hor.) x 30′-8″ (vert.) channel and 100′ (hor.) x 20′-2″ (vert.) channel. These clearances were set to accommodate any existing recreational use that have grown accustomed to the existing navigational clearances and would likely be the minimum clearance criteria for a U.S. Coast Guard Section 9 Bridge Permit.

Other geometric constraints include minimum vertical clearances required by MassDOT that must be maintained over the railroad and local roads in which the proposed crossing would span over. The high water elevation found on the existing bridge plans was used to determine the minimum elevation of the abutment beam seats. The Study Team presumed that during a 100 year flood the proposed beam seats would remain "in the dry."

The Study Team presumed barge construction to construct the bridge piers and erect the superstructure in the waterway to reduce excessive temporary impacts. The north shore of the river is relatively shallow preventing barge access close to the shore. The piers closest to the shore, with the exception of Alternate 5, were offset far enough from the water's edge to allow for barge construction for the entire structure within the waterway.

As the bridge spans increase, the superstructure depth also increases. The Study Team determined the pier layouts and roadway profiles by using a maximum profile grade of 5 percent and preliminary span-to-depth ratios for steel plate girder bridges. The subsequent roadway profiles result in raising the existing roadway profile as much as 10 feet. See Section 5.1 for further details on the span arrangements of the various alternatives.

4.8.2 Conceptual Bridge Costs

The conceptual bridge costs evaluated by the Study Team included construction costs, inspection costs, and preventive maintenance costs. All of the costs were determined in existing dollars[10] and then escalated as required at an presumed inflation rate of 2.5 percent per year until years 2020-2025 depending on the item to be priced. The preliminary construction costs include only what is required to build the bridge. Other costs including land acquisitions, temporary and permanent easements, and demolition of the existing bridge should be included in a more detailed cost analysis. Highway construction costs beyond the bridge approaches were also not included.

The Study Team used historical data including MassDOT's latest average weighted bid prices, recent long span bridge construction prices, and the RSMeans Heavy Construction Cost Data to estimate the construction costs for the retained alternatives. Since defining a preferred structure type is beyond the scope of this study, the Study Team determined an average cost per square foot (cost/sf) from recent projects that encompass multiple bridge types. The cost/sf was escalated at an presumed inflation rate of 2.5 percent per year to 2020 dollars (assume a conservative five year construction duration). The 2020 cost/sf was then multiplied by the footprint of each retained alternative to acquire a conceptual construction cost.

The Study Team performed two separate cost estimations; one using approach embankments and the other using vertical cast-in-place concrete retaining walls. An approach embankment is a mound of earth used to support the approach roadway that consists of a standard 2:1 descending slope on each side of the roadway. The

▼

[10] Existing dollars were considered 2013 dollars.

bridge approaches could also be constructed by replacing the embankments with vertical cast-in-place concrete retaining walls. Retaining wall construction may cost more than approach embankments but will have less potential for property and/or environmental impacts. Since cost and environmental impacts are both important factors for obtaining a preferred alternative, it would be difficult to assume what type of approach would be used. The final design would likely have a combination of both embankment and retaining wall construction. The method (embankments or retaining walls) resulting in the greater cost estimate was used to obtain the most conservative conceptual construction cost.

The existing Rourke Bridge will be required to remain open until the proposed bridge is opened to traffic around the year 2025. Preventative maintenance and bridge inspections will continue to be required to maintain the existing bridge's current condition while it remains open to traffic. In addition to the preventative maintenance completed thus far, the Study Team proposes that the superstructure below the deck be cleaned and repainted at least once by the year 2025 to prevent further section losses and load capacity reductions. Table 4-4 summarizes the cumulative bridge maintenance and inspection costs required to maintain the condition of the existing bridge until year 2025. Refer to the No-Build Alternative Section 3.5 for further discussion on the costs summarized in Table 4-4.

Table 4-4 Cumulative Maintenance and Inspection Costs (2013-2025)

Name	2025 Total Cost
Bridge Inspection	$ 336,000
Programmatic Maintenance[1]	$ 454,000
Clean & Paint Structural Steel	$ 940,000
Total Cost	$ 1,730,000

1 Refer to Section 2.6.3 for a description of Programmatic Maintenance

4.8.3 Potential Permanent and Temporary Impacts

With the bridge profiles defined, the potential permanent and temporary impact areas for each retained alternative could be determined. The Study Team used embankments for the bridge approaches rather than retaining walls because they have a larger footprint and therefore would ensure the most conservative potential impact areas.

A stub abutment is one that contains a relatively short abutment built back away from the river or road to be bridged and up on the back slope. The Study Team used stub abutments since they usually require a larger footprint and longer bridge spans than that of a full height abutment. Certain geometrical constraints did not allow for fill to extend beyond the face of some abutments. These constrained abutments were considered to be full height vertical walls that extend from the streambed (or roadway) to the bottom of the superstructure. This type of abutment is called a "full height" or "closed" type abutment.

The preliminary pier sizes were based on average pier sizes of recently built bridges over large waterways. The bridge piers, abutments, and approach embankments are all considered potential permanent impacts and are marked with a red hatch on the bridge alternative graphics included in the Report Appendix.

Temporary support towers are required to aid in the erection of the steel plate girders. The temporary towers were positioned to allow for the erection of the steel girders using a presumed maximum girder segment of 120 feet. A maximum girder segment of 120 feet was based on presumable acceptable lifting capacities of commonly available cranes.

Temporary construction access roads are required to allow for the construction of the approaches, piers, temporary towers and erection of the superstructure on land or in shallow waters that could not be accomplished by barge. A temporary access road and dock are required to gain access to the river and to launch construction equipment onto barges. Temporary construction laydown areas, or staging areas, are required to field splice the plate girders before erection and for storage of construction materials and equipment.

The Study Team considered temporary cofferdams for constructing the bridge piers and temporary towers within the waterway. The temporary towers, construction access roads, laydown areas, barge docks, and cofferdams are all considered potential temporary impacts and are marked with a blue hatch on the bridge alternative graphics included in the Report Appendix.

From these defined areas, the Study Team was able to quantify likely property and environmental impacts. Property impacts may include temporary/permanent easements, land acquisitions, and layout alterations. Refer to section 5.1 for details on environmental impacts.

4.8.4 Pedestrian Accommodations

Each alternative will provide outboard sidewalks on both sides of the bridge to accommodate pedestrians. Each sidewalk will be protected from vehicular traffic by an interior vehicular barrier at the face of each curb. An increase in bridge length over the existing bridge would result in a longer travel distance for pedestrians crossing the bridge. The Study Team recognized that longer travel distances would be less desirable and would result in a negative impact to the pedestrian experience on the bridge.

4.8.5 Constructability Issues

The Study Team considered certain constructability issues to provide a "buildable" alternative. The railroad running along the south side of the Merrimack River would make it difficult for construction materials and equipment to access the river from the south. Presumably, access to the river would be obtained from the north. The Study Team determined a feasible construction material delivery route based on the findings of the study area infrastructure assessment discussed in Section 2.6.4. The construction materials were assumed to be transported via Route 3, the closest highway to the construction site. With the recent rehabilitation of the Tyngsborough Bridge now complete and the University Ave Bridge construction near completion, there are possible river crossings up and down stream of the project site. Route 3 would be a viable travel route due to the recent construction of the bridges along the corridor, providing structures without any weight restrictions. Delivery routes would be limited east of the existing bridge (in and around downtown Lowell) due to traffic congestion, tightly woven roads, and weight restricted bridges. With the impending travel restrictions to the east, traveling on Route 3 to Exit 35, across the Tyngsborough Bridge, and then east on Route 113 to the project site was deemed the most feasible delivery route. See Figure 4-13 for a graphical depiction of this delivery route.

MassDOT is planning on completing reconstruction of the Route 110 rotary in Methuen, MA (east of the project study area) with new on/off-ramps by the spring of 2016. This rotary interchange reconstruction may result in another feasible delivery route that runs from I-93 (at Exit 46) to the project site via Route 110 westbound. There are several crossings along Route 110 outside of the study area that may be weight restricted. If this construction route is considered, the crossings along Route 110 should be evaluated to determine the feasibility of this travel route.

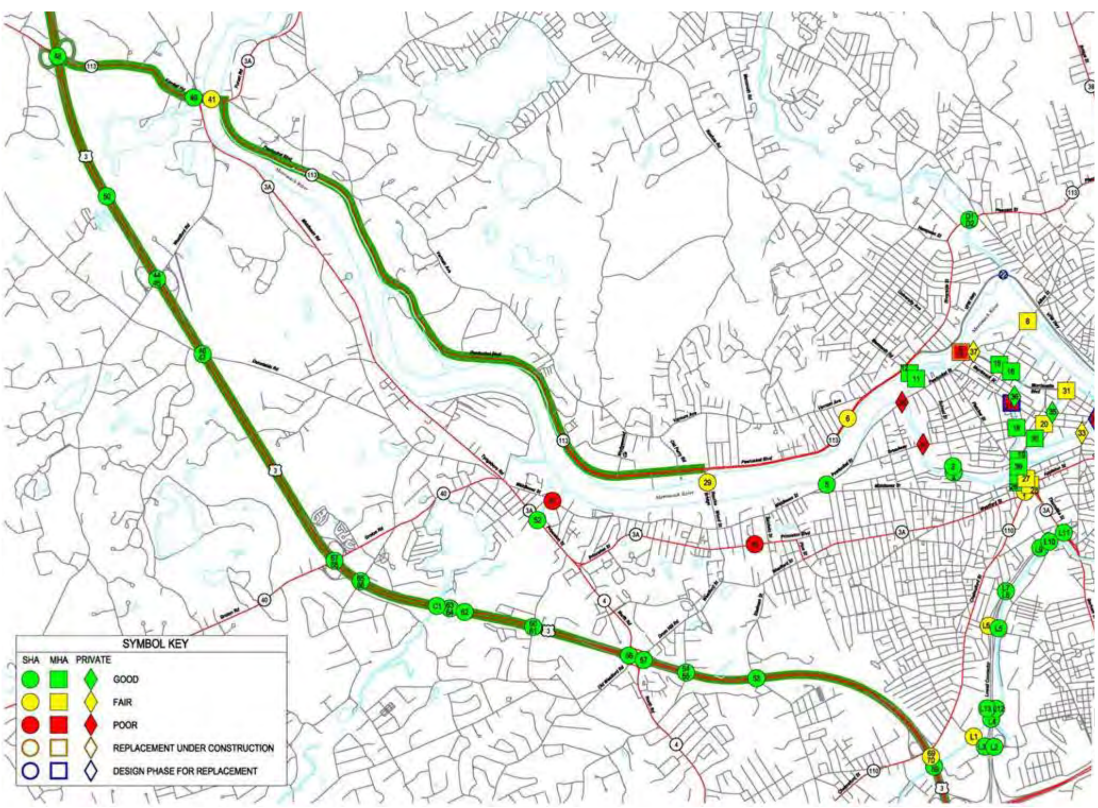


Figure 4-13 **Potential Construction Delivery Route**

5

Alternatives Analysis

Chapter 4 presented a preliminary "fatal flaw" screening of the alternatives that were identified as having the potential to address the transportation system issues and deficiencies and meet the goals and objectives of this study. This chapter presents more detailed evaluations of each option carried forward.

5.1 Rourke Bridge Alternatives

Table 5-1 summarizes the results of the initial screening of bridge alternatives, presented in Section 4.2. As shown, the following alternatives were advanced for further evaluation and are discussed in detail in this section:

- Alternative 2: Maintain Existing Alignment (4-lane)
- Alternative 4: Western Bypass Alignment (4-lane)
- Alternative 5: Western Bypass Alignment with Grade-Separation (4-lane)
- Alternative 6: Skewed Bypass Alignment (4-lane)
- Alternative 7: Western Relocation Alignment - Vinal Square (4-lane)

Concept plans for each of the five alternatives discussed in this section are included in the Report Appendix. Each alternative includes construction of a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound). Turn lanes at the ends of the bridge in addition to the 4-lane section are described below.

An analysis comparing the visual aspects of the existing Rourke Bridge to the proposed steel girder bridge was completed as part of the alternatives analysis. Figure 5-1 shows the existing Rourke Bridge looking west from the north side of the river. Each alternative section below presents a computer simulation of the proposed new bridge from the same vantage point for comparison purposes, as it can be expected to look based on the alternative alignment. Further visual analysis may be necessary if the structure type changes during the design phase of the project. Visual analysis was not completed for Alternative 7 as this option was ultimately discarded from further study. A full size version of each computer simulation is provided in the Alternative Concept Plans section of the Report Appendix.

Table 5-1 Rourke Bridge Alternatives – Initial Screening Results

Retained for Further Consideration	Discarded from Further Consideration	Comments
	No-Build Alternative: Remove Existing Bridge	Impacts to regional mobility and emergency access Use for comparison with Build alternatives
	Alternative 1: Maintain Existing Alignment (2-lane)	Inadequate improvements to regional mobility and emergency access
Alternative 2: Maintain Existing Alignment (4-lane)		Retain for further study
	Alternative 3: Eastern Bypass Alignment (4-lane)	Impacts to recreational land
Alternative 4: Western Bypass Alignment (4-lane)		Retain for further study
Alternative 5: Western Bypass Alignment with Grade-Separation (4-lane)		Retain for further study
Alternative 6: Skewed Bypass Alignment (4-lane)		Retain for further study
Alternative 7: Western Relocation Alignment - Vinal Square (4- lane)		Retain for further study
	Alternative 8: Eastern Relocation Alignment (4- lane)	Impacts to State-owned protected and recreational open space
	Alternative 9: Rourke Bridge plus New Crossing	Construction and maintenance costs

Figure 5-1 Existing Rourke Bridge Visual Analysis

An analysis of travel times along the Rourke Bridge/Wood Street/Westford Street/Drum Hill Road corridor was completed as part of the alternatives analysis. The evaluation considers both the travel time on roadway segments (i.e. between intersections) and the average delay at signalized intersections along the corridor from Pawtucket Boulevard in the north to Drum Hill Square in the south. The approximate travel times under the 2035 Baseline condition are as follows:

- AM Peak Hour – Northbound: 9.7 minutes
- AM Peak Hour – Southbound: 13.2 minutes
- PM Peak Hour – Northbound: 10.2 minutes
- PM Peak Hour – Southbound: 9.4 minutes

Each alternative section below presents the results of travel time analysis for the corridor. The analyses take into account the change in travel times as a result of constructing a new Rourke Bridge and do not reflect the influence of other potential study area intersection or roadway improvements (discussed in detail in subsequent sections). Detailed travel time analysis results are included in the Report Appendix. Travel time analysis was not completed for Alternative 7 as this option was ultimately discarded from further study.

5.1.1 Alternative 2: Maintain Existing Alignment (4-lane)

Alternative 2 includes construction of a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound). This alternative would maintain the alignment of the existing Rourke Bridge and connections to Pawtucket Boulevard to the north and the Wood Street corridor to the south, as shown graphically in Figure 5-2. In addition to signal timing optimization, the following intersection upgrades are included as part of Alternative 2:

- **Pawtucket Boulevard at Rourke Bridge**
  - Provide dual eastbound right-turn lanes;
  - Provide dual westbound left-turn lanes; and

- Provide dual northbound left-turn lanes.

➤ **Pawtucket Boulevard at Old Ferry Road** – Provide a southbound right-turn lane.

➤ **Old Ferry Road at Varnum Avenue**

- Install a fully-actuated traffic signal; and
- Provide westbound left-turn lane.

If this alternative advances, signal coordination across the bridge and along Pawtucket Boulevard should be investigated further and incorporated into the design as appropriate. Conceptual improvements to the intersection of Middlesex Street at Rourke Bridge/Wood Street, the southern end of the bridge, are discussed in a subsequent section. The final improvements would be determined and vetted through the environmental permitting process, once a preferred bridge alternative has been selected.

Figure 5-2 Alternative 2: Maintain Existing Alignment

In order to maintain traffic flow on the existing Rourke Bridge through the duration of Alternative 2 construction, the new bridge would be built in stages. First, the two southbound travel lanes, bicycle lane/shoulder, and sidewalk would be constructed adjacent to the existing Rourke Bridge. During this stage, the existing structure would remain open for bi-directional vehicular traffic. Traffic would then be diverted to this new structure with one travel lane northbound and one travel lane southbound while the existing Rourke Bridge was demolished. Finally, the northbound travel lanes, bicycle lane/shoulder, and sidewalk would be constructed.

Alternative 2 would have the following effects:

- **Transportation Mobility** – Travel demand modeling of Alternative 2 determined that there is a mobility benefit and demand for a widened Rourke Bridge.
  - **Demand** – Alternative 2 would attract approximately 285 weekday morning peak hour trips (an increase of 12 percent) and 120 weekday evening peak hour trips (an increase of 5 percent) to the Rourke Bridge (Table 5-2). The majority of these shifted trips would access the Rourke Bridge via Wood Street and/or Pawtucket Boulevard/Route 113.
  - **Regional Impacts** – The majority of new Rourke Bridge trips would shift from the O'Donnell (School Street) Bridge/Pawtucket Street, alleviating some of the congestion issues currently experienced along this route. No additional significant regional impacts are anticipated as a result of this alternative (Table 5-2).
  - **Operations** – With the intersection enhancements discussed above, Alternative 2 would improve operations at intersections on either side of the bridge to LOS D or better during both peak hours. Detailed capacity analysis results are included in the Technical Appendix.
  - **Travel Times** - With the Alternative 2 alignment and the intersection enhancements discussed above, approximate travel times along the corridor would improve from the 2035 Baseline conditions by between 1 and 4 minutes during the peak hours. Detailed travel time analysis results are included in the Report Appendix.
  - **Emergency Vehicle Access** – Alternative 2 would improve emergency vehicle access and mobility by providing additional travel lanes, reducing congestion on the bridge, and reducing travel times along the corridor to the Drum Hill Rotary (discussed above).
- **Safety** – Alternative 2 would mitigate the high crash intersection of Pawtucket Boulevard at Rourke Bridge.
- **Multimodal Benefits** – Alternative 2 would improve pedestrian and bicycle accommodations across the bridge by providing 6-foot sidewalks and 5-foot bicycle lanes (minimum) in both directions. It should be noted that if a pedestrian railing is installed, 6-foot bicycle lanes may be required to provide adequate separation between users of both facilities. A separate, multi-use path may be considered by MassDOT in the design process. While the path would be beneficial in further removing bicycles from the traffic stream, there may be operational and safety concerns with how pedestrians and bicyclists cross traffic ramps at either end of the bridge, particularly on the north side. The new Rourke Bridge would be designed to accommodate transit vehicles.

Table 5-2 Rourke Bridge Peak Hour Traffic Shifts: 2035 Baseline to Alternatives 2, 4, 5, & 6

	2035 Traffic Volume Differences	
Roadway	**AM Peak Hour**	**PM Peak Hour**
Rourke Bridge	+285	+120
Wood Street	+110	+40
Route 113	+180	+55
Varnum Avenue	+20	+5
Old Ferry Road	+35	+15
Pawtucket Street	-190	-20
O'Donnell Bridge	-140	-25

➤ **Structural**

- **Total Bridge Length** – By taking advantage of building in nearly the same footprint as the existing bridge, Alternative 2 would maintain the existing overall bridge length of approximately 1,100 feet.
- **Span Arrangement** – Four continuous spans with a maximum span of 330 feet.
  - Proposed piers presumed to be offset from the existing piers to prevent overlap during the first stage of construction.
  - Pier assumed to support widened portion of bridge to accommodate right turn lane near the north approach.
- **Temporary Potential Impacts** – Construction laydown areas and access roads would be required to construct the south approach, abutment and landlocked temporary tower. Access is also required at the north approach to construct the temporary tower and erect the plate girders inaccessible by barge. Water access would be obtained by extending an existing road located to the west of the bridge down to the river. Additional laydown area may be required for parking and additional storage in the privately owned field north of Pawtucket Boulevard. It should be noted that Alternative 2 may be able to take advantage of the existing piers by using them as temporary erection towers. Since the bridge must remain open, these towers would need to be extended to the west for stage 1 construction. The Study Team considered pier 2 (southernmost pier in the waterway) to act as one of these erection towers for the proposed span arrangement. Cofferdams would be placed

around all of the piers and temporary towers in the waterway assuming a 10-foot offset from existing and proposed structures. The temporary potential impact areas presented in this alternative are approximately 122,000 SF.

