BSC GROUP

Memorandum

To:	Roland Bartl, AICP Town of Acton	Date:	September 3, 2008
From:	Sam Offei-Addo, P.E., PTOE	Proj. No:	2.8228.01
Re:	Peer Review of Traffic Impact Assessment Residences at Quail Ridge, Acton, MA		

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BSC Group (BSC) has performed a review of traffic impacts associated with the proposed Senior Residences Permit for the Residences at Quail Ridge (RQR) located at 354B Great Road. The site currently contains an 18-hole golf course with a clubhouse, tennis courts, and swimming pool. The proposed project involves the conversion of the 18-hole golf course into a 9-hole course and the construction of 174-units of age restricted (55 years and older) housing. Access to the site is via Skyline Drive off Great Road (Route 2A/119). BSC's review is in relation to the provision of adequate secondary access to the RQR site and an assessment of how the local residential streets in the neighboring Acorn Park might be impacted if a connection were to be constructed.

1.0 Traffic Impact and Access Study Review

1.1 Review Materials

The following documents made available by the Town of Acton formed the basis of our review of the permit application:

1. Senior Residence Special Permit Application for the Residences at Quail Ridge, Acton, MA, July 20, 2007, including -
2. Part 3.15 of the above: Traffic Impact Study, Conley Associates, March 2007.
3. Memorandum, Conley Associates, June 8, 2007.
4. Memorandum, Conley Associates, October 19, 2007
5. Memorandum, Conley Associates, November 2, 2007.
6. Memorandum, Conley Associates, December 4, 2007.
7. Plan for The Residences at Quail Ridge, Senior Residence Special Permit, Acton, MA, July 18, 2007, Stamski and McNary, Inc., 43 sheets.
8. (Alternative) Site Layout Plan for the above, by Stamski and McNary, Inc. dated October 18, 2007.
9. Plan for Acorn Park subdivision (overview and plan & profile sheets for Phases I, II, & III). Additional plan sheets are available at Acton Planning Department.
10. Miscellaneous correspondence: Town of Acton departmental reviews, Engineering firm letter, letters from abutters and others, etc.
11. Traffic Impact Assessment, Proposed Quail Ridge Country Club Redevelopment, Acton, Massachusetts, September 20, 2007, Woodland Design Group, Inc. for Acorn Park Condominium Association.
12. Decision 08-02 of the Acton Planning Board, dated February 12, 2008.
13. Traffic Impact Assessment, Proposed Quail Ridge Country Club Redevelopment, Acton, Massachusetts, July 7, 2008, Woodland Design Group, Inc. for Acorn Park Condominium Association.

In addition to the above documents, several other references were consulted in the course of our review and have been cited in this memorandum.

1.2 General Overview

Based on our review of the traffic study and the supplemental memoranda prepared by Conley Associates, and Woodland Design Group, BSC concludes that traffic-engineering methodology that was employed is in general conformance with accepted Institute of Transportation Engineers and MassHighway standards. Comments on specific items are made below.

1.3 Existing Conditions

Traffic Volume Data

The Conley Associates study involved three Great Road intersections with: Main Street (Route 27), Skyline Drive, and Acorn Park Drive. The traffic counts were obtained in February 2007 and the report noted that the counts in February were lower than the average month by a factor of 5.4%. The existing counts were appropriately increased by this factor to reflect average conditions. Due to the time of year in which the counts were performed, standard rates from the Institute of Transportation Engineers Trip Generation manual were used to determine the trips associated with the existing 18-hole golf course.

Woodland Design Group performed supplemental automatic traffic counts within the Acorn Park residential area in April 2008. BSC concurs that these counts provided a more accurate representation of traffic generation by the residences in Acorn Park and fall within the range of rates contained in the ITE Trip Generation manual.

Accident Data

The Conley Associates report contained a summary of the latest three-year crash history at the study area. The number, type, severity of injury, weather condition, road surface, and light conditions were tabulated. The results showed that the Route 119 and Route 27 intersection exceeded the MassHighway district crash rate average. No explanation was given as to the higher than average crash rate (1.23 compared to the MassHighway District 3 average rate of 0.84 per million entering vehicles). BSC reviewed MassHighway data for vehicle crashes within Acorn Park Subdivision. There were no reported accidents between 2004 and 2006, the latest three years on record.

1.4 Future Conditions

Information on two site-specific development projects by others that would impact traffic in the study area as well as general traffic growth was provided in the report. Traffic volumes from these developments were included as background data in the analysis. In addition, an annual growth rate of 1.7 percent per year was applied based on comments from the Town of Acton Engineering Department to the existing condition traffic volumes and used to estimate the future year (2012) traffic volumes. BSC agrees with the methodology used to determine the future year no-build traffic volumes.

1.5 Project Generated Traffic

Trip Generation

Data published by the Institute of Transportation Engineers (ITE) in the Trip Generation Manual 7th Edition was used to determine the number of trips that would be generated by the proposed age restricted residential development and golf-course. The trip generation

estimates were derived based on the average of the ITE rates for Senior Adult housing-Detached (LUC251) and Residential Condominium/Townhouse (LUC 230). BSC concurs with the rates used since the Senior Housing category appears to be low for an Active Adult community and the Residential Condominium may be high due factors as school related trips. The average rates used by Conley Associates are similar to empirical results compiled by BSC from several sources for age-restricted residential development projects.

The proposed project also includes the conversion of the golf course from 18 to 9 holes. Reduction in trips generation initially estimated by Conley Associates assumed a proportionate decrease without consideration of other fixed trip generators such as the number of employees, the clubhouse and its amenities. BSC concurs with the use of the trips associated with the 18-hole golf course for the purposes of the analysis. With respect to the proposed restaurant, the ITE manual notes that the data obtained for the golf-course land use included some locations with club houses, restaurants and other ancillary uses. The trip rates therefore have some of the restaurant trips already included. The assumption by Conley Associates that 15 percent of the trips would be generated externally given the foregoing discussion and the presence of residences on the property is an acceptable assumption.

As noted earlier, Woodland Design Group obtained traffic counts within Acorn Park. These local data represent trip generation characteristics more accurately in the residential area and therefore are acceptable for use in conjunction with estimating the number of trips on roadway segments within Acorn Park.

