CONCEPTUAL DESIGN REPORT

for the

WASHINGTON STREET
CORRIDOR IMPROVEMENTS

HOLLISTON, MASSACHUSETTS

FEBRUARY 2014

PREPARED FOR:

TOWN OF HOLLISTON, MA

PREPARED BY:

McMAHON
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Introduction

This Conceptual Design Report pertains to the analysis and improvements of the Washington Street (Route 16/126) corridor between Hollis Street/ Charles Street and Green Street/Exchange Street in Holliston, Massachusetts (see Figure 1). The Town of Holliston initiated this project to conduct traffic analysis, including signal warrant analysis, and conceptual design of intersection improvements for three major downtown intersections including:

- Washington Street (Route 16/126) and Central Street
- Washington Street (Route 16/126) and Hollis Street/Charles Street
- Washington Street (Route 16/126) and Exchange Street/Green Street

Project Purpose

The purpose of the study is to evaluate the three downtown intersections, determine whether the intersection conditions warrant signalization, and develop two conceptual designs for comparison and evaluation. The town is interested in creating a pedestrian friendly, multi-modal atmosphere in their downtown, which is currently dominated by vehicular use, by implementing a context sensitive solution that balances the modes of transportation and parking needs within the current right-of-way.

Existing Conditions

Roadway Network

Washington Street (Route 16/126)
Washington Street (Route 16/126) is a two-way, two lane urban principal arterial under Town of Holliston jurisdiction that runs in the north/south direction abutting retail properties within the study area. Washington Street at approximately 51 feet wide when not at an intersection with 35 feet split between the northbound and southbound travel lanes and 8-foot wide lanes on either side of the roadway for on-street parking. There is a raised mid-block crosswalk spanning Washington Street (Route 16/126) between the intersections with Hollis Street and Central Street that has push activated warning lights for vehicles to yield to pedestrians. Along either side of Washington Street (Route 16/126) there are sidewalks with handicap ramps available at driveways and cross streets that are between 5 and 13 feet wide depending on the section of the roadway. On the majority of Washington Street (Route 16/126) there is also a brick barrier with tree planters in several locations between the roadway and sidewalk.

Hollis Street
Hollis Street is a two-way, two lane urban minor arterial under Town of Holliston jurisdiction that runs in the east/west direction abutting residential properties to the west and terminating at Washington Street (Route 16/126) to the east. Hollis Street is approximately 24 feet wide until

it approaches the intersection with Washington Street (Route 16/126) where it widens. There are sidewalks on the southern side of the roadway that are approximately 5 feet wide.

Charles Street
Charles Street is a one-way, one lane local roadway under Town of Holliston jurisdiction that runs in the eastern direction from Washington Street (Route 16/126) into a residential area. There are sidewalks along the northern side of the roadway adjacent to the Washington Street (Route 16/126) intersection.

Central Street
Central Street is a two-way, two lane urban minor arterial under Town of Holliston jurisdiction that runs in the east/west direction abutting residential properties to the east and terminating at Washington Street (Route 16/126) to the west. Central Street is approximately 30 feet wide adjacent to the intersection with Washington Street (Route 16/126) with 15-foot wide travel lanes in either direction. There are sidewalks on both sides of the roadway that are six feet wide and there is on-street parking on the north side of the roadway further east.

Green Street
Green Street is a two-way, two lane local roadway under Town of Holliston jurisdiction that runs in the east/west direction abutting residential properties to the west and terminating at Washington Street (Route 16/126) to the east. Green Street is approximately 28 feet wide and is only striped adjacent to Washington Street (Route 16/126). There is on-street parking along the north side of the roadway and sidewalks on both sides of the road that are 4 to 5 feet in width.

Exchange Street
Exchange Street is a two-way, two lane local roadway under Town of Holliston jurisdiction that runs in the east/west direction abutting residential properties to the east and terminating at Washington Street (Route 16/126) to the west. Green Street is approximately 27 feet wide with a 3-foot wide shoulder on the south side. There is on-street parking along the north side of the roadway and sidewalks on both side of the roadway that are 4 to 5 feet in width.

Intersections

Washington Street (Route 16/126) at Hollis Street/Charles Street
Washington Street (Route 16/126) at Hollis Street/Charles Street is an unsignalized intersection with the Hollis Street approach stop controlled. In the northbound and southbound directions there are exclusive left turn lanes with approximately 100 feet of storage that are 12 feet wide and shared through right lanes that are also 12 feet wide. In the eastbound direction, Hollis Street widens at the intersection from a one lane to a two lane approach with a shared left and through lane that is 12 feet wide and an exclusive right turn lane that is 16 feet wide. Charles Street is a one-way roadway traveling eastbound and does not add an approach to the intersection. There are 10-foot wide crosswalks spanning Charles Street and Hollis Street.

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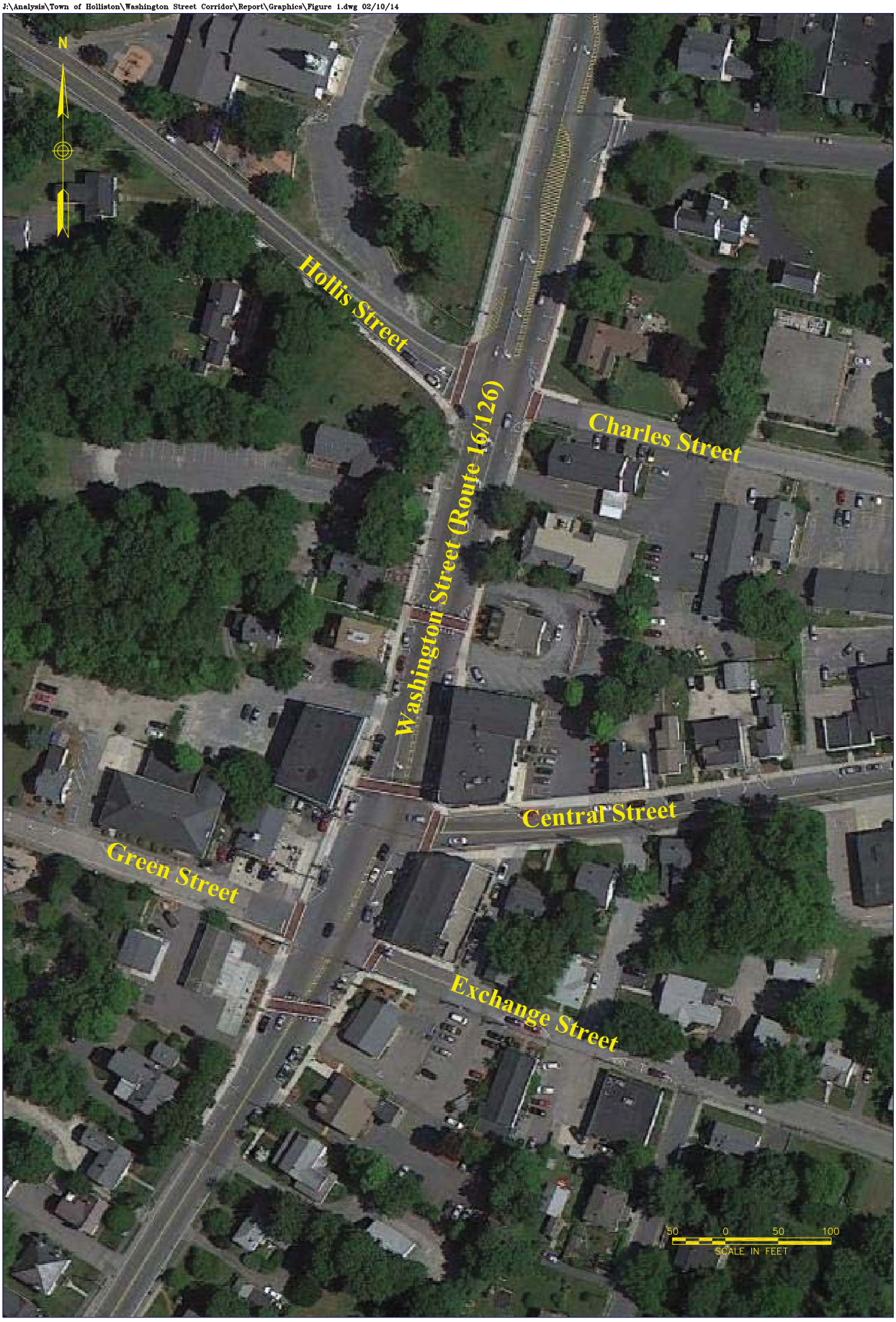

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Figure 1
Project Location Map
Washington Street Corridor Improvements
Holliston, Massachusetts

Washington Street (Route 16/126) at Central Street

Washington Street (Route 16/126) at Central Street is an unsignalized intersection with the Central Street approach stop controlled. In the northbound direction, there is an exclusive right turn lane that has approximately 70 feet of storage before the adjacent intersection and an exclusive through lane. In the southbound direction, there is an exclusive left turn lane with approximately 90 feet of storage and an exclusive through lane. In the westbound direction, Central Street has a single, multi-use approach that is approximately 15 feet wide at the intersection with Washington Street (Route 16/126). There is a 12-foot wide crosswalk spanning the southbound approach of Washington Street (Route 16/126) with signage for vehicles to yield to pedestrians as well as a push button activated warning light to further indicate when there are pedestrians in the crosswalk. There is also a 10-foot wide crosswalk spanning Central Street at the intersection.

Washington Street (Route 16/126) at Exchange Street/Green Street

Washington Street (Route 16/126) at Exchange Street/Green Street is an unsignalized intersection with the Green Street and Exchange Street approaches stop controlled. In the northbound direction, there is a shared, multi-use lane that is approximately 15 feet wide, and widens at the intersection with room observed for vehicles to pass left turning vehicles on the right. In the southbound direction, there is a multi-use lane that is approximately 30 feet wide. Though it is not striped for two lanes, it is used as a turning lane and passing lane. In the eastbound and westbound directions, there are exclusive multi-use lanes that are both 12 feet wide. There are 10-foot wide crosswalks that span both Green Street and Exchange Street and there is a 12-foot wide crosswalk spanning the southbound approach of Washington Street (Route 16/126) with signage for vehicles to yield to pedestrians as well as a push button activated warning light to further indicate when there are pedestrians in the crosswalk.