- **Permanent Potential Impacts** – A full height abutment was used at the north approach to maintain the existing pedestrian path that runs along the face of the existing north abutment. A stub abutment was used at the south approach since there were relatively no restrictions. The span arrangement presented will consist of three permanent piers in the waterway. The permanent potential impact areas presented in this alternative are approximately 143,000 SF.
- **Constructability Issues** – Phased construction will be required to build within the existing bridge footprint while keeping the existing bridge open to traffic. This phased construction process would consist of building a portion of the structure adjacent to the existing bridge wide enough to accommodate two lanes of traffic and one sidewalk. Traffic would then be shifted over to the newly constructed portion of the bridge allowing the existing bridge to be removed. The remaining portion of the proposed bridge is then constructed. Phased construction may require temporary easements. Figures 5-3 through 5-5 show a graphical representation of this preliminary phased construction concept.

Cost and construction duration may increase due to additional traffic moves, large equipment mobilizations, and material deliveries associated with multiple stage construction. For example, the material and equipment required to construct the bridge piers will have to be mobilized at least twice since the existing bridge must be removed before the second half of the piers can be constructed.

Alternative 2 proposes having construction occur close to the existing structure while it remains open to pedestrians and traffic. To meet vertical clearance requirements, the bridge profile will be raised above the existing bridge profile resulting in construction above passing pedestrians. The existing outboard sidewalk is also located on the west side of the bridge, closest to the first phase of construction. Public safety will be a concern with adjacent construction of this nature and should be considered when evaluating this alternative.

Coordination will be required with the B&M Railroad for all construction in close proximity of the railroad.

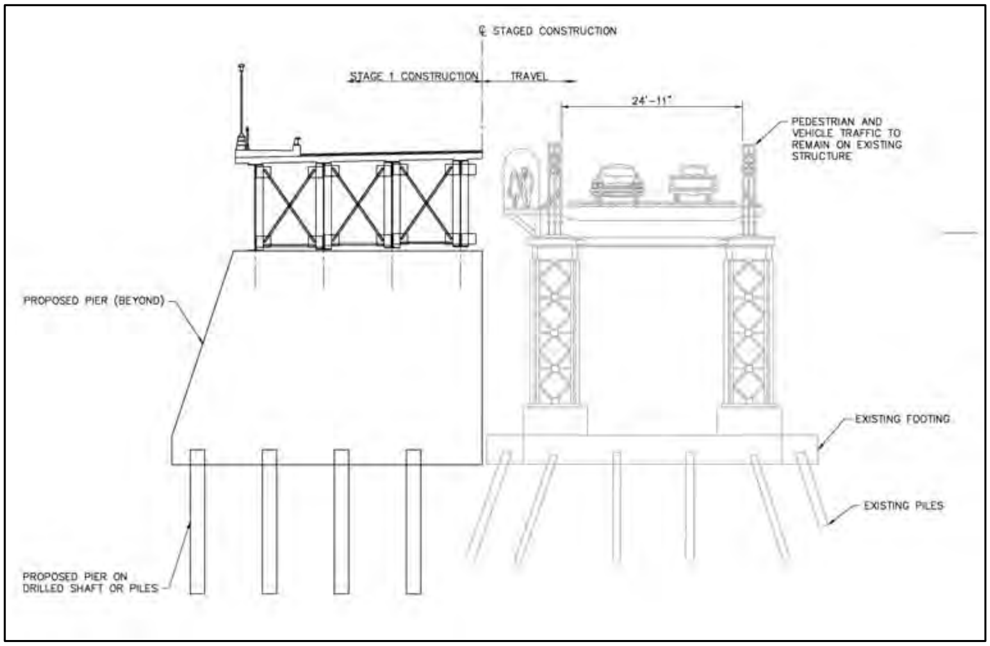


Figure 5-3 Phase Construction – Stage 1

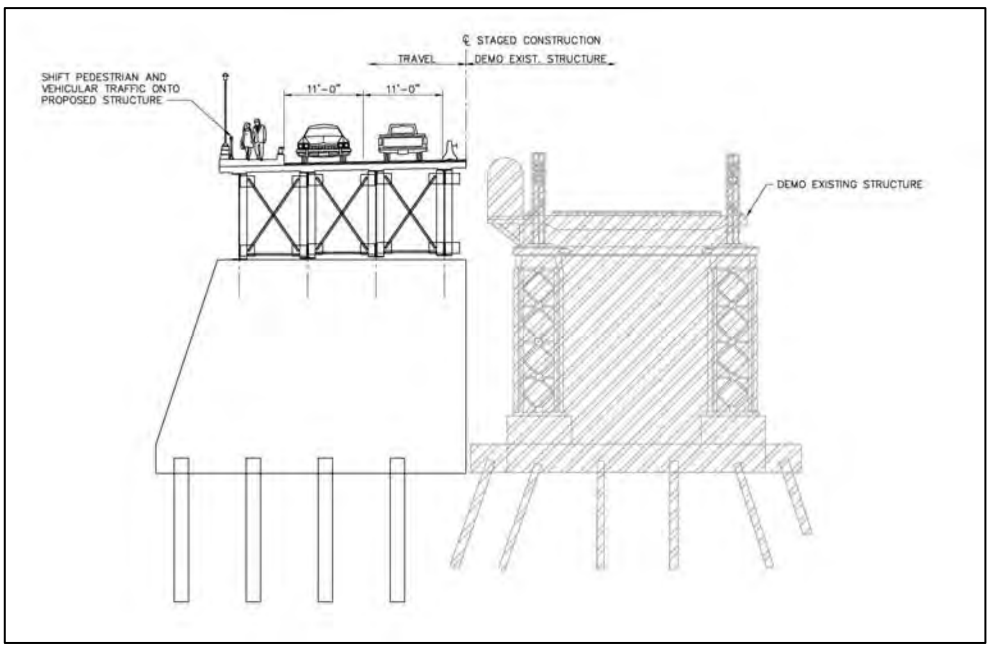


Figure 5-4 Phase Construction – Stage 2

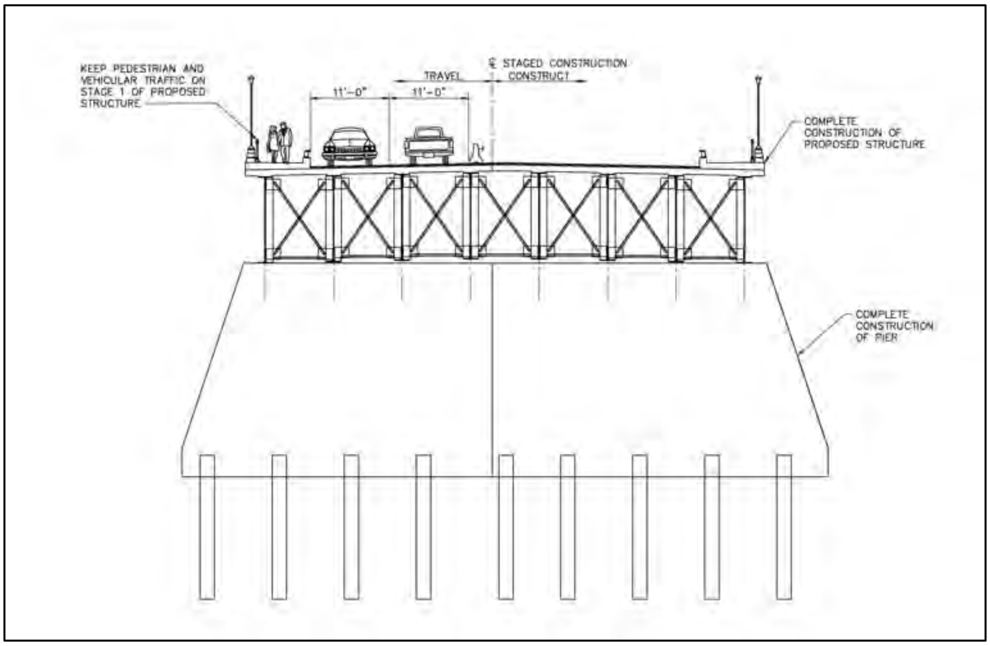


Figure 5-5 Phase Construction – Final Stage

- **Economic Development –** Alternative 2 would reduce travel time and move people and goods more efficiently over the Rourke Bridge, improving economic development potential in the region. If this alternative advances, potential impacts to the bowling alley, CVS, and the proposed Lowell Charter School (visual only) should be reviewed in detail.
- **Environmental Justice (EJ) –** Alternative 2 would improve pedestrian and bicycle mobility for the adjacent minority and disadvantaged population.
- **Environmental –** Alternative 2 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure. This alternative would potentially require as much as 779 linear feet of Bank, 4,214 square feet of Bordering Vegetated Wetland (BVW), 32,935 square feet of Land Under Water, 34,850 square feet of Bordering Land Subject to Flooding (BLSF) and 1,994 square feet of Riverfront Area and 0.78 acres of disturbance to protected open space, as shown in Figures 5-6 and 5-7.
- **Lasting Benefits –** This alternative is projected to accommodate 2035 traffic volumes. The bridge structure itself would be designed with a lifespan of 75 years.
- **Community Support** – Alternative 2 is generally supported by members of the TWG, SAC, and the public. The Lowell City Council has voted to endorse Alternative 2 for further study.

- ***Preliminary Order of Magnitude Cost Estimate: $54.5 million (details included in the Report Appendix)***

Source: VHB 2013, BING 2009, MassGIS 2008, 2009, 2012 & 2013, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

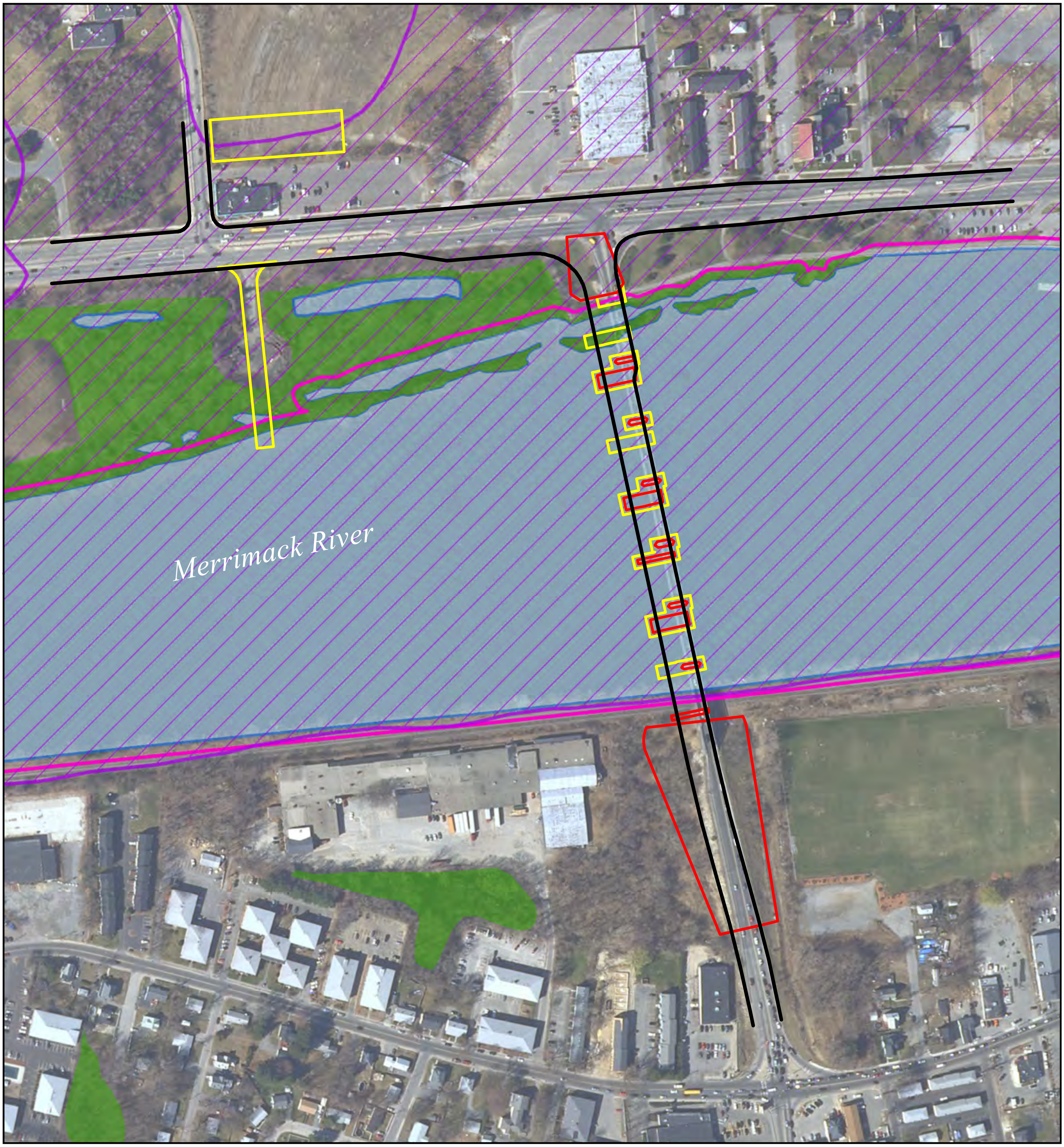
Protected and Recreational Open Space
Municipal
Private
State Owned
Massachusetts Historical Areas
State Registered Historic Places
State Registered Historic Sites
Natural Heritage & Endangered Species Program
Priority & Estimated Habitat
Certified Vernal Pool
Potential Vernal Pool

Figure 5-6
March 2013
Alternative 2
Cultural Resources & Protected Species

Alternative 2
Permanent Impact Area
Temporary Impact Area

N

0 125 250 500 Feet



Source: VHB 2013, BING 2009, MassGIS 1997 & 2009, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Wetlands
- Bordering Land Subject to Flooding
- Riverfront Area
- Bank
- Land Under Water & Waterbodies
- Bordering Vegetated Wetland

N

0 125 250 500 Feet

Figure 5-7
March 2013
Alternative 2
Wetland Resource Areas

- Alternative 2
- Permanent Impact Area
- Temporary Impact Area

> ➤ **Recommendation – Retain Alternative 2 for consideration in future studies.**

5.1.2 Alternative 4: Western Bypass Alignment (4-lane)

Alternative 4 includes construction of a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) just west of the existing bridge with improved pedestrian and bicycle accommodations. The new bridge would maintain connections to Pawtucket Boulevard to the north and the Wood Street corridor to the south, as shown graphically in Figure 5-8. Alternative 4 intersection improvements would be the same as those discussed as part of Alternative 2 with one exception. Due to the slight relocation under Alternative 4, the Rourke Bridge would be aligned with the bowling alley driveway, creating a four-legged intersection with Pawtucket Boulevard.

If this alternative advances, signal coordination across the bridge and along Pawtucket Boulevard should be investigated further and incorporated into the design as appropriate. Conceptual improvements to the intersection of Middlesex Street at Rourke Bridge/Wood Street, the southern end of the bridge, are discussed in a subsequent section. The final improvements would be determined and vetted through the environmental permitting process, once a preferred bridge alternative has been selected.

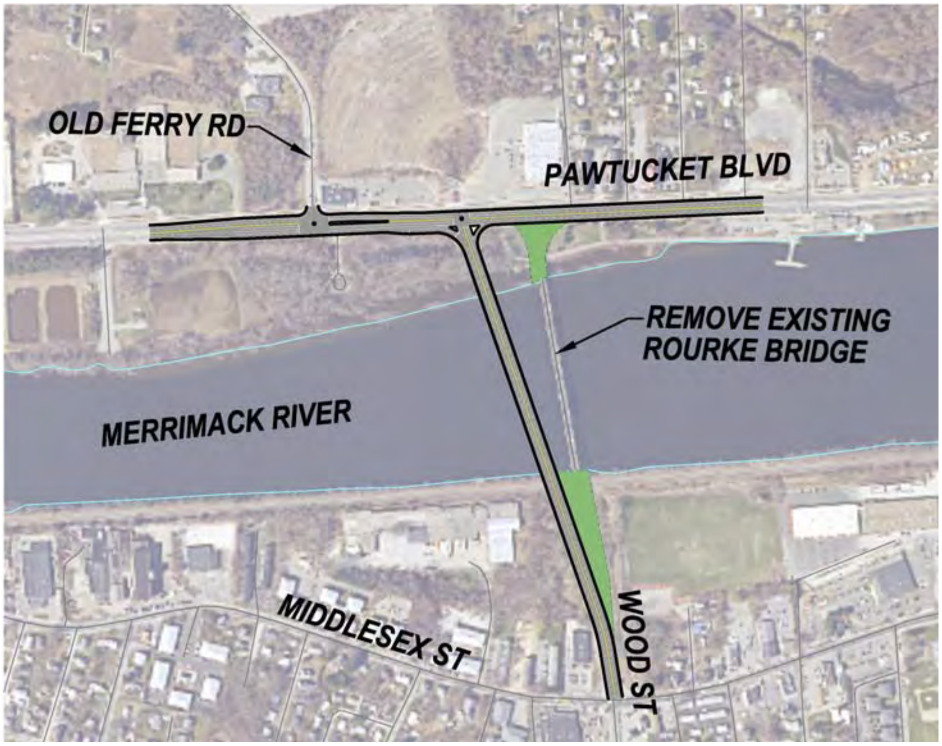


Figure 5-8 **Alternative 4: Western Bypass Alignment**

Alternative 4 would have the following effects:

- **Transportation Mobility** – The transportation mobility impacts of Alternative 4 are identical to those discussed under Alternative 2.
- **Safety** – Alternative 4 would mitigate the high crash intersection of Pawtucket Boulevard at Rourke Bridge.
- **Multimodal Benefits** – The multimodal benefits of Alternative 4 are identical to those discussed under Alternative 2.
- **Structural**
    - **Total Bridge Length** – With the slight skew to the west, the total bridge length would increase to approximately 1,200 feet – a 10 percent increase from the existing bridge alignment.
    - **Span Arrangement** – A total of five spans with a maximum span of 305 feet. Four continuous spans over the waterway and one simple span between the south abutment and southernmost pier.
        - All piers in waterway accessible by barge – reducing environmental impacts.

- A balanced continuous span layout that greatly reduces the number of waterway piers while maintaining all of the required clearances.
- An overall wider channel that would stretch throughout the entire 305' span.
- The pier south of the railroad was added to reduce the span over the railroad and satisfy minimum railroad clearances.

- **Temporary Potential Impacts –** Construction laydown areas and access roads would be required to construct the south approach, abutment and pier south of the railroad. Access is also required at the north approach to construct the temporary tower and erect the plate girders inaccessible by barge. Water access would be obtained through the construction access road at the north abutment. Additional laydown area may be required for parking and additional storage in the privately owned field north of Pawtucket Boulevard. Cofferdams would be placed around all of the piers and temporary towers in the waterway assuming a 10-foot offset from existing and proposed structures. The temporary potential impact areas presented in this alternative are approximately 113,000 SF.
- **Permanent Potential Impacts** – A full height abutment was used at the north approach to prevent any susceptibility to scour and excessive wetland impacts. A stub abutment was used at the south approach since there were relatively no restrictions. There is a potential property impact where the southwest approach embankment overlaps a portion of the adjacent private property. The span arrangement presented will consist of three permanent piers in the waterway and one pier inland. The permanent potential impact areas presented in this alternative are approximately 153,000 SF.
- **Constructability Issues** – Alternative 4 provides an alignment where the bridge can be built in one phase. Coordination will be required with the B&M Railroad for all construction in close proximity to the railroad.

➤ **Economic Development –** Alternative 4 would reduce travel time and move people and goods more efficiently over the Rourke Bridge, improving economic development potential in the region. If this alternative advances, potential impacts to the bowling alley, CVS, and the proposed Lowell Charter School (visual only) should be reviewed in detail.

➤ **Environmental Justice (EJ) –** Alternative 4 would improve pedestrian and bicycle mobility for the adjacent minority and disadvantaged population.

➤ **Environmental –** Alternative 4 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure. This alternative would potentially impact 985 linear feet of Bank, 24,577 square feet of BVW, 46,215 square feet of Land Under Water, 28,169 square feet of BLSF and 4,597 square feet of Riverfront Area and 1.12 acres of disturbance to protected open space, as shown in Figures 5-9 and 5-10.

