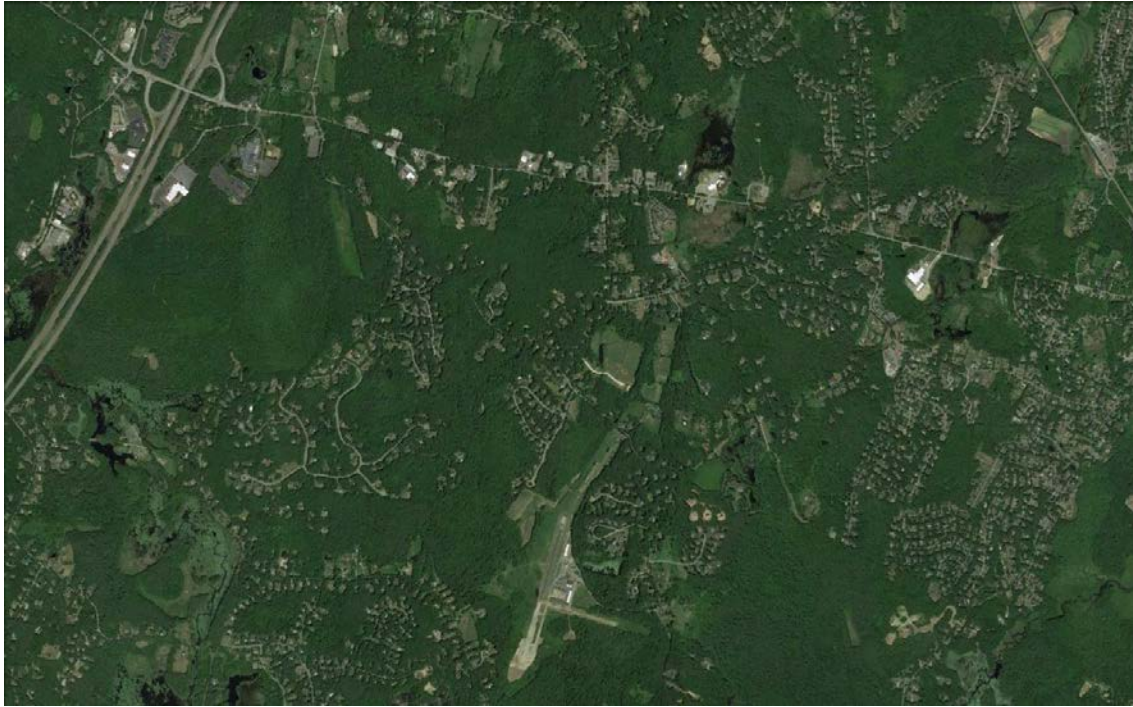


ENCLAVE AT BOXBOROUGH Massachusetts Avenue



**Boxborough, MA
August 2, 2019**

Prepared by:



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Prepared for:

Boxborough Town Center, LLC

TRAFFIC IMPACT AND ACCESS STUDY

ENCLAVE AT BOXBOROUGH

Stow Road
Boxborough, Massachusetts

Prepared for:

Boxborough Town Center LLC

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SECTION 1: EXECUTIVE SUMMARY

Bayside Engineering has prepared this study to assess the traffic impact and to evaluate the access requirements of the proposed Enclave at Boxborough residential development in Boxborough, Massachusetts.

This report identifies existing traffic operating parameters on key roadways and intersections within the study area, evaluates the anticipated traffic volume increases as a result of the proposed project, analyzes the project's traffic-related impacts, determines the projects access/egress requirements and identifies appropriate mitigating measures designed to minimize the traffic-related impacts created by the project. The following provides a brief summary of the study findings.

PROJECT DESCRIPTION

The existing site is located along the south side of Massachusetts Avenue (Route 111) west of the intersection of Stow Road and Middle Road in Boxborough, MA. Currently, the site contains a single-family home. Access to the home is currently provided by way of a single driveway to Massachusetts Avenue.

As currently proposed, the project will consist of razing the existing home and the construction of 50 age-restricted homes. Access to the site will be provided by way of a connection to the existing Sheriff's Meadow/Tisbury Meadow shared full-movement driveway to Stow Road (approximately 1,000 feet south of Massachusetts Avenue). All construction access will be provided by way of an existing driveway to Massachusetts Avenue. Upon project completion, this driveway will be removed. Figure 1 shows the site location in relation to the surrounding area.

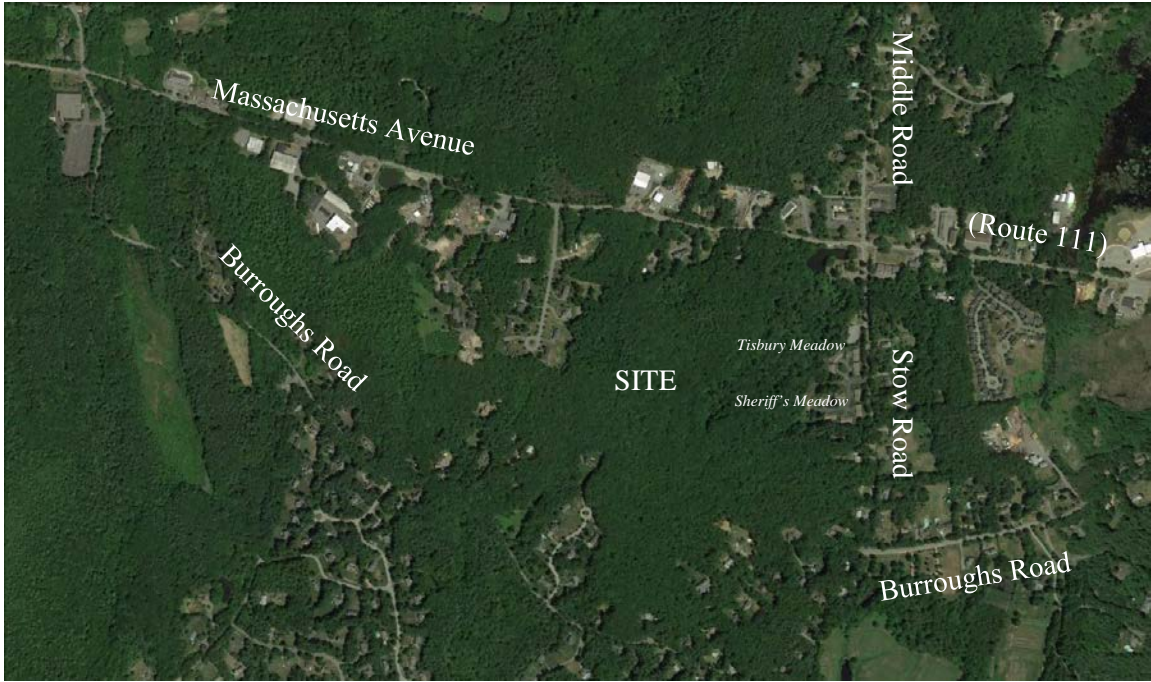


Figure 1
Site Location Map

STUDY METHODOLOGY

This study has been prepared in three stages. The first stage involved an assessment of existing conditions within the study area and included an inventory of roadway geometrics, pedestrian and bicycle facilities and public transportation services. Existing traffic counts were performed at the study area intersections.

In the second stage of the study, future traffic conditions were projected and analyzed. Specific travel demand forecasts for the project were assessed along with future traffic demands due to expected traffic growth independent of the proposed project. In accordance with Massachusetts Department of Transportation (MassDOT) guidelines, the year 2026 was selected as the basis for modeling future transportation impacts of the proposed development to reflect the opening year conditions and a seven-year planning horizon.

The third stage of the study presents and evaluates measures to address traffic issues, if any, and necessary improvements to accommodate the development.

STUDY AREA

Roadway geometry and traffic control information was collected for the following locations:

- Massachusetts Avenue, Middle Road and Stow Road
- Stow Road and Sheriff's Meadow/Tisbury Meadow Driveway
- Stow Road and Burroughs Road

EXISTING CONDITIONS

Evaluation of existing conditions within the study area includes a description of roadway geometrics, traffic constraints, land uses at the intersections, and quantification of traffic volumes.

Existing Traffic Volumes

To establish base traffic conditions within the study area, manual turning movement and vehicle classification counts were obtained in July 2019. Peak-period turning movement counts were conducted during the weekday morning period (7:00 to 9:00 AM) and the weekday evening peak period (4:00 to 6:30 PM). Daily traffic counts were conducted on Stow Road and Massachusetts Avenue for a two (2) day period using automatic traffic recorders (ATR). The weekday morning commuter peak hour was found to generally occur between 7:45 AM and 8:45 AM and the weekday evening commuter peak hour generally occurs between 4:30 PM and 5:30 PM.