Parking

Parking observations were taken on Tuesday, September 17, 2013 for the on-street parking locations along Washington Street (Route 16/126) within the study area. The observation sheets can be viewed in Appendix D of this report. Adjacent to the intersection of Washington Street (Route 16/126) at Hollis Street, the parking spaces to the north along the western side of the street, next to the church, were observed to be vacant during both peak hours with a total of 13 spaces available between Jasper Hill Road and Hollis Street. The parking along the eastern side of the roadway north of Charles Street was observed to have a maximum of three vehicles parked during both peak hours with a capacity of nine spaces between Church Street and Charles Street. To the south of the intersection on the western side of the roadway, the single available space adjacent to the mid-block crosswalk was observed to be occupied during 25% of the weekday morning peak hour and for approximately 75% of the weekday afternoon peak hour. The parking along the eastern side of the roadway between Charles Street and the

midblock crosswalk had a maximum of one space filled during the weekday morning peak hour and a maximum of two spaces filled during the weekday afternoon peak hour, with a total five spaces available in this section.

The parking spaces between the mid-block crosswalk and the Washington Street (Route 16/126) at Central Street intersection along the western side of the roadway were observed to have a maximum of one vehicle parked in this section during the weekday morning peak hour and three vehicles during the weekday afternoon peak hour with an available five spaces. On the eastern side of Washington Street (Route 16/126) north of Central Street, a maximum of one vehicle was observed during the weekday morning peak hour and four vehicles during the weekday afternoon peak hour, with a total of five spaces available in this section. To the south of Central Street along the western side of the roadway, there is one space before the gas station site driveway. This space was occupied for approximately 40% of the weekday morning peak hour and 75% of the weekday afternoon peak hour.

Along the eastern side of the roadway between Central Avenue and Exchange Street, a maximum of two vehicles were observed during the weekday morning peak hour and a maximum of three vehicles were observed during the weekday afternoon peak hour, with a total of three spaces available. On the western side of the roadway north of Green Street and south of the gas station site driveway, there is one space available. The space was occupied for approximately 75% of the weekday morning peak hour and 85% of the afternoon peak hour. In the area south of Exchange Street on the eastern side of Washington Street (Route 16/126), there were a maximum of three vehicles parked during the weekday morning peak hour and four vehicles parked during the weekday afternoon peak hour with five available spaces in this section.

Overall, the majority of the parking between Hollis Street and Exchange Street on either side of the roadway is utilized throughout the day. There is, however, a large amount of parking availability north of Hollis Street on either side of Washington Street (Route 16/126) during both weekday peak hours. Due to the proximity of the two adjacent churches, it is expected that these spaces would be utilized much more on weekends.

Previous Studies

Traffic Signal Warrant Analysis, VHB (1995)

A previous traffic signal warrant analysis was conducted by Vanasse Hangen Brustlin, Inc. (VHB) in 1995. The report reviewed the same study area intersections with the addition of Washington Street (Route 16/126) at Church Street, just north of Hollis Street. The report summarized the existing traffic volumes and the MUTCD signal warrants that were met. Based on this report, it was determined that there is a need for traffic signal control at the intersections of Washington Street 9Route 16/126) at Hollis Street as well as Washington Street (Route 16/126) at Central Street.

A comparison of traffic volumes from this 1995 report and the 2013 existing traffic volumes indicates there was an overall reduction in traffic volumes for both the weekday morning peak hour and weekday afternoon peak hour. During the weekday morning, there was an overall reduction of approximately 9.5% throughout the study area and in the weekday afternoon, there was a reduction of approximately 6%.

Route 126 Corridor – Transportation Improvement Study, Boston Regional MPO (2011)

A previous study conducted by the Boston Regional Metropolitan Planning Organization (MPO) details improvements along the Route 126 corridor from Bellingham to Framingham including a portion through Holliston. It was noted in the report that several improvements are recommended for the intersection of Washington Street (Route 16/126) at Hollis Street including:

- Considering the installation of a new traffic signal or modern roundabout.
- Constructing curb extensions, medians, and/or islands to channelize the intersection area.
- Repaint faded crosswalks and lane markings.
- Redesign and move the church driveway farther west on Hollis Street away from the intersection.
- Consider the addition of a bicycle lane on this portion of Washington Street (Route 16/126) through Holliston.

Road Safety Audit – Washington Street, MassDOT (2012)

A road safety audit (RSA) was conducted by the Massachusetts Department of Transportation (MassDOT) for the Washington Street (Route 16/126) corridor from Church Street to the north and Exchange Street/Green Street to the south. The RSA team was composed of a diverse group of representatives from the Town of Holliston as well as engineers from MassDOT and Howard Stein/Hudson Associates who prepared the report.

The findings in the report detailed several issues within this corridor including speeding, driver frustration, crashes due to driver confusion, parking/access management, and pedestrian bicycle conditions. The increase in crashes due to driver confusion is a result of drivers yielding the right of way to vehicles entering from a cross street or allowing pedestrians to cross the roadway and the unexpected stop causes a collision. Additionally, since there are large queues and substantial delays at several side streets, drivers have a tendency to become frustrated and accept inappropriate gaps in traffic that cause collisions.

Traffic Conditions

Traffic Volume Data

Traffic count data was collected on study area roadways and intersections. The data consists of manual turning movement counts (MTMC) and automatic traffic recordings (ATR).

The ATRs were collected on Thursday, September 12, 2013 for a 24-hour period at the following locations:

- Washington Street (Route 16/126) north of Hollis Street
- Hollis Street west of Washington Street (Route 16/126)
- Central Street East of Washington Street (Route 16/126)

A summary of the ATR data is provided in Table 1 and in Appendix A of this report.

Table 1: ATR Summary Table

	ADT	HV* (%)	85th Percentile Speed (mph)	AM Peak (7 AM to 8 AM)	PM Peak (5 PM to 6 PM)
Washington Street (Route 16/126)					
Northbound	10,900	5.3	39	1,067	589
Southbound	10,400	5.3	39	532	953
TOTAL	21,300	5.3	39	1,599	1,542
Hollis Street					
Eastbound	3,300	4.3	36	367	261
Westbound	3,600	5.6	36	326	369
TOTAL	6,900	5.0	36	693	630
Central Street					
Eastbound	4,500	5.3	31	378	410
Westbound	3,900	5.9	30	286	316
TOTAL	8,400	5.6	31	664	726

HV = Heavy Vehicle Percentage

The ATR data was used to determine the highest two peak periods during the day to collect MTMCs. The MTMCs were collected from 7:00 AM to 9:00 AM and 4:00 PM to 6:00 PM at the following intersections on Tuesday, September 17, 2013:

- Washington Street (Route 16/126) at Hollis Street/Charles Street
- Washington Street (Route 16/126) at Central Street
- Washington Street 9Route 16/126) at Green Street/Exchange Street

Since the traffic volumes were collected during the months of September, seasonal adjustment factors were not applied, as September yields traffic volumes higher than average, resulting in a conservative evaluation.

Based on the MTMC data, the weekday morning and afternoon peak hours within the study area were determined to be 7:00 AM to 8:00 AM and 5:00 PM to 6:00 PM, respectively. The existing traffic flow networks for the weekday morning and weekday afternoon peak hours are presented below in Figure 2 and Figure 3, respectively. The bicycle and pedestrian volumes are shown in Figure 4. A complete set of MTMC data can be found in Appendix B of this report.

Future Conditions

To determine future traffic demands on the study area roadways, the 2013 existing traffic volumes were projected to the year 2023. Independent of the proposed project, traffic volumes on the roadways in 2023 are assumed to include existing traffic, as well as new traffic resulting from general growth in the study area and from other planned development projects.

Future Roadway Improvements

Planned roadway improvement projects can affect area travel patterns and future traffic operations. At the time of this study, there are no additional planned roadway projects that will affect the study area intersections.

Background Traffic Growth

Traffic growth is primarily a function of changes in motor vehicle use and expected land development in the region. To predict a rate at which traffic on the study area roadways can be expected to grow during the ten-year forecast period (2013 to 2023), both historic traffic growth and planned area developments were examined.

Historic Traffic Growth

Based on discussions with the Town of Holliston, a background growth rate of 1.0% per year was used to forecast increases in traffic volumes on the study area roadways and intersections. This rate captures growth associated with general changes in population and accounts for other small developments in the vicinity of the study area.

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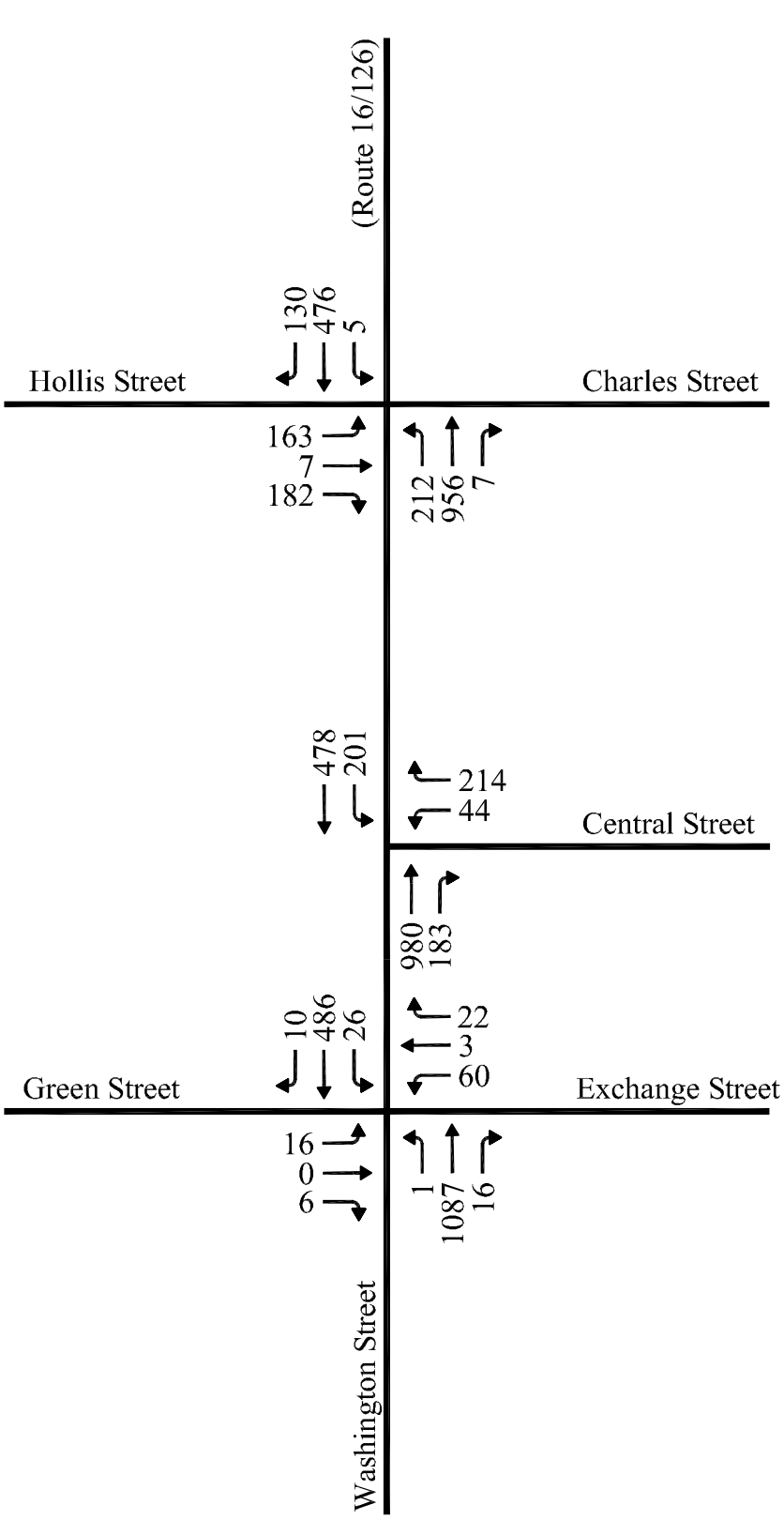