Source: VHB 2013, BING 2009, MassGIS 2008, 2009, 2012 & 2013, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Protected and Recreational Open Space
- Municipal
- Private
- State Owned

Massachusetts Historical Areas
- State Registered Historic Places
- State Registered Historic Sites

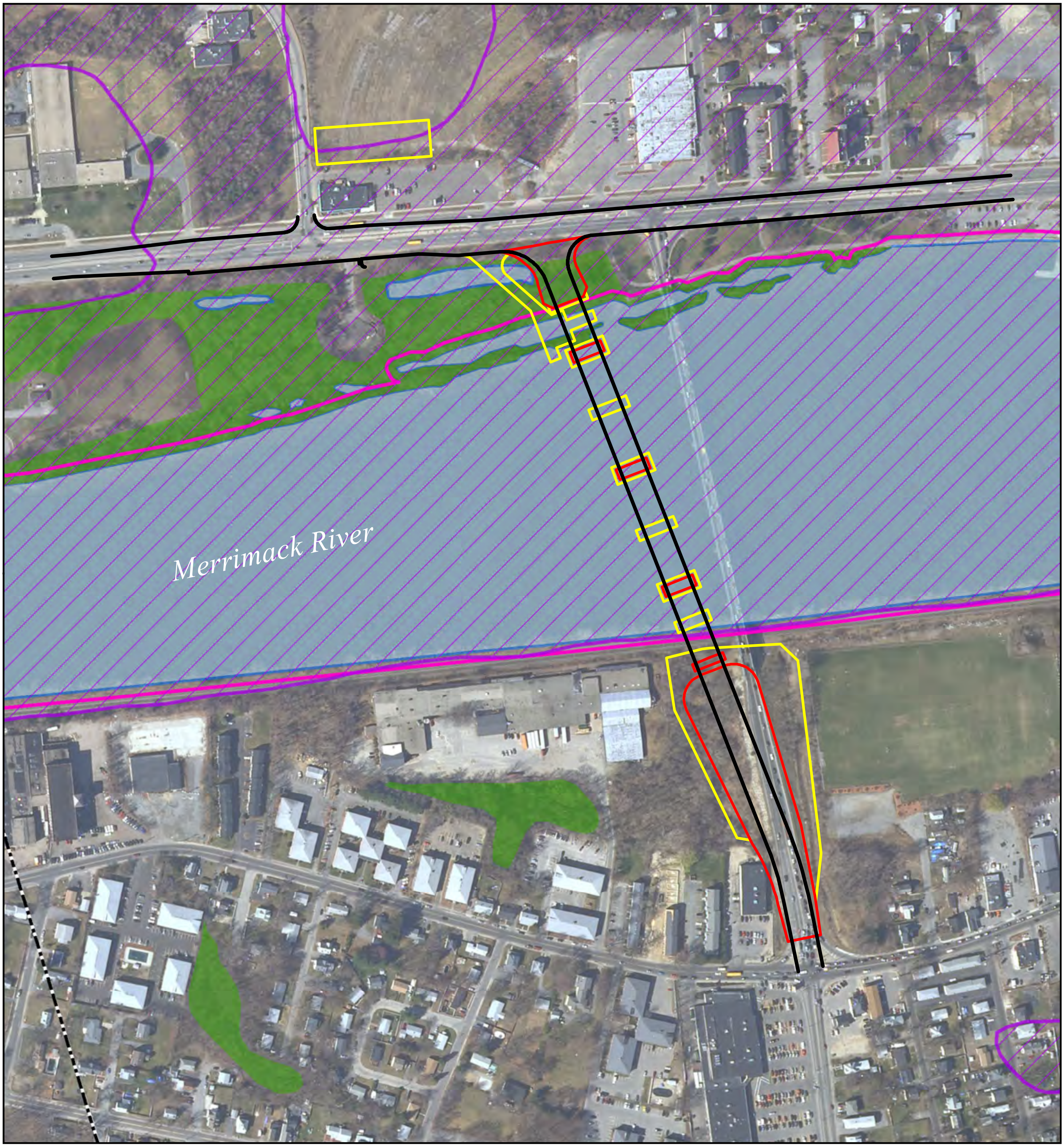
Natural Heritage & Endangered Species Program
- Priority & Estimated Habitat
- Certified Vernal Pool
- Potential Vernal Pool

Figure 5-9
March 2013
Alternative 4
Cultural Resources & Protected Species

- Alternative 4
- Permanent Impact Area
- Temporary Impact Area

N

0 155 310 620 Feet



Source: VHB 2013, BING 2009, MassGIS 1997 & 2009, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Wetlands
- Bordering Land Subject to Flooding
- Riverfront Area
- Bank
- Land Under Water & Waterbodies
- Bordering Vegetated Wetland

Figure 5-10
March 2013
Alternative 4
Wetland Resource Areas

- Alternative 4
- Permanent Impact Area
- Temporary Impact Area

N

0 150 300 600 Feet

- **Lasting Benefits –** This alternative is projected to accommodate 2035 traffic volumes. The bridge structure itself is designed with a lifespan of 75 years.
- **Community Support** – Alternative 4 is generally supported by members of the TWG, SAC, and the public. The Lowell City Council has voted to endorse Alternative 4 for further study.

- ***Preliminary Order of Magnitude Cost Estimate: $60.9 million (details included in the Report Appendix)***

- **Recommendation – Retain Alternative 4 for consideration in future studies.**

5.1.3 Alternative 5: Western Bypass Alignment (4-lane) with Grade-Separation

Alternative 5 is a variation on Alternative 4 and would modify connections on the north side of the river, as shown graphically in Figure 5-11:

- The new Rourke Bridge would travel over Pawtucket Boulevard and intersect Old Ferry Road at a signalized, at-grade, "T" intersection;
- "Right-on/right-off" connections from/to Pawtucket Boulevard to the bridge would be maintained via slip ramps;
- Bicycle accommodations would be provided along the length of the structure to the at-grade intersection with Old Ferry Road; and
- Pedestrian accommodations at Pawtucket Boulevard would be modified to connect the sidewalks on both sides of the new Rourke Bridge with the pedestrian pathways along the river.

In addition to signal timing optimization, the following intersection upgrades are included under Alternative 5:

- **Old Ferry Road at Rourke Bridge**
  - Provide separate westbound left-turn and right-turn lanes off of the Rourke Bridge;
  - Provide a northbound right-turn lane; and
  - Provide a southbound left-turn lane.

- **Old Ferry Road at Varnum Avenue**
  - Install a fully-actuated traffic signal; and
  - Provide westbound left-turn lane.

If this alternative advances, signal coordination across the bridge and along Old Ferry Road should be investigated further and incorporated into the design as appropriate. Conceptual improvements to the intersection of Middlesex Street at Rourke Bridge/Wood Street, the southern end of the bridge, are discussed in a subsequent section. The final improvements would be determined and vetted through the environmental permitting process, once a preferred bridge alternative has been selected.

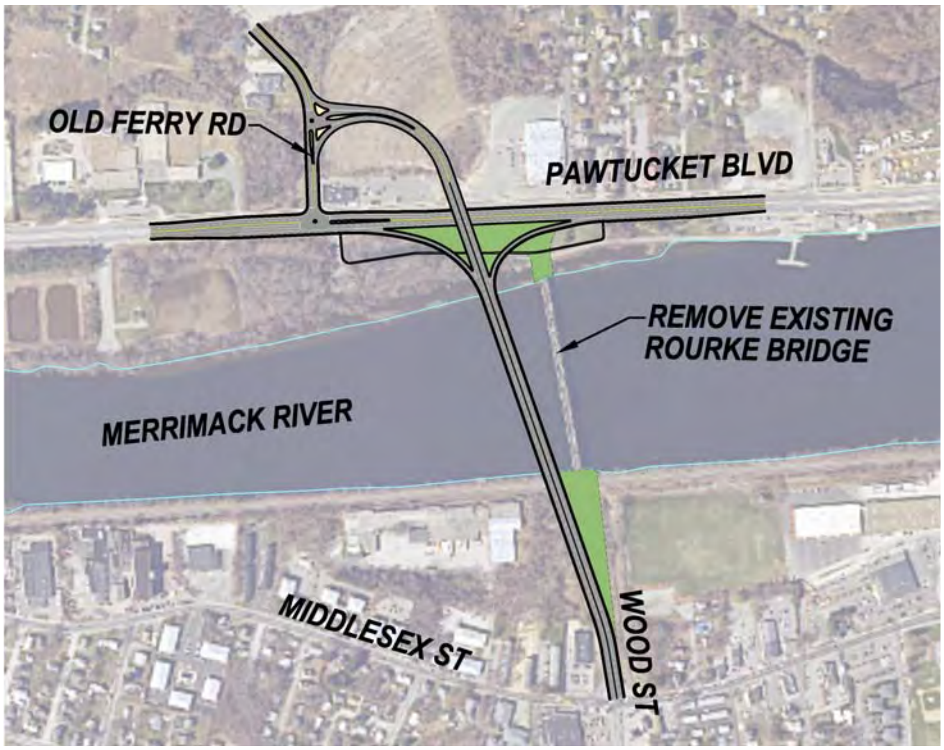


Figure 5-11 Alternative 5: Western Bypass Alignment

The impacts of Alternative 5 (the grade-separated option) differ from Alternative 4 in the following ways:

- **Transportation Mobility** – The transportation mobility impacts of Alternative 5 are identical to those discussed under Alternatives 2 and 4.
- **Safety** – Alternative 5 would mitigate the high crash intersection of Pawtucket Boulevard at Rourke Bridge.
- **Multimodal Benefits** – The multimodal benefits of Alternative 5 are identical to those discussed under Alternatives 2 and 4, with one exception. It should be

noted that due to the grade-separation of the Rourke Bridge over Pawtucket Boulevard, bicyclists would travel further under Alternative 5 (when compared to the existing Rourke Bridge) to access Pawtucket Boulevard. The choice of a multi-use path in lieu of bicycle lanes and sidewalks may add to the support needs of the grade-separated structure, increasing costs associated with design and construction. The pedestrian crossing distance would be comparable to the existing Rourke Bridge; however, pedestrians would be required to walk down steps/ramps to access the paths along Pawtucket Boulevard under this alternative. Accommodations would be compliant with the Americans with Disabilities Act.

- **Structural**
  - **Total Bridge Length** – As a result of spanning over the Pawtucket Boulevard the total bridge length would increase to approximately 1,500 feet - a 36 percent increase from the existing bridge alignment. The on/off flyover ramps north of the river total approximately 370 feet in addition to the 1,500 foot main structure.
  - **Span Arrangement** – A total of nine spans (including the on/off ramps) with a maximum span of 360 feet. Five continuous spans and four simple spans including the on/off ramps and spans over and south of the railroad.
    - Single span curved girders structures were used for the on/off ramps to span over a majority of the wetlands.
    - A pier was assumed to support the on/off ramps at their connection to the main bridge.
    - The grade separation north of the river enabled the main span to be centered on the waterway, stretching nearly the entire 360 foot span.
    - Piers were considered north and south of the river to meet the roadway and railroad clearance requirements.
  - **Temporary Potential Impacts** – Construction laydown areas and access roads would be required to construct the south approach, abutment and pier south of the railroad. Access is also required north of the river to construct the temporary towers and piers to erect the plate girders inaccessible by barge. Water access would be obtained through the construction access road between Pawtucket Boulevard and the river. Additional laydown area may be required for parking and additional storage in the privately owned field north of Pawtucket Boulevard. Cofferdams would be placed around all of the piers and temporary towers in the waterway assuming a 10-foot offset from existing and proposed structures. The temporary potential impact areas presented in this alternative are approximately 124,000 SF.
  - **Permanent Potential Impacts** – The Study Team considered full height abutments at the on/off ramps due to the pedestrian path to the east and excessive wetland impacts to the west. To help with clearance issues, the span over Pawtucket Boulevard was minimized by assuming a full

height abutment at the north approach. A stub abutment was used at the south approach since there were relatively no restrictions. There is a potential property impact where the southwest approach embankment overlaps a portion of private property. Land acquisition would be required to construct the north approach connected to Old Ferry Road. The span arrangement presented will consist of four permanent piers in the waterway and two piers inland. The permanent potential impact areas presented in this alternative are approximately 263,000 SF.

- **Constructability Issues** – The bridge segment construction spanning over Pawtucket Boulevard may require a temporary tower in the roadway. This temporary tower along with the superstructure erection over the Boulevard may cause disruptions in the surrounding traffic networks.

  The east off-ramp cannot be constructed until the existing bridge is removed. The only access onto Pawtucket Boulevard during the removal of the existing bridge would be through Old Ferry Road. This temporary longer travel route would cause a user inconvenience for vehicles and pedestrians that wish to travel eastbound on Pawtucket Boulevard.

- Coordination will be required with the B&M Railroad for all construction in close proximity of the railroad.

➤ **Economic Development –** Alternative 5 would reduce travel time and move people and goods more efficiently over the Rourke Bridge, improving economic development potential in the region. This alternative would bisect the currently vacant drive-in movie parcel on the north side of the river, impacting future development potential for this property. If this alternative advances, potential impacts to the bowling alley, CVS, and the proposed Lowell Charter School (visual only) should be reviewed in detail.

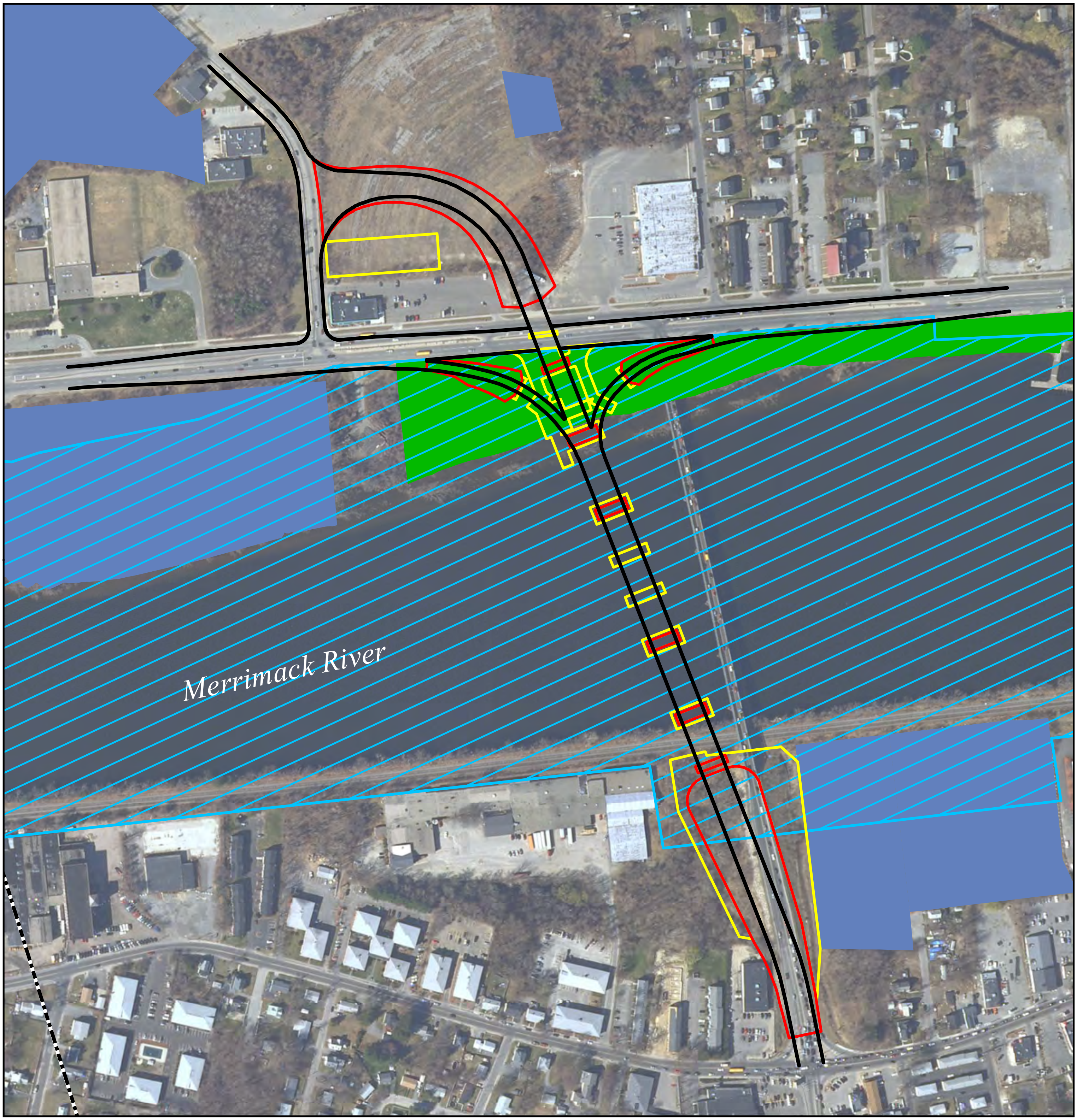
➤ **Environmental Justice (EJ) –** Alternative 5 would improve pedestrian and bicycle mobility for the adjacent minority and disadvantaged populations.

➤ **Environmental –** Alternative 5 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure. This alternative would potentially impact 939 linear feet of Bank, 21,989 square feet of BVW, 47,673 square feet of Land Under Water, 94,882 square feet of BLSF and 5,597 square feet of Riverfront Area and 1.83 acres of disturbance to protected open space, as shown in Figures 5-12 and 5-13.

➤ **Lasting Benefits –** This alternative is projected to accommodate 2035 traffic volumes. The bridge structure itself is designed with a lifespan of 75 years.

➤ **Community Support** – After a review of the alternatives, the Lowell City Council has voted to eliminate Alternative 5 from further consideration due to economic development impacts to the currently vacant drive-in movie parcel on the north side of the river.