Trip Distribution

The trip distribution, according to the Conley Associates report was based on the existing travel patterns in the study area. This pattern shows a distinct southbound directional movement in the morning peak hour and a reverse northbound movement during the evening peak hour. BSC independently calculated the trip distribution based on the daily traffic volumes on Great Road and also on the residential patterns at the Acorn Park entrance. BSC concludes that the 30/65 percent northbound/southbound split on Great Road and 5 percent on Harris Street is acceptable.

1.6 Deceleration Lane on Great Road at Skyline Drive

The Town of Acton Engineering Department and Police Chief suggested the construction of a deceleration lane for vehicles turning right into Skyline Drive from Great Road southbound. Conley Associates responded that adding a right turn lane would not improve operations at the intersection. A deceleration lane is not primarily meant to increase capacity of an intersection, but to enhance safety for both vehicles that are turning and those through vehicles following them. The posted speed limit on Great Road is 40 miles per hour. As vehicles approach Skyline Drive on a downgrade on Great Road, a deceleration lane would allow right turning vehicles to slow down safely and reduce the potential of being rear-ended by through traffic before entering Skyline Drive. BSC recommends construction of a deceleration lane as a safety feature at this intersection.

1.7 Traffic Operation Analysis

Analysis of the study area signalized and unsignalized intersections were performed in general accordance with the Highway Capacity Manual, the standard methodology for

traffic analysis. Based on our review of the Synchro files, it appears Conley Associates showed default values of two percent heavy trucks for both Skyline Drive and Acorn Park Drive. The raw counts showed that there were no trucks on these side streets. These are minor, however, and should not affect the results of the analysis, which appeared to be in line with the traffic volumes and intersection configuration. Traffic signal timings used in the analysis for Great Road/Main Street differed from the signal permits BSC received from MassHighway District 3. The applicant should confirm if it is their intent to modify the traffic signal timings at this intersection.

The results of the unsignalized intersection analysis show long delays for the side streets during the both weekday morning and evening peak hours. This is to be expected on unsignalized intersections with major road traffic exceeding 1,200 vehicles per hour. The volume to capacity ratios for Acorn Park is greater than one for both morning and afternoon peak hours with or without the project in place.

2.0 RQR Access Considerations

2.1 Field Visit

BSC staff visited the project site on August 17th and 19th 2008 to observe peak period traffic operations, roadway geometry, and traffic controls at study area intersections. BSC also measured pavement widths at several roadway sections within Acorn Park. BSC also performed a gap study analysis to determine if adequate gaps existed on Great Road for vehicles exiting Skyline Drive and Acorn Park Drive.

2.2 Great Road Intersections

During the field visits, BSC observed traffic operations at the intersections of Great Road with Acorn Park Drive and Skyline Drive in the morning and evening peak hours. Traffic volumes on Great Road appeared to be low due to the summer season. The observed number of vehicles queued on either Acorn Park Drive or Skyline at any one time was three or less. Vehicles turning left from Great Road onto Acorn Park Road could be bypassed by through traveling vehicles due to the wide intersection and shoulders. Traffic operations on Acorn Park Drive did not seem to be impacted by its interaction with the commercial driveways.

Queued vehicles on Great Road extended from Main Street to Skyline Drive for brief moments during the morning peak hour. Vehicles waiting to turn left onto Skyline Drive could not be easily by-passed by through vehicles on Great Road. Widening the Great Road approach to accommodate a by pass lane at this intersection would improve vehicle operations.

2.3 Gap Analysis

Peak hour gap data on Great Road was obtained on Wednesday, August 20, 2008 to assess if gaps existed for vehicles entering from the side streets. According to the Highway Capacity Manual, the minimum available gap that would be accepted by left turn vehicles from the minor road onto the major road is 7.1 seconds. The gap available simultaneously in both directions on the major road (Great Road) is called the combined gap, and it represents the minimum gap for drivers turning left from the minor street. Drivers following the lead vehicle would usually take a gap of a shorter time. Table 1

below summarizes the combined gaps measured on Great Road at the Acorn Park Drive and Skyline Drive intersections that were greater than 7 seconds.

Delays on side street approaches result from the unavailability of adequate minimum gaps for minor street traffic to enter or cross the major street traffic. In practice, this could lead to frustration on the part of drivers who, in some cases decide to take gaps that are shorter, leading to a potential unsafe driving environment.

Table 1: Gap Analysis - Combined Gaps on Great Road

	Total Combined Gaps > 7 seconds	
Intersection	AM	PM
Great Road at Skyline Drive	120	104
Great Road at Acorn Park Drive	90	84

The analysis showed that at least 80 gaps of greater than 7 seconds were available for vehicles to exit either Skyline Drive or Acorn Park Drive during the peak hour. The number of available gaps could be lower during the non- summer months and therefore BSC recommends that an updated gap study should be performed after the summer season when schools return to session and summer vacation season ends to reflect normal traffic conditions. Such data should provide an accurate accounting of existing gaps and assist in the assessment of future traffic operations at the intersections.

2.4 Acorn Park Subdivision

The Acorn Park subdivision may be described as a low-density residential area with 2.0 or fewer dwelling units per gross acre. Narrow travel lanes, short horizontal curves, resulting in low speeds, reflect the local/neighborhood nature of the roadways. During our visits, we noticed two vehicles parked on Hazelnut Street, and 1-2 vehicles parked on Acorn Park Drive. Three to five children were observed riding their bikes on the sidewalk and the roadway. Others were playing in the driveways. Some people were also seen walking their dogs on the sidewalk, which is constructed along one side of the streets in the Acorn Park subdivision.

Roadway widths at several locations were measured in the field and are listed below:
Acorn Park Drive:

- South of Walnut Street – 24 feet
- South of Chestnut St – 24 feet
- South of Hazelnut Street – 20 feet
- South of Palmer Lane – 20 feet
- North of Palmer Lane – 20 feet

Palmer Lane west of Acorn Park – 20 feet
Hazelnut Street (2 locations) – 20 feet

Sight Distance

Stopping Sight Distance (SSD) is the required distance for vehicles on the major road to stop in time to avoid a collision with a stationary object. The required sight distance is a function of the perception/reaction time of the approaching motorist and the required braking distance, which is based on vehicular speed. Sight distance was recorded in conformance with accepted procedures established by the American Association of State

Highway and Transportation Officials (AASHTO)[1]. BSC measured stopping sight distance from the edge of the travel way at Acorn Park Drive/Palmer Lane and Hazelnut Street/access to water treatment facility and at Acorn Park Drive/Hazelnut Street (north end). This is the point at which an object becomes an obstruction to a moving vehicle on the major road. The available SSD, as recorded in the field, was compared to the minimum requirements for SSD for both 20 and 25 miles per hour speeds.