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Figure 2
2013 Existing Weekday Morning
Peak Hour Traffic Volumes
Washington Street Corridor Improvements
Holliston, MA

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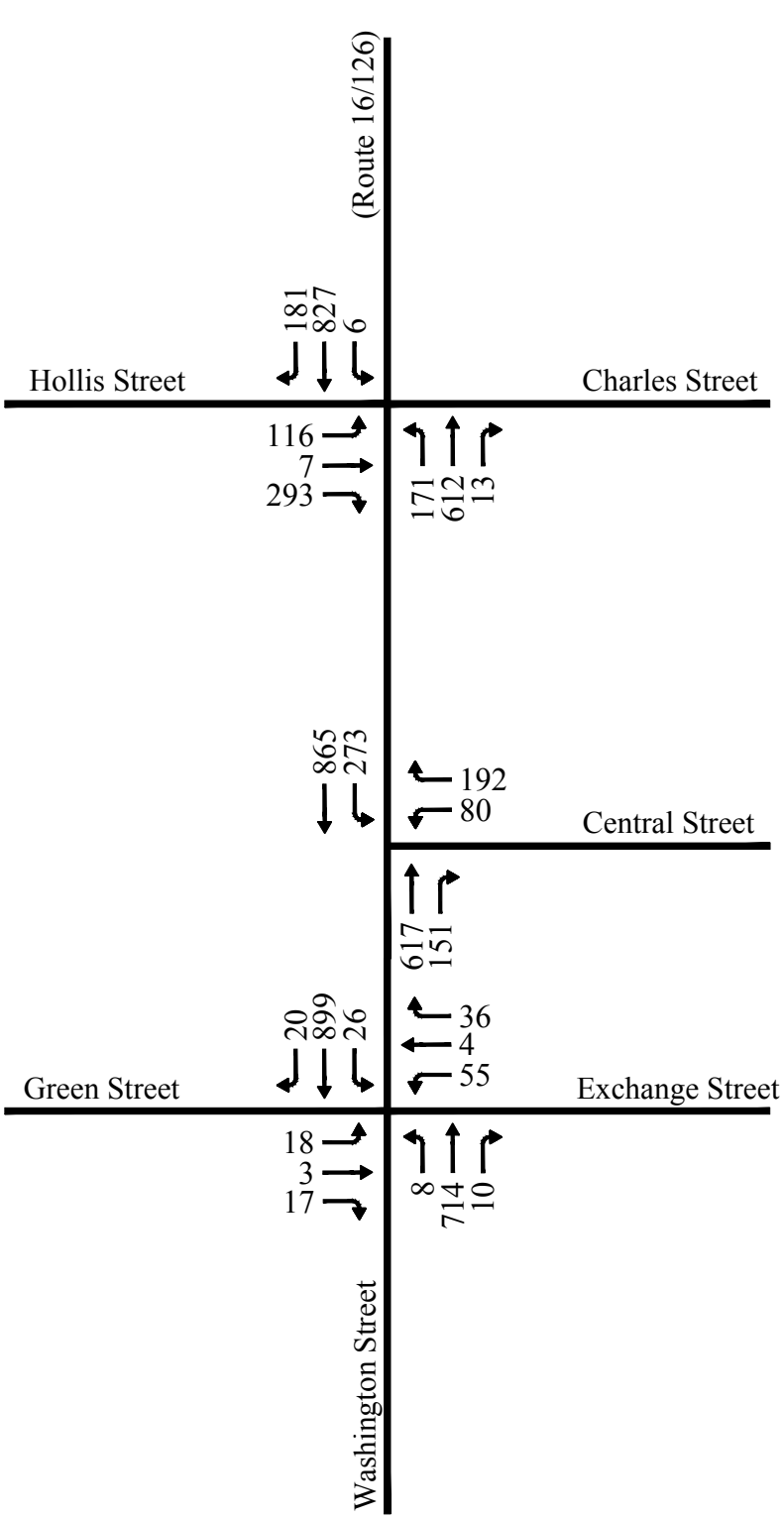

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Figure 3
2013 Existing Weekday Afternoon
Peak Hour Traffic Volumes
Washington Street Corridor Improvemments
Holliston, MA

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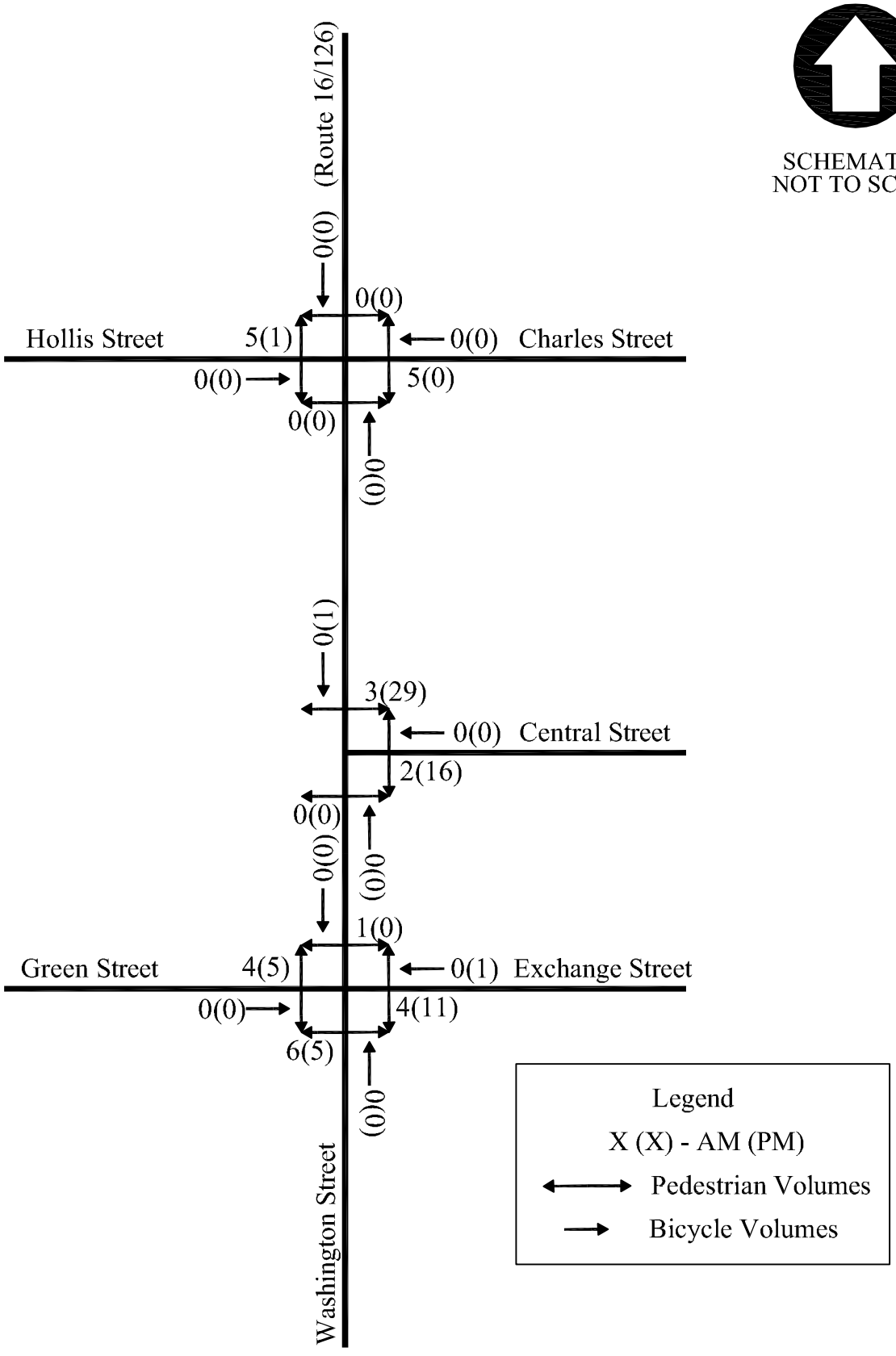

Figure 4
2013 Existing Pedestrian and Bicycle Peak Hour Volumes
Washington Street Corridor Improvements
Holliston, MA

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Site-Specific Growth

Based on conversations with the Town of Holliston, there is one planned development that would add traffic to the study area roadways and intersections. The Foxwoods Resort Casino is proposed to be constructed adjacent to Route 16 and I-495 in Milford. The proposed facility is expected to generate several trips that will travel along the Route 16 corridor and pass through the Washington Street (Route 61/126) roadway corridor in Holliston. Based on the report provided by Tetra Tech from June 2013, 19 site trips (seven northbound, 12 southbound) will be added to Washington Street (Route 16/126) during the weekday morning peak hour, and 55 site trips (21 northbound, 34 southbound) will be added during the weekday afternoon peak hour.

2023 Build Traffic Volumes

The 2013 existing peak hour traffic volumes were grown by 1.0% per year over the ten-year study horizon (2013 to 2023) and the development traffic was added to establish the 2023 build traffic volumes. The 2023 build weekday morning and weekday afternoon peak hour traffic volume networks are illustrated in Figures 5 and 6, respectively, and are documented in the traffic projection model presented in Appendix C of this report.