\\mawatr\ts\11906.00\GIS\Project\Alternative_5_CRPS.mxd



Source: VHB 2013, BING 2009, MassGIS 2008, 2009, 2012 & 2013, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

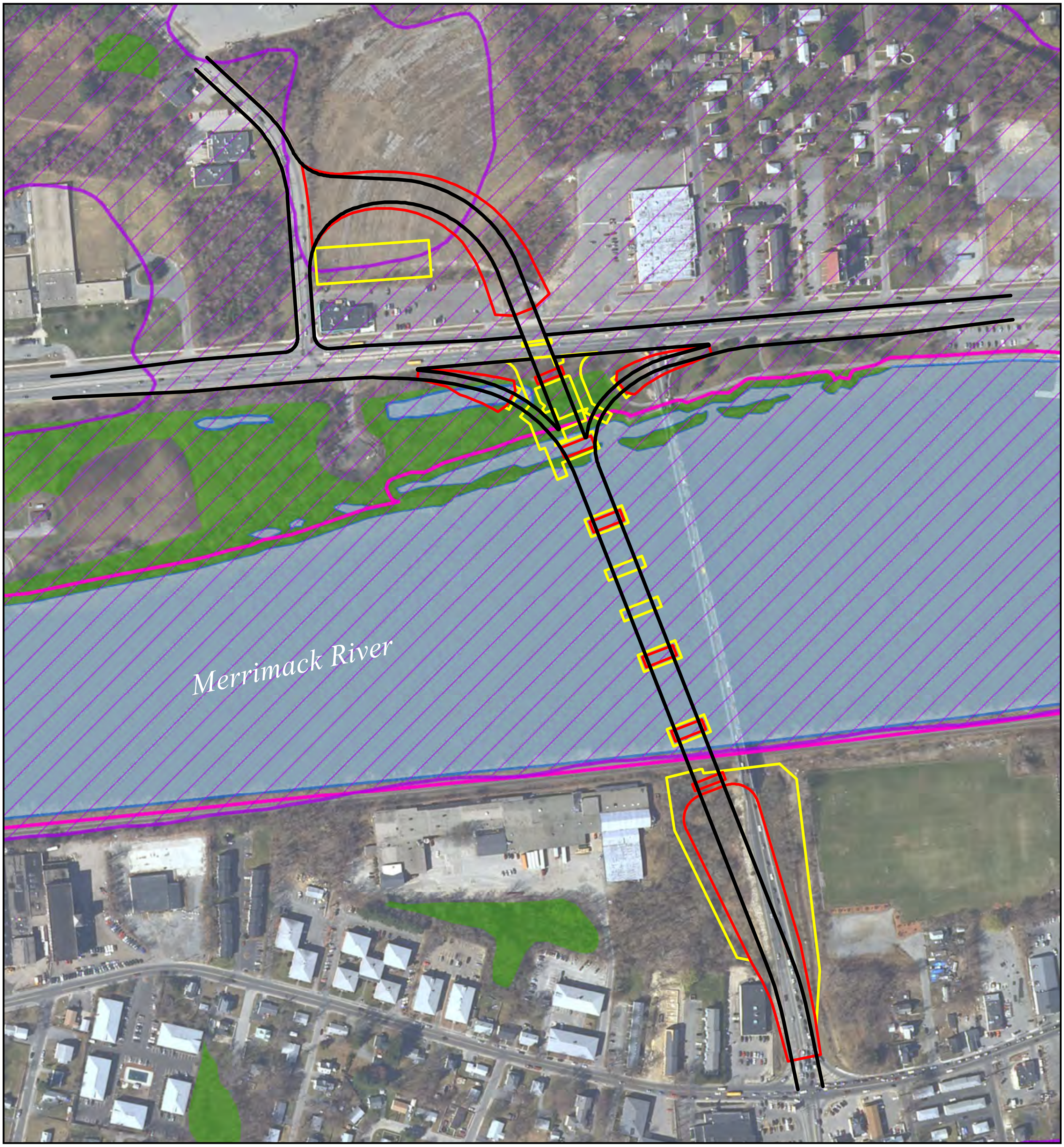
Protected and Recreational Open Space
Municipal
Private
State Owned
Massachusetts Historical Areas
State Registered Historic Places
State Registered Historic Sites
Natural Heritage & Endangered Species Program
Priority & Estimated Habitat
Certified Vernal Pool
Potential Vernal Pool

Figure 5-12
March 2013
Alternative 5
Cultural Resources & Protected Species

Alternative 5
Permanent Impact Area
Temporary Impact Area

N

0 150 300 600 Feet



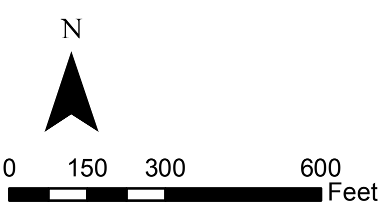
Source: VHB 2013, BING 2009, MassGIS 1997 & 2009, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Wetlands
- Bordering Land Subject to Flooding
- Riverfront Area
- Bank
- Land Under Water & Waterbodies
- Bordering Vegetated Wetland

Figure 5-13
March 2013
Alternative 5
Wetland Resource Areas

- Alternative 5
- Permanent Impact Area
- Temporary Impact Area



- ***Preliminary Order of Magnitude Cost Estimate: $82.4 million (details included in the Report Appendix)***

- **Recommendation – Discard Alternative 5 from consideration in future studies <u>based on public input due to potential economic development impacts.</u> Although is alternative is being eliminated from further consideration at this stage, it is possible that a NEPA review would require a full assessment at a later date since the alternative was not discarded for technical reasons.**

5.1.4 Alternative 6: Skewed Bypass Alignment (4-lane)

Alternative 6 includes construction of a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) west of the existing bridge with improved pedestrian and bicycle accommodations. The new bridge would be skewed in a northwesterly direction, providing a northern connection along Pawtucket Boulevard opposite Old Ferry Road; the existing connection to the Wood Street corridor to the south would be maintained. Alternative 6 is shown graphically in Figure 5-14 and includes the following intersection upgrades:

- **Pawtucket Boulevard at Old Ferry Road /Rourke Bridge**
  - Provide dual eastbound right-turn lanes;
  - Provide dual westbound left-turn lanes;
  - Provide separate northbound left-turn, through, and right-turn lanes; and
  - Provide southbound left-turn, through, and through/right-turn lanes.

- **Old Ferry Road at Varnum Avenue**
  - Install a fully-actuated traffic signal; and
  - Provide a westbound left-turn lane.

If this alternative advances, signal coordination across the bridge and along Old Ferry Road should be investigated further and incorporated into the design as appropriate. Conceptual improvements to the intersection of Middlesex Street at Rourke Bridge/Wood Street, the southern end of the bridge, are discussed in a subsequent section. The final improvements would be determined and vetted through the environmental permitting process, once a preferred bridge alternative has been selected.

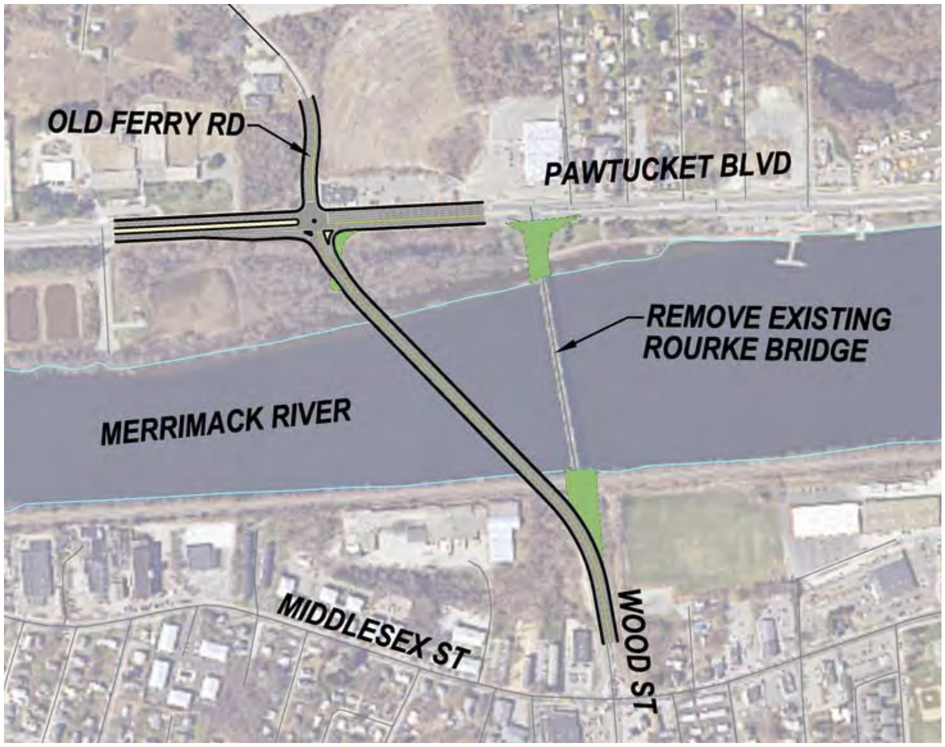


Figure 5-14 **Alternative 6: Skewed Bypass Alignment**

Alternative 6 would have the following effects:

- **Transportation Mobility** – The transportation mobility impacts of Alternative 6 are identical to those discussed under Alternatives 2, 4, and 5.
- **Safety** – Alternative 6 would mitigate the high crash intersection of Pawtucket Boulevard at Rourke Bridge.
- **Multimodal Benefits** – The multimodal benefits of Alternative 6 are identical to those discussed under Alternatives 2, 4, and 5.
- **Structural**
  - **Total Bridge Length –** With the skew to the west aligning with Old Ferry Road, the total bridge length would increase to approximately 1,380 feet – a 25 percent increase from the existing bridge alignment.
  - **Span Arrangement** – A total of six spans with a maximum span of 320 feet. Five continuous spans over the waterway and railroad and a simple span south of the railroad.

  - Overall wider channel stretching a majority of the 320 foot center span.
  - All waterway piers accessible by barge – reducing environmental impacts.
  - Additional pier considered south of the railroad to satisfy the required vertical clearances.

- **Temporary Potential Impacts** – Construction laydown areas and access roads would be required south of the bridge to construct the south approach, abutment and landlocked pier and temporary tower. Access would be required at the north approach to construct the temporary tower and erect the plate girders inaccessible by barge. Water access would be obtained through the construction access road near the north abutment. Additional laydown area may be required for parking and additional storage in the privately owned field north of Pawtucket Boulevard. Cofferdams would be placed around all of the piers and temporary towers in the waterway assuming a 10-foot offset from existing and proposed structures. The temporary potential impact areas presented in this alternative are approximately 125,000 SF.
- **Permanent Potential Impacts** – The Study Team considered a full height abutment at the north approach to prevent excessive wetland impacts. A stub abutment was used at the south approach since there were relatively no restrictions. The span arrangement presented will consist of four permanent piers in the waterway and one pier inland. There are potential property impacts on both sides of Old Ferry Road due to the upgrades at the Pawtucket Boulevard at Old Ferry Road/Rourke Bridge intersection. The permanent potential impact areas presented in this alternative are approximately 165,000 SF.
- **Constructability Issues** – Coordination will be required with the B&M Railroad for all construction in close proximity of the railroad.

➤ **Economic Development –** Alternative 6 would reduce travel time and move people and goods more efficiently over the Rourke Bridge, improving economic development potential in the region. If this alternative advances, potential impacts to the bowling alley, CVS, and the proposed Lowell Charter School (visual only) should be reviewed in detail.

➤ **Environmental Justice (EJ) –** Alternative 6 would improve pedestrian and bicycle mobility for the adjacent minority and disadvantaged population.

➤ **Environmental –** Alternative 6 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure. This alternative would potentially impact 943 linear feet of Bank, 18,687 square feet of BVW, 45,646 square feet of Land Under Water, 50,871 square feet of BLSF and 6,299 square feet of Riverfront Area and 0.11 acre of disturbance to protected open space, as shown in Figures 5-15 and 5-16.

Source: VHB 2013, BING 2009, MassGIS 2008, 2009, 2012 & 2013, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

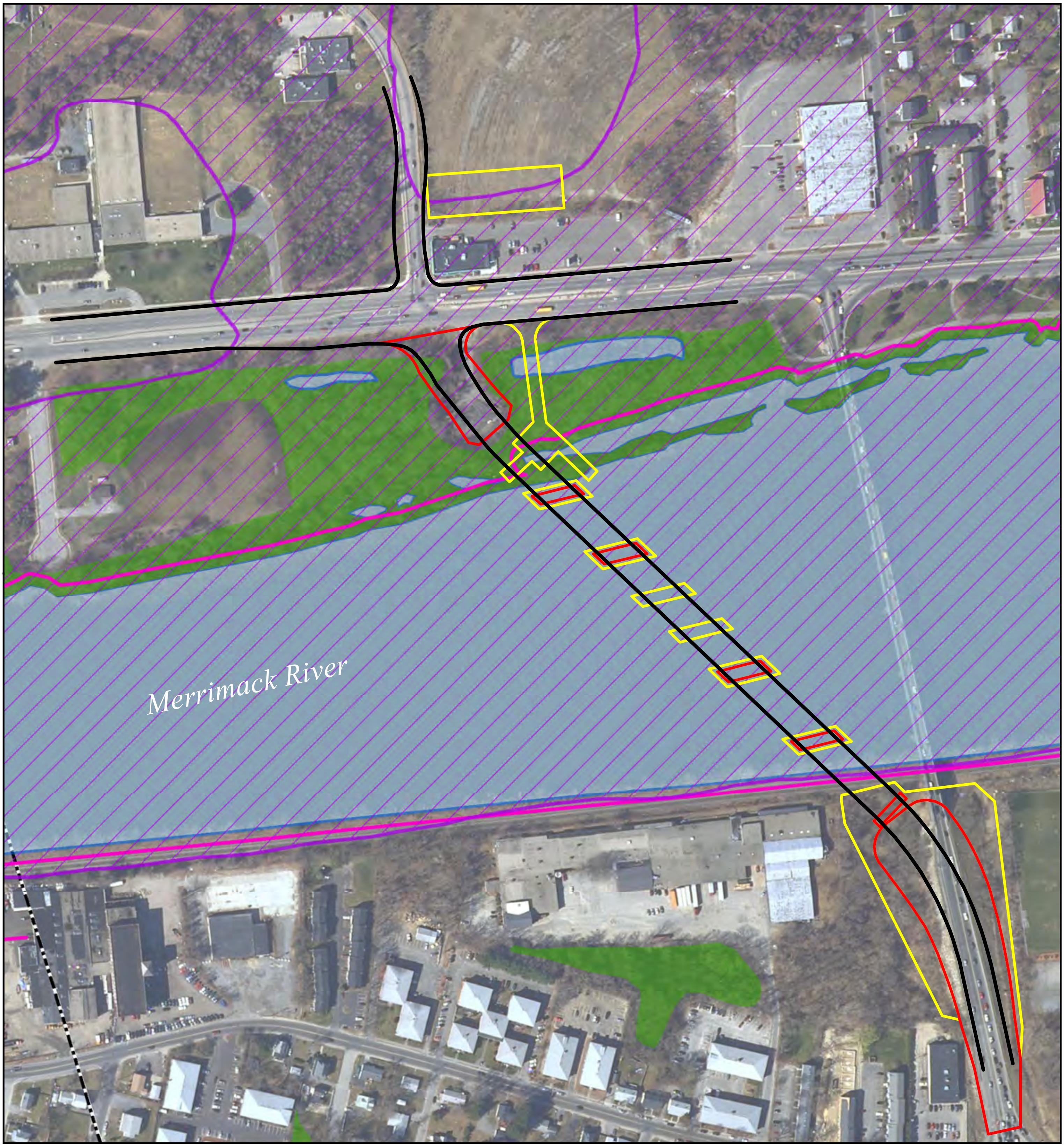
Protected and Recreational Open Space
Municipal
Private
State Owned
Massachusetts Historical Areas
State Registered Historic Places
State Registered Historic Sites
Natural Heritage & Endangered Species Program
Priority & Estimated Habitat
Certified Vernal Pool
Potential Vernal Pool

Figure 5-15
March 2013
Alternative 6
Cultural Resources & Protected Species

Alternative 6
Permanent Impact Area
Temporary Impact Area

N

0 125 250 500 Feet



Source: VHB 2013, BING 2009, MassGIS 1997 & 2009, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Wetlands
- Bordering Land Subject to Flooding
- Riverfront Area
- Bank
- Land Under Water & Waterbodies
- Bordering Vegetated Wetland

Figure 5-16
March 2013
Alternative 6
Wetland Resource Areas

- Alternative 6
- Permanent Impact Area
- Temporary Impact Area

N

0 125 250 500 Feet

- **Lasting Benefits –** This alternative is projected to accommodate 2035 traffic volumes. The bridge structure itself is designed with a lifespan of 75 years.
- **Community Support** – Alternative 6 is generally supported by members of the TWG, SAC, and the public. The Lowell City Council has voted to endorse Alternative 6 for further study.

- ***Preliminary Order of Magnitude Cost Estimate: $67.8 million (details included in the Report Appendix)***

- **Recommendation – Retain Alternative 6 for consideration in future studies.**

5.1.5 Alternative 7: Western Relocation Alignment - Vinal Square (4- lane)

Alternative 7 includes construction of a new 4-lane permanent structure (2 lanes northbound and 2 lanes southbound) with improved pedestrian and bicycle accommodations. The new bridge would be located approximately one-mile west of the current Rourke Bridge and would replace the existing structure. Under Alternative 7, the bridge would intersect Pawtucket Boulevard opposite Wedgewood Circle to the north and Vinal Square to the south. This alternative would require the reconfiguration of intersections and/or roadways in Vinal Square. Access to Route 3 would be provided along the Route 40/Groton Road and Route 4/North Road corridors. Alternative 7 is shown graphically in Figure 5-17.

Figure 5-17 **Alternative 7: Western Relocation Alignment – Vinal Square**

Alternative 7 would have the following effects:

- **Transportation Mobility** – Travel demand modeling and capacity analysis of Alternative 7 determined the following:
  - **Demand** – Alternative 7 would result in between 5 and 15 percent fewer peak hour trips than the existing Rourke Bridge, indicating that the relocated bridge does not serve origin-destination needs as well as the existing bridge location (Table 5-3).
  - **Regional Impacts** – As shown in Table 5-3, Alternative 7 would divert approximately 30 percent of existing Rourke Bridge peak hour trips to the O'Donnell (School Street) and University Avenue bridges (includes trips that cross the river twice). Also, the volume of peak hour trips crossing the river twice would more than double under Alternative 7, resulting in additional traffic on the O'Donnell (School Street) Bridge and University Avenue Bridge. Alternative 7 would reduce traffic volumes on the Wood Street corridor and would increase traffic volumes on Route 4/North Road and, to a lesser extent, the Route 40/Groton Road for trips accessing Route 3.
  - **Operations** – Based on capacity analysis results presented in the "Vinal Square Traffic and Safety Study[11] and included in the Technical Appendix, the signalized intersection in Vinal Square is projected to

▼

[11] Vinal Square Traffic and Safety Study; Northern Middlesex Council of Governments; August 2012.

operate at LOS F under 2025 future conditions (with the proposed commuter rail station). Should Alternative 7 advance, intersections in Vinal Square would be reconfigured and an additional signal to accommodate the new Rourke Bridge approach would likely be required. With these improvements, it is likely that operations in Vinal Square could improve over 2025 projected future conditions. (Note: The "Vinal Square Traffic and Safety Study" presented a different future horizon year, which is why comparisons are made to 2025.)

- **Travel Times** – Travel time analysis was not completed for Alternative 7 as this option was ultimately discarded from further study.
- **Emergency Vehicle Access** – Alternative 7 degrades emergency vehicle access for Lowell General Hospital and other medical facilities along the Wood Street corridor. While the capacity of the existing Rourke Bridge is limited, the location of the structure serves the emergency response access needs of these facilities.

Table 5-3 Rourke Bridge Peak Hour Traffic Shifts: 2035 Baseline to Alternatives 7

	2035 Traffic Volume Differences	
Roadway	**AM Peak Hour**	**PM Peak Hour**
Rourke Bridge	-85	-330
Wood Street	-665	-750
Route 113	+210	-50
Varnum Avenue	-85	-90
Old Ferry Road	-115	-135
Pawtucket Street	+685	+715
O'Donnell Bridge	+395	+485

- **Safety** – Alternative 7 would remove traffic volumes from the high crash intersections on either side of the existing Rourke Bridge and along the Wood Street/Westford Street/Drum Hill Road corridor.
- **Multimodal Benefits** – Similar to other alternatives, Alternative 7 would improve pedestrian and bicycle accommodations across the bridge by providing 6-foot sidewalks and 5-foot bicycle lanes in both directions. A multi-use path can also be considered. However, this alternative removes the pedestrian/bicycle connection between residential neighborhoods and parkland on the north side of the river with retail land uses and neighborhoods along the south side of the

river. The new Rourke Bridge would be designed to accommodate transit vehicles.

- **Structural**
  - **Total Bridge Length** – By taking advantage of a narrow portion of the Merrimack River, the bridge would have a total span over the waterway of approximately 800 feet – a 27 percent decrease from the existing bridge alignment. However, this alignment alternative requires that a bridge be built over Wotton Street and the adjacent B&M railroad resulting in a total structure length of 1,115 feet.
  - **Span Arrangement** – A total of eight spans with a maximum span of 250 feet. A four span continuous bridge over the river, a single span bridge over Wotton Street and a three span bridge over the railroad.
    - Maximized the main channel width while keeping the outer most piers far enough away from the shoreline to take advantage of barge construction.
  - **Temporary Potential Impacts** – The Study Team considered separate construction laydown areas and access roads at the bridge over Wotton Street, the B&M Railroad, and at each approach adjacent to the river. An additional space may be required in a privately owned parking lot north of the river at 1001 Pawtucket Boulevard to accommodate employee parking and further storage. These laydown areas and access roads may require temporary easements from adjacent private properties such as the Parlee Building and Adams Farm Condominiums. Water access could be obtained through the laydown area at the east approach. Cofferdams would be placed around all of the piers and temporary towers in the waterway assuming a 10-foot offset from existing and proposed structures. The temporary potential impact areas presented in this alternative are approximately 190,000 SF.
  - **Permanent Potential Impacts** – The Study Team presumed that embankments rather than additional bridge structure would be used between the Wotton Street, B&M Railroad and river crossings. To prevent susceptibility to scour, the east abutment at the waterline was considered full height rather than a stub abutment. The remaining abutments allowed for the use of stub abutments. The span arrangement presented will consist of three permanent piers in the waterway and two piers inland adjacent to the railroad. Alternative 7 has the most permanent property impacts out of all of the alternatives considered. A land acquisition will be required near the Parlee Building to construct the west approach. Another land acquisition may be required north of Adams Farm Condominiums located just south of the proposed railroad crossing. The proposed intersection southwest of the west approach will run through several parcels and will require the removal of several buildings including the Reed Factory Building and the Lincoln Drake House. The permanent potential impact areas presented in this alternative are approximately 304,000 SF.