The traffic volume data gathered as part of this study was collected during the month of July. Data from MassDOT was reviewed to determine the monthly variations of the traffic volumes. Based upon available data, July volumes were found to be slightly lower than average month conditions. The counts were adjusted upward to reflect the seasonal adjustment and for school activity (schools were not in session at the time of the traffic counts).

Stow Road, south of the Sheriff's Meadow/Tisbury Meadow driveway was recorded to carry approximately 1,420 vehicles per day (vpd) on a weekday. During the weekday morning peak hour, approximately 161 vehicles per hour (vph) were recorded and during the weekday evening peak hour, 142 vph were recorded.

Massachusetts Avenue, west of Stow Road was recorded to carry approximately 7,960 vpd on a weekday. During the weekday morning peak hour, approximately 672 vph were recorded on Massachusetts Avenue and during the weekday evening peak hour, 639 vph were recorded.

Vehicle Speeds

Existing speed data for Stow Road and Massachusetts Avenue was also collected. The average speed of vehicles travelling northbound or southbound on Stow Road, south of the Sheriff's Meadow/Tisbury Meadow driveway was found to be 28 or 20 mph. The 85th percentile speed was found to be 33 or 32 mph for northbound or southbound vehicles, respectively. The average speed of vehicles travelling eastbound or westbound on Massachusetts Avenue, west of Stow Road was found to be 39 or 35 mph, respectively. The 85th percentile speed was found to be 43 or 38 mph for eastbound or westbound vehicles, respectively.

Motor Vehicle Crash Data

Motor vehicle crash data for the study area intersections, Massachusetts Avenue and Stow Road were obtained from the Town of Boxborough Police Department from 2014 to 2018. The motor vehicle crash data was reviewed to determine crash trends in the study area. Six (6) crashes were reported. Four crashes (4) occurred at the intersection of Massachusetts Avenue, Middle Road and Stow Road and two (2) were reported on Massachusetts Avenue west of Stow Road. None of the study area intersections experienced a significant crash rate and no fatalities were reported.

PROBABLE IMPACTS OF THE PROJECT

No-Build Traffic Volumes

To determine the impact of site-generated traffic volumes on the roadway network under future conditions, baseline traffic volumes in the study area were projected to the year 2026. Traffic volumes on the roadway network at that time, in the absence of the proposed project, would include existing traffic, new traffic due to general background traffic growth, and traffic related to specific developments by others expected to be completed by 2026. A review of available MassDOT traffic volume data shows that growth in the area has been approximately 1.0 percent per year.

The Town's peer review engineer was contacted to determine if there are any other projects that could affect study area traffic volumes. Based on these discussions, there are no substantial projects in the area that would affect future traffic volumes.

Build Traffic Volumes

Site generated traffic was based on trip-generation data published by the ITE *Trip Generation* manual¹. The proposed site redevelopment is expected to consist of fifty (50)

¹*Trip Generation*, Tenth Edition; Institute of Transportation Engineers; Washington, DC; 2017.

age-restricted homes. Trip generation data for Land Use Code (LUC) 251 – Senior Adult Housing-Detached was reviewed.

On a typical weekday, the proposed development is expected to generate 306 daily vehicle trips. During the weekday morning peak hour, 24 vehicle trips (8 vehicles entering and 16 vehicles exiting) are expected. During the weekday evening peak hour, 28 vehicle trips (17 vehicle entering and 11 vehicles exiting) are expected.

TRAFFIC OPERATIONS ANALYSIS

In order to assess the impacts of the proposed project on the roadway network, traffic operations analyses were performed at the study area intersections under 2019 Existing, 2026 No-Build and 2026 Build conditions. These analyses indicate that the proposed project will not result in a significant impact on traffic operations at the study area intersections over No-Build conditions.

RECOMMENDATIONS

The final phase of the analysis process will be to identify the mitigation measures necessary to minimize the impact of the project on the transportation system.

It is recommended that the exit to Stow Road (the Sheriff's Meadow/Tisbury Meadow driveway) be under STOP control. It is recommended that any signage or landscaping that would occur along the Stow Road frontage be set back and designed to not impact sight lines.

A sidewalk is to be constructed along the west side of Stow Road from the driveway northerly to Massachusetts Avenue. With the construction of this sidewalk, sight lines looking out of the driveway to the north will significantly improve.

It is also recommended that Construction Entrance Ahead and Trucks Entering signs be installed on the Massachusetts Avenue approaches to the construction entrance. Existing growth within the Massachusetts Avenue layout and to the extent feasible, on-site, be trimmed back to maintain sight lines.

SUMMARY

Review of the proposed project and the access plan shows that in relation to roadway capacity, traffic safety, and traffic impacts upon the surrounding roadway network, the proposed project will meet safety standards and have a minimal impact on existing traffic conditions. Project-related increases are in the range of 0 to 18 bi-directional vehicles during the peak hours at the study area boundaries. This is approximately equivalent to

one additional vehicle every nine (9) minutes or less per direction on average during the peak hours.

The proposed access, in conjunction with the mitigation measures described above and maintaining sight distances from the driveway (clear sight lines along the site frontage), can provide safe and efficient access to the residents of the proposed project and to the motoring public in the area.

SECTION 2: EXISTING TRAFFIC CONDITIONS

STUDY AREA

Roadway geometry and traffic control information was collected for the following locations:

- Massachusetts Avenue, Middle Road and Stow Road
- Stow Road and Sheriff's Meadow/Tisbury Meadow Driveway
- Stow Road and Burroughs Road

FIELD SURVEY

A comprehensive field inventory of the proposed site was conducted in July 2019. The inventory included collection of existing roadway geometrics, traffic volumes, and safety data for the existing study area intersections and site access driveway locations. Traffic volumes were measured by means of automatic traffic recorder (ATR) counts and substantiated by manual turning movement counts (TMCs) conducted at the study area intersections.

GEOMETRICS

Primary study area roadways are described below.

Roadways

Massachusetts Avenue (Route 111)

Massachusetts Avenue (Route 111) is classified as an Urban Minor Arterial and is under the jurisdiction of the MassDOT. Route 111 traverses northeastern Massachusetts in an east-west direction from its eastern terminus at the Concord Rotary in Concord, MA to

Route 110 in Harvard, MA where the roadway then turns northerly to the New Hampshire state line. In the study area, Massachusetts Avenue is a two-lane roadway. Additional turn lanes are provided at major signalized intersections. The posted speed limit is 40 miles per hour (mph). Land use along Massachusetts Avenue in the study area is primarily residential, with several commercial properties along the north side of the road.

Stow Road

Stow Road is a local street extending in a north/south direction from Massachusetts Avenue southerly to the intersection of Boxboro Road, Fifers Lane and Flagg Hill Road. Stow Road is under the jurisdiction of the Town of Boxborough. Stow Road provides one travel lane per direction. The posted speed limit is 30 mph. Land use along Stow Road is residential.

Intersections

Massachusetts Avenue, Middle Road and Stow Road

Stow Road intersects Massachusetts Avenue from the south and Middle Road intersects from the north to form this four-legged, unsignalized intersection. The Massachusetts Avenue eastbound and westbound approaches each consist of a through lane permitting left- or right-turns. The Stow Road approach consists of a single lane permitting all movements and is under STOP-sign control. The Middle Road approach consists of a single lane permitting all movements and is under STOP-sign control. A sidewalk exists along the south side of Massachusetts Avenue east of the intersection and along the east side of Middle Road. Land use in the vicinity of the intersection consists of a church, a single-family home, a multi-family apartment complex and a small commercial building.

Stow Road and Sheriff's Meadow/Tisbury Meadow Driveway

The Sheriff's Meadow/Tisbury Meadow driveway intersects Stow Road from the west to form this three-legged, unsignalized intersection. This intersection is located on the west side of Stow Road approximately 1,000 feet south of Massachusetts Avenue. The Stow Road northbound and southbound approaches each consist of a through lane permitting left- or right-turns. The Sheriff's Meadow/Tisbury meadow driveway approach consists of a single lane permitting all movements and is under STOP-sign control. Land use in the vicinity of the intersection consists of wooded land and residential homes.