Table 2: Sight Distance

Location	Measured (feet)	Min. Required[a] (feet) 20 MPH	Min. Required[b] (feet) 25 MPH
Palmer Lane at Acorn Park Drive			
Acorn Park Drive Northbound	325	115	155
Acorn park Drive Southbound	295	115	155
Hazelnut Street (north end) at Acorn Park			
Acorn Park Drive Northbound	250	115	155
Acorn park Drive Southbound	300	115	155
Hazelnut Street at Water Treatment access			
Hazelnut Street northbound	290	115	155
Hazelnut Street southbound	150	115	155

[a] Values based on AASHTO requirements for 20 MPH
[b] Values based on AASHTO requirements for 25 MPH

Horizontal Curve Radius

BSC reviewed radius of horizontal curves within Acorn Park as shown on the subdivision plans prepared by Stamski and McNary Inc dated July 1993. According to the MassHighway Project Design Guidelines[2], referring to the AASHTO Green Book, the minimum design radius for 20 miles per hour design speed and superelevation rate of 4 percent is 90 feet. For 25 miles per hour, the minimum radius is 155 feet. Table 3 below provides a tabulation of design radii contained in the Acorn Park subdivision plans.

Table 3: Horizontal Curve Radius – Acorn Park Subdivision

Roadway	Location	Station	Radius (feet)
Acorn Park Drive			
	Between Chestnut St/Hazelnut St	15+50	180
	Between north and south Hazelnut St intersections	20+00	150
	South Hazelnut St intersection	23+00	120
		27+00	100
	At Palmer Lane	33+00	120
	North of Palmer Lane	38+50, 41+00, 43+00, 44+50	110
Hazelnut Street			120
Palmer Lane			80

[1] American Association of State Highway and Transportation Officials (AASHTO)[1] ***Policy on Geometric Design of Highways and Streets (5th ed., 2004). Also called the Green Book***
[2] MassHighway Project Development & Design Guide, January 2006

Based on the values for centerline radius, the corresponding design speed for Acorn Park Drive and Hazelnut Street is 20 miles per hour. The design speed on Palmer Lane is closer to 15 miles per hour.

2.5 Roadway Capacity

Several publications were reviewed with respect to low volume roads and their traffic volume threshold. The Town of Acton's Subdivision Rules and Regulations (SRR) defines a "Local Street" as a street having an average daily traffic of 2,000 or fewer vehicles. The SRR, under the horizontal design guidelines, permits low intensity Local Streets, with ADT of 250 or less to have a roadway width of 20 feet.

In ***AASHTO –Geometric Design of Highways and Streets*** (Green Book) [3], design considerations for local roads and streets include speed, traffic volumes, and lane width. The Green Book notes that traffic volume and design speed are not major factors in designing residential streets. The overriding consideration is to foster a safe and pleasant environment. Design speeds should not exceed 30 miles per hour. The width of travel lanes should be at least 10 feet wide (20-foot roadway for two lanes).

A very low-volume local road is defined by AASHTO[4] as a local road with a design volume of 400 vehicles or fewer per day. For this roadway classification, AASHTO notes that the major functional requirements include "the ability of vehicles traveling in opposite directions to pass one another, the need to pass parked or stopped vehicles, the need to provide for fire trucks and other emergency vehicles and the occasional larger delivery vehicles". AASHTO citing ITE guidelines[5], states that roadway widths for low residential development density (2.0 or fewer dwellings per acre) range from 20 to 28 feet. The 20-foot roadway width is applicable to subdivision streets where there is adequate off-street parking (driveway or garages) and that on-street parking is infrequently used by visitors and delivery trucks.

Other ITE recommended practices[6][7] discuss issues related to neighborhood street design. Residential density, roadway widths, and vehicle speeds, pedestrian and bicyclist considerations are discussed. For a low-density residential development, a roadway width of 20-22 feet is recommended. Target vehicle speeds are between 20-25 miles per hour. Bicyclists are to be accommodated on the roadway and sidewalks. Sidewalks for pedestrians should be continuous with safe and convenient connections to all parts of the neighborhood.

The capacity of a local street network is controlled by traffic operations at the intersection, more so than by the roadway segment. The Highway Capacity Manual[8] provides methodology for determining intersection and roadway segment capacity. For an unsignalized intersection the theoretical capacity of free movements (through movements on the major street) is approximately 1600 vehicles per hour per lane. A review of the daily traffic obtained by Woodland Design Group at Acorn Park Drive, west

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[3] ***Ibid, AASHTO***

[4] ***Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT < 400), AASHTO, 2001***

[5] ***Institute of Transportation Engineers, Guidelines for Residential Subdivision Street Design***

[6] ***Institute of Transportation Engineers Recommended Practice, Traditional Neighborhood Development, Street Design Guidelines, 1997***

[7] ***Institute of Transportation Engineers Proposed Recommended Practice, Neighborhood Street Design Guidelines, 2003***

[8] ***Transportation Research Board, National Research Council, Washington DC, 2000***

of the commercial driveways indicated that the highest hourly volume per lane was 63 vehicles in the westbound direction (between 6 and 7 PM). The volume to capacity (v/c) ratio at this segment would therefore be estimated at 0.39 (63/1600), well below the capacity of the roadway.

2.6 Projected Build-out Conditions and Secondary Access Options

The projected build-out of the Residences at Quail Ridge project include the construction of 174 age-restricted residential units, conversion of the 18-hole golf course into a 9-hole course, and the expansion of the clubhouse to include a restaurant. Trips associated with the golf course, and clubhouse currently use Skyline Drive to access and exit the site onto Great Road and are anticipated to continue to do so in the future. According to the average rates used by Conley Associates, the age-restricted residential development would generate a total of 56 trips (10 in, 46 out) during the morning peak hour, and 68 trips (46 in, 22 out) during the evening peak hour. These residential trips would be in addition to trips generated by the existing uses at the site and the proposed restaurant.