- **Constructability Issues** – Construction of the bridge spanning over Wotton Street may impact the surrounding traffic networks. This alignment proposes rebuilding an intersection south of Route 3A. This intersection will require land takings and the demolition of historic buildings. Access and the delivery of materials may be difficult west of the river due to the limited available local roads adjacent to the site, crossing of the railroad, and isolated the location of the west approach spanning the river. Coordination may be required with the B&M Railroad for all construction in close proximity of the railroad.

- **Economic Development –** While Alternative 7 would reduce travel time and move people and goods more efficiently over the Rourke Bridge itself, the alternative would have impacts to the broader transportation network that could degrade economic development potential in the region. If this alternative advances, potential impacts to the businesses and residential properties in Vinal Square and to the existing office building on the north side of the river should be reviewed in detail. Removal of traffic from the Wood Street corridor could adversely affect businesses in the vicinity of the existing bridge crossing.

- **Environmental Justice (EJ) –** Alternative 7 would improve pedestrian and bicycle mobility in Vinal Square, but it would degrade conditions for the adjacent minority and disadvantaged populations in the vicinity of the existing Rourke Bridge.

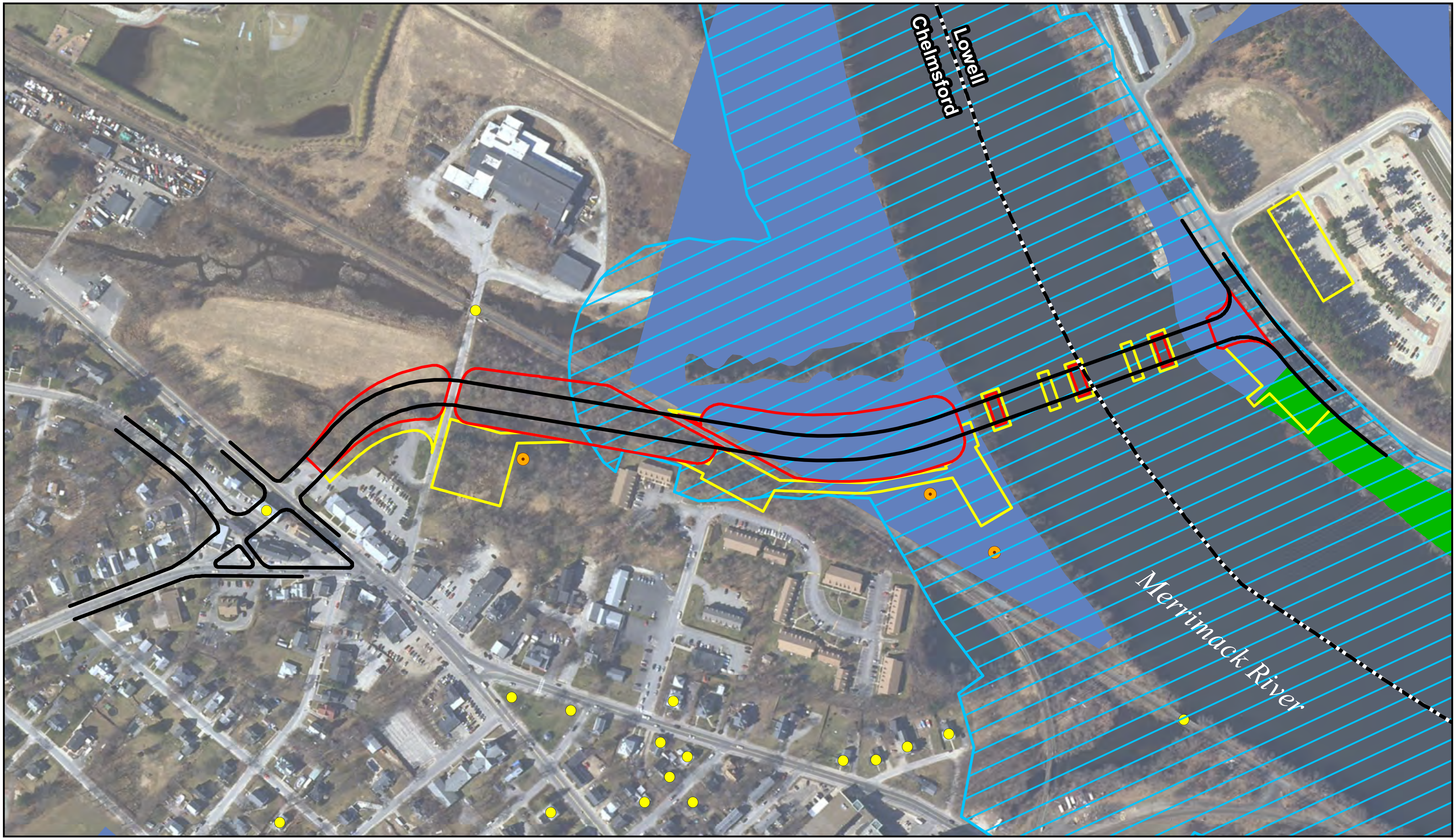
- **Environmental –** Alternative 7 would have environmental and cultural impacts associated with work required to remove the temporary structure and construct the new 4–lane permanent structure. This alternative would potentially impact 714 linear feet of Bank, 244,578 square feet of BVW, 34,342 square feet of Land Under Water, 196,928 square feet of BLSF, and 206,462 square feet of Riverfront Area and 4.62 acres of disturbance to protected open space, as shown in Figures 5-18 and 5-19. Alternative 7 would also require the removal of the historic Adams Reed Factory, located at 15-21 Dunstable Road in Chelmsford.

- **Lasting Benefits –** This alternative is projected to accommodate 2035 traffic volumes. The bridge structure itself is designed with a lifespan of 75 years.

- **Community Support** – Alternative 7 generally is not supported by members of the TWG, SAC, and the public.

- ***Preliminary Order of Magnitude Cost Estimate: $61.3 million (details included in the Report Appendix)***

- **Recommendation – Discard Alternative 7 from consideration in future studies due to <u>transportation, construction, and environmental impacts and limited public support.</u>**



Source: VHB 2013, BING 2009, MassGIS 2008, 2009, 2012 & 2013, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Protected and Recreational Open Space
- Municipal
- Private
- State Owned

Massachusetts Historical Areas
- State Registered Historic Places
- State Registered Historic Sites

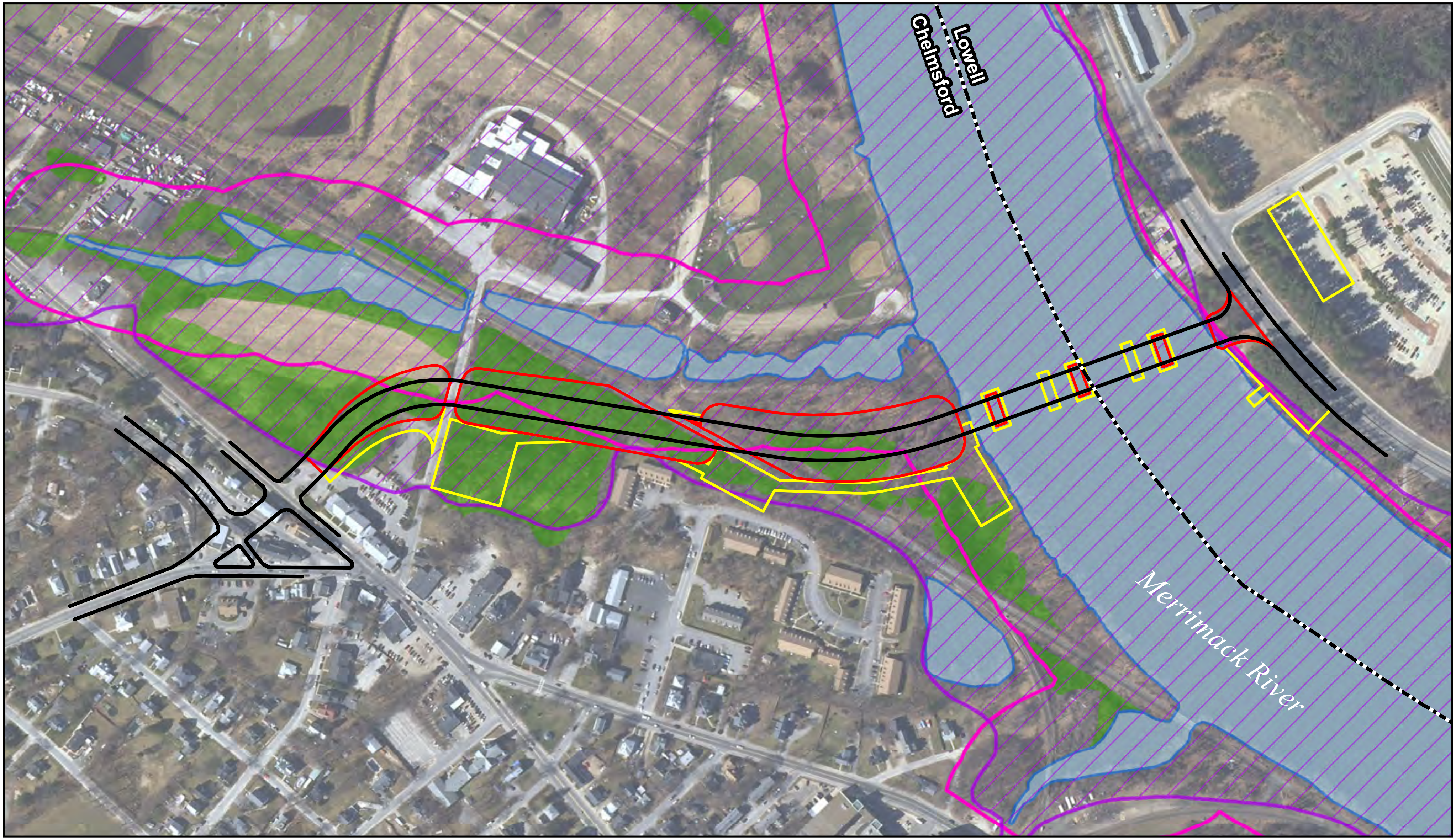
Natural Heritage & Endangered Species Program
- Priority & Estimated Habitat
- Certified Vernal Pool
- Potential Vernal Pool

Figure 5-18
March 2013
Alternative 7
Cultural Resources & Protected Species

- Alternative 7
- Permanent Impact Area
- Temporary Impact Area

N

0 200 400 800 Feet



Source: VHB 2013, BING 2009, MassGIS 1997 & 2009, & TEC, Inc 2013

Vanasse Hangen Brustlin, Inc.

Wetlands
- Bordering Land Subject to Flooding
- Riverfront Area
- Bank
- Land Under Water & Waterbodies
- Bordering Vegetated Wetland

Figure 5-19
March 2013
Alternative 7
Wetland Resource Areas

- Alternative 7
- Permanent Impact Area
- Temporary Impact Area

N

0 200 400 800 Feet

5.1.6 Rourke Bridge Alternatives Summary

The transportation, construction, and environmental impacts of the following five Rourke Bridge alternatives were evaluated in detail:

- Alternative 2: Maintain Existing Alignment (4-lane)
- Alternative 4: Western Bypass Alignment (4-lane)
- Alternative 5: Western Bypass Alignment with Grade-Separation (4-lane)
- Alternative 6: Skewed Bypass Alignment (4-lane)
- Alternative 7: Western Relocation Alignment - Vinal Square (4- lane)

The details of these analyses are discussed above and are summarized in a screening matrix included in the Report Appendix.

Based on the level of analysis conducted in this study, Alternatives 2, 4, 5, and 6 all warrant further evaluation from an environmental, transportation, and structural perspective. There are minimal property constraints on the north side of the river, which allows for flexibility in establishing a connection to the existing transportation infrastructure. Alternatives 2, 4, 5, and 6 all consider different northern connections that will need to be evaluated in greater detail through the environmental process and subsequent design efforts. It should be noted that the Lowell City Council has reviewed the alternatives and has voted to discard Alternative 5 based on potential economic development impacts to the currently vacant drive-in movie parcel on the north side of the river. Although Alternative 5 is being eliminated from further consideration at this stage, it is possible that a NEPA review of this alternative would require a full assessment at a later date.

Based on transportation, construction, and environmental impacts and limited public support, it is recommended that Alternative 7 be discarded from further evaluation in future studies.

5.2 Roadway and Intersection Capacity Enhancements

Roadway and intersection capacity improvements seek to enhance the capacity of the study area transportation network. Two alternatives were developed and evaluated, as discussed below. Capacity analysis results for these improvements are included in the Technical Appendix.

5.2.1 Wood Street/Drum Hill Road Widening

This improvement considers widening of the Wood Street/Westford Street/Drum

Hill Road corridor from the Rourke Bridge to Drum Hill Square. The roadway would be widened from 2-lanes to 4-lanes, with turn lanes at key intersections. The sub-area travel demand model was used to evaluate this alternative and indicated that the widening would have limited regional benefits (i.e. only approximately 100 peak hour trips would be diverted to the widened corridor from other congested roadways in the region).

Analysis of this improvement indicated that widening Wood Street and Westford Street would not substantially improve operations at signalized intersections along the corridor, with the exception of the intersection of Princeton Boulevard at Wood Street in the morning peak hour. For the Drum Hill Road portion of the corridor, operations at signalized intersections are anticipated to improve during both peak hours as a result of widening the roadway from 2-lanes to 4-lanes.

Based on available right-of-way data from the City of Lowell and Town of Chelmsford, it is anticipated that significant commercial and/or residential property impacts and/or takings would be necessary to obtain the required right-of-way for the widened corridor, as shown in Figures 5-20a and 5-20b. The Drum Hill Road section of the corridor (south of Parkhurst Road) has more available right-of-way than the northern portion. Based on a preliminary assessment, parking would be impacted along Drum Hill Road, south of Parkhurst Road, but no impacts to existing buildings are anticipated. Between Parkhurst Road and Technology Drive additional parking spaces would be impacted by widening. An evaluation of the feasibility of reconfiguring the affected parking lots to minimize impacts would be recommended if widening was pursued along this section of the corridor.

North of Technology Drive, the available right-of-way narrows and impacts would be more significant than along the southern portion of the corridor. In particular, environmental resources south and east of Westford Street could be impacted. The Wood Street Apartments to the west of Wood Street and the Jerathmell Bowers House (the oldest home in Lowell) to the east of Wood Street are both in close proximity to the existing roadway and may be impacted by widening. Parking for a condominium complex south of Princeton Boulevard and Market Basket shopping plaza to the west of Wood Street would also be substantially impacted. The exact property impacts and corresponding mitigation measures would be further evaluated during environmental permitting and design, should this improvement advance.

Based on the evaluation of this alternative, it is recommended that widening of the Wood Street/Westford Street/Drum Hill Road corridor be discarded from further consideration due to limited regional transportation benefits and significant commercial property impacts. Evaluation of the feasibility of widening the Drum Hill Road section of the corridor (south of Parkhurst Road or Technology Drive) could be considered further if commercial parking can be reconfigured to accommodate need.

Figure 5-20a Drum Hill Road Widening Concept – Northern Section

Figure 5-20b Drum Hill Road Widening Concept – Southern Section

Middlesex Street at Rourke Bridge/Wood Street

Through the public process, some residents expressed concern that the bridge reconstruction does not address congestion adequately, especially at the intersection of Middlesex Street and Wood Street. Four potential transportation improvements for the Wood Street corridor have been conceptually outlined for discussion purposes, and further analysis of property impacts will be needed in order for decision-makers to determine whether implementation is possible or desirable. As the project is not in the design stages, adequate right-of-way information is not available. Impacts are expected to range from minor encroachment on the property at the northwest corner intersection (currently a CVS) to substantial impacts along the entire west side of the Wood Street corridor (currently occupied by the Market Basket shopping plaza and a condominium complex south of Princeton Boulevard). The exact property impacts and corresponding mitigation measures should be further evaluated during environmental permitting and design. It should be noted that any property acquisitions required to expand the roadway corridor south of the Rourke Bridge would not be funded as part of the construction project. Right-of-way acquisition costs would be the responsibility of the municipality, not MassDOT.

Figures 5-21 through 5-24 present the potential transportation improvement concepts currently under consideration. It should be noted that half of traffic traveling southbound over the Rourke Bridge is destined straight to Wood Street. The remaining half turns right and left to Middlesex Street. Therefore, the inclusion of turn lanes is important. The first two figures illustrate different geometric roadway transitions from two lanes to separate left, through, and right turn lanes. The third (Figure 5-23) widens the bridge departure to four-lanes, providing separate turn lanes and two through lanes. Figure 5-24 illustrates the provision of two through lanes by creating a shared left-through lane. There are no changes along the other intersection approaches. Concepts 1, 2, and 3 all operate at LOS D during both the weekday morning and evening peak hours. Concept 4 operates at LOS E and LOS D during the weekday morning and evening peak hours, respectively. Operations for Concept 4 are reflective of the lack of a left-turn lane for vehicles travelling southbound off the bridge. These results are included in the Technical Appendix.

The concepts shown in Figure 5-21 through 5-24 do not include bicycle accommodations. While bicycle accommodations along this corridor are important and should be considered, the decision on what facility is provided (shared lane markings or bike lane) is contingent on what alternative is ultimately selected for the Middlesex Street at Rourke Bridge/Wood Street intersection and for the corridor as a whole (i.e. widened or not). As such, bicycle accommodations along the Wood Street corridor will be determined and vetted through the environmental permitting process, once a preferred alternative has been selected. In the interim, recommended bike improvements within the existing ROW that could be installed prior to widening of the bridge or Wood Street are discussed in Section 5.6.1.