Stow Road and Burroughs Road

Burroughs Road intersects Stow Road from the east and west to form this four-legged, unsignalized intersection. All approaches to the intersection consist of a through lane permitting left- or right-turns. The Burroughs Road approaches are under STOP-sign control. Land use in the vicinity of the intersection consists of wooded land, a cemetery and a single-family home.

TRAFFIC VOLUMES

Existing Traffic Volumes

To establish base traffic conditions within the study area, manual turning movement and vehicle classification counts were obtained in July 2019. Peak-period turning movement counts were conducted on Wednesday, July 17, 2019 during the weekday morning and evening peak periods (7:00 to 9:00 AM and 4:00 to 6:30 PM). Counts were performed at the following intersections:

- Massachusetts Avenue, Middle Road and Stow Road
- Stow Road and Sheriff's Meadow/Tisbury Meadow Driveway
- Stow Road and Burroughs Road

Daily traffic counts were conducted on Stow Road and Massachusetts Avenue for a two (2) day period using automatic traffic recorders (ATR) on Wednesday, July 17, 2019 and Thursday, July 18, 2019.

Analysis of the peak-period traffic counts indicated that the weekday morning commuter peak hour generally occurs between 7:45 AM and 8:45 AM and the weekday evening commuter peak hour generally occurs between 4:30 PM and 5:30 PM. The traffic count worksheets are provided in the Appendix.

Seasonal Adjustment

The traffic volume data gathered as part of this study was collected during the month of July 2019. Data from the MassDOT was reviewed to determine the monthly variations of the traffic volumes. The traffic data showed July volumes to be slightly lower than average month conditions. Therefore, the July traffic volumes were adjusted upward by 1.04 to represent average month conditions.

Also, the July volumes were adjusted upward to account for schools being out of session. Data was obtained from the Blanchard Memorial School and the Acton Boxborough Regional School system website relative to busing and pick-up/drop-off activity of students by parents and used to adjust the existing traffic volumes accordingly. Based on this data, turning movements approaching the Blanchard Memorial School (located east of Stow Road on Massachusetts Avenue) were increased by ten (10) percent to account for school activity.

The 2019 existing weekday daily and peak hour traffic volumes for average-month conditions are summarized in Table 1. The 2019 Existing weekday morning and weekday evening peak hour traffic flow networks are shown graphically on Figure 2. The seasonal worksheets are provided in the Appendix.

**TABLE 1
EXISTING WEEKDAY TRAFFIC VOLUME SUMMARY^a**

Location	Daily Traffic Volume ^b	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
		Traffic Volume ^c	K Factor ^d	Directional Distribution ^e	Traffic Volume	K Factor	Directional Distribution
Stow Road, south of Sheriff's Meadow/Tisbury Meadow Driveway	1,420	161	11.3	52.2% NB	142	10.0	68.3% NB
Massachusetts Avenue, west of Stow Road	7,960	672	8.4	53.9% EB	639	8.0	59.6% WB

^aTwo-way traffic volume.

^bDaily traffic expressed in vehicles per day.

^cExpressed in vehicles per hour.

^dPercent of daily traffic volumes which occurs during the peak hour.

^ePercent of peak-hour volume in the predominant direction of travel.

NB = northbound; SB = southbound; EB = eastbound; WB = westbound.

Stow Road, south of the Sheriff's Meadow/Tisbury Meadow driveway was recorded to carry approximately 1,420 vehicles per day (vpd) on a weekday. During the weekday morning peak hour, approximately 161 vehicles per hour (vph) were recorded and during the weekday evening peak hour, 142 vph were recorded.

Massachusetts Avenue, west of Stow Road was recorded to carry approximately 7,960 vpd on a weekday. During the weekday morning peak hour, approximately 672 vph were recorded on Massachusetts Avenue and during the weekday evening peak hour, 639 vph were recorded.

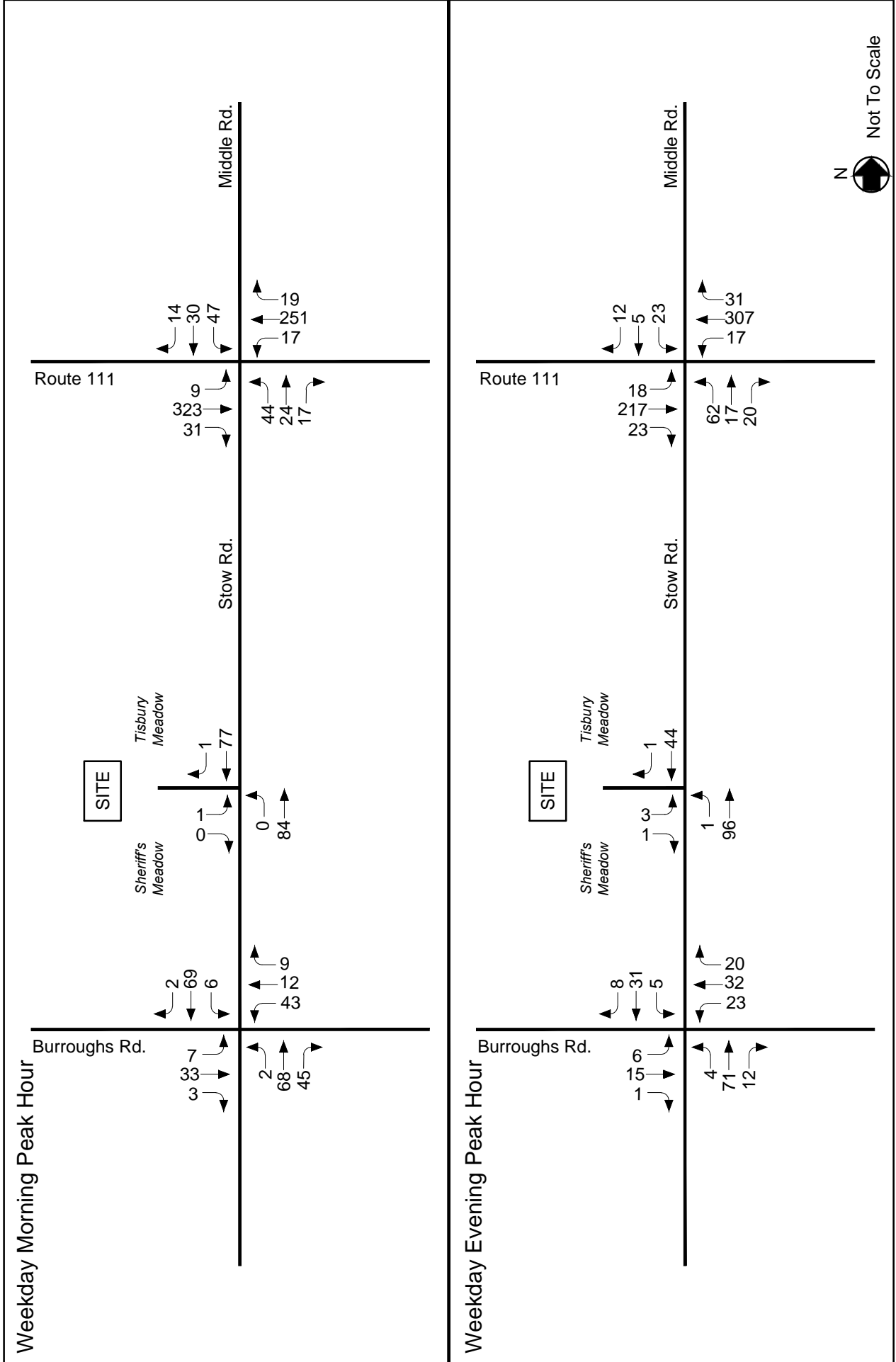


Figure 2
2019 Existing
Peak Hour Traffic Volumes

Enclave at Boxborough, MA

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VEHICLE SPEEDS

Existing speed data for Stow Road south of the Sheriff’s Meadow/Tisbury Meadow driveway and Massachusetts Avenue west of Stow Road was also collected using the ATR. The posted speed limit on Stow Road is 30 mph at the site driveway. The posted speed limit on Massachusetts Avenue is 40 mph. The speed data is summarized in Table 2.

**TABLE 2
OBSERVED VEHICLE SPEEDS**

Direction	Posted Speed Limit (mph)	Direction	Average Observed Speed ^a (mph)	85 th Percentile Speed (mph)
Stow Road, south of Sheriff’s Meadow/Tisbury Meadow driveway	30	NB	28	33
	30	SB	20	32
Massachusetts Avenue, west of Stow Road	40	EB	39	43
	40	WB	35	38

^aBased on speed data compiled on July 17 and 18, 2019.
NP = Not Posted

As shown in Table 2, the average speed of vehicles travelling northbound or southbound on Stow Road, west of the Sheriff’s Meadow/Tisbury Meadow driveway was found to be 28 or 20 mph. The 85th percentile speed was found to be 33 or 32 mph for northbound or southbound vehicles, respectively.