Traffic Analysis of Existing Roadway Conditions

Existing Analysis

A detailed capacity and level-of-service analysis was performed based on existing traffic flows in the study area. The methodologies employed and analysis results yielded are described in detail below and provided in Appendix E. Detailed existing conditions capacity/queue analysis worksheets can be found in Appendix F of this report.

Based on standard methodologies contained in the *Highway Capacity Manual* (HCM), a detailed capacity/level-of-service analysis was performed for the existing morning and afternoon peak hour traffic volumes for the three intersections in the study area.

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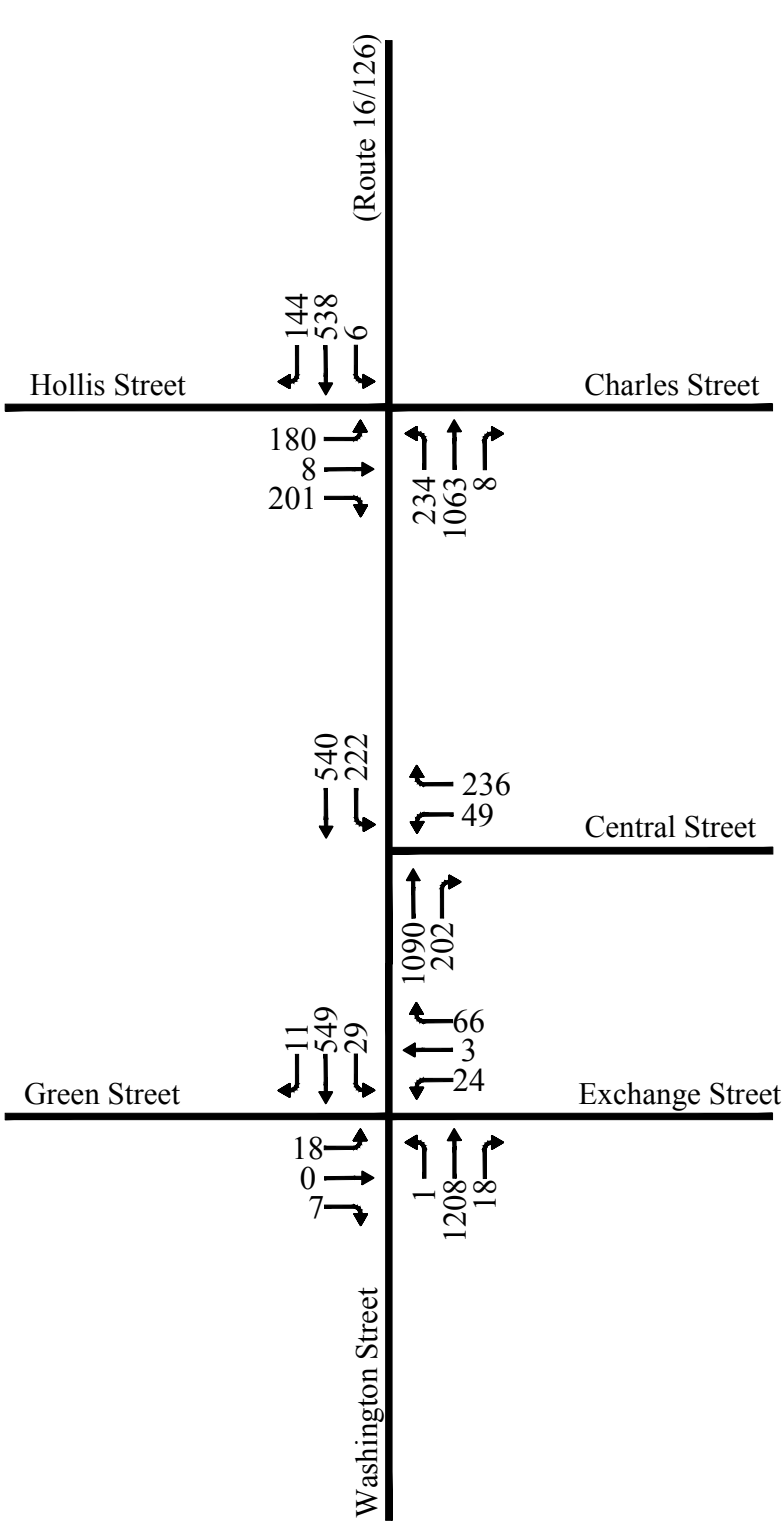

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Figure 5
2023 Build Weekday Morning
Peak Hour Traffic Volumes
Washington Street Corridor Improvements
Holliston, MA

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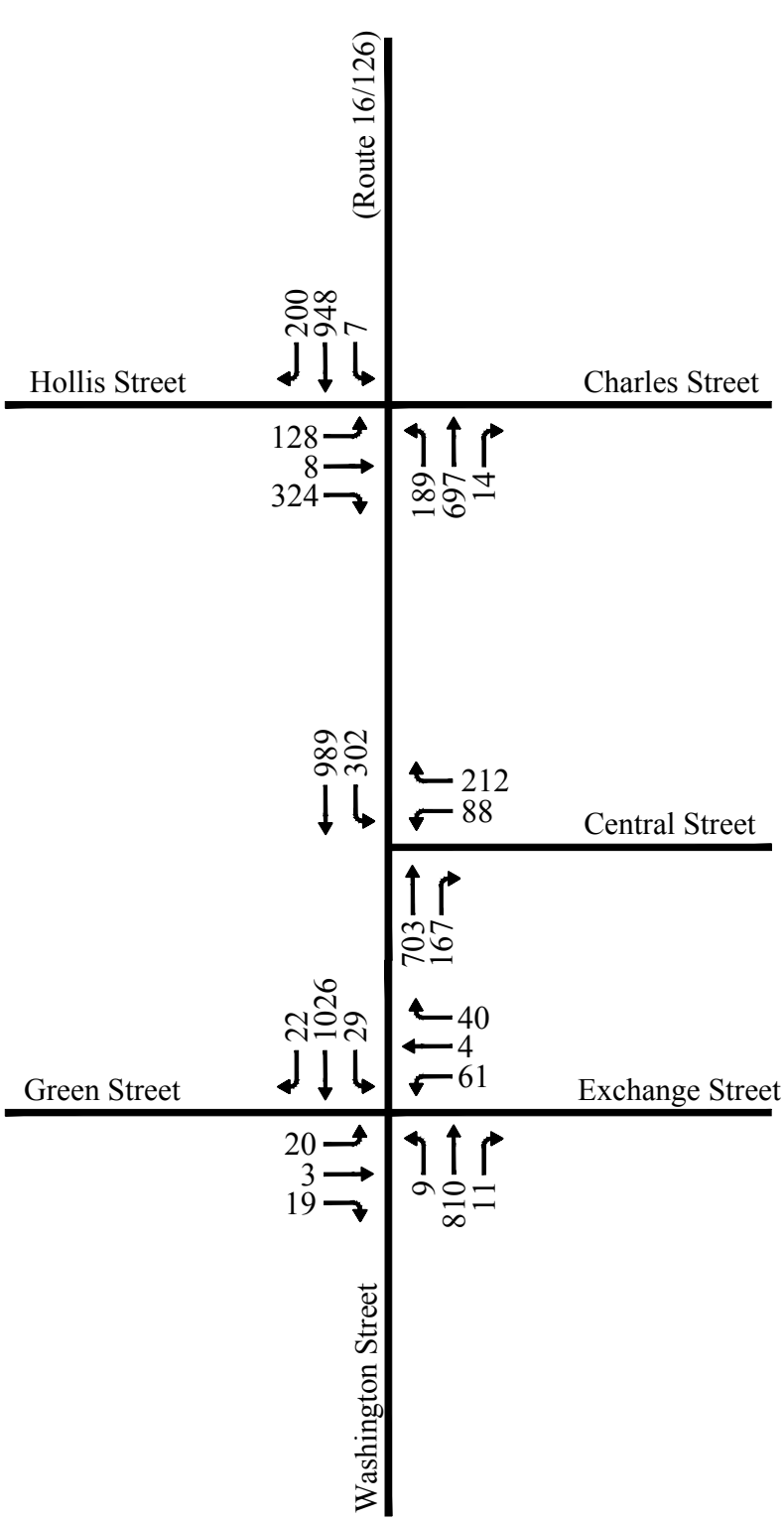

Figure 6
2023 Build Weekday Afternoon
Peak Hour Traffic Volumes
Washington Street Corridor Improvements
Holliston, MA

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

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

The concept of stop-controlled or yield-controlled intersection analysis is based on the estimate of average total delay on minor streets. The methodology of analysis relies on three elements: the size and distribution of gaps in the major traffic stream, the usefulness of these gaps to the minor stream drivers, and the relative priority of the various traffic streams at the intersection. The results of the analysis provide an estimate of average total delay for the various critical movements at the unsignalized intersections. Correlation between average total delay and the respective levels of service for unsignalized intersections are provided in Table 2.

Table 2: Level of Service Criteria for Unsignalized Intersections

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

The capacity/level-of-service analysis results for the existing weekday morning and weekday afternoon peak hours are summarized in Table 3 on the following page.

As seen in Table 3, the minor stop controlled approaches at all three intersections operate at LOS F during the weekday morning and weekday afternoon peak hours. The through movements along Washington Street (Route 16/126) all operate at LOS A and the northbound and southbound left turning movements operate at either LOS A or LOS B though out the study area.

At the intersection of Washington Street (Route 16/126) at Hollis Street, there are substantial delays and the approach is over four times the capacity during both peak hours. This is largely due to the high volumes of through traffic on Washington Street (Route 16/126) and the unavailability of gaps for vehicles to turn on Washington Street (Route 16/126). Additionally, the westbound right turn from Hollis Street would suffer much more than the analysis would indicate due to queuing impacts from the left turn movement. At the intersection of Washington Street (Route 16/126) at Central Street, the shared left and right turn lane on Central Street suffers large delays and operates well over capacity. The intersection of Washington Street (Route 16/126) at Green Street and Exchange Street also operates at LOS F, but does not operate over capacity. The higher delays are due to the unavailability in gaps on Washington Street (Route 16/126), but there is not a large volume of vehicles attempting to exit to Washington Street (Route 16/126) at this location.