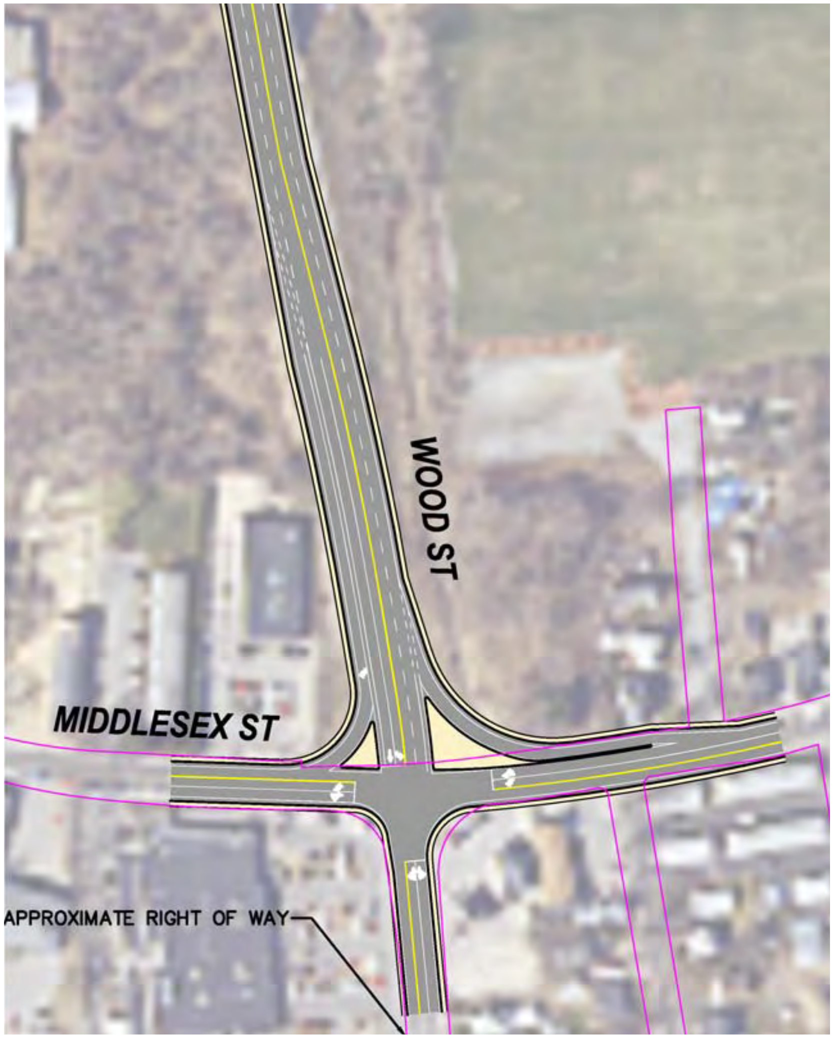


Figure 5-21 Rourke Bridge/Wood Street at Middlesex Street Concept 1

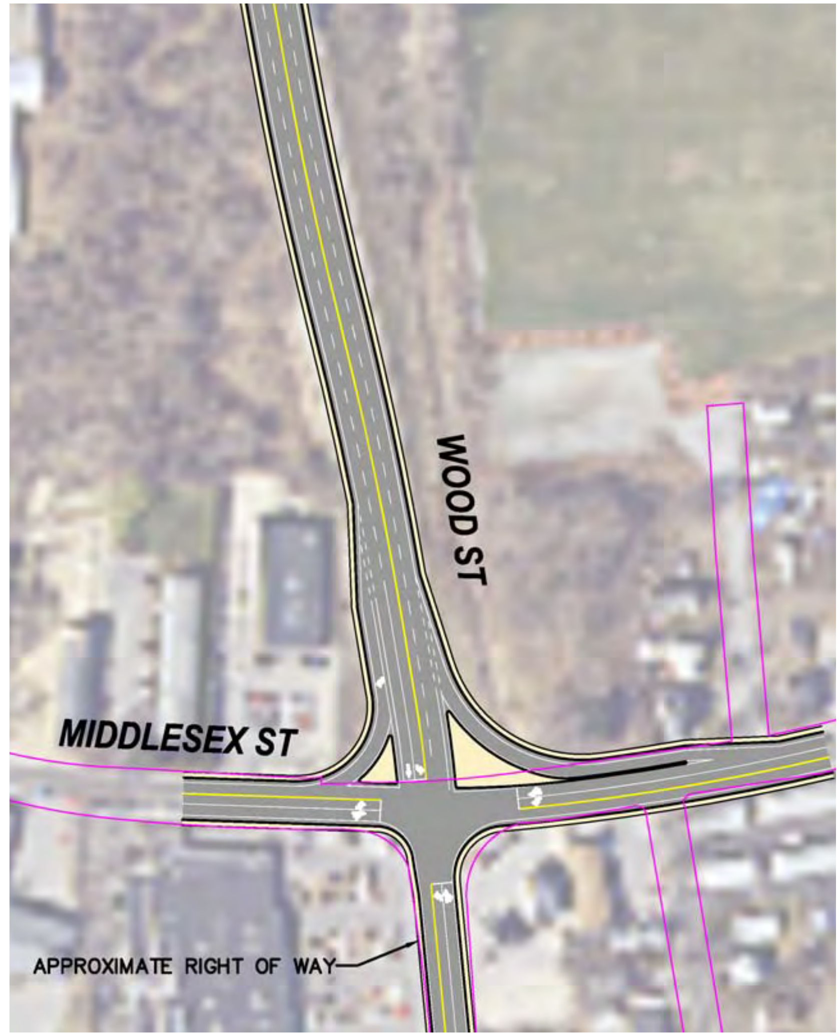


Figure 5-22 Rourke Bridge/Wood Street at Middlesex Street Concept 2

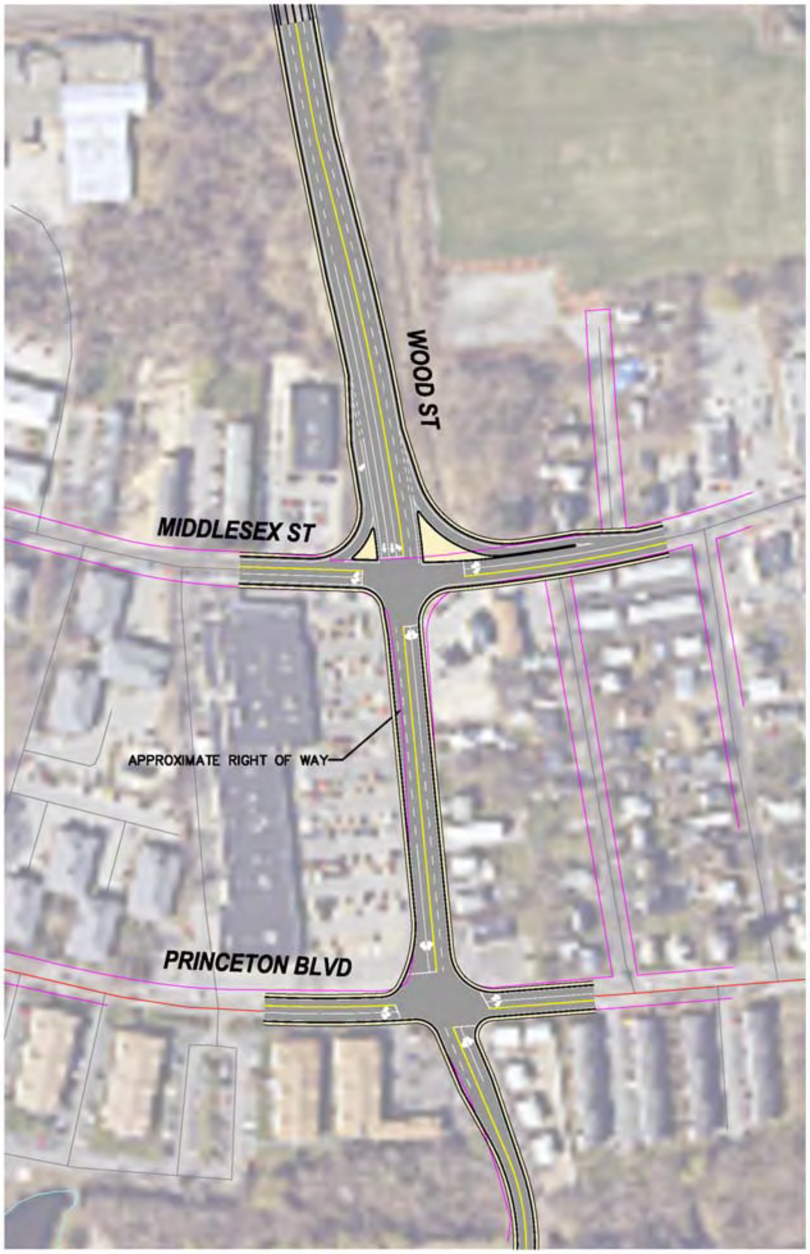


Figure 5-23 Rourke Bridge/Wood Street at Middlesex Street Concept 3

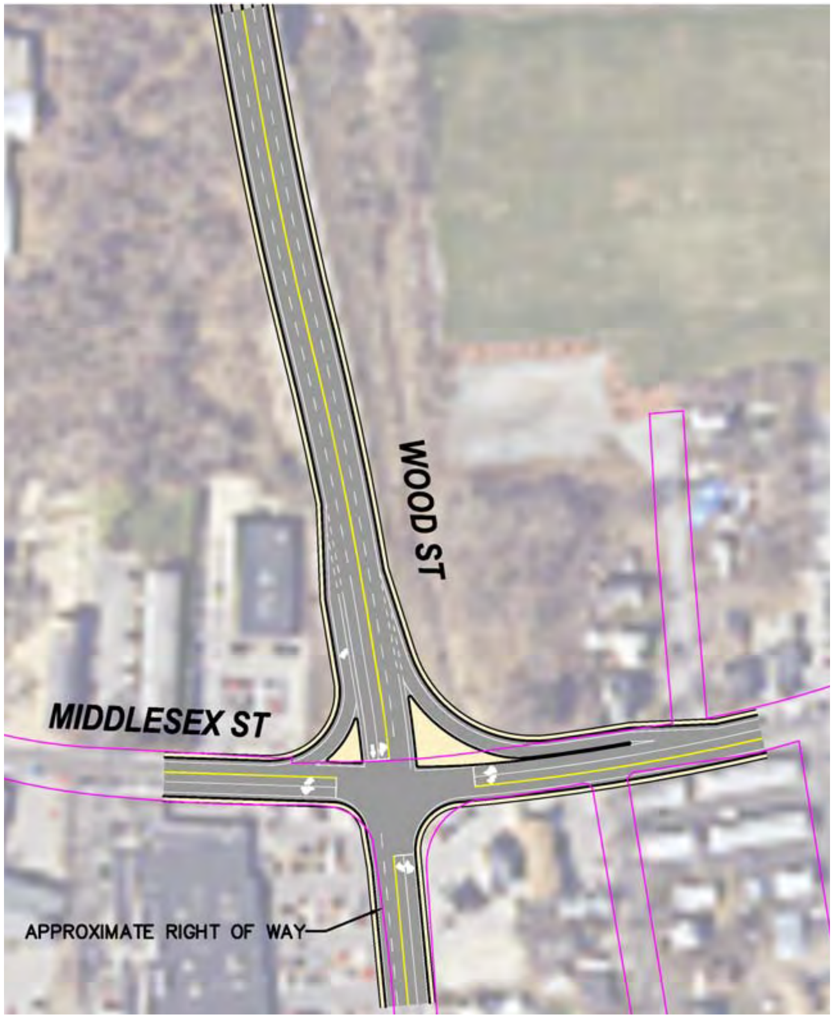


Figure 5-24 Rourke Bridge/Wood Street at Middlesex Street Concept 4

5.2.2 Geometric Improvements

This improvement considers localized geometric improvements aimed at improving operations. From the improvements identified previously in Table 4-3, three improvements appear to be feasible within the existing right-of-way and would have operational benefits. It is recommended that the following three improvements be implemented:

- Riverside Street at University Avenue
  - Modify the northbound University Avenue lane geometry from one shared lane to a left-turn/through lane and right-turn only lane with 100 feet of storage
  - Coordinate improvements with UMass Lowell transit
- Riverside Street at VFW Highway
  - Install a traffic signal at this location (see Section 5.3.1 below) and modify the eastbound Riverside Street geometry from one shared left-turn/through lane and one through lane to a left-turn only lane with 100 feet of storage and two through lanes
- Westford Street at Wood Street
  - Lengthen the Westford Street northbound right-turn lane to provide approximately 225 feet of storage (to north of Carl Street)
  - Improve pavement markings on the Westford Street northbound approach

A member of the public noted queuing issues on the northbound Westford Street approach at the intersection of Westford Street at Wood Street. The northbound through queue frequently blocks access to the right-turn lane, especially during peak hours. Pavement markings for the right-turn lane are in poor condition which exacerbates the issue. Improvements discussed above seek to address these issues.

The following improvements would benefit operations, but have substantial right-of-way or property impacts, and were therefore discarded from further consideration:

- Riverside Street at University Avenue
  - Add a left-turn only lane to the westbound Riverside Street approach
- University Avenue at VFW Highway
  - Add a second through lane to the southbound University Avenue approach
- Wood Street at Princeton Boulevard
  - Add a second through lane to both the northbound and southbound Wood Street approaches

5.3 Transportation System Management Strategies

The Transportation System Management (TSM) strategies discussed below seek to improve the management and operation of existing transportation facilities within the study area. These enhancements are intended to improve traffic flow, air quality, and the movement of vehicles and goods, as well as improve system accessibility and safety. Six alternatives were developed and evaluated, as discussed below. Capacity analysis results and signal warrant analyses for these improvements are included in the Technical Appendix.

5.3.1 Signalization

This alternative evaluated the signalization of eight unsignalized study area intersections projected to perform at unacceptable levels of service under 2035 Baseline Conditions. At each of these locations, a traffic signal warrant analysis was performed. The Manual on Uniform Traffic Control Devices (MUTCD) [2] lists specific criteria, or warrants, for the consideration of installation of a traffic signal at an intersection. The MUTCD also notes that, "the satisfaction of a traffic signal warrant or warrants shall not, in itself, require the installation of a traffic control signal." The traffic signal warrant analysis provides guidance as to locations where signals would not be appropriate and locations where they could be considered further.

Traffic signal warrant analyses for two volume-based warrants (Warrant 2: Four-Hour Vehicular Volume; and Warrant 3: Peak Hour Volume) are summarized in Table 5-4. Signals that meet warrants under existing or No-Build conditions would be evaluated further under Warrant 1: Eight-hour vehicular Volume, prior to signalization per MassDOT requirements. None of the unsignalized intersections meet the traffic signal warrants based on pedestrian volumes or history of vehicle crashes; although several come close to meeting the traffic signal warrant based on vehicle crashes and should be monitored in the future (as noted below).

Table 5-4 Traffic Signal Warrant Analyses

Location/Warrant	MUTCD Volume Warrant Met?	Existing or No-Build Condition
VFW Highway at Riverside Street		Existing and No-Build
Warrant 2: 4-Hour Volume	yes	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	
Varnum Avenue at Old Ferry Road		No-Build Only
Warrant 2: 4-Hour Volume	no	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	
Middlesex Street at Baldwin Street		Existing and No-Build
Warrant 2: 4-Hour Volume	no	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	
Westford Street at Stedman Street		Existing and No-Build
Warrant 2: 4-Hour Volume	yes	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	
Westford Street at Technology Drive		Existing and No-Build
Warrant 2: 4-Hour Volume	yes	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	
Drum Hill Road at Shopping Center north		Existing and No-Build
Warrant 2: 4-Hour Volume	no	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	
Drum Hill Road at Shopping Center south		N/A
Warrant 2: 4-Hour Volume	no	
Warrant 3: Peak Hour Volume [AM and/or PM]	no	
Middlesex Street at Princeton Street/Tyngsboro Road		No-Build Only
Warrant 2: 4-Hour Volume	yes	
Warrant 3: Peak Hour Volume [AM and/or PM]	yes	

Source: 2009 MUTCD

If the intersection met at least one volume-based warrant, the operational impacts of installation of an actuated signal with pedestrian accommodations were evaluated. Based on the warrant and operational analyses, installation of traffic signals at the following three intersections is recommended:

- VFW Highway at Riverside Street
- Westford Street at Stedman Street
- Westford Street at Technology Drive

In addition to addressing operational deficiencies, all three of these intersections have documented safety issues and the installation of traffic signals could improve mobility and safety at these locations. The Commonwealth has recently installed new STOP-signs and advanced warning signage and has improved pavement markings at the intersection of Westford Street at Stedman Street as part of a statewide project at high crash locations.

At locations where only the peak hour traffic signal warrants are met or warrants are met only during the No-Build condition, the installation of traffic signals is not recommended at this time. These locations should be periodically monitored by the appropriate municipality or MassDOT to determine if/when conditions change such that a traffic signal becomes a viable improvement option:

- Varnum Avenue at Old Ferry Road
- Middlesex Street at Baldwin Street
- Drum Hill Road at Shopping Center north
- Middlesex Street at Princeton Street/Tyngsboro Road

The monitoring should include a review of traffic and pedestrian volumes and crash statistics, as the intersections also come close to meeting the crash warrant for traffic signal installation. During the public outreach process, the intersection of Middlesex Street at Baldwin Street was anecdotally noted as problematic from a pedestrian perspective. While the intersection currently does not meet pedestrian warrants for traffic signal installation, it is recommended that the location be monitored, as discussed above. It should be noted that the Commonwealth has recently installed new STOP-signs and advanced warning signage and has improved pavement markings at this location as part of a statewide project at high crash locations.

As noted in Section 5.1, some bridge alignment alternatives necessitate installation of a traffic signal at Varnum Avenue at Old Ferry Road. Under those conditions, a signal would be installed at this location as part of the bridge construction.

5.3.2 Signal Optimization

Signal optimization improves capacity through traffic signal timing adjustments at key intersections. Equipment upgrades, coordination among intersections, and geometric improvements are not considered as part of this alternative. Based on 2035 Baseline traffic operations, timing changes at the following intersections were considered:

- University Avenue at Riverside Street
- University Avenue at VFW Highway
- University Avenue at Father Morissette Boulevard
- Riverside Street at Mammoth Road
- Pawtucket Street at School Street
- Pawtucket Boulevard at Rourke Bridge
- Rourke Bridge/Wood Street at Middlesex Street

- Princeton Boulevard at Wood Street
- Princeton Boulevard at North Road

Based on the results of this analysis, the following intersections are recommended for traffic signal timing modifications by 2035:

- Pawtucket Street at School Street
- Pawtucket Boulevard at Rourke Bridge
- Princeton Boulevard at North Road

Based on existing traffic volumes, optimization plans can be implemented as soon as possible at the intersections of Pawtucket Boulevard at Rourke Bridge and Princeton Boulevard at North Road.

5.3.3 Signal Coordination

This improvement investigated the coordination of traffic signals along several study area corridors to improve traffic progression and reduce overall delay:

- Westford Street/Drum Hill Road corridor: Technology Drive to Drum Hill Square
- University Avenue Bridge
- O'Donnell (School Street) Bridge

In addition, coordination among all intersections along the University Avenue Bridge and O'Donnell (School Street) Bridge corridors was evaluated.

Based on operational analysis, it is recommended that coordination across the O'Donnell (School Street) Bridge be implemented as a short-term improvement. Coordination along the Drum Hill Road corridor from Technology Drive to Drum Hill Square will require a more detailed data collection effort to understand the effects of turning traffic at every driveway along the corridor.

Coordination across the University Avenue Bridge is being considered as part of the University Avenue Bridge replacement project, coordinated through the City of Lowell.

5.3.4 Address Signal Issues

This improvement considers addressing the following issues noted during field inventories of the signalized intersections within the study area:

- 2009 Manual on Uniform Traffic Control Devices (MUTCD) issues/violations;
- Defective and/or broken equipment;
- Americans with Disabilities Act (ADA) non-compliance issues (discussed in *Section 5.6 - Improved Pedestrian Mobility at Intersections*); and
- Other issues (i.e. poor pavement condition, faded markings, "yellow traps," etc.).

Such issues were noted at all 24 study area signalized intersections (a complete list of issues by intersection is included in the Report Appendix). Prioritization of the improvements is discussed in detail in Chapter 6. Many of the improvements to address these issues are low-cost in nature and can be implemented immediately. It should be noted that both the City of Lowell and the Town of Chelmsford have been proactive in addressing some of the noted deficiencies at intersections under their respective jurisdictions. For example, Lowell expects to upgrade signal equipment and address ADA compliance issues at the intersections of University Avenue at Riverside Street and School Street at Pawtucket Street in 2014. Chelmsford has addressed several noted issues/deficiencies at the intersections of Drum Hill Road at Parkhurst Road and Drum Hill Road at Drum Hill Shopping Center - main driveway.

5.3.5 Access Management

Access management improvements were considered for the Drum Hill Road corridor from Drum Hill Square to Parkhurst Road; the Middlesex Street corridor from Wood Street/Rourke Bridge to Pawtucket Street; and for the Market Basket supermarket plaza.

Drum Hill Road

There are numerous driveways that provide access to private developments along Drum Hill Road from Drum Hill Square to Parkhurst Road. This study investigated the feasibility of eliminating and/or consolidating some of these driveways. Implementing access management would benefit the transportation system by reducing the number of conflict points that exist along the Drum Hill Road corridor.

The Drum Hill Master Plan[12] recommended the elimination and/or consolidation of driveways along this corridor. Specifically, the study recommended that access to

▼

[12] Drum Hill Master Plan: Updated Recommendations and Next Steps, NMCOG, December 2008.

Drum Hill Plaza and the Sunoco gas station be revised. The study also suggested shared access, where possible, and noted that "access easements may be utilized to allow legal use of shared driveways over properties under separate ownership."

Since the completion of the Drum Hill Master Plan, there have been additional locations where consolidation has been recommended, although no property owners have been directly contacted. It is recommended that access management improvements to the Drum Hill Road corridor discussed in the Drum Hill Master Plan be implemented. The next step is to notify property owners and begin the process of obtaining shared access easements. Recommended improvements related to the coordination of traffic signals along Drum Hill Road can be further enhanced by controlling access throughout the corridor.