The average speed of vehicles travelling eastbound or westbound on Massachusetts Avenue, west of Stow Road was found to be 39 or 35 mph. The 85th percentile speed was found to be 43 or 38 mph for eastbound or westbound vehicles, respectively. The 85th percentile speed is the speed at which sight distances are typically evaluated.

MOTOR VEHICLE CRASH DATA

Motor vehicle crash data for the study area intersections and roadways were obtained from the Boxborough Police Department for 2014 through 2018. The motor vehicle crash data was reviewed to determine crash trends in the study area. The crash data is included in the Appendix. The crash data is summarized in Table 3.

**TABLE 3
MOTOR VEHICLE CRASH DATA SUMMARY^a**

Scenario	Location		
	Massachusetts Avenue, Middle Road and Stow Road	Stow Road/Sheriff's Meadow/Tisbury Meadow Driveway	Stow Road/Burroughs Road
<i>Year^b:</i>			
2014	0	0	0
2015	1	0	0
2016	1	0	0
2017	1	0	0
2018	<u>1</u>	<u>0</u>	<u>0</u>
Total	4	0	0
Average ^b	0.8	0.0	0.0
Crash Rate ^c	0.25	0.0	0.0
Significant ^d	No	No	No
<i>Type:</i>			
Angle	2	0	0
Rear-End	2	0	0
Sideswipe	0	0	0
Head-On	0	0	0
Bicycle	0	0	0
Single Vehicle Crash	0	0	0
<u>Unknown</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	4	0	0
<i>Time of Day:</i>			
Morning (7:00 to 9:00 AM)	0	0	0
Evening (4:00 to 6:00 PM)	0	0	0
<u>Remainder of Day</u>	<u>4</u>	<u>0</u>	<u>0</u>
Total	4	0	0
<i>Pavement Conditions:</i>			
Dry	4	0	0
Wet	0	0	0
Snow/Ice/Slush	0	0	0
<u>Unknown</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	4	0	0
<i>Severity:</i>			
Property Damage Only	4	0	0
Personal Injury	0	0	0
Fatal Accident	0	0	0
<u>Unknown</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	4	0	0

^aSource: Boxborough Police Department.

^bAverage crashes over analysis period.

^cCrash rate per million entering vehicles (mev).

^dSignalized intersections are significant if rate >0.73 crashes per million vehicles, and unsignalized intersections are significant if rate >0.56 crashes per million vehicles.

A total of six (6) crashes were reported during the five-year interval at the study area intersections or on Massachusetts Avenue. Four crashes (4) occurred at the intersection of Massachusetts Avenue, Middle Road and Stow Road and two (2) were reported on Massachusetts Avenue west of Stow Road. The two crashes on Massachusetts Avenue occurred where vehicles hit guardrail and ran off the road. None of the study area intersections experienced a significant crash rate and no fatalities were reported.

PLANNED ROADWAY IMPROVEMENTS

Officials for the Town of Boxborough were contacted regarding roadway improvements planned for the study area intersections. No capacity related improvements are currently planned.

SECTION 3:

FUTURE NO-BUILD AND BUILD TRAFFIC CONDITIONS

To determine the impact of site-generated traffic volumes on the roadway network under future conditions, baseline traffic volumes in the study area were projected to the year 2026. Traffic volumes on the roadway network at that time, in the absence of the proposed project, would include existing traffic, new traffic due to general background traffic growth, and traffic related to specific developments by others expected to be completed by 2026. Consideration of these factors resulted in the development of 2026 No-Build traffic volumes. Anticipated site-generated traffic volumes were then superimposed upon these No-Build traffic flow networks to develop the 2026 Build conditions.

FUTURE 2026 NO-BUILD TRAFFIC VOLUMES

Traffic growth on area roadways is a function of the expected land development in the immediate area as well as the surrounding region. Several methods can be used to estimate this growth. A procedure frequently employed estimates an annual percentage increase in traffic growth and applies that percentage to all traffic volumes under study. The drawback to such a procedure is that some turning volumes may actually grow at either a higher or a lower rate at particular intersections.

An alternative procedure identifies the location and type of planned development, estimates the traffic to be generated, and assigns it to the area roadway network. This produces a more realistic estimate of growth for local traffic. However, the drawback of this procedure is that the potential growth in population and development external to the study area would not be accounted for in the traffic projections.

To provide a conservative analysis framework, both procedures were used.

Background Traffic Growth

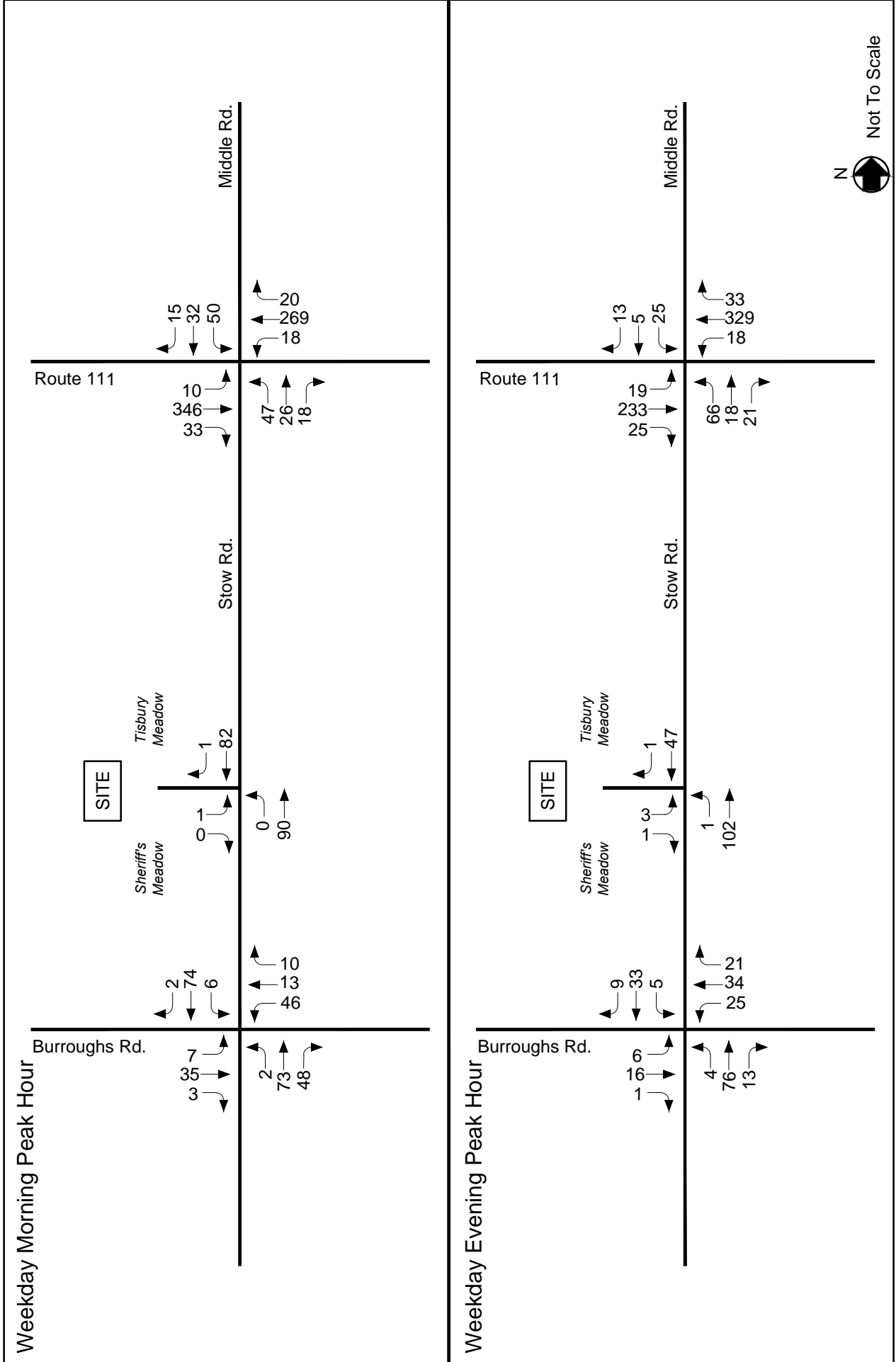
Review of available MassDOT traffic count data indicates that there has been little growth over the past several years. Traffic count data from MassDOT was reviewed. Specifically, permanent count station data was reviewed. Based on this data, growth is expected to occur at a rate of approximately 1.0 percent per year. To provide a conservative analysis, a background growth rate of 1.0 percent per year was applied.