Table 3: 2013 Existing Level-of-Service Analysis Summary

			2013 Existing Peak Hours					
			Weekday AM			Weekday PM		
Intersection		**Lane**	**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**
Washington Street (Route 16/126)	EB	L	F	>80.0	>1.0	F	>80.0	>1.0
at Hollis Street/Charles Street		R	C	15.0	0.29	F	50.9	0.81
	NB	L	B	10.1	0.24	B	12.6	0.29
		TR	A	0.0	0.00	A	0.0	0.00
	SB	L	B	11.0	0.01	A	9.0	0.01
		TR	A	0.0	0.00	A	0.0	0.00
	Overall		N/A	N/A	N/A	N/A	N/A	N/A
Washington Street (Route 16/126)	WB	LR	F	>80.0	>1.0	F	>80.0	>1.0
at Central Street	NB	T	A	0.0	0.00	A	0.0	0.00
		R	A	0.0	0.00	A	0.0	0.00
	SB	L	B	13.1	0.34	B	11.3	0.34
		T	A	0.0	0.00	A	0.0	0.00
	Overall		N/A	N/A	N/A	N/A	N/A	N/A
Washington Street (Route 16/126)	EB	LTR	F	>80.0	0.62	F	>80.0	0.92
at Green Street/Exchange Street	WB	LTR	F	69.9	0.70	F	>80.0	0.79
	NB	L	A	8.6	0.00	B	10.1	0.01
		TR	A	0.0	0.00	A	0.0	0.00
	SB	L	B	11.3	0.05	A	9.5	0.03
		TR	A	0.0	0.00	A	0.0	0.00
	Overall		N/A	N/A	N/A	N/A	N/A	N/A

Highway Capacity Manual (HCM) 2010

1 - Level-of-Service

2 - Average Vehicle Delay in Seconds

3 - Volume to Capacity Ratio

N/A - Not Applicable

Queue Analysis

The 95th percentile queue lengths are reported for unsignalized intersections and are shown for the three study area intersections in Table 4 below.

Table 4: 2013 Existing Queue Length Summary

			Existing Queue Lengths (feet)			
Intersection		**Lane**	**Weekday AM 95th Queue[1]**	**Weekday PM 95th Queue[1]**	**Storage**	**Capacity**
Washington Street (Rotue 16/126)	EB	L	777	762	60	Exceeds
at Hollis Street/Charles Street		R	30	167	60	Exceeds[2]
	NB	L	24	30	100	Meets
		TR	0	0	N/A	N/A
	SB	L	1	1	100	Meets
		TR	0	0	N/A	N/A
Washington Street (Route 16/126)	WB	LR	563	768	N/A	N/A
at Central Street	NB	T	0	0	N/A	N/A
		R	0	0	75	Meets
	SB	L	38	38	75	Meets
		T	0	0	N/A	N/A
Washington Street (Route 16/126)	EB	LTR	58	117	N/A	N/A
at Green Street/Exchange Street	WB	LTR	102	118	N/A	N/A
	NB	L	0	1	N/A	N/A
		TR	0	0	N/A	N/A
	SB	L	4	3	N/A	N/A
		TR	0	0	N/A	N/A

Highway Capacity Manual (HCM) 2010

1 - 95th percentil queue length

2 - Left turn queue limits right turning vehicles.

N/A - Not Applicable

As seen in Table 4, the queue lengths along Hollis Street and along Central Street during both the weekday morning and weekday afternoon peak hours are extremely high. As mentioned, both of these approaches are well over capacity. When an intersection is over capacity, the vehicles queue as they are not being processed through the intersections. These queue lengths can affect the operations of adjacent site driveways within these queue distances, particularly on Central Street where there are several abutting properties, including the Holliston Fire Station located approximately 425 feet east of Washington Street, as well as on street parking on the northern side of the roadway.

Existing Conditions Summary

Based on the existing conditions capacity analysis summarized in the tables above and in Figure 7 and Figure 8 below, the current unsignalized study area intersections do not operate well. The minor approaches along Hollis Street and Central Street operate over capacity and have substantial delays and queuing problems. The intersection of Washington Street (Route16/126) at Green Street and Exchange Street operates at LOS F along the minor stop controlled approaches, but operates under capacity and with minor queuing.

MUTCD Signal Warrants

Signal warrant analyses were performed for three study area intersections based on procedures outlined in the latest edition of the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD establishes eight criteria, referred to as warrants, for the installation of traffic signals. The warrants are based upon traffic volumes, existing roadway conditions, crash history, pedestrian volumes and proximity to schools. The manual states that satisfaction of these warrants does not in itself require the installation of a traffic signal. However, a traffic signal should not be installed unless one or more of the warrants is met. The analyses performed for this report are based on the existing traffic volumes and the criteria for the eight-hour, four-hour and peak hour volume warrants. The following warrants are not applicable to this project, Warrant 5 (school crossing), Warrant 6 (coordinated signal system), Warrant 8 (roadway network), and Warrant 9 (intersection near a grade crossing).

The eight-hour (Warrant 1) and four-hour (Warrant 2) vehicular volume signal warrants are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing traffic signal control at an intersection. For the eight-hour signal warrant to be met, minimum vehicular volumes for the major street and minor street, found in Table 4C-1 of the MUTCD, must be exceeded. To satisfy the four-hour signal warrant, the plotted points representing the hourly volumes on the major street and minor street intersection approaches during any four hours of an average weekday must fall above the applicable curve in Figure 4C-1 of the MUTCD. The aforementioned table and figure can be found in Appendix G of this report.

The peak hour (Warrant 3) signal warrant is intended for use at a location where traffic conditions are such that for a minimum of one hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street. The warrant is satisfied when the plotted point representing the total hourly traffic volume of both approaches on the major street and the corresponding hourly volume of the higher-volume minor street approach for one hour of an average day falls above the applicable curve in Figure 4C-3 of the MUTCD. Figure 4C-3 can be found in Appendix G of this report.

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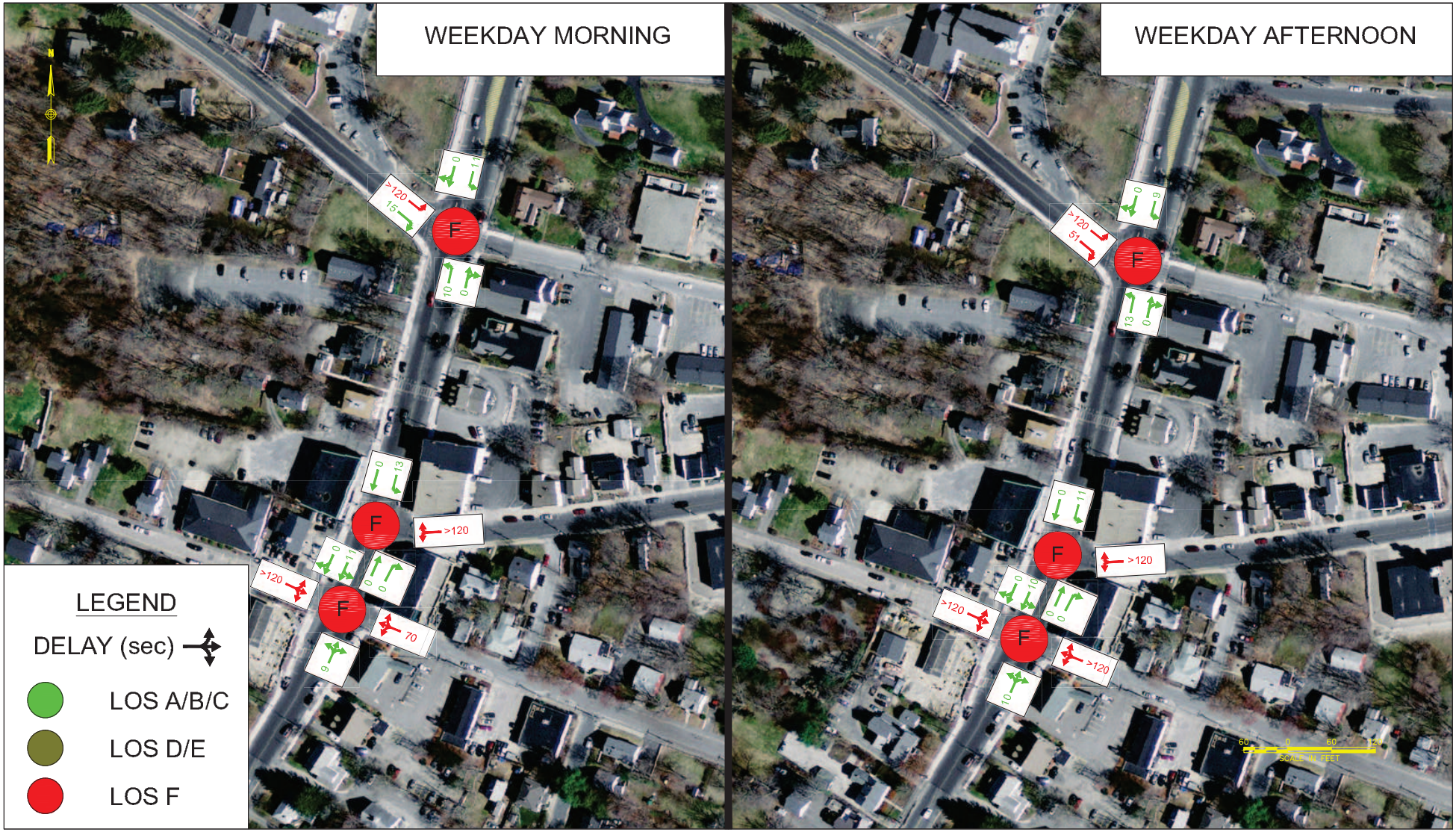

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Figure 7
2013 Existing Peak Hour
Level of Service and Delay Summary
Washington Street Corridor Improvements
Holliston, MA

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Figure 8
2013 Existing Peak Hour
Queue Lengths
Washington Street Corridor Improvements
Holliston, MA

The pedestrian volumes (Warrant 4) signal warrant is intended to be used when there are high volumes of pedestrian traffic conflicting with the major street vehicular volumes. There is both a peak hour and four hour warrant that must be satisfied in for this warrant. The warrant is satisfied when the plotted point representing the total hourly traffic volume of both approaches on the major street and the corresponding hourly volume of the conflicting pedestrian traffic for one hour of an average day falls above the applicable curve in Figure 4C-7 and for 4 hours of the average day on Figure 4C-5 of the MUTCD. Figures 4C-5 and 4C-7 can be found in Appendix G of this report.