Middlesex Street

Access management issues along Middlesex Street were noted by a member of the public during the draft report public comment process. Similar to Drum Hill Road, there are numerous driveways along Middlesex Street from Wood Street/Rourke Bridge to Pawtucket Street that provide access to private developments along the corridor. Excessively wide and/or multiple curb cuts to adjacent parcels are prevalent along Middlesex Street. Also, while there are sidewalks along both sides of the corridor, the pedestrian realm is inconsistent and poorly defined in sections. For example, along Middlesex Street eastbound between Cornell Street and Hadley Street, there is an asphalt sidewalk travelling along the northern edge of two parcels. The sidewalk is buffered from the parking field at the westerly parcel by a landscaped strip. Then, the sidewalk is immediately adjacent to parking for the easterly parcel without any delineation between the two spaces.

This study recommends that improvements to both access and the pedestrian realm be considered along the Middlesex Street corridor to reduce conflict points and to improve multimodal safety. A comprehensive review of the corridor to identify specific improvements is recommended.

Market Basket Plaza

The Market Basket supermarket plaza located on Wood Street is served by three driveways. The Middlesex Street driveway has been noted as an operational and safety concern by members of the TWG and the public. Specifically, entering vehicles from Middlesex Street westbound are frequently blocked by the eastbound queue at the Middlesex Street at Wood Street/Rourke Bridge intersection. This results in queues along Middlesex Street westbound which impact operations at the Wood Street intersection.

The potential to relocate or close this driveway was evaluated. The driveway serves as a primary access point to the shopping plaza from those originating west of the

Middlesex Street/Wood Street intersection. The driveway also provides immediate access to drive-through bank operations along the northerly side of the building. Modification to the driveway would significantly impact vehicle circulation and bank operations. Further, elimination of the driveway would require additional traffic to travel through the Middlesex Street/Wood Street intersection, adding traffic volume to an already congested Wood Street in order to access the shopping plaza. For this reason, revisions to access to the Market Plaza should not be advanced for further study or implemented at this time. If a large-scale reconfiguration of the parking lot or redevelopment of the shopping plaza is considered in the future, eliminating or restricting access at the Middlesex Street driveway to right-turn in/right-turn out only should be considered.

5.3.6 Overhead Signage

During the public outreach process, it was noted that lane control at complex intersections is often not well marked. Irregular maintenance of pavement markings for left-turn or right-turn only lanes coupled with inconsistent or missing lane indication signage causes confusion for drivers and leads to unnecessary merging and potential safety concerns. To alleviate these issues, installation of overhead lane indication signage is recommended. An initial review of the study area intersections was conducted and the following locations are candidates for overhead signage:

- Mammoth Road/School Street at Varnum Avenue/Riverside Street;
- Middlesex Street at Rourke Bridge/Wood Street;
- Westford Street at Wood Street; and
- VFW Highway at Riverside Street (signalization recommended as part of this study).

It is recommended that installation of overhead lane indication signage be considered for these locations as deemed appropriate and feasible by their respective jurisdiction. Additionally, both the University Avenue Bridge and the Tyngsborough Bridge have recently been reconstructed. The addition of overhead lane indication signage at these locations could be considered if deemed necessary once traffic volumes and patterns stabilize post-construction.

It should be noted that the installation of overhead signage on an existing mast arm assembly or span wire would require an evaluation of the equipment to accommodate the additional load.

5.4 Transportation Demand Management Strategies

Transportation Demand Management (TDM) strategies seek to increase overall system efficiency by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes, or shifting auto trips out of peak periods. For many regions, TDM strategies are organized and implemented by a regional Transportation Management Association/Organization (TMA/TMO). A TMA is non-profit association of businesses, employers, land developers, and/or property managers in a given region with the goal of easing commutes and reducing local traffic congestion through improved commuting options. The study area is not currently served by a TMA. It is recommended that the feasibility of creating a TMA for the region be evaluated in greater detail. Potential services that a regional TMA could offer could include:

- Carpool/vanpool ride matching
- Emergency/guaranteed ride home
- Commuter incentive programs
- Public transportation, bike and walk assistance
- Shuttle bus services
- Transportation advocacy at the state and/or federal level

5.5 Transit System Enhancements

The improvements in this section focus on making transit options more attractive, available, and efficient with an overarching goal of increasing transit utilization and reducing reliance on the automobile.

5.5.1 Transit Improvements

Several improvements were evaluated to enhance transit within the study area. First, access to existing transit routes could be improved with sidewalk installation and/or upgrades to existing sidewalks on major study area corridors. These improvements are discussed in detail in *Section 5.6 – Improved Pedestrian Mobility along Roadways* which follows.

Two additional improvements seek to enhance the LRTA transit experience. Improving bus stop facilities at existing high volume LRTA stops through the use of bus shelters and/or informational signage (route, schedule) could enhance the transit experience for riders of the LRTA. Providing transit access between Lowell General Hospital and the Drum Hill Road corridor with modification of an existing LRTA route or an additional bus route is also considered. It is envisioned that this route could utilize the new Rourke Bridge. However, based on rising operating costs, coupled with overall decreased ridership over the past ten years on the LRTA and reduced state assistance, it is unlikely that either of these improvements would be able to be advanced at this time. Regardless, they should be considered as potential improvements if the LRTA financial situation changes.

5.5.2 Support New Hampshire Commuter Rail Extension

The proposed 12-mile extension of an existing commuter rail line from Lowell to Nashua, New Hampshire is in the preliminary planning stages. A commuter rail station in Vinal Square (Chelmsford) along this line is being considered. It is recommended that as improvements to study area roadways and intersections advance, they support access to this station wherever feasible.

5.6 Bicycle/Pedestrian Enhancements

The improvements in this section focus on improving pedestrian and bicycle mobility throughout the study area.

5.6.1 Improved Bicycle Mobility

This improvement includes enhancing bicycle accommodations where possible and appropriate. All bridge alternatives include 5-foot bicycle lanes in both directions, providing an important link across the river and to existing paths along the north side. It should be noted that if a pedestrian railing is installed, 6-foot bicycle lanes may be required to provide adequate separation from the vertical obstruction.

Additionally, potential bike lanes, bike shoulders, or shared lanes ("sharrows") along major study area corridors would improve bicycle mobility in the region, as shown graphically in Figure 5-25 and described below:

- **Wood Street/Westford Street/Drum Hill Road:** Shared lane markings from Middlesex Street to Parkhurst Road.
- **Middlesex Street:** Bike shoulder from Route 3A to Tobin Avenue; bike lanes from Tobin Avenue to Pawtucket Street.
- **Princeton Street/Princeton Boulevard:** Bike shoulder from North Road/Route 3A to Wightman Street; shared lane markings from Wightman Street to Dingwell Street; bike shoulder from Dingwell Street to Lauriat Street; and shared lane markings from Lauriat Street to Pine Street. It should be noted that the continuation of bike shoulders/shared lane markings along Pine Street/Westford Street/Route 3A may be possible beyond the limits of the study area. Additionally, right-of-way and property impacts along the sections from

Wightman Street to Dingwell Street and Lauriat Street to Pine Street should be reviewed. While it is not possible to accommodate bicycles in the shoulder without physical roadway modifications it may be beneficial to make these changes if they can occur without impacts to private property. The provision of a shoulder accommodation for bicycles along the entire corridor is beneficial for connectivity and access to transit.

- **Pawtucket Boulevard:** Bicycle lanes from Wedgewood Circle to Varnum Avenue. It should be noted that the continuation of bike lanes west of Wedgewood Circle may be possible beyond the limits of the study area.

It appears that the recommended bicycle facilities presented in Figure 5-25 and discussed above could be accommodated within the existing right-of-way and without restriping the roadway. With restriping, improved accommodations may be possible along the following sections:

- **Middlesex Street:** Bike lane from Route 3A to Highland Avenue.
- **Princeton Street:** Bike shoulder from Wightman Street to Cashin Street.
- **Princeton Boulevard:** Bike shoulder from Baldwin Street to Pine Street.

A review of parking regulations by the City/Town/State would be required prior to implementation or any bicycle accommodations along study area roadways. In addition to the facilities discussed above, the City of Lowell has a bicycle accommodation plan which includes bike lanes along Varnum Avenue and shared lane markings along Pawtucket Street.

It is recommended that identification of strategic locations for destination/guide signage for bicyclists be considered to supplement the bicycle facilities discussed above.

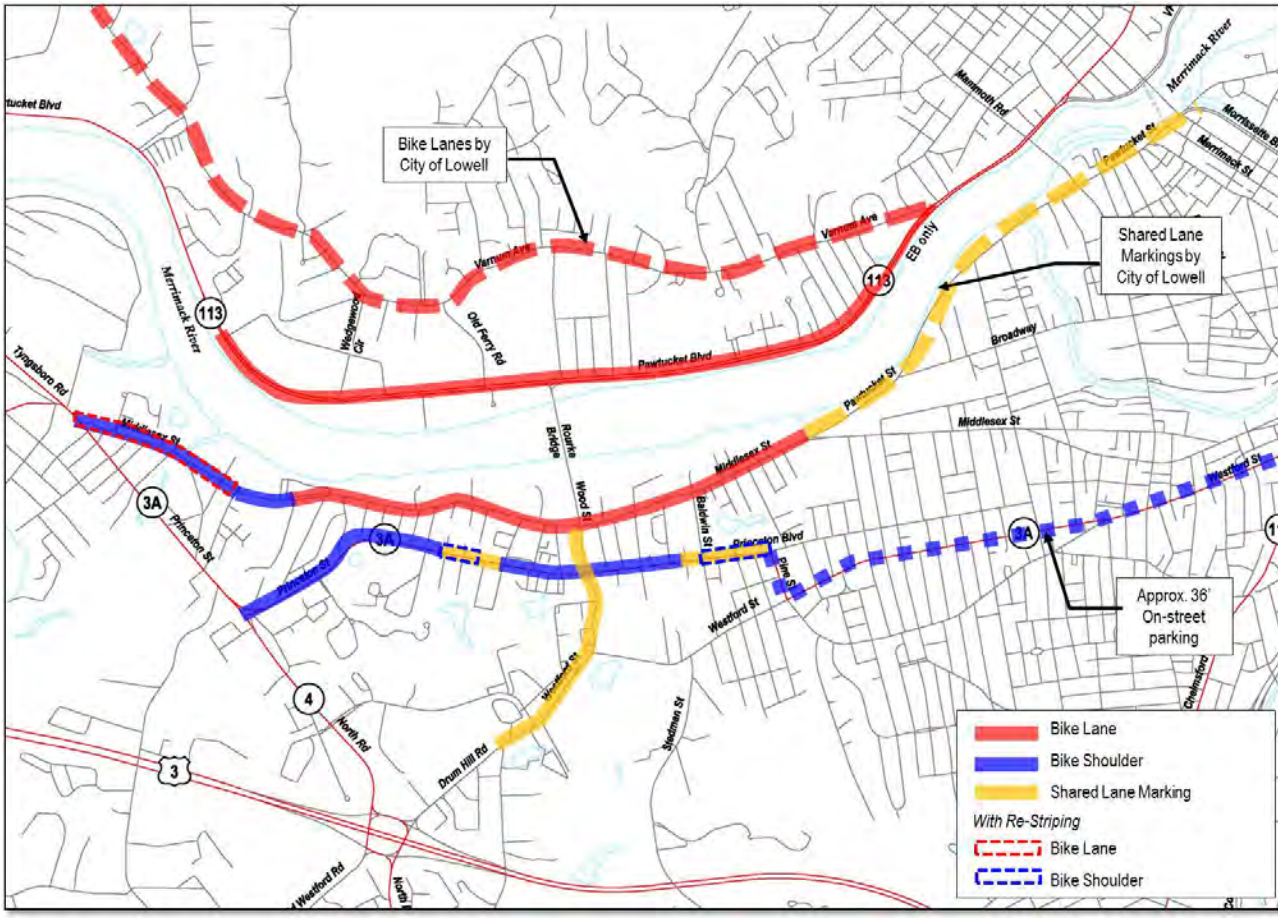


Figure 5-25 **Bicycle Improvements**

5.6.2 Improved Pedestrian Mobility at Intersections

This improvement includes intersection enhancements to address pedestrian mobility at study area intersections. During signal inventories, issues were noted at 10 locations (Figure 5-26) including pedestrian push button, wheelchair ramp, and warning panel ADA non-compliance. It is recommended that these ADA non-compliance issues be addressed as intersections are upgraded to improve pedestrian access and mobility.

It was also noted that no pedestrian accommodations (signal equipment/phasing) are provided at eight signalized study area intersections, as shown in Figure 5-26. It is recommended that when these intersections are upgraded, installation of pedestrian accommodations be implemented. A complete inventory of issues is included in the Report Appendix.

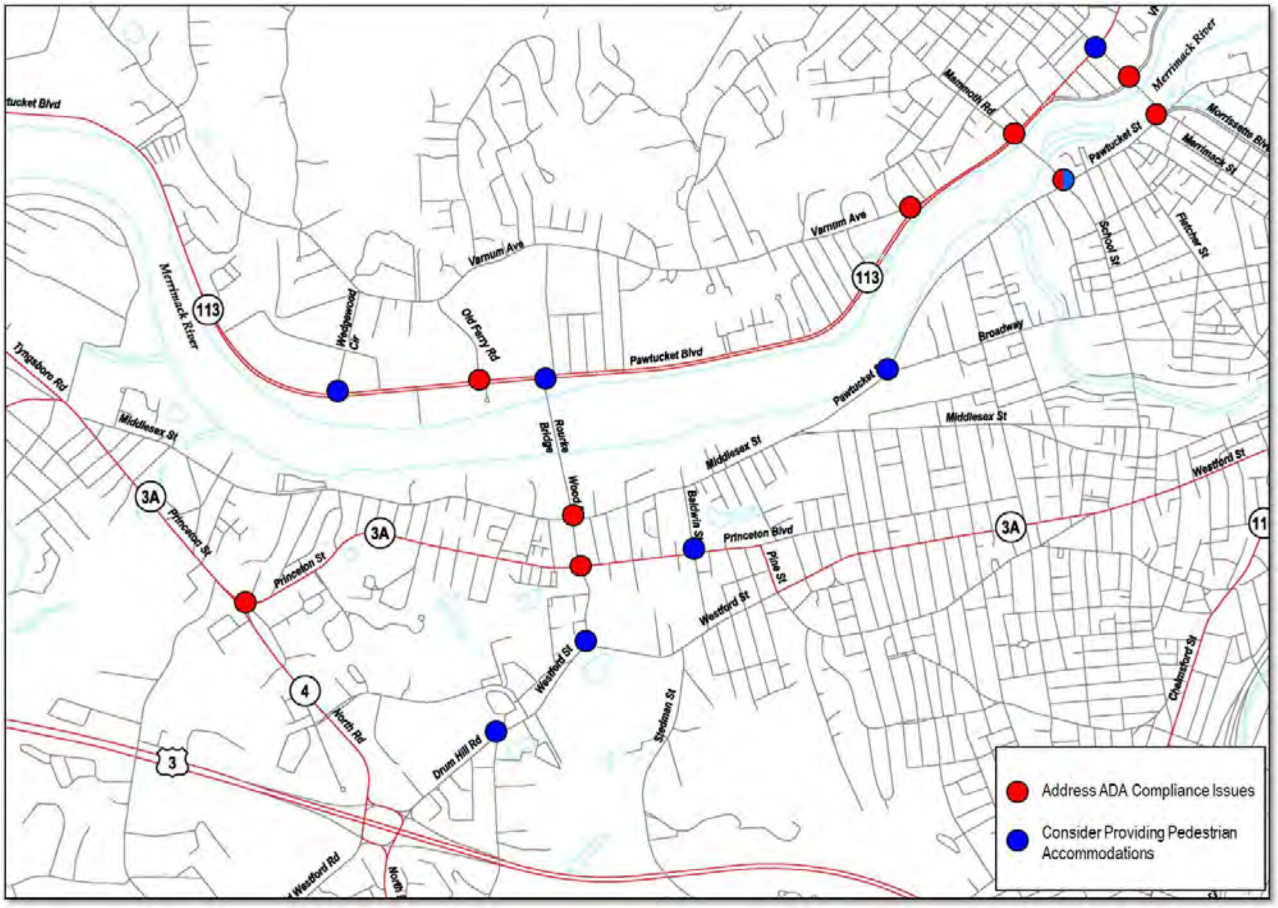


Figure 5-26 Pedestrian Improvements at Intersections

5.6.3 Improved Pedestrian Mobility along Roadways

This improvement includes the installation of new sidewalks/sidewalk upgrades aimed at improving mobility and eliminating gaps in the network along key routes. These improvements will enhance access to existing LRTA bus routes along Middlesex Street, Princeton Street/Princeton Boulevard, and Wood Street/Westford Street/Drum Hill Road. Figure 5-27 depicts sections where the feasibility of sidewalk installation or widening of the existing sidewalk should be investigated further. For sections with an existing narrow sidewalk, widening may be accomplished by using a portion of the existing grass buffer strip, where available.

In addition to the improvements discussed above, existing sidewalks should maintain a 5-foot clear zone. Debris and/or obstructions such as sign posts, utility poles, street furniture, etc. should be removed or relocated whenever feasible. The Town of Chelmsford has been proactive in improving sidewalk conditions along Drum Hill Road as part of a Planning Board project.

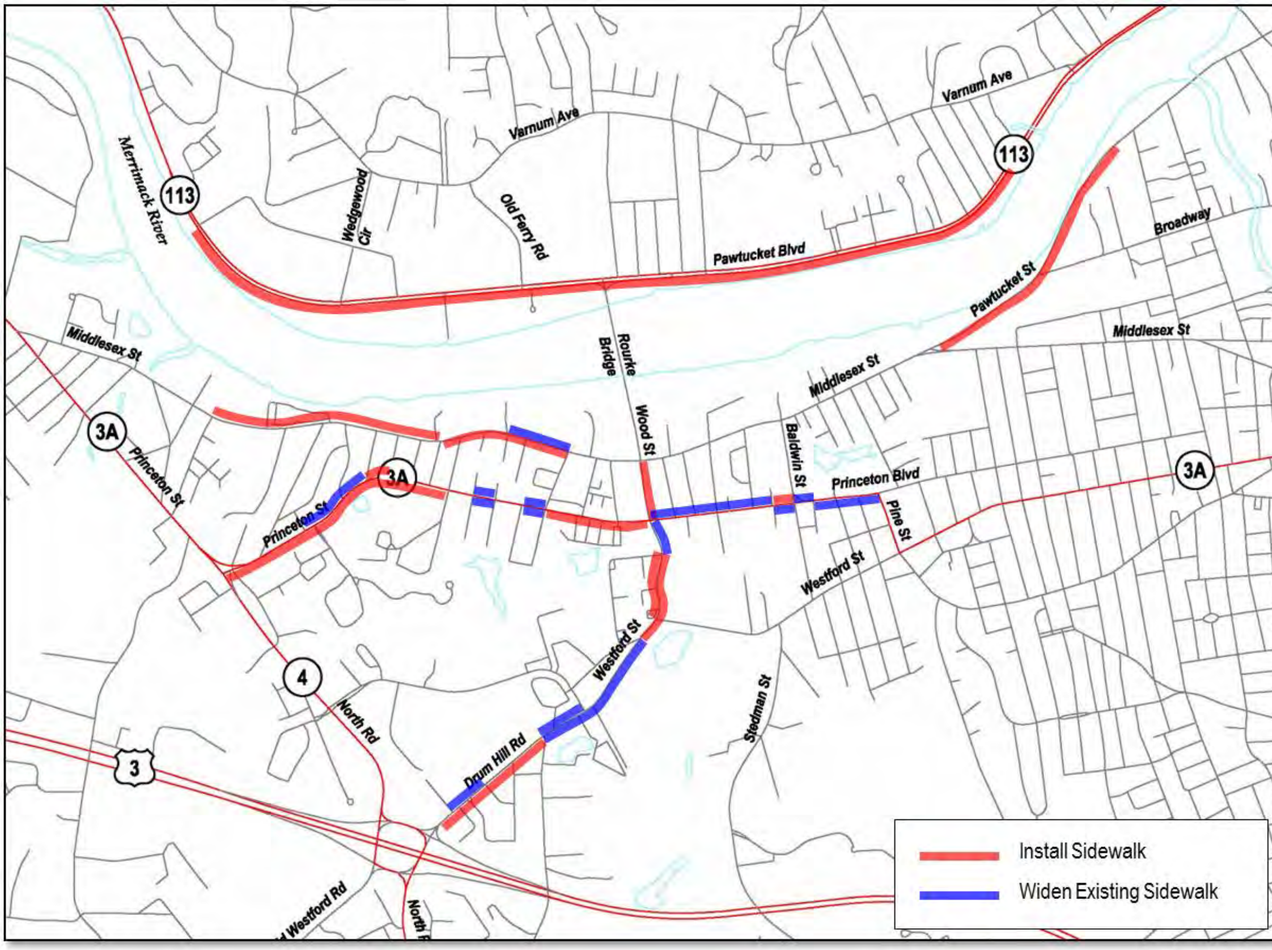


Figure 5-27 Pedestrian Improvements along Roadways

This page intentionally left blank

6

Management and Operations Plan

Chapters 4 and 5 developed, screened, and analyzed a group of potential transportation and mobility improvements for the Rourke Bridge study area. These efforts resulted in identification of a number of recommended improvement projects to be considered for implementation. This chapter presents an "**Action Plan**" for implementation of the study recommendations.