Given the proximity of some of the proposed residential units to the Acorn Park Subdivision, there is the likelihood that some of the residential trips would use the streets in Acorn Park to access Great Road, if the two developments were connected. Changes in travel patterns as a result of any connection would depend on the direction the vehicle is heading once it reaches Great Road, savings in travel-time due to shorter distance traveled, and also traffic operations at the intersections on Great Road. The table below shows some distances measured from the site plans.

Table 4: Approximate Travel Distances – Quail Ridge Connection Options

	From	To	Distance (feet)	Comment
Quail Ridge Drive	Skyline Drive (Station 0+00)	Station 33+00 (last residential unit)	3,300	
Skyline Drive	Quail Ridge Drive	Great Road	1,800	Total distance from the last unit to Great Road is 5,100 feet
Skyline Drive	Greenside Lane	Great Road	2,600	
Acorn Park	Palmer Lane (turn around)	Great Road via Acorn Park Drive	2,450	
Acorn Park	Hazelnut Street	Great Road via Acorn Park Drive	2,650	
Great Road	Acorn Park Drive	Skyline Drive	3,900	Total distance from Hazelnut Street through Acorn Park to Skyline Drive is 6,550 feet

The distances above indicate that Palmer Lane to Great Road via Acorn Park Drive is comparable to traveling on Skyline Drive from residences near Greenside Lane. The farthest distance of travel would be from the end of Quail Ridge Drive to Great Road via Skyline Drive.

Using these distances to Great Road, BSC reviewed projected build out traffic volumes and traffic distribution network for the residential component under alternative scenarios. Trips from residential portion of Quail Ridge according to their phases were distributed onto the network.

- All RQR traffic will enter and exit the site on Skyline Drive with no connection to the Acorn Park Subdivision.

- Connection to Acorn Park Subdivision would be permitted at two locations – Hazelnut Street and Palmer Lane.
- Connection to Acorn Park Subdivision would be permitted at one location, either at Hazelnut Street or at Palmer Lane.

A summary of the trips assigned based on logical trip patterns for Phases I and II of RQR is presented in Table 5 below.

Palmer Lane: It is assumed that all RQR Phase 1 residential trips traveling north on Great Road and Harris Street would use Palmer Lane to Acorn Park Drive if connected. About 10 homes would divert to Skyline Drive from Acorn Park. It is not anticipated that any vehicles from Phase II would use Palmer Lane. The resulting increase in daily trips on Palmer Lane would be 272 trips (136 in, 136 out). Total traffic volume on Palmer Lane is projected to be 326 vehicles trips per day.

Hazelnut Street: It is assumed that all RQR Phase II trips would travel to points north on Great Road and Harris Street through Hazelnut Street to Acorn Park Drive. Trips heading south are expected to use Quail Ridge Drive to Skyline Drive. The resulting increase on Hazelnut Street would be a total of 128 daily trips. None of the Phase 1 vehicles are expected to use Hazelnut Street.

If RQR were allowed two connections to Acorn Park Subdivision, the net increase (include diversion of some trips from the Subdivision through RQR) on Acorn Park Drive south of the commercial driveways would be about 113 vehicles a day.

Table 5: Projected Build-out daily traffic volumes - Increases on Acorn Park Streets assuming two-way connections at Palmer Lane and Hazelnut Street

Roadway Segment	Palmer Lane east of Acorn Park Drive	Hazelnut St west of Acorn Park Drive	Acorn Park Drive north of Palmer Lane*	Acorn Park Drive south of Commercial Driveways	Acorn Park Drive south of Rte 119/2A
Existing					
Enter	27	100	81	444	605
Exit	27	87	82	450	910
Total	54	187	163	894	1,515
Phase I Residential (97 units)					
Enter	81	0	81	81	81
Exit	81	0	81	81	81
Total	162	0	162	162	162
Phase II Residential (77 units)					
Enter	0	64	0	64	64
Exit	0	64	0	64	64
Total	0	128	0	128	128
Acorn Park** Traffic Diversions					
Enter	55	0	-22	-76	-76
Exit	55	0	-22	-77	-77
Total	110	0	-44	-153	-153
Full Build (RQR)					
Enter	163	164	140	513	662
Exit	163	151	141	518	966
Total	326	315	281	1031	1,628
Increase in trips (total)	272	128	118	137	137

*10 on Acorn Park Drive between Palmer lane and Hazelnut St
**14 homes including 4 on Palmer Lane would divert onto Skyline to go south. The homes on Palmer Lane would not contribute additional traffic to that street.

Peak hour trip assignments for RQR Phases I and II as a result of the alternative connections between RQR and Acorn Park Subdivision are presented in Tables 6a and 6b below. Table 6a shows that the Palmer Lane would have a total of 18 and 22 trips during the AM and PM peak hour respectively if two-way connection with RQR is constructed. If both Palmer Lane and Hazelnut Street were connected to RQR, the resulting increase in traffic at Great Road/Acorn Park Drive would total 11 and 13 trips respectively during the AM and PM peak hours.

Table 6a: Projected Phase 1 Build-out Peak Hour traffic volumes - Secondary Access Options								
Roadway Segment	Phase 1 RQR Trips via Skyline (A)		Acorn Park Drive Diversion through Skyline Drive (B)		Palmer Lane east of Acorn Park Drive (A+B)		Acorn Park Drive south of Commercial Driveways (A-B)	
	AM	PM	AM	PM	AM	PM	AM	PM
RQR –Skyline Drive two-way connection to Palmer Lane								
Enter	2	9	2	6	4	15	0	3
Exit	9	4	5	3	14	7	4	1
Total	11	13	7	9	18	22	4	4
RQR –Skyline Drive one-way out to Palmer Lane								
Enter	0	0	2	6	2	6	-2	-6
Exit	9	4	0	0	9	4	9	4
Total	9	4	2	6	11	10	7	-2
RQR –Skyline Drive one-way in from Palmer Lane								
Enter	2	9	0	0	2	9	2	9
Exit	0	0	5	3	5	3	-5	-3
Total	2	9	5	3	7	12	-3	6

Table 6b: Projected Phase II Build-out Peak Hour traffic volumes - Secondary Access Options								
Roadway Segment	Phase II RQR Trips via Hazelnut Street		Acorn Park Drive Diversion through Hazelnut Street Drive		Phase II trips through Palmer Lane		Acorn Park Drive south of Commercial Driveways	
	AM	PM	AM	PM	AM	PM	AM	PM
RQR Quail Ridge Drive two-way connection to Hazelnut Street								
Enter	1	7	0	0	0	0	1	7
Exit	7	4	0	0	0	0	7	4
Total	8	11	0	0	0	0	8	11
Quail Ridge Dr one-way out to Hazelnut Street								
Enter	0	0	0	0	0	0	0	0
Exit	7	4	0	0	0	0	7	4
Total	7	4	0	0	0	0	7	4
Quail Ridge Dr one-way in from Hazelnut Street								
Enter	1	7	0	0	0	0	1	7
Exit	0	0	0	0	0	0	0	0
Total	1	7	0	0	0	0	1	7

2.7 Traffic Analysis of Build-out options

Palmer Lane would experience the most increase in the number of vehicle trips from both RQR Phase 1 and diversion from nearby Acorn Park residents who might cut though RQR. Restricting access to Palmer Lane as a one-way from Skyline Drive would reduce the number of trips to about 81 vehicles per day, and 11 and 10 trips during the weekday AM and PM respectively.