Specific Development by Others

Traffic volumes generated by the specific local developments by others were included in the 2026 No-Build condition. The Town of Boxborough's peer review consultant was contacted to identify any specific planned developments. Based on these discussions, there are no projects that are currently planned, approved or under construction in the immediate area that would impact future traffic volumes beyond the general background traffic growth rate.

No-Build Condition Traffic Volumes

The 2026 No-Build weekday morning and weekday evening peak-hour traffic volumes were developed by applying a compounded one (1.0) percent annual growth rate to the 2019 Existing peak-hour traffic volumes. Figure 3 shows the projected 2026 No-Build peak hour traffic volumes for the respective weekday morning and weekday evening peak hours.



FUTURE 2026 BUILD CONDITIONS

Project Description

As currently proposed, the project will consist of razing the existing home and the construction of 50 age-restricted homes. Access to the site will be provided by way of a connection to the Sheriff's Meadow/Tisbury Meadow full-movement driveway to Stow Road.

Site Traffic Generation

Site generated traffic for the redevelopment was based on trip-generation data published by the Institute of Transportation Engineers (ITE) in the *Trip Generation* manual². Trip generation data for Land Use Code (LUC) 251 – Senior Adult Housing-Detached was reviewed. The trip generation for the project is summarized in Table 4 and the worksheets are included in the Appendix.

TABLE 4
PROPOSED RESIDENTIAL
TRIP-GENERATION SUMMARY

	<u>Total Trips^a</u>
Average Weekday Daily Traffic	306
<i>Weekday Morning Peak Hour:</i>	
Entering	8
<u>Exiting</u>	<u>16</u>
Total	24
<i>Weekday Evening Peak Hour:</i>	
Entering	17
<u>Exiting</u>	<u>11</u>
Total	28

^aBased on ITE LUC 251 – Senior Adult Housing-Detached; 50 units.

On a typical weekday, the proposed residential development is expected to generate 306 daily vehicle trips. During the weekday morning peak hour, 24 vehicle trips (8 vehicles entering and 16 vehicles exiting) are expected. During the weekday evening peak hour, 28 vehicle trips (17 vehicle entering and 11 vehicles exiting) are expected.

²*Trip Generation*, Tenth Edition; Institute of Transportation Engineers; Washington, DC; 2017.

Trip Distribution

The directional distribution of the vehicular traffic approaching and departing the site is a function of population densities, the location of employment, existing travel patterns, similar uses, and the efficiency of the existing roadway system. For the proposed residences, locations of employment from the recent 2010 census was reviewed. Table 5 summarizes the expected trip distribution for the residences, also shown on Figure 4.

TABLE 5
PROPOSED TRIP DISTRIBUTION

<u>Route</u>	<u>Direction</u>	<u>Percent of Trips</u>
Massachusetts Avenue	East	31
Massachusetts Avenue	West	65
Stow Road	North	3
Middle Road	South	<u>1</u>
TOTAL		100

Future Traffic Volumes - Build Condition

The site-generated traffic was distributed within the study area according to the percentages summarized in Table 5 and are shown on Figure 5. The site generated volumes shown on Figure 5 were then superimposed onto the 2026 No-Build traffic volumes to represent the 2026 Build traffic volume conditions. The anticipated 2026 Build weekday morning and weekday evening peak-hour traffic volumes are graphically presented in Figure 6. These volumes were used as the basis for all analysis as well as to identify potential mitigation measures to ameliorate the project's impacts.

A summary of 2026 peak-hour projected traffic volume changes in the site vicinity are shown in Table 6. These volumes are based on the expected increases from the site traffic generation.