The recommended list of projects range from transportation systems management and operations (TSM&O) alternatives to the major infrastructure project (MIP) of construction of a permanent Rourke Bridge. TSM&O projects allow transportation agencies and municipalities to enhance the safety, reliability and operations of transportation systems in the near term without incurring the high cost associated with major infrastructure projects.

The following Management and Operations Plan provides a guide to developing an integrated approach to optimizing the performance of existing infrastructure through the implementation of multimodal, intermodal and cross-jurisdictional systems, services and projects. It also provides a framework for advancing the Rourke Bridge replacement as a major infrastructure project, from inception to implementation.

This chapter does not identify funding sources for each recommendation because of the many variables and the uncertainty associated with funding sources and schedules for projects. Funding opportunities vary depending on Federal programs, State programs, and the private sector which are all influenced by the economy. Moreover, project priorities and schedules change with administration changes, federal guidance, and political influence.

It is acknowledged that the recommendations presented herein represent a significant (greater than $50 million) investment in potential transportation-related infrastructure. These projects represent an investment in total that currently far exceeds available funding as presently programmed. The advancement of the recommendations developed as part of this study will require prioritization by NMCOG, LRTA, MassDOT, and the study area communities to address current fiscal constraints as related to transportation improvements.

The recommended improvement projects identified by this study can be classified into the following two categories:

- **Major Infrastructure Project**
  - Rourke Bridge Replacement
- **Transportation Systems Management and Operations (TSM&O) Projects:**
  - Geometric Improvements
  - Signalization
  - Signal Optimization
  - Signal Coordination
  - Address Signal Issues
  - Access Management: Drum Hill Road Corridor
  - Access Management: Middlesex Street Corridor
  - Overhead Signage
  - Transit Improvements
  - Support New Hampshire Commuter Rail Extension
  - Improved Bicycle Mobility
  - Improved Pedestrian Mobility at Intersections
  - Improved Pedestrian Mobility along Roadways

6.1 Major Infrastructure Project

The replacement of the existing Rourke Bridge is classified as a Major Infrastructure Project and will require significantly more time and resources to proceed from inception to implementation than other improvements discussed in this study. This project will need to progress through the environmental review process, as established by Federal and State agencies.

6.1.1 Project Development Summary

This study has examined the feasibility of replacing the existing Rourke Bridge with a permanent structure. The need for the project has been defined and the study has identified a series of constraints and considerations that will need to be evaluated in more detail as the project progresses.

As discussed in detail in previous chapters, the need to replace the existing temporary Rourke Bridge with a permanent structure has been established from both a transportation and structural perspective. Future traffic volume projections indicate a peak demand of approximately 2,250 vehicles per hour for the existing 2-lane bridge. Based on guidance in the HCM, a 4-lane bridge is warranted to accommodate this projected demand. Additionally, the existing bridge lacks bicycle accommodations and has inadequate pedestrian accommodations. Therefore, all bridge alternatives include 4 travel lanes (2-lanes northbound and 2-lanes southbound), 5-foot (minimum) bicycle lanes, and 6-foot sidewalks. From a structural perspective, continuous preventive maintenance and rehabilitation activities necessary to maintain the bridge's current posting would be required as long as the existing temporary Rourke Bridge remains in place.

The cumulative bridge maintenance costs required to keep the bridge in use until 2035 are estimated at $3.9 million dollars. From a structural perspective, MassDOT should continue to budget for preventive maintenance and rehabilitation activities as long as the existing temporary Rourke Bridge remains in place. If the preventative maintenance were to stop, significant load carrying elements may become Structurally Deficient (SD). Bridges are considered SD if significant load carrying elements are found to be in "poor" condition; having an NBI general condition rating of a 4 or less. Once a bridge is considered SD it may trigger the need for a rerating, resulting in additional engineering costs and potentially more stringent weight restrictions. According to FHWA Bridge Preservation Guide, delaying or forgoing warranted preservation activities will often result in worsening condition and can escalate the feasible treatment or activity from preservation to a more costly major reconstruction or replacement.

The study also evaluated the most appropriate location for a permanent Rourke Bridge. Alternatives east, west, and in the vicinity of the existing alignment were considered. At the beginning of the study, an origin-destination study was conducted to more fully understand the travel patterns of motorists using the existing Rourke Bridge. The results of this study indicated that the Rourke Bridge is in an appropriate location to serve travel needs of the surrounding towns. This is largely driven by the bridge's connection to Wood Street/Westford Street/Drum Hill Road which provides access to Route 3. The preliminary alternatives screening and alternatives evaluation process further supported constructing a new Rourke Bridge in the immediate vicinity of the existing structure. Relocation of the bridge to the east would impact State-owned protected and recreational open space. Relocation of the bridge to the west (Vinal Square) would have significant environmental, transportation, and construction impacts. Therefore, it is recommended that a permanent Rourke Bridge be constructed in the vicinity of the existing structure to serve travel needs and to minimize impacts.

While this study was able to establish that the existing bridge is in an appropriate location, a preferred alignment alternative was not identified. Based on the level of analysis conducted in this study, Alternatives 2, 4, 5, and 6 all warrant further evaluation from an environmental, transportation, and structural perspective. There are minimal property constraints on the north side of the river, which allows for flexibility in establishing a connection to the existing transportation infrastructure. Alternatives 2, 4, 5, and 6 all consider different northern connections that will need to be evaluated in greater detail through the environmental process and subsequent design efforts. On the south side of the river, buildings and property impacts immediately to the east and west of the existing bridge limit the potential to modify the southern connection. Therefore, Alternatives 2, 4, 5, and 6 all consider maintaining the existing connection at Middlesex Street.

Based on public comments received at the fourth of five public meetings, potential transportation improvements at this intersection will need to be evaluated in greater detail as this project progresses. Four potential transportation improvements have been conceptually outlined for discussion purposes and are presented in Section 5.2.1. Further analysis of property impacts will be needed in order for decision-makers to determine whether implementation is possible or desirable.

It should be noted that the Lowell City Council has reviewed the alternatives and has voted to discard Alternative 5 based on potential economic development impacts to the currently vacant drive-in movie parcel on the north side of the river. Although Alternative 5 is being eliminated from further consideration at this stage, it is possible that a NEPA review of this alternative would require a full assessment at a later date. At this time, it is recommended that Alternatives 2, 4, and 6 be advanced for further study.

6.1.2 Next Steps

The Rourke Bridge replacement project will need to follow a process that will include the following steps:

Step 1: Problem/Need/Opportunity Identification
Step 2: Project Planning
Step 3: Project Initiation
Step 4: Environmental Review and Permitting /Design/ROW Acquisition
Step 5: Funding/Programming on the Regional and State Transportation Improvement Programs
Step 6: Advertise/Bid and Contract Award
Step 7: Construction

While steps 1, 2 and 3 are largely satisfied by the completion of this study, a Project Needs Form (PNF) and Project Initiation Form (PIF) must be completed and approved in order to finalize the project planning/initiation process. This planning report would accompany those documents through the initiation process. Step 4 can be the most time consuming including the development of Plans, Specifications and Estimates (PS&E), environmental studies, right-of-way plans, and permits. Additionally, it is likely that the Rourke Bridge replacement project will require FHWA involvement, review, and comment. Step 5 is critical in that it is where the project is added to the regional and State TIP and funding is programmed.

In order to refine the analysis completed to date and identify a preferred alternative among Alternatives 2, 4and 6, the following specific tasks are required:

- Preliminary structural analysis to refine span arrangements and property impacts;
- Evaluation of Alternative 2 to determine if phased construction at the existing alignment outweighs the cost of the longer spans built in a single phase in Alternatives 4 and 6;
- Evaluation of additional construction costs for highway and property impacts;
- Determine how the proposed bridge layouts impact pedestrian accommodation on the north side of the river;
- Wetland delineation;
- Refinement of the 100-year floodplain using elevation data;
- Detailed bicycle and pedestrian connection evaluations;
- Refinement of intersection capacity analysis, including a comprehensive evaluation of signal coordination across the bridge; and
- Evaluation of noise and microscale air quality impacts.

Once a preferred alternative is identified, the Rourke Bridge replacement project will require the following regulatory permits:

- Local/State
  - Order of Conditions – Lowell Conservation Commission
  - Superseding Order of Conditions – MassDEP (if Bordering Vegetated Wetland impacts exceed 5,000 square feet)
  - Variance Order of Conditions – MassDEP (if Bordering Vegetated Wetland impacts exceed 5,000 square feet)
  - Water Quality Certificate – MassDEP
  - Chapter 91 License – MassDEP
  - Article 97 Process
- Federal
  - Section 10/404 Permit - U.S. Army Corps of Engineers
  - Section 9 Bridge Permit – U.S. Coast Guard
  - NPDES Construction General Permit – U.S. Environmental Protection Agency

6.1.3 Recommended MIP Action Plan

The success of any MIP depends upon collaboration and coordination across the traditional and organizational boundaries. Advancing the Rourke Bridge replacement project will rely on consistent communication and cooperation among MassDOT (Boston and District 4 Offices), NMCOG, the City of Lowell and surrounding towns, Fire, Police and Emergency responders, the Federal Highway Administration (FHWA), and state and federal permitting agencies. The recommended action plan presented herein can only be successful if the collaboration and coordination is a deliberate, sustained activity.

Major Infrastructure Project (MIP) Recommendation – Development of a Rourke Bridge Replacement Committee

The major infrastructure project of replacing the Rourke Bridge will involve, by mandated process, a number of steps that will allow for input, comment and revision by public officials and private citizens. However, to ensure that the project is advancing and developing properly, it is recommended that *a Rourke Bridge Replacement Committee be formed*.

Given the potentially extended time frame from concept to construction of this project, less frequent discussion and updates should be sufficient (as compared to TSM&O). This committee can meet annually or bi-annually to evaluate the progress and/or problems related to advancement of the project. It is recommended that members of this committee be *limited to key policy and decision makers within State and local government*.

Some areas for consideration for initial discussion/focus include:

- Priority of the Rourke Bridge replacement project versus other regional projects/needs
- Alternatives refinement and economic development analysis
- Methods to establish regional, State and local support for the project
- Identification of funding and programming of the project in the RTP and TIP/STIP
- Tracking of project development and implementation schedule
- Detailed/updated evaluation of potential construction material delivery route(s)

6.2 Transportation Systems Management and Operations

As with the Major Infrastructure Project, a successful TSM&O plan relies on collaboration and coordination across the traditional and organizational boundaries. This is critical with regard to the Rourke Bridge study area as numerous jurisdictional agencies and service providers are responsible for safely and efficiently operating various aspects of the transportation system. Consistent communication and cooperation among MassDOT (Boston and District 4 Offices), NMCOG, LRTA, the City of Lowell and surrounding towns, and Fire, Police and Emergency responders will be critical to advancing these projects.

The keys to a successful TSM&O plan rely on collaboration and coordination and revolves around (1) formalizing the process for communication, (2) focusing on specific action items based on need rather than jurisdiction, and (3) linking these efforts with the regional transportation planning and decision making process. A key goal of this plan is to strengthen the link between planning and operations. Coordination between planners and operators helps ensure that regional transportation investment decisions reflect full consideration of all available strategies and approaches to meeting regional goals and objectives.

It is recommended that the implementation of enhanced TSM&O strategies within the region focus on the following goals:

- Improve service efficiency;
- Enhance public safety and security;
- Reduce traveler delays;
- Enhance multimodal mobility; and
- Improve access to information for travelers.

Formalizing the Process

As noted above, a successful plan will rely on formalizing the process for collaboration and coordination. As always, the ad hoc approach will continue to be important and available, however, solely relying on ad hoc arrangements based on long-term relationships will not fully address the needs of the region.

TSM&O Plan Recommendation – Development of RCTOs

A Regional Concept for Transportation Operations (RCTO) is a management tool to assist in planning and implementing management and operations strategies in a collaborative and sustained way. Developing an RCTO helps bring multijurisdictional parties together and develop a consensus around their goals and objectives related to transportation systems management and operations. Typically an RCTO will develop a formal plan to be put into action within the next 3-5 years.

Within any given region there may be multiple RCTOs that focus on different operations functions or services. As a result of the work completed for this study, it is recommended to establish two individual RCTOs:

- Intersection and Corridor Management (Signal Improvements, Capacity Enhancement); and
- Multimodal Enhancements (Bike and Pedestrian).

Through the development of an RCTO, a consensus can be reached in establishing measurable operations objectives and a specific approach and strategy to meeting those objectives. This strategy can then be included into the regional transportation plan and compete for funding.

Table 6-1 begins to establish timeframes for implementation and potential jurisdictional participants associated with the recommendations of this study. It is recommended, that once established, the RCTO participants *meet quarterly* to develop their objectives, approach and strategy for implementation. In addition to the jurisdictional players, it is recommended to *include members of fire, police and emergency responders* into the RCTO discussion at early stages to ensure incorporation of their needs into strategies developed. Consideration for inclusion of members of the general public into the RCTO with regard to multimodal enhancements, specifically *related to those with specific bicycle or pedestrian interests*, should also be considered.

The success of an RCTO is directly related to *identification of a champion*. Experience shows that little happens unless someone or some group of people is committed to making it happen. The recommendation is for an *ad hoc group of MassDOT personnel and NMCOG staff to meet initially* to discuss who is best suited to take the lead (e.g., District 4 Office for intersection and corridor management under state jurisdiction, NMCOG for locally controlled locations and multimodal enhancements, etc.).

Within each RCTO it will be important to establish the scope of items and tasks to be discussed and completed. Based on the work completed for this study, the following preliminary list of scope items could be considered within each RCTO:

- **Intersection and Corridor Management (Signal Improvements, Capacity Enhancements)**
  - Review intersections and corridors identified as part of this study to establish consensus and priority of need (e.g., Westford Street at

Stedman Street, Wood Street/Westford Street/Drum Hill Road corridor, etc.);

- Identify any additional intersections or corridors to be included;
- Identify areas of jurisdiction of the facilities in question;
- At signalized locations, evaluate existing equipment and capabilities for upgrades/coordination/synchronization;
- At unsignalized locations, collect data necessary to fully evaluate signal warrants;
- Identify regional transportation plan programming and potential funding sources to implement improvements (CMAQ, HSIP, municipal [Chapter 90], etc.);
- Perform comprehensive traffic analysis and design to develop details of recommended improvements (this step will largely fall to the municipality regardless of funding source);
- If funding related to programs such as CMAQ and HSIP can be identified, work with the MPO to program funds on the TIP and continue design process;
- If municipal funding is required, work with communities to identify Chapter 90 monies or other funding opportunities to proceed; and
- Develop a schedule for implementation, including permitting and design as necessary based on the specific project.

➤ **Multimodal Enhancements (Bike and Pedestrian)**

- Review recommendations from this study for consensus and priority of need;
- Develop and conduct outreach plan to key stakeholders, e.g., UMass Lowell, etc. to establish current or future needs with regard to bicycle and pedestrian enhancements;
- Develop a priority list of intersection level pedestrian improvements based on the inventory included in this study regarding accessibility issues, pedestrian signal timing, signage and markings and equipment functionality;
- Review priorities for bicycle accommodations versus parking needs along corridors with the appropriate jurisdiction and stakeholders;
- Conduct a more detailed corridor review for priority sidewalk installations/upgrades to identify obstructions, etc.;
- Identify potential funding sources to implement improvements, including Safe Routes to School Program, CMAQ, TAP funds or state funds available for ADA compliance projects; and

- Develop a schedule for implementation of various components of multimodal enhancements.

Within each RCTO, an important first step would be to establish and *identify institutional impediments* to success and develop solutions that best address traditional impediments to coordination and collaboration.

Table 6-1 TSM&O Recommendations - Implementation Timeframe and Commitment Matrix

	Cost	Implementation Timeframe			Potential Facilitating Organizations							Notes
		Immediate (<5 years)	Mid-term (5-10 years)	Long-term (10+ years)	MassDOT	NHDOT/ MBTA	LRTA	NMCOG	City of Lowell	Town of Chelmsford	Other Study Area Communities	
Geometric Improvements: University Avenue at Riverside Street	$1,000	✓			X				X			Improvement may be accomplished within the existing right-of-way.
Geometric Improvements & Signalization: VFW Highway at Riverside Street	$280,00		✓		X				X			Geometric improvement may require box widening. Conceptual cost estimate for traffic signal includes emergency vehicle pre-emption.
Geometric Improvements: Westford Street at Wood Street	$3,500	✓							X			Improvement may be accomplished within the existing right-of-way.
Signalization: Westford Street at Stedman Street	$210,000		✓						X			Conceptual cost estimate for traffic signal includes emergency vehicle pre-emption.
Signal Optimization: Pawtucket Boulevard at Rourke Bridge	$5,000	✓							X			Based on existing traffic volumes, optimization plans can be implemented as soon as possible at this intersection.
Signal Optimization: Princeton Street at North Road	$5,000	✓			X					X		Based on existing traffic volumes, optimization plans can be implemented as soon as possible at this intersection.
Signalization: Westford Street at Technology Drive **Signal Coordination & Optimization:** Drum Hill Road Intersections	$615,000		✓		X				X	X		Conceptual cost estimate for traffic signal at Westford Street at Technology Drive includes emergency vehicle pre-emption ($220,000). Conceptual cost estimate for signal coordination assumes hardwire (copper) interconnection to maintain consistency with Drum Hill Square system; costs may be reduced with GPS interconnection ($405,000).
Signal Coordination & Optimization: School Street Bridge Intersections	$16,000	✓			X				X			Conceptual cost estimate assumes GPS interconnection and the replacement of one traffic signal controller.
Address Signal Issues	Varies	✓	✓	✓	X				X	X	X	See Report Appendix for detailed summary of signal issues, jurisdiction, recommended implementation timeframe, and conceptual cost estimates.
Access Management: Drum Hill Road Corridor	TBD		✓				X	X		X		Improvements will need to be coordinated with private property owners.
Access Management: Middlesex Street Corridor	TBD		✓				X	X	X			Improvements will need to be coordinated with private property owners.
Overhead Signage	Varies	✓			X				X	X	X	Conceptual cost estimate varies depending on location (minimum cost of $100 for an R3-5 sign panel). Signage installation on existing mast arm assembly or span wire would require an evaluation of the equipment's loading capabilities.
Transit Improvements	TBD		✓	✓	X		X	X	X	X		Based on rising operating costs, coupled with decreased ridership over the past ten years on the LRTA and reduced state assistance, it is unlikely that these improvements would be able to be advanced at this time. They should be considered as potential improvements if the LRTA financial situation changes.
Support New Hampshire Commuter Rail Extension	n/a	✓	✓	✓		X	X	X		X		
Improved Bicycle Mobility	Varies	✓	✓	✓	X			X	X	X		Prioritize corridors for bicycle accommodation and conduct more detailed review of parking regulations/usage.
Improved Pedestrian Mobility at Intersections	Varies	✓	✓	✓	X			X	X	X		Prioritize intersection improvements. Many issues could be addressed with low-cost improvements; others require a longer-term approach.
Improved Pedestrian Mobility along Roadways	Varies	✓	✓	✓	X		X	X	X	X		Prioritize corridors for pedestrian accommodation; concentrate resources on improving pedestrian mobility along roadways with existing transit routes.

This page intentionally left blank

VHB

Vanasse Hangen Brustlin, Inc.

www.vhb.com