Eight-hour, four-hour and peak hour signal warrant analyses were performed using existing traffic volumes at the intersections of Washington Street (Route 16/126) at Hollis Street/Charles Street, Washington Street at Central Street, and Washington Street at Green Street/Exchange Street. The results of the signal warrant analyses are provided in Appendix G, a summary of the results of the signal warrant analyses is presented below in Table 5.

Table 5: Signal Warrant Summary

Intersection	Eight- Hour	Four-Hour	Peak Hour	Pedestrian
Washington Street (Route 16/126) at Hollis Street/Charles Street	Yes	Yes	Yes	No
Washington Street (Route 16/126) at Central Street	Yes	Yes	Yes	No
Washington Street (Route 16/126) at Green Street/Exchange Street	No	Yes	No	No

Washington Street (Route 16/126) at Hollis Street/Charles Street Signal Warrants

As shown in Table 5, the intersection of Washington Street (Route 16/126) at Hollis Street/Charles Street meets the criteria to justify the installation of a new traffic control signal under Warrants 1, 2, and 3. We have assumed that there are two or more approach lanes on both the major roadway (Washington Street) as well as the minor roadway (Hollis Street) for the warrant analyses. Currently, there is one through travel lane and one turning lane in either direction on Washington Street (Route 16/126). The pedestrian volumes do not meet the requirements to satisfy the peak or four-hour portions of Warrant 4.

Washington Street (Route 16/126) at Central Street

As shown in Table 5, the intersection of Washington Street (Route 16/126) at Central Street meets the criteria to justify the installation of a new traffic signal under Warrants 1, 2, and 3. The pedestrian volumes do not meet the requirements to satisfy the peak or four-hour portions of Warrant 4.

Washington Street (Route 16/126) at Green Street/Exchange Street

As shown in Table 5, the intersection of Washington Street (Route 16/126) at Central Street only meets the criteria to justify the installation of a new traffic signal under Warrant 2. The eight-hour warrant (Warrant 1) and the peak hour warrant (Warrant 3) were not met. Based on the six hours of turning movement data collected, the traffic volumes would not continue to meet the eight-hour warrant criteria for additional hours during the midday. The pedestrian volumes do not meet the requirements to satisfy the peak or four-hour portions of Warrant 4.

Concept Development

Improvements along the Washington Street (Route 16/126) corridor are desired for a variety of reasons including the following:

- To improve the safety and operations of the vehicular traffic flow.
- To better balance the modes of transportation.
- To manage vehicle queues between intersections, avoiding gridlock situations.
- To improve the pedestrian safety and create a more inviting pedestrian atmosphere by strategically placing crosswalks, reducing the crosswalk lengths, improving the pedestrian signals, and providing amenities that clearly designate the pedestrian's space on the roadway.

The concept designs were developed with goals of balancing transportation modes, limiting property acquisition, minimizing impacts to parking, and improving safety, efficiency, and operations.

Initially, unsignalized improvement concepts were explored. Ultimately these concepts were not carried forward due to poor traffic operations and/or extensive property acquisition. For example, replacing the downtown intersections with roundabouts would require substantial property acquisition, and this concept was eliminated based upon this adverse impact. Design concepts that involved adding capacity to the unsignalized intersections were tested and eliminated based upon poor traffic operations. Lastly, a design concept that involved signalizing two of the three downtown intersections was explored. This concept was eliminated due to poor traffic operations and excessive queue lengths.

Modifications to the roadway cross-section were explored in an effort to include bicycle lanes on the Washington Street corridor. However, this would require either property acquisition or significant reduction to on-street parking. For these reasons, bicycle lanes were not included in the design concepts. Efforts were made to provide minimum travel lane widths of 12 feet and a minimum shoulder width of four feet, where feasible.

Ultimately two design concepts were advanced, both of which include signalizing the three downtown intersections. One design concept involves modifications within the existing curb

line and the second concept involves curb line modifications. The design concepts are compared to an existing geometry alternative, which signalizes the three downtown intersections without modifications to the current lane arrangements and geometry. In each alternative, the proposed signals include pedestrian accommodations with exclusive pedestrian signal phases. Also, the traffic signals at the closely spaced intersections of Washington Street (Route 16/126) at Exchange Street/Green Street and Washington Street at Central Street will operate under one controller, with the signal phasing and timings designed to manage queues between the intersections. The design concepts are further described in the following sections.

Existing Geometry Alternative

In an effort to minimize impacts along the Washington Street (Route 16/126) corridor, the first concept developed entailed signalizing the three study area intersections with no geometric improvements. The three study area intersections will operate in an actuated-coordinated signal system.

The intersection of Washington Street (Route 16/126) at Hollis Street/Charles Street will operate with two phases for vehicular traffic including a northbound and southbound protected through phase with permitted left turns onto Hollis Street and Charles Street, and an exclusive eastbound approach phase on Hollis Street for all movements. Additionally, there will be an exclusive push button activated pedestrian phase with crossings on the northbound Washington Street (Route 6/126) approach and on both side streets.

Since the intersections of Washington Street (Route 16/126) at Central Street and Washington Street (Route 16/126) at Green Street/Exchange Street are closely spaced, they will operate in a clustered intersection controlled by one signal controller. The signal will operate with four vehicular phases with split phasing between the two intersections. The phases will include a protected southbound left and through phase, a protected northbound and southbound through phase with permitted left turns onto the side streets, a protected westbound phase on Central Street for all movements, and a protected through and right turn phase for the Green Street and Exchange Street approaches with permitted left turns onto Washington Street (Route 16/126).

<u>Pros:</u>

- No loss of on-street parking
- Minimal cost
- Exclusive pedestrians phases at signalized intersections

Cons:

- Signals operate over capacity
- Queues will extend into adjacent intersections

Modified Alternatives

Alternative 1 - Modified Lane Usage

To further facilitate traffic through the Washington Street (Route 16/126) corridor, the second concept builds upon the first concept with coordinated signal phasing throughout the corridor and adds improvements in key locations as shown in Figure 9. These improvements hold the existing curb lines while restriping existing roadways to increase capacity.

The northbound approach to the intersection of Washington Street (Route 16/126) at Green Street/Exchange Street will be changed from a single multi-use lane to a shared left turn and through lane and a shared through and right turn lane. The additional lane at this approach will help manage queuing and delays. The lane is approximately 50 feet long before it tapers back to a single lane south of the study area. Additionally, the southbound approach will be improved to a shared left turn and through lane and a shared through and right turn lane from the wide multi-use lane under existing conditions. Since there will be through traffic from both southbound lanes, an additional receiving lane is needed. The receiving lane then tapers back to one lane south of the study area. These improvements are expected to greatly improve the capacity at this intersection; however, a total of 10 on street parking spaces will be lost between the southern project limit and Green Street as a result of the proposed lane modifications.

At the intersection of Washington Street (Route 16/126) at Central Street, the existing northbound right turn lane will be restriped to be a shared through and right turn lane while maintaining the exclusive northbound through lane. Since two lanes will allow through traffic, an additional receiving lane is needed to the north of the intersection. This additional receiving lane tapers to one lane before the Hollis Street intersection. Since the receiving lanes are widened to allow an additional lane, there will be a loss of five on street parking spaces along the eastern side of the roadway between Green Street and Hollis Street/Charles Street. On the western side of the roadway, one on street parking space is lost between Green Street and Hollis Street/Charles Street but two on street parking spaces will be added at the existing mid-block crosswalk location.

At the intersection of Washington Street (Route 16/126)/Hollis Street/Charles Street, there are no lane use modifications. A crosswalk is proposed on Washington Street (Route 16/126) south of the cross streets. The existing midblock crosswalk will to be removed, encouraging pedestrians to cross at the intersections, where exclusive pedestrian phasing is provided and pedestrians will have opportunity to cross without vehicular conflict.

Pros:

- Traffic operates well throughout the corridor
- Exclusive pedestrian phases at signalized intersections

Cons:

- Higher cost
- Greatest loss of on street parking (16 spaces total)

Alternative 2 – Curb Line Modification

The second design alternative adds to Alternative 1 by providing curb extensions at crossing locations in an effort to shorten pedestrian crossing distance and to provide traffic calming. This alternative can be seen in Figure 10.

The curb extensions are proposed at two crosswalks on Washington Street (Route 16/126), including the crosswalks at the intersections with Central Street and Hollis Street/Charles Street. Pedestrian crossing distances are shortened by 6 feet at the Central Street intersection and by 13 feet at the Hollis Street/Charles Street intersection.

In addition to the curb extensions, curb modifications have been proposed along both sides of Washington Street (Route 16/127) south of the Green Street/Exchange Street intersection to provide a 4-foot shoulder for bicycle accommodation and preserve two existing on street parking spaces on the east side of Washington Street (Route 16/126). Curb line modifications are also proposed on the east side of Washington Street (Route 16/126) between Central Street and Hollis Street/Charles Street to preserve four existing on street parking spaces.

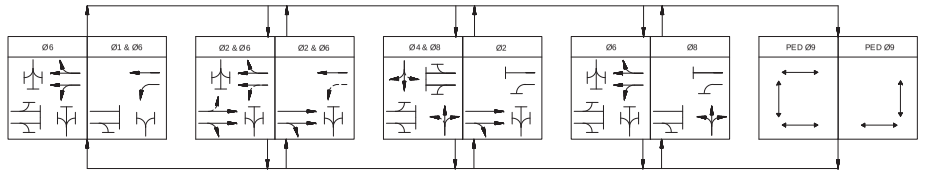
Pros:

- Shortened crossing distances for pedestrians
- Traffic calming through the corridor

Cons:

- Highest cost
- Some loss of on street parking (10 spaces total)

PREFERENTIAL PHASING SEQUENCE
(WASHINGTON ST/EXCHANGE ST/GREEN ST AND WASHINGTON ST/CENTRAL ST)