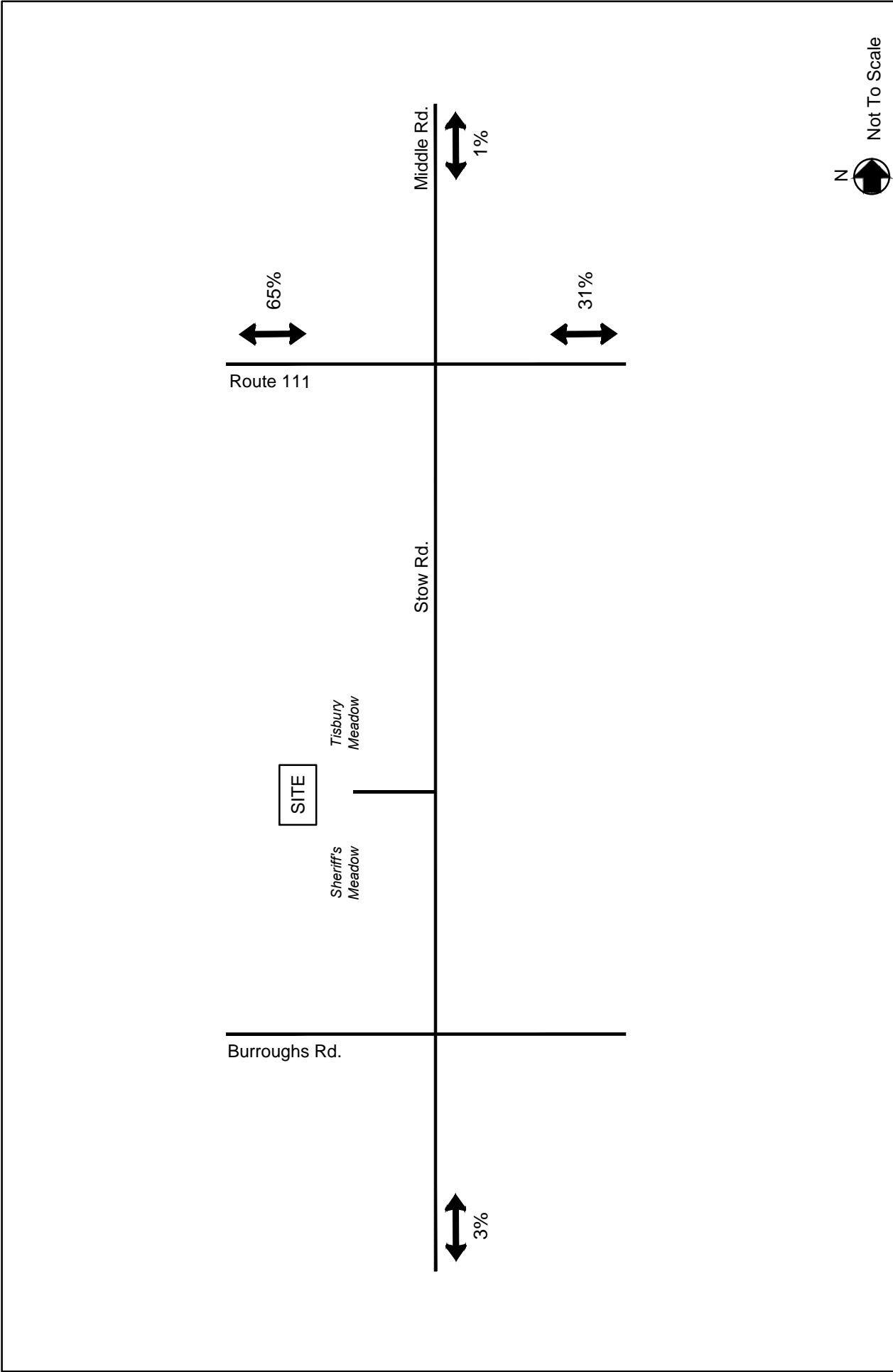


Figure 4
Trip Distribution

Enclave at Boxborough, MA

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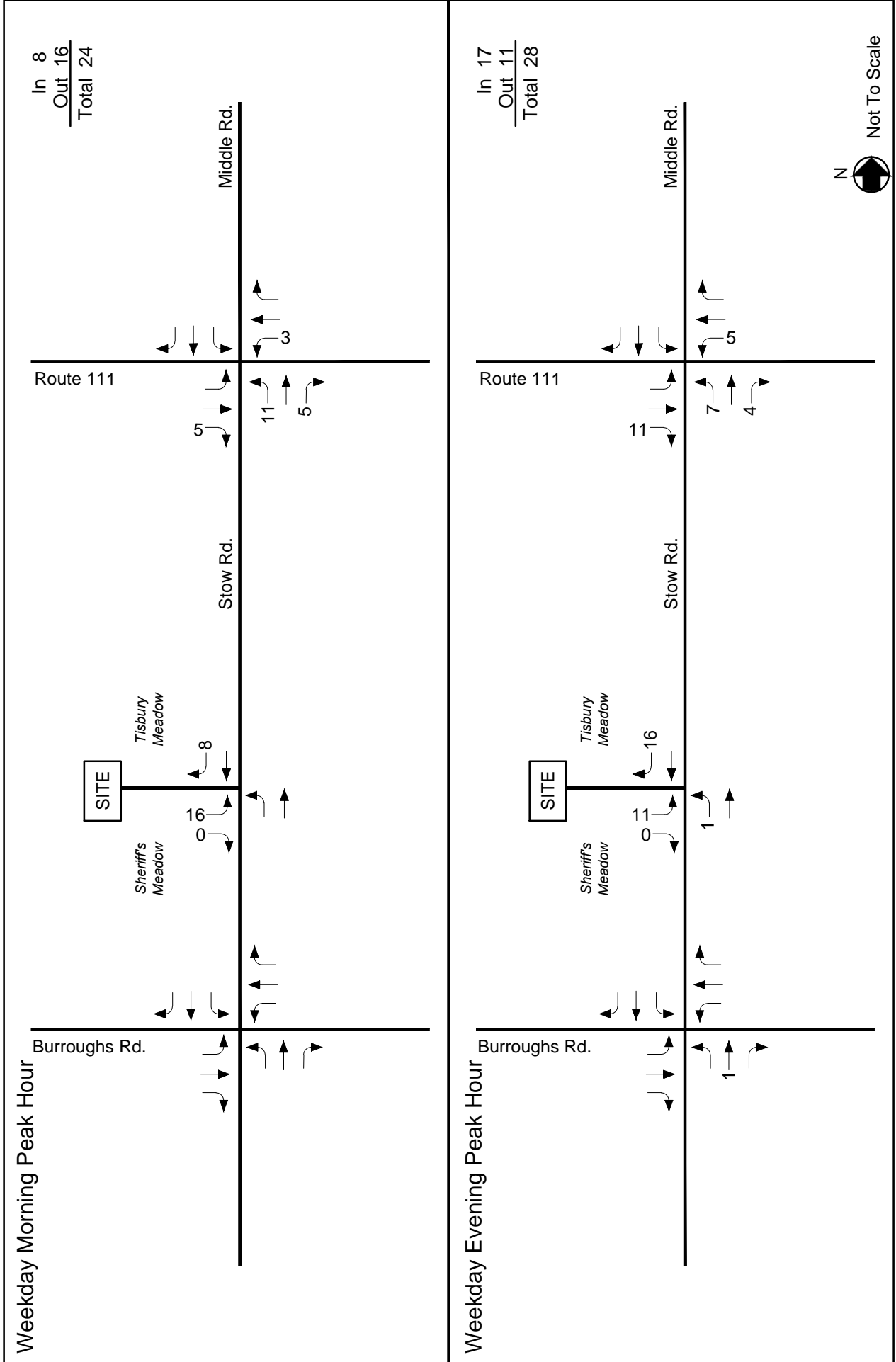
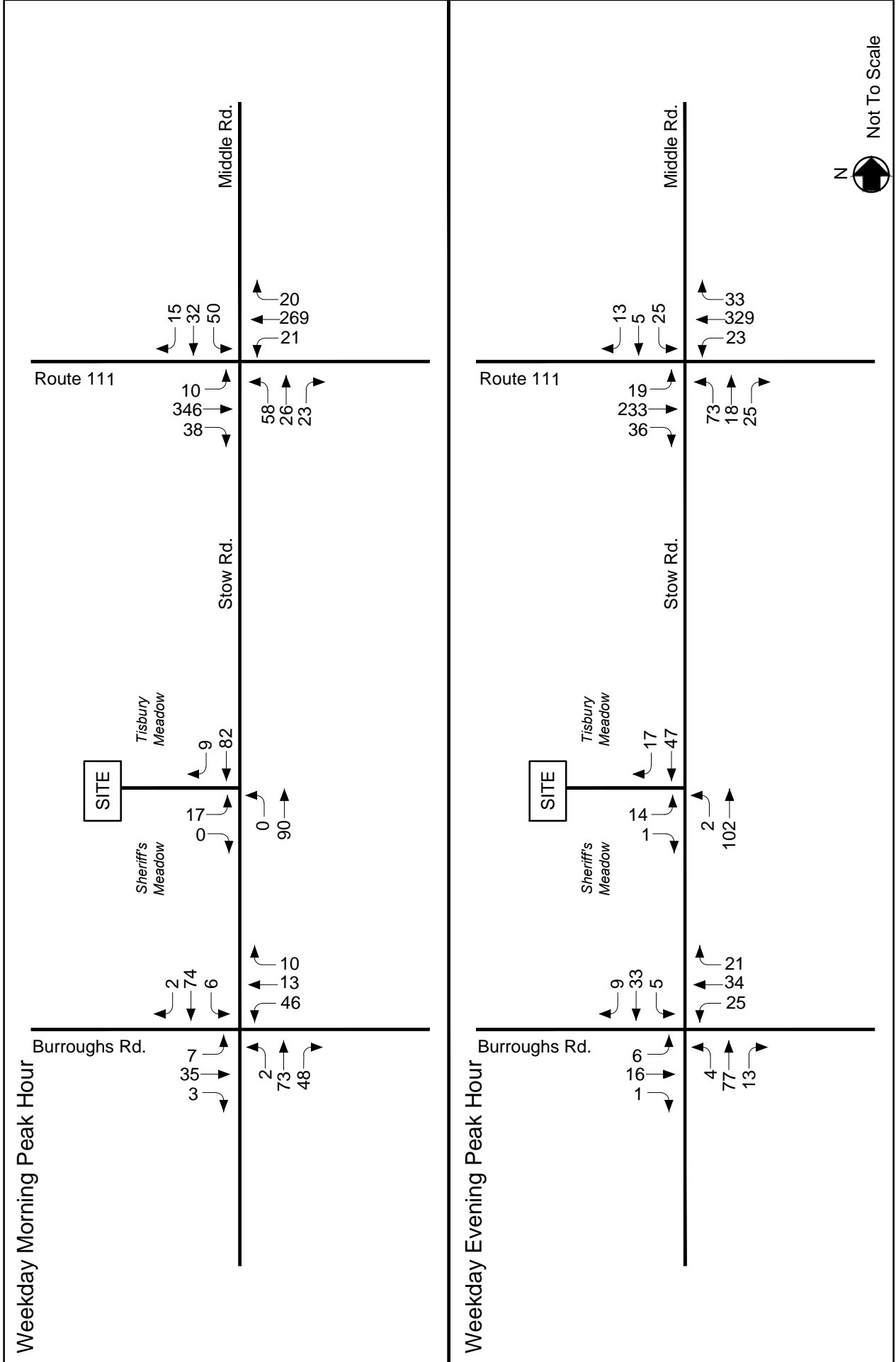


Figure 5
 Site Generated
 Peak Hour Traffic Volumes

Enclave at Boxborough, MA

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**TABLE 6
TRAFFIC VOLUME INCREASES^a**

Location/Peak Hour	2026 No-Build	2026 Build	Volume Increase over No-Build
<i>Stow Road, south of Burroughs Road</i>			
Weekday Morning	246	246	0
Weekday Evening	152	153	1
<i>Middle Road, north of Massachusetts Avenue</i>			
Weekday Morning	153	153	0
Weekday Evening	113	113	0
<i>Massachusetts Avenue, east of Stow Road</i>			
Weekday Morning	721	729	8
Weekday Evening	659	668	9
<i>Massachusetts Avenue, west of Stow Road</i>			
Weekday Morning	720	736	16
Weekday Evening	685	703	18

^aAll volumes are vehicles per hour, total of both directions.

As shown in Table 6, project-related increases are in the range of 0 to 18 bi-directional vehicles during the peak hours entering or exiting the study area. This is approximately equivalent to one additional vehicle every nine (9) minutes or less per direction on average during the peak hours.

SECTION 4: ANALYSIS

To assess intersection operations, capacity analyses were conducted for Existing, No-Build, and Build traffic volume conditions. Capacity analyses provide an indication of how well the study area intersections serve existing and projected traffic volumes. Vehicle queue analyses provide a secondary measure of the operational characteristics of an intersection or section of roadway under study in terms of lane use and demand.