In terms of reducing travel time, RQR Phase II residents traveling through Hazelnut Street / Acorn Park Drive to head north on Great Road would benefit the most. The increase in trips through Hazelnut Street would be 128 vehicles per day, and 8 and 11 vehicle trips

respectively during the weekday AM and PM respectively. Restricting this access to a one-way (either way) would result in a total change of 64 vehicles per day. Figures 1 to 3 depict the peak hour project trip assignments to the study intersections under the various options.

BSC reviewed the trip assignments for the above options and analyzed two of them in addition to the option analyzed by Conley Associates.

a) No vehicular connection between RQR and Acorn Park Subdivision. Conley Associates analyzed this option and it shows that Skyline Drive would operate at LOS F.
b) A one-way connection from Palmer Lane to Skyline Drive. Some residents on Acorn Park would divert through Skyline Drive especially during the morning peak hour. During the evening peak hour RQR Phase I residents coming from the north on Great Road would most likely divert through Acorn Park Drive and Palmer Lane.
c) Two-way connections between RQR and Acorn Park through both Palmer Lane and Hazelnut Street. This option would have the most impact on Acorn Park Drive at Great Road.

The results of the analyses are summarized in Tables 7a and 7b below. It must be noted that the signalized intersection was not analyzed since the various options would not change the number of trips assigned to it. All the options show that both Acorn Park Drive and Skyline Drive approaches would operate at LOS F during the morning and evening peak hours, primarily due to the volume of traffic on Great Road. Volume to capacity ratios are less than one during the morning peak hour but much greater than 1 during the evening peak hour.

Table 7a: Level of Service Summary – Weekday Morning Peak Hour - Unsignalized Intersections

	2012 Build No Access to Acorn Park Drive				2012 Build – One-Way connection – Palmer Lane to Skyline Drive				2012 Build – Two way connection – Palmer Lane and Hazelnut Street			
	Ave. Delay (sec)	LOS	V/C Ratio	Queue Length (feet)	Ave. Delay (sec)	LOS	V/C Ratio	Queue Length (feet)	Ave. Delay (sec)	LOS	V/C Ratio	Queue Length (feet)
Great Rd / Acorn Park Dr/Harris St												
Acorn Park Dr EB L	>100	F	0.33	27	>100	F	0.33	27	>100	F	0.61	52
Acorn Park Dr EB TR	28.8	D	0.22	20	28.9	D	0.19	17	32.7	D	0.23	21
Harris Street WB LT	>100	F	0.57	51	>100	F	0.52	47	>100	F	0.52	47
Harris Street WB R	12.6	B	0.15	13	12.6	B	0.15	13	12.4	B	0.15	13
Great Road NB TR	0.6	A	0.02	2	0.6	A	0.02	2	0.5	A	0.02	1
Great Road SB TR	3.7	A	0.12	10	3.6	A	0.12	10	3.6	A	0.12	10
Great Rd / Skyline Dr												
Skyline Dr EB L	>100	F	0.37	33	>100	F	0.42	38	83.1	F	0.07	5
Skyline Dr EB R	22.1	C	0.16	14	23.0	C	0.20	18	22.9	C	0.20	18
Great Road NB TR	1.3	A	0.05	4	1.9	A	0.07	6	2.0	A	0.07	6
Great Road SB TR	0.0	A	0.67	0	0.0	A	0.66	0	0.0	A	0.66	0

Note: Only critical movements are shown
Abbreviations: EB = Eastbound, WB = Westbound, NB = Northbound, SB = Southbound, L = Left, T = Through, R = Right

Table 7b: Level of Service Summary – Weekday Evening Peak Hour - Unsignalized Intersections

	2012 Build No Access to Acorn Park Drive				2012 Build – One-Way connection – Palmer Lane to Skyline Drive				2012 Build – Two way connection – Palmer Lane and Hazelnut Street			
	Ave. Delay (sec)	LOS	V/C Ratio	Queue Length (feet)	Ave. Delay (sec)	LOS	V/C Ratio	Queue Length (feet)	Ave. Delay (sec)	LOS	V/C Ratio	Queue Length (feet)
Great Rd / Acorn Park Dr/Harris St												
Acorn Park Dr EB L	>100	F	2.14	92	>100	F	2.53	95	>100	F	2.48	106
Acorn Park Dr EB TR	35.4	E	0.22	20	38.7	E	0.22	20	40.1	E	0.24	22
Harris Street WB LT	>100	F	1.07	79	>100	F	1.14	83	>100	F	0.96	73
Harris Street WB R	35.1	D	0.49	61	37.7	E	0.51	65	34.9	D	0.49	61
Great Road NB TR	1.7	A	0.04	3	1.8	A	0.04	3	1.3	A	0.04	3
Great Road SB TR	4.7	A	0.16	15	4.9	A	0.17	15	4.6	A	0.16	15
Great Rd / Skyline Dr												
Skyline Dr EB L	Err	F	>5	Err	Err	F	>5	Err	Err	F	>5	Err
Skyline Dr EB R	15.4	C	0.08	7	15.7	C	0.12	10	15.6	C	0.12	10
Great Road NB TR	3.1	A	0.06	5	3.5	A	0.07	6	3.8	A	0.08	6
Great Road SB TR	0.0	A	0.49	0	0.0	A	0.48	0	0.0	A	0.48	0

Note: Only critical movements are shown
Abbreviations: EB = Eastbound, WB = Westbound, NB = Northbound, SB = Southbound, L = Left, T = Through, R = Right

2.8 Safety – Traffic volume/speed factors.

Multiple factors, some of them quantifiable based on field measurements while others are based on human behavior contribute to the occurrence of each accident. These factors include the roadway environment, equipment failure, vehicle speeds, pedestrian activities, driver behavior, and many more. Predicting the number of accidents for a particular segment of roadway or intersection is therefore a complex task. The Highway Safety Manual indicates that for pedestrian accidents, pedestrian volume is one of the most influential factors in predicting pedestrian crashes. Other factors include traffic volume especially the amount of turning traffic volume and the presence or absence of sidewalks.