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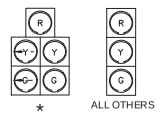
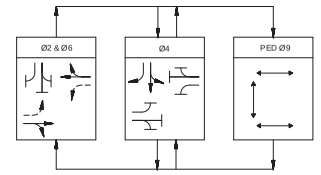
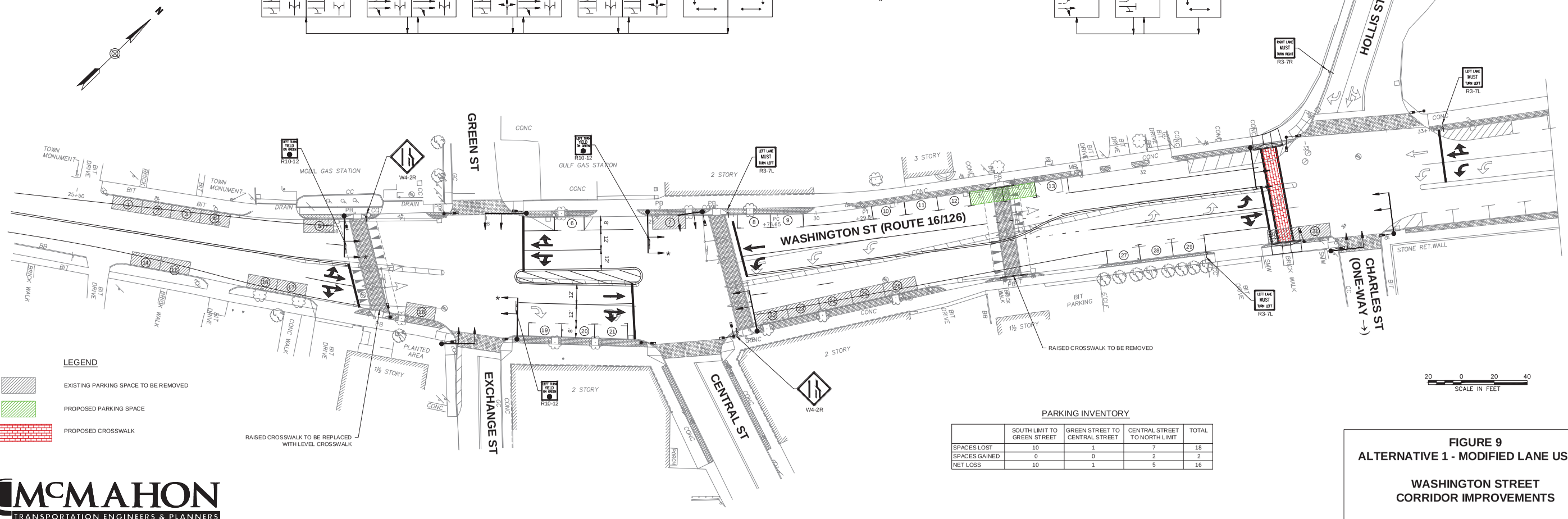


PREFERENTIAL PHASING SEQUENCE
(WASHINGTON ST/HOLLIS ST/ CHARLES ST)





LEGEND

- EXISTING PARKING SPACE TO BE REMOVED
- PROPOSED PARKING SPACE
- PROPOSED CROSSWALK

PARKING INVENTORY

	SOUTH LIMIT TO GREEN STREET	GREEN STREET TO CENTRAL STREET	CENTRAL STREET TO NORTH LIMIT	TOTAL
SPACES LOST	10	1	7	18
SPACES GAINED	0	0	2	2
NET LOSS	10	1	5	16

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FIGURE 9
ALTERNATIVE 1 - MODIFIED LANE USAGE

WASHINGTON STREET
CORRIDOR IMPROVEMENTS

HOLLISTON, MA

Preliminary Cost Estimate

The preliminary cost estimate for the recommended improvements, as outlined above and depicted in Figure 9 and Figure 10, is $1,335,000. The breakdown of this estimate can be seen below in Table 6.

Table 6: Preliminary Cost Estimate

Item	Alternative 1 Cost	Alternative 2 Cost
Cold Plane and Overlay	$200,000	$200,000
Signing and Striping	$10,000	$10,000
Curb/Sidewalks	$10,000	$160,000
Traffic Signals	$500,000	$570,000
Stamped Crosswalks	$25,000	$25,000
20% Miscellaneous	$149,000	$193,000
Subtotal	$894,000	$1,158,000
15% Contingency	$134,100	$173,700
Total	$1,028,100	$1,331,700
Say	**$1,100,000**	**$1,400,000**

Assumptions:
Estimated prices based on MassDOT Weighted Average Bid Prices (November 2013).
Unit cost for stamped crosswalks = $200/LF (Obtained from Street Prints website.)
Alternative 2 - Curb/sidewalk costs include paver accent strip.
Alternative 2 - Traffic signal costs include ornamental mast arms and pedestal poles.

Traffic Analysis of Build Conditions

Build Analysis

Under the 2023 build conditions, the study area intersections are proposed to be signalized in a coordinated signal system. For signalized intersections, an additional element must be considered from unsignalized intersections: time allocation. Level of service is based primarily on the average control delay per vehicle for various movements within the intersection. Volume-to-capacity relationships also affect level of service. Thus, both volume/capacity and delay must be considered to evaluate the overall operation of a signalized intersection. Correlation between average delay per vehicle and the respective levels of service are provided for signalized intersections as indicated in Table 7.

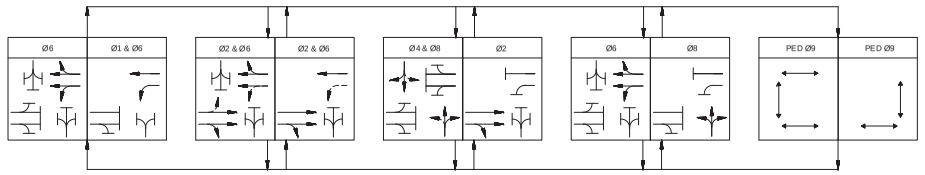
Table 7: Level of Service Criteria for Signalized Intersections

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

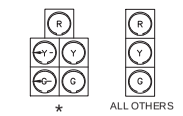
The capacity/level-of-service analysis results for the existing weekday morning and weekday afternoon peak hours are summarized in Table 8 on the following page. Detailed build condition capacity/queue analysis worksheets can be found in Appendix F of this report. Table 8 provides a comparison of the capacity analysis under signalized conditions with the existing roadway geometry and the proposed geometry. Figure 11 shows the LOS for the proposed geometry.

As seen in Table 8, the intersection of Washington Street (Route 16/126) and Hollis Street/Charles Street operates at overall LOS B during the weekday morning and LOS D during the weekday afternoon for both build concepts. During the weekday afternoon for the existing geometry concept, the northbound left turn operates over capacity. For the build concepts, all movements operate under capacity.

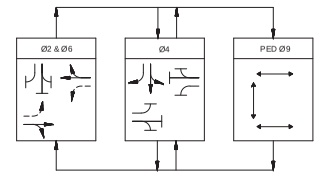
PREFERENTIAL PHASING SEQUENCE
(WASHINGTON ST/EXCHANGE ST/GREEN ST AND WASHINGTON ST/CENTRAL ST)

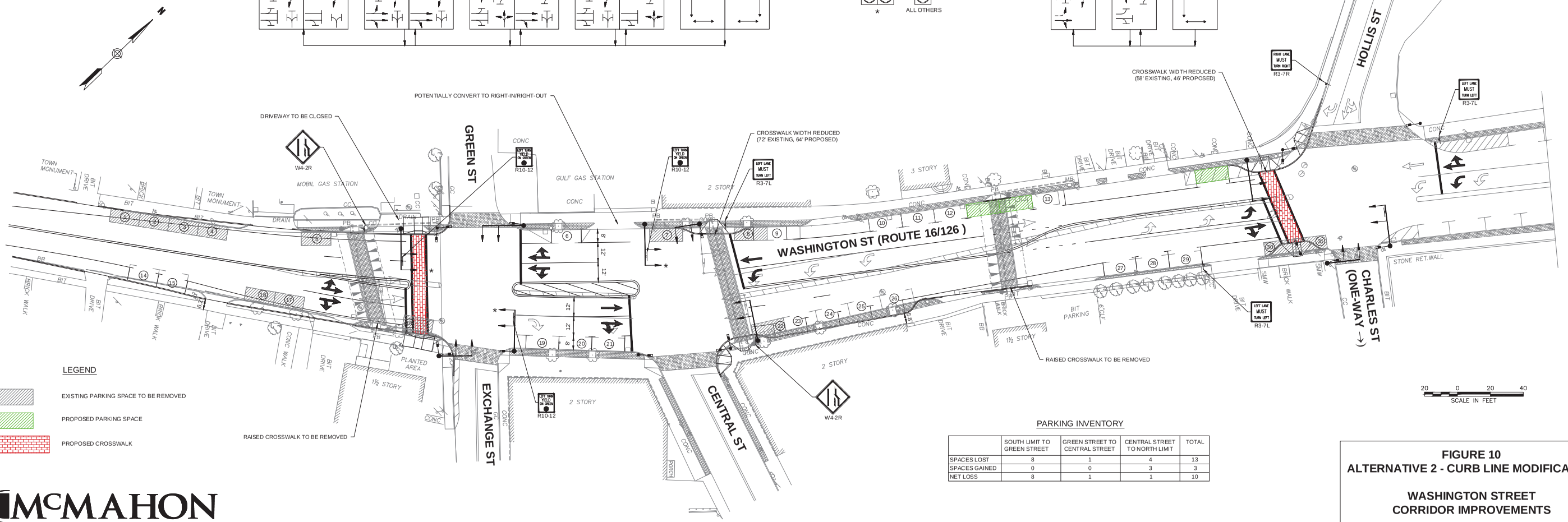


SIGNAL IDENTIFICATION



PREFERENTIAL PHASING SEQUENCE
(WASHINGTON ST/HOLLIS ST/ CHARLES ST)





LEGEND

- EXISTING PARKING SPACE TO BE REMOVED
- PROPOSED PARKING SPACE
- PROPOSED CROSSWALK

PARKING INVENTORY

	SOUTH LIMIT TO GREEN STREET	GREEN STREET TO CENTRAL STREET	CENTRAL STREET TO NORTH LIMIT	TOTAL
SPACES LOST	8	1	4	13
SPACES GAINED	0	0	3	3
NET LOSS	8	1	1	10

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FIGURE 10
ALTERNATIVE 2 - CURB LINE MODIFICATION

WASHINGTON STREET
CORRIDOR IMPROVEMENTS

HOLLISTON, MA

The intersection of Washington Street (Route 16/126) at Central Street operates at LOS D and LOS E for the weekday morning and weekday afternoon peak hours, respectively, for the existing geometry concept. The intersection improves to overall LOS B and LOS D for the weekday morning and weekday afternoon peak hours, respectively, for the build concepts. Additionally, several movements operate over capacity for the existing geometry concept. For the build concepts, the westbound approach operates just over capacity during the weekday morning peak hour, and is the only movement to operate over capacity during either peak hour.