METHODOLOGY

Levels of Service

Level of service (LOS) is a quantitative measure used to describe the operation of an intersection or roadway segment. The level of service definition is described by the quality of traffic flow and is primarily defined in terms of traffic delays. The primary result of capacity analyses³ is the assignment of a level of service to traffic intersections or roadway segments under various traffic-flow conditions. Six levels of service are defined for traffic intersections and roadway segments. Levels of service range from LOS A to LOS F. LOS A represents very good operating conditions and LOS F represents very poor operating conditions.

Signalized Intersections

Levels of service for signalized intersections are calculated using the methodology and procedures described in the 2010 *Highway Capacity Manual*. The methodology assesses the intersection based on type of signal operation, signal timing and phasing, progression, vehicle mix, and intersection geometrics. Level-of-service designations are based on the delay per vehicle. Table 7 summarizes the relationship between level of service and delay. The calculated delay values result in level-of-service designations which are applied to individual lane groups, to individual intersection approaches, and to the entire

³The capacity analysis methodology is based on procedures presented in the *Highway Capacity Manual*; Transportation Research Board; Washington, DC; 2010.

intersection. In the 2010 HCM methodology, the critical lane group volume to capacity ratio is reported.

TABLE 7
LEVEL-OF-SERVICE CRITERIA FOR SIGNALIZED INTERSECTIONS^a

Delay per Vehicle (Seconds)	Resulting Level of Service $v/c^b < 1.0$	Resulting Level of Service $v/c^b > 1.0$
≤ 10.0	A	F
10.1 to 20.0	B	F
20.1 to 35.0	C	F
35.1 to 55.0	D	F
55.1 to 80.0	E	F
> 80.0	F	F

^a*Highway Capacity Manual*; Transportation Research Board; Broad, DC; 2010; page 18-6.

^bVolume to capacity ratio.

Unsignalized Intersections

The level of service for an unsignalized intersection is determined by the methodology and procedures described in the 2010 *Highway Capacity Manual*.⁴ The level of service for unsignalized intersections is measured in terms of average delay for the critical movements (typically side street turning movements or mainline turning movements). The delay for the critical movements is a function of the available capacity for the movement and the degree of saturation of the lane group containing the critical movement. The delay calculation includes the effects of initial deceleration delay approaching a STOP sign, stopped delay, queue move-up time, and final acceleration delay from a stopped condition. The definitions for level of service at unsignalized intersections are also provided in the 2010 *Highway Capacity Manual*. Table 8 summarizes the relationship between level of service and average control delay for the critical movements at unsignalized intersections.

⁴*Highway Capacity Manual*; Transportation Research Board; Washington, DC; 2010.

TABLE 8
LEVEL-OF-SERVICE CRITERIA FOR UNSIGNALIZED INTERSECTIONS^a

Average Delay (seconds per vehicle)	Resulting Level of Service $v/c^b < 1.0$	Resulting Level of Service $v/c > 1.0$
≤ 10.0	A	F
10.1 to 15.0	B	F
15.1 to 25.0	C	F
25.1 to 35.0	D	F
35.1 to 50.0	E	F
>50.0	F	F

^aHighway Capacity Manual; Transportation Research Board; Broad, DC; 2010; page 19-2

^bVolume to capacity ratio.

The analytical methodologies used for the analysis of unsignalized intersections use conservative analysis parameters, such as high critical gaps. The critical gap is defined as the minimum time between successive main line vehicles for a side street vehicle to execute the appropriate turning maneuver. Actual field observations indicate that drivers on minor streets accept smaller gaps in traffic than those used in the analysis procedures and therefore experience less delay than calculated by the HCM methodology. **The analysis results overstate the actual delays experienced in the field.** It should be noted that the unsignalized intersections along heavily trafficked roadways operate at constrained levels and the resulting calculated results of the unsignalized intersection analyses should be considered highly conservative.

CAPACITY ANALYSIS RESULTS

Level-of-service analyses were conducted for 2019 Existing, 2026 No-Build, and 2026 Build conditions for the intersections within the study area. The proposed project has very little, if any, impact on intersection operations. The results of the 2026 analyses are summarized in Table 9. Detailed analysis sheets are presented in the Appendix.

Massachusetts Avenue, Middle Road and Stow Road

Under 2019 Existing conditions, the critical movements at this unsignalized intersection (all movements out of Stow Road) are modeled to operate at LOS C during the weekday morning peak hour and at LOS C during the weekday evening peak hour. Under future 2026 No-Build conditions, the critical movements are projected to operate at LOS D during the weekday morning peak hour and at LOS C during the weekday evening peak hour. Under 2026 Build conditions, with the project, the critical movements are projected to operate at LOS E during the weekday morning peak hour and at LOS C

during the weekday evening peak hour⁵. The Stow Road northbound left-turn volume is less than 60 vehicles per hour during the morning peak hour with a volume-to-capacity (v/c) ratio that will be well below 1.00, indicating there will be adequate capacity to accommodate the anticipated traffic volumes. The additional traffic generated by the proposed project is not anticipated to increase queues within this lane by more than one (1) vehicle.

Stow Road and Sheriff's Meadow/Tisbury Meadow Driveway

Under 2019 Existing conditions, the critical movements at this unsignalized intersection (all movements out of the driveway) are modeled to operate at LOS A during the weekday morning and weekday evening peak hours. Under future 2026 No-Build and Build conditions, the critical movements are projected to operate at LOS B during the weekday morning peak hour and at LOS A during the weekday evening peak hour.

Stow Road and Burroughs Road

Under 2019 Existing conditions, the critical movements at this unsignalized intersection (all movements out of Burroughs Road) are modeled to operate at LOS B during the weekday morning peak hour and at LOS B during the weekday evening peak hour. Under future 2026 No-Build and Build conditions, the critical movements are projected to operate at LOS B during both the weekday morning and weekday evening peak hours.

⁵ It should be noted that the weekday morning peak hour, the projected delay is just over the threshold into the LOS E range from LOS D.

**TABLE 9
UNSIGNALIZED LEVEL-OF-SERVICE ANALYSIS SUMMARY**

Critical Movement/ Peak Hour	2019 Existing					2026 No-Build					2026 Build				
	Demand ^a	V/C ^b	Delay ^c	LOS ^d	Queue ^e	Demand	V/C	Delay	LOS	Queue	Demand	V/C	Delay	LOS	Queue
Massachusetts Avenue, Middle Road and Stow Road															
<i>All movements from Middle Road:</i>															
Weekday Morning	91	0.41	23.7	C	1.9	97	0.48	28.1	D	2.5	97	0.50	29.6	D	2.6
Weekday Evening	40	0.13	15.9	C	0.4	43	0.15	17.0	C	0.5	43	0.16	17.6	C	0.5
<i>All movements from Stow Road:</i>															
Weekday Morning	85	0.46	24.7	C	2.3	91	0.54	30.0	D	3.0	107	0.64	36.6	E	4.1
Weekday Evening	99	0.33	19.1	C	1.4	105	0.38	21.2	C	1.7	116	0.42	22.9	C	2.0
Stow Road and Sheriff's Meadow/Tisbury Meadow Driveway															
<i>All movements from driveway:</i>															
Weekday Morning	1	0.01	9.8	A	0.0	1	0.01	10.0	B	0.0	17	0.09	10.5	B	0.3
Weekday Evening	4	0.01	9.3	A	0.0	4	0.01	9.3	A	0.0	15	0.04	9.7	A	0.1
Stow Road and Burroughs Road															
<i>All movements from Burroughs Road EB:</i>															
Weekday Morning	43	0.09	11.8	B	0.3	45	0.09	12.1	B	0.3	45	0.09	12.1	B	0.3
Weekday Evening	22	0.04	10.2	B	0.1	23	0.04	10.3	B	0.1	23	0.04	10.3	B	0.1
<i>All movements from Burroughs Road WB:</i>															
Weekday Morning	64	0.13	11.8	B	0.4	69	0.14	12.2	B	0.5	69	0.14	12.2	B	0.5
Weekday Evening	75	0.11	10.2	B	0.4	80	0.12	10.3	B	0.4	80	0.12	10.3	B	0.4

^aDemand of critical movements in vehicles per hour.

^bVolume-to-capacity ratio.

^cDelay in seconds per vehicle.

^dLevel of service.

^e95%tile queue in vehicles.