Risk assessment thresholds for rural and urban low speed facilities are contained in the AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads[9]. It notes that "For urban or low speed facilities, an acceptable safety risk is represented by an action or proposed action that is expected to result in no more than one additional traffic crash per mile of roadway every 4 to 6 years.

A review of available accident records from MassHighway showed no accidents within the Acorn Park Subdivision for the latest three years of available crash data.

The US Department of Transportation, Federal Highway Administration provides predictive models for safety performance on two-lane rural roadways. Although the streets in Acorn Park are not rural, they could be evaluated using the general principles

[9] Ibid

contained in the FHWA report[10]. For a base model, the number of accidents per mile of roadway segment is:

$N_{br} = (ADT)(L)(365)(10^{-6}) \exp(-0.4865)$

Where:
ADT is the average daily traffic volume (veh/day)
L is the length of the roadway segment in miles

The base model assumes twelve-foot travel lanes, six-foot shoulders, no horizontal or vertical curvature and level grade. Driveway density per mile is three. While the base conditions are different from conditions in Acorn Park, there is a linear relationship between the ADT and the number of vehicles per mile. The model shows that the number of accidents increases with traffic volume.

The table below provides an illustration of this equation for three ADT levels and the number of crashes per mile, all other things being equal.

Table 8: Traffic Volume vs. Predicted Number of Accidents

ADT (vehicles per day)	Accidents per mile per year
100	.0224
250	.0561
400	.09

2.9 Conclusions

Based on our review of the plans and documents, and field visits, BSC offers the following conclusions and recommendation s with respect to the provision of secondary access to the propose Residences at Quail Ridge, in the Town of Acton:

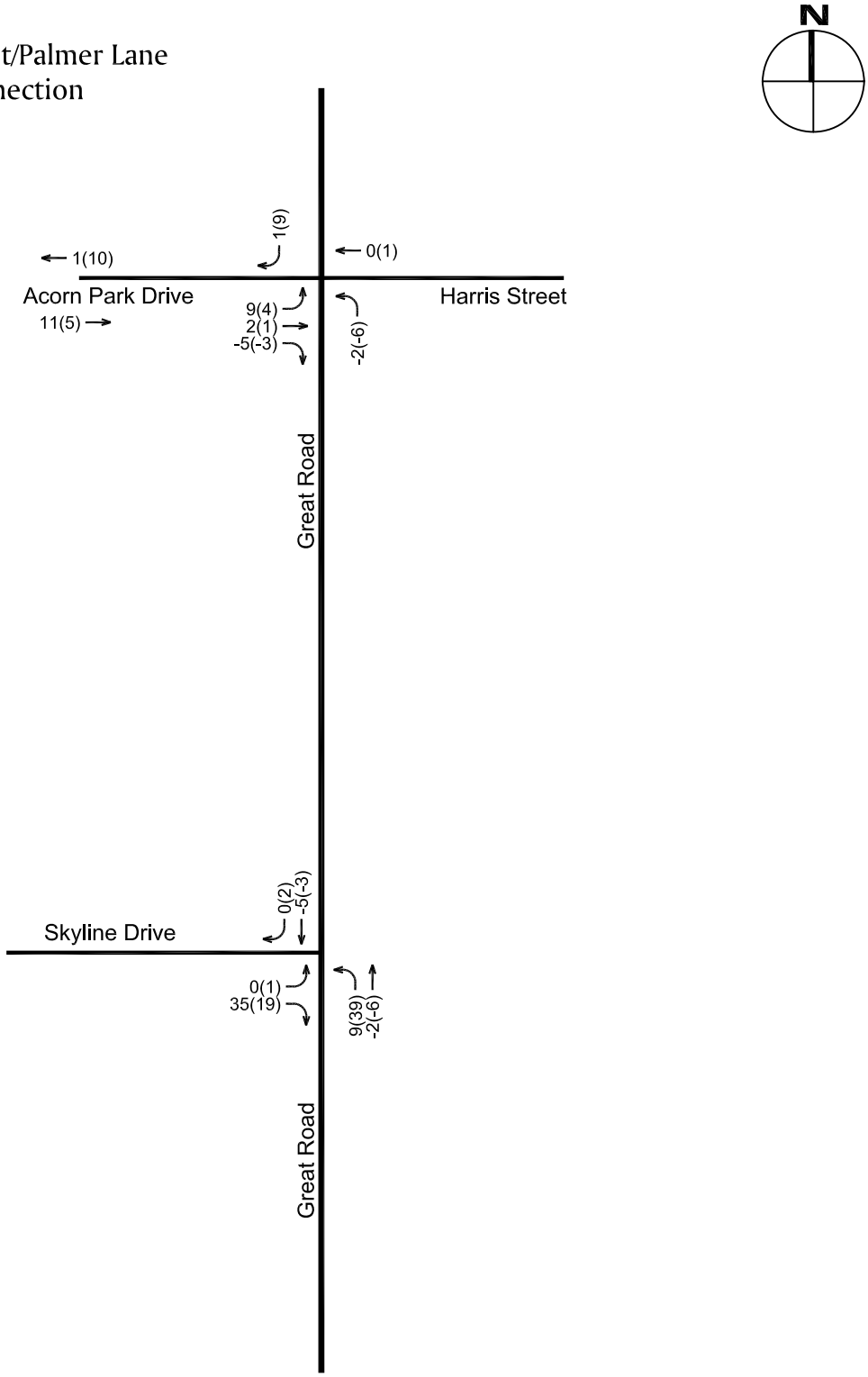
- Providing secondary access to RQR is desirable from a traffic circulation. In recommending a possible connection route, BSC considered the travel distance and the existing horizontal alignment within the Acorn Park subdivision.
    - Residents in RQR Phase II would have to travel almost a mile through Quail Ridge Drive and Skyline Drive to get to Great Road. This is almost twice as long as going through Hazelnut Street and Acorn Park Drive.
    - The distance from Palmer Lane to Great Road is comparable to traveling on Skyline Drive from the proposed Greenside Lane to Great Road. Palmer Lane has a short horizontal curve with an 80-foot radius and that is suitable for a 15 mile per hour vehicle speed.
- BSC recommends a full two-way connection through Hazelnut Street, given the distance of Quail Ridge Drive to Great Road. The horizontal alignment on Hazelnut Street is similar to Acorn Park Drive and with a 20 mile per hour design speed. If the Planning Board decides on a one-way access, BSC would recommend that the direction of travel be from Acorn Park to Quail Ridge Drive. This would result in a lesser impact to Acorn Drive/Great Road intersection.