Queue Analysis

The 50th and 95th percentile queue lengths are reported for signalized intersections and are shown for the three study area intersections in Table 9 on the following page. The queues are shown graphically in Figure 12.

As shown in Table 9, several of the queue lengths for the existing geometry concept will extend to adjacent intersections for both the 50th and 95th percentile queue lengths. Other queues, such as the northbound queue at Washington Street (Route 16/126) and Green Street/Exchange Street, and the southbound queue at Washington Street (Route 16/126) and Hollis Street/Charles Street, extend beyond the study area intersections, blocking private driveways, on street parking, and other cross streets. Many of these queuing problems are mitigated by the lane usage modifications proposed in the alternative concepts. As seen in Table 9, queue lengths are manageable and are not expected to greatly interfere with traffic signal operations at adjacent intersections within the corridor.

Build Conditions Summary

Based on the build conditions capacity analysis summarized in the tables above and below in Figure 11 and Figure 12, the proposed signalized study area intersections operate much better overall as a coordinated system as compared to existing conditions. The existing geometry concept, however, still has several capacity and queuing concerns. These issued are largely mitigated under the build condition where all study area intersections operate at an overall LOS D or better and each approach operates under capacity with the exception of the westbound approach at the Washington Street (Route 16/126) at Central Street intersection during the weekday morning peak hour and the westbound approach at the Washington Street (Route 16/126) at Green Street/Exchange Street intersection, which both operate just over capacity.

Table 8: 2023 Build Condition Capacity/Level of Service Analysis Comparison

			2023 Build Concepts											
			Exisiting Geometry						Modified Geometry					
			Weekday AM			Weekday PM			Weekday AM			Weekday PM		
Intersection	**Lane***		**LOS[1]**	**Delay[2]**	**V/C[3]**	**LOS**	**Delay**	**V/C**	**LOS[2]**	**Delay[3]**	**V/C[4]**	**LOS**	**Delay**	**V/C**
Washington Street (Route 16/126)	EB	L	E	64.4	0.83	F	90.7	0.90	E	75.4	0.88	F	115.6	0.99
at Hollis Street/Charles Street		R	B	19.2	0.56	E	78.9	0.80	C	21.3	0.59	F	82.6	0.83
	NB	L	A	4.3	0.56	E	69.4	1.03	A	5.4	0.54	E	63.4	0.95
		TR	A	9.6	0.92	A	3.5	0.57	B	19.4	0.91	A	5.2	0.56
	SB	L	A	4.3	0.04	A	2.0	0.02	A	3.7	0.04	A	1.7	0.02
		TR	A	8.6	0.62	D	41.2	0.96	A	7.7	0.61	D	44.4	0.95
	Overall		B	14.5		D	41.0		B	19.8	0	D	44.4	0
Washington Street (Route 16/126)	WB	LR	F	103.9	1.07	F	117.2	1.11	F	105.2	1.01	E	66.1	0.94
at Central Street	NB	T	D	53.8	1.03	E	57.7	0.84	N/A	N/A	N/A	N/A	N/A	N/A
		R	E	68.0	0.24	E	75.7	0.24	N/A	N/A	N/A	N/A	N/A	N/A
		TR	N/A	N/A	N/A	N/A	N/A	N/A	A	1.7	0.62	A	2.8	0.62
	SB	L	C	29.3	0.55	C	24.8	0.59	C	20.3	0.56	B	17.5	0.56
		T	A	6.3	0.48	E	66.7	0.94	A	6.7	0.48	E	70.4	0.98
	Overall		D	47.2		E	65.7		B	17.6		D	40.5	
Washington Street (Route 16/126)	EB	LTR	A	2.6	0.18	D	42.3	0.46	A	3.1	0.21	D	41.6	0.46
at Green Street/Exchange Street	WB	LTR	D	35.7	0.64	F	146.3	1.06	C	33.1	0.64	F	132.0	1.06
	NB	LTR	F	303.4	1.61	F	515.3	2.08	C	21.5	0.73	C	30.0	0.68
	SB	L	A	2.7	0.09	A	5.6	0.06	N/A	N/A	N/A	N/A	N/A	N/A
		TR	A	1.3	0.38	A	9.0	0.71	N/A	N/A	N/A	N/A	N/A	N/A
		LTR	N/A	N/A	N/A	N/A	N/A	N/A	A	1.0	0.25	A	5.8	0.46
	Overall		F	187.4		F	210.3		B	15.3		C	23.2	

Table 9: 2023 Build Condition Queue Analysis Summary Comparison

			2023 Build Queue Lengths (Feet)							
			Existing Geometry				Modified Geometry			
			Weekday AM		Weekday PM		Weekday AM		Weekday PM	
Intersection		Lane	50th Queue[1]	95th Queue[2]	50th Queue	95th Queue	50th Queue[1]	95th Queue[2]	50th Queue	95th Queue
Washington Street (Route 16/126)	EB	L	139	#218	105	#200	143	#240	106	#211
at Hollis Street/Charles Street		R	46	102	38	108	50	108	41	#135
	NB	L	35	m34	~140	m#173	21	m30	99	m#244
		TR	171	m159	82	m92	318	m#814	91	m103
	SB	L	1	4	1	3	1	4	1	3
		TR	185	286	500	#1044	166	257	462	#1033
			0	0	0	0	0	0	0	0
Washington Stree (Route 16/126)	WB	LR	~103	#274	~184	#358	~83	#261	149	#320
at Central Street	NB	T	102	m15	15	m9	N/A	N/A	N/A	N/A
		R	0	m0	0	m0	N/A	N/A	N/A	N/A
		TR	N/A	N/A	N/A	N/A	6	12	3	m0
	SB	L	107	181	152	m169	66	129	121	m137
		T	131	149	418	m#657	108	143	526	m#854
			0	0	0	0	0	0	0	0
Washington Street (Route 16/126)	EB	LTR	0	0	18	48	0	0	18	48
at Green Street/Exchange Street	WB	LTR	21	60	~78	#162	21	60	~77	#162
	NB	LTR	~1172	#1438	~884	#1105	705	821	236	298
	SB	L	1	m1	1	m1	N/A	N/A	N/A	N/A
		TR	13	m15	28	m36	N/A	N/A	N/A	N/A
		LTR	N/A	N/A	N/A	N/A	6	m7	4	m6

Highway Capacity Manual (HCM) 2010

1 - 50th percentile queue length

2 - 95th percentil queue length

N/A - Not Applicable

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Figure 11
2023 Build Peak Hour
Level of Service and Delay Summary
Washington Street Corridor Improvements
Holliston, MA

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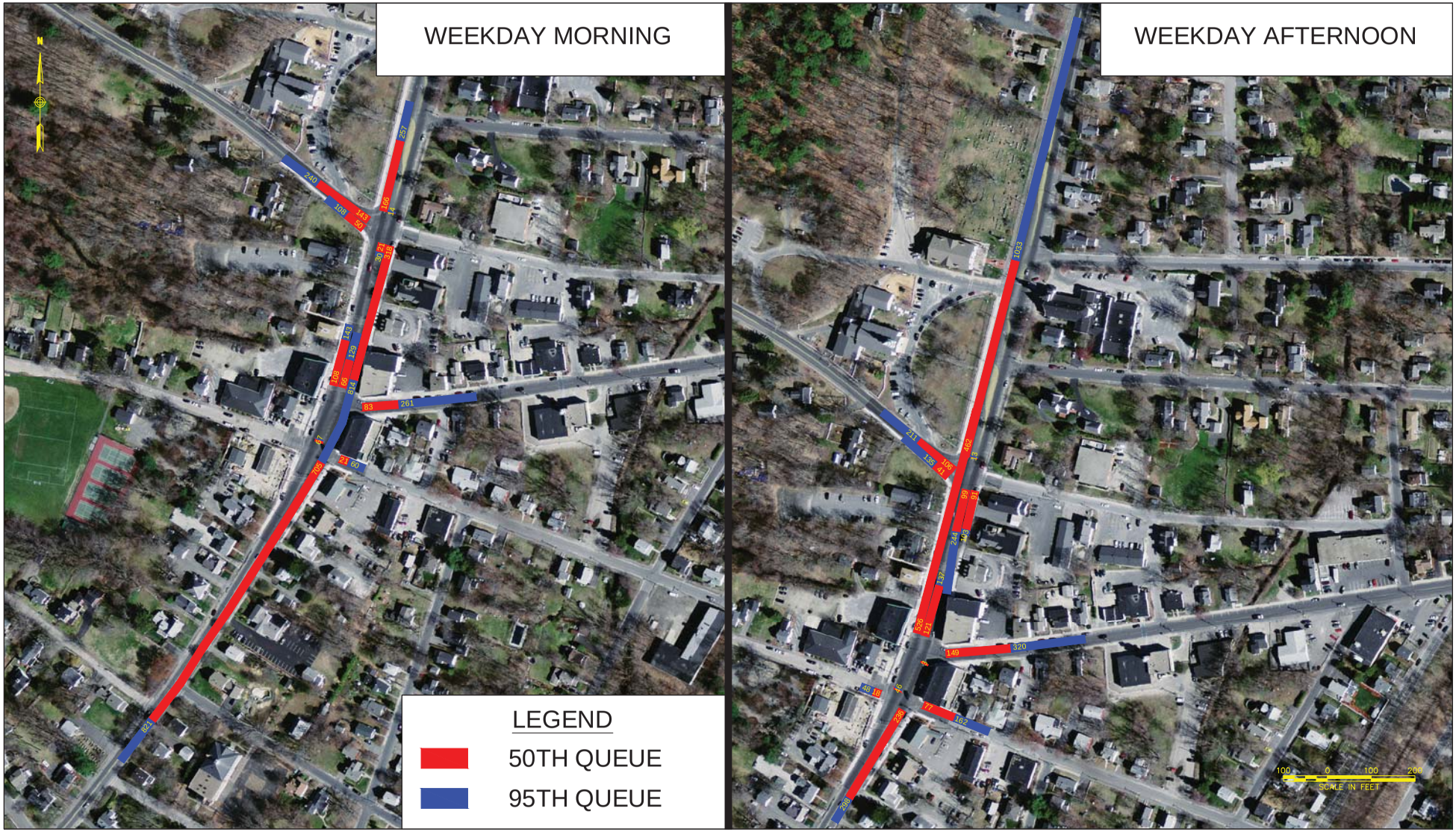

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Figure 12
2023 Build Peak Hour
Queue Lengths
Washington Street Corridor Improvements
Holliston, MA