SIGHT DISTANCE

Sight distance measurements were performed at the existing intersection of Stow Road and the existing Sheriff’s Meadow/Tisbury Meadow driveway in accordance with Massachusetts Department of Transportation (MassDOT) and American Association of State Highway and Transportation Officials (AASHTO) standards. Stopping sight distance (SSD) measurements were performed. In brief, SSD is the distance required by a vehicle traveling at the design speed of a roadway, on wet pavement, to stop prior to striking an object in its travel path. Intersection sight distance (ISD) or corner sight distance (CSD) is the sight distance required by a driver entering or crossing an intersecting roadway, to perceive an on-coming vehicle and safely complete a turning or crossing maneuver with on-coming traffic. Table 10 presents the measured SSD/ISD at the driveway intersection. The sight distance calculations are included in the Appendix.

TABLE 10
STOW ROAD AND SHERIFF’S MEADOW/TISBURY MEADOW
SIGHT DISTANCE SUMMARY

	Required Minimum (Feet) ^a	Measured (Feet)
<i>Stow Road and Sheriff’s Meadow/Tisbury Meadow Driveway</i>		
<i>Stopping Sight Distance:</i>		
Stow Road approaching from the North	216	335
Stow Road approaching from the South	226	350
<i>Intersection Sight Distance:</i>		
Stow Road looking to the North	315/364 ^c	335 ^d
Stow Road looking to the South	315 ^b /364 ^c	350 ^d

^aRecommended minimum values obtained from *A Policy on Geometric Design of Highways and Streets*; American Association of State Highway and Transportation Officials (AASHTO); 2010, and based on observed 85th percentile speed.

^bRecommended minimum value for vehicles turning right exiting a roadway under STOP-sign control.

^cRecommended minimum value for vehicles turning left exiting a roadway under STOP-sign control.

^dExisting signage blocks intersection site distance. Reported distances are for a point where the driver’s eye is 15 back from the center of travelled way (Stow Road).

As can be seen in Table 10, the SSD measurements performed at Stow Road and the Sheriff’s Meadow/Tisbury Meadow driveway intersection indicate that the SSD exceeds the recommended minimum requirements based on the 85th percentile speeds. In accordance with the AASHTO manual, “*If the available sight distance for an entering or crossing vehicle is at least equal to the appropriate stopping sight distance for the major road, then drivers have sufficient sight distance to anticipate and avoid collisions. However, in some cases, this may require a major-road vehicle to stop or slow to accommodate the maneuver by a minor-road vehicle. To enhance traffic operations, intersection sight distances that exceed stopping sight distances are desirable along the*

major road.” Accordingly, the ISD should be at least equal to the SSD, which would allow a driver approaching the minor road to safely stop. It is recommended that any signage or landscaping that would occur along the Stow Road frontage be set back and designed to not impact sight lines. It should also be noted that with the addition of a proposed sidewalk along the west side of Stow Road to Massachusetts Avenue, the ISD will improve.

Summarized in Table 11 are the sight distance requirements based on the Federal Highway Administration’s recommendations for use with an aging population as identified in the Handbook for Designing Roadways for the Aging Population⁶.

**TABLE 11
STOW ROAD AND SHERIFF’S MEADOW/TISBURY MEADOW
SIGHT DISTANCE SUMMARY FOR THE AGING POPULATION**

	Required Minimum (Feet) ^a	Measured (Feet)
<i>Stow Road and Sheriff’s Meadow/Tisbury Meadow Driveway</i>		
<i>Stopping Sight Distance:</i>		
Stow Road approaching from the North	216	335
Stow Road approaching from the South	226	350
<i>Intersection Sight Distance:</i>		
Stow Road looking to the North	329 ^b /388 ^c	335 ^d
Stow Road looking to the South	329 ^b /388 ^c	350 ^d

^aRecommended minimum values obtained from *A Policy on Geometric Design of Highways and Streets*; American Association of State Highway and Transportation Officials (AASHTO); 2010, and based on observed 85th percentile speed.

^bRecommended minimum value for vehicles turning right exiting a roadway under STOP-sign control.

^cRecommended minimum value for vehicles turning left exiting a roadway under STOP-sign control.

^dExisting signage blocks intersection site distance. Reported distances are for a point where the driver’s eye is 15 back from the center of travelled way (Stow Road).

As shown in Table 11, the SSD requirements remain the same and the ISD requirements are slightly higher for the aging population calculations.

Table 12 presents the measured SSD/ISD at the construction driveway intersection to Massachusetts Avenue. The sight distance calculations are included in the Appendix.

⁶ *Handbook for Designing Roadways for the Aging Population*; US Department of Transportation, Federal Highway Administration; Washington, D.C.; June 2014.

**TABLE 12
CONSTRUCTION ENTRANCE
SIGHT DISTANCE SUMMARY**

	Required Minimum (Feet) ^a	Measured (Feet)
<i>Construction Entrance and Massachusetts Avenue</i>		
<i>Stopping Sight Distance:</i>		
Massachusetts Avenue approaching from the East	267	410
Massachusetts Avenue approaching from the West	352	290
<i>Intersection Sight Distance:</i>		
Construction Entrance looking to the East	411 ^b /531 ^c	335
Construction Entrance looking to the West	411 ^b /531 ^c	350

^aRecommended minimum values obtained from *A Policy on Geometric Design of Highways and Streets*; American Association of State Highway and Transportation Officials (AASHTO); 2010, and based on observed 85th percentile speed.

^bRecommended minimum value for vehicles turning right exiting a roadway under STOP-sign control.

^cRecommended minimum value for vehicles turning left exiting a roadway under STOP-sign control.

As shown in Table 12, the stopping sight distance from the west is less than the desired distance of 352 feet. The project proponent has raised the grade of the construction entrance at Massachusetts Avenue to maximize the available sight distance. The recommendation is to install Construction Entrance Ahead and Trucks Entering signs on the Massachusetts Avenue approaches to the construction entrance. Existing growth within the Massachusetts Avenue layout and to the extent feasible, on-site, be trimmed back to maintain sight lines.

The recommended stopping sight distances for trucks are based on passenger car operations and do not explicitly consider design for truck operation. Trucks as a whole, especially the larger and heavier units, need longer stopping distances for a given speed than passenger vehicles. However there is one factor that tends to balance the additional braking limits for trucks with those for passenger cars. The truck driver is able to see substantially farther beyond vertical site obstructions because of the higher position of the seat in the truck. Separate stopping sight distances for trucks and passenger cars are not generally used in highway design.

SECTION 5: RECOMMENDATIONS AND CONCLUSION

RECOMMENDATIONS

The final phase of the analysis process is to identify the mitigation measures necessary to minimize the impact of the project on the transportation system. The analyses performed for 2019 Existing and 2026 future No-Build and Build conditions indicate some traffic deficiencies currently exist within the study area. The addition of the site generated traffic will marginally increase projected delays.

Mitigation Related to Project

The capacity analyses performed for the unsignalized study area intersections indicate that the new project trips will not significantly impact intersection operations. There is no significant reduction in level of service at the study area intersections. The analysis shows the site driveway is projected to operate at a good level of service.

The following measures have been identified to mitigate the project's impacts and improve intersection operations. The project proponent is committed to working with the Town of Boxborough to implement the mitigation measures listed below.

It is recommended that the exit to Stow Road be under STOP control. It is recommended that any signage or landscaping that would occur along the Stow Road frontage be set back and designed to not impact sight lines.

A sidewalk is to be constructed along the west side of Stow Road from the driveway northerly to Massachusetts Avenue. With the construction of this sidewalk, sight lines looking out of the driveway to the north will significantly improve.

It is also recommended that Construction Entrance Ahead and Trucks Entering signs be installed on the Massachusetts Avenue approaches to the construction entrance. Existing growth within the Massachusetts Avenue layout and to the extent feasible, on-site, be trimmed back to maintain sight lines.

CONCLUSION

Review of the proposed project and the access plan shows that in relation to roadway capacity, traffic safety, and traffic impacts upon the surrounding roadway network, the proposed project will meet safety standards and have a minimal impact on existing traffic conditions. Project-related increases are in the range of 0 to 18 bi-directional vehicles during the peak hours at the study area boundaries. This is approximately equivalent to one additional vehicle every nine (9) minutes or less per direction on average during the peak hours.

The proposed access, in conjunction with the mitigation measures described above and maintaining sight distances from the driveway (clear sight lines along the site frontage), can provide safe and efficient access to the residents of the proposed project and to the motoring public in the area.