[10] US Department of Transportation, Federal Highway Administration, ***Prediction of the Expected Safety Performance of Rural Two-Lane Highways, 2000***

- Due to the short curves on Palmer Lane, and the potential to redirect traffic from Acorn Park through it, BSC recommends that the an emergency access through Palmer Lane should be considered.
- AASHTO classifies “very low-volume local roads” as roads with a design volume of 400 or fewer vehicles per day. There is excess capacity on the streets within Acorn Park Subdivision based on the existing traffic volumes recorded by Woodland Design Group.
- According to the Highway Capacity Manual, the theoretical capacity of free movements (through movements on a major street) at an unsignalized intersection is approximately 1600 vehicles per hour per lane.
- All other factors being equal, the risk of an accident increases with an increase in traffic volumes. While no comparable rate was found for two-lane urban roads, the accident rate for a two-lane rural highway with an ADT of 400 vehicles per day is 0.09 crashes per mile per year. A review of the latest three years of MHD data showed no reported accidents within Acorn Park Subdivision.
- Streets in Acorn Park Subdivision are mostly 20 feet and have several short horizontal curves. The combination of narrow roads and tight curves promote slower speeds. BSC does not recommend any further narrowing of the roadways. On-street parking should not impact traffic operations. In some cases, it should contribute to reducing speeds. The Town of Acton should consider posting 20 miles per hour speed limit sign at the entrance to the Subdivision to conform to the design speed of the horizontal curves.
- Traffic on side street approaches at Acorn Park Drive and Skyline Drive intersections with Great Road experience delays especially during the weekday evening peak hour due to heavy through-traffic on Great Road. These approaches currently operate at Level of Service F and will continue under all future build scenarios. It must be noted that in spite of the long delays, traffic signals are not warranted at either of the intersections due to the low side street traffic volumes.

cc:

Hazelnut Street/Palmer Lane
Two Way Connection



Residential Plus
Restaurant Trips

	AM	PM
Enter	10	51
Exit	46	25
Total	56	76

Legend

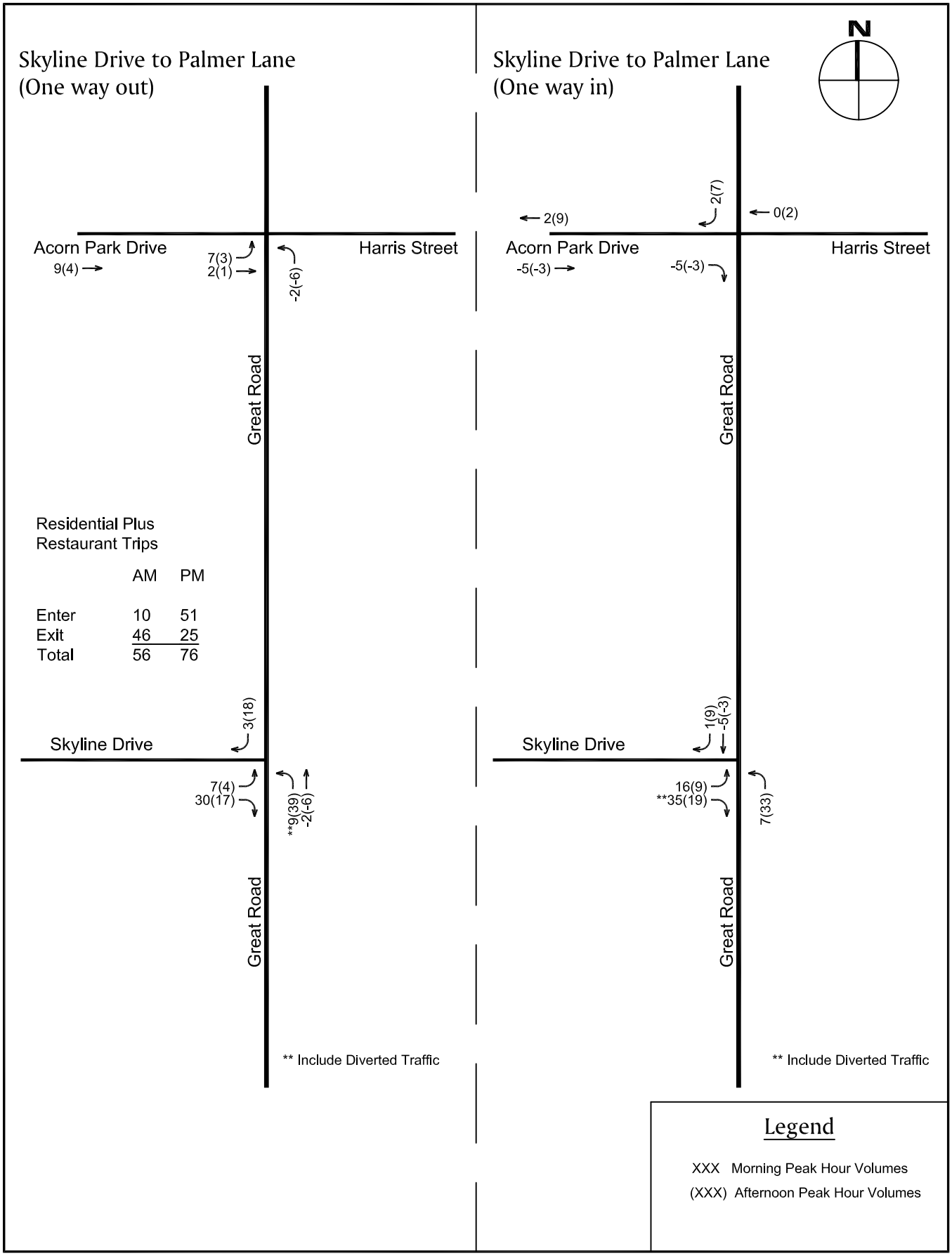
XXX Morning Peak Hour Volumes

(XXX) Afternoon Peak Hour Volumes

RQR Connection to Acorn Park
Residences at Quail Ridge
Acton, Massachusetts

Figure 1
Not to Scale

BSC GROUP



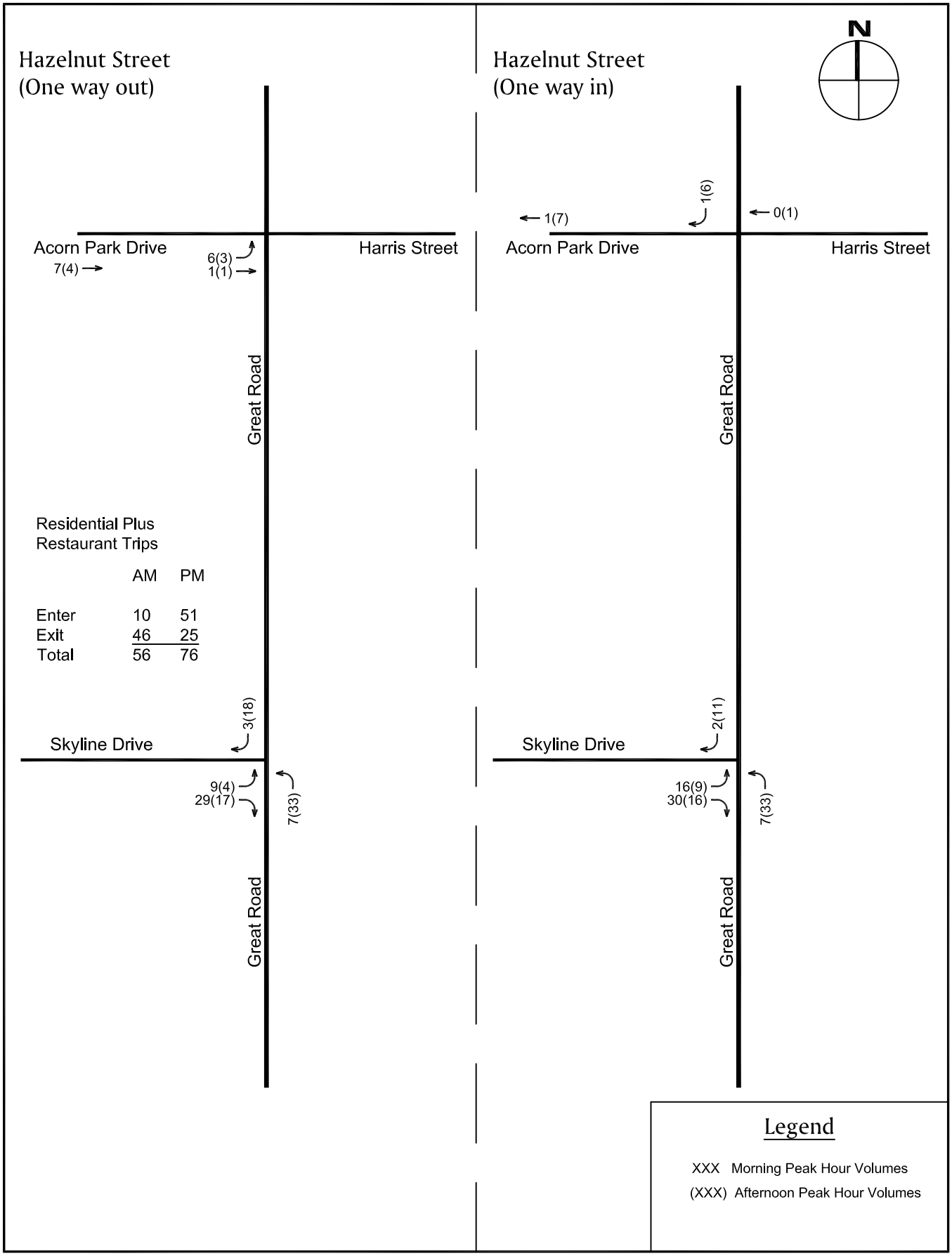
Residential Plus Restaurant Trips

	AM	PM
Enter	10	51
Exit	46	25
Total	56	76

RQR Connection to Acorn Park
Residences at Quail Ridge
Acton, Massachusetts

Figure 2
Not to Scale

BSC GROUP



RQR Connection to Acorn Park
Residences at Quail Ridge
Acton, Massachusetts

Figure 3
Not to Scale

BSC GROUP

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Volume (veh/h)	10	4	34	16	5	78	13	473	11	115	1012	4
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	11	4	37	17	5	85	14	514	12	125	1100	4
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	1988	1907	1102	1940	1903	520	1104			526		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	1988	1907	1102	1940	1903	520	1104			526		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	67	93	86	52	91	85	98			88		
cM capacity (veh/h)	33	60	260	36	60	560	632			1041		

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	SB 1
Volume Total	11	41	23	85	540	1229
Volume Left	11	0	17	0	14	125
Volume Right	0	37	0	85	12	4
cSH	33	192	40	560	632	1041
Volume to Capacity	0.33	0.22	0.57	0.15	0.02	0.12
Queue Length 95th (ft)	27	20	51	13	2	10
Control Delay (s)	163.4	28.8	179.3	12.6	0.6	3.7
Lane LOS	F	D	F	B	A	A
Approach Delay (s)	56.9		47.9		0.6	3.7
Approach LOS	F		E			

Intersection Summary			
Average Delay	6.7		
Intersection Capacity Utilization	104.0%	ICU Level of Service	G
Analysis Period (min)	15		

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Volume (veh/h)	18	38	28	534	1032	11
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	20	41	30	580	1122	12
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None					
Median storage veh)						
Upstream signal (ft)				576		
pX, platoon unblocked	0.80					
vC, conflicting volume	1769	1128	1134			
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1962	1128	1134			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)						
tF (s)	3.5	3.3	2.2			
p0 queue free %	63	84	95			
cM capacity (veh/h)	54	251	616			

Direction, Lane #	EB 1	EB 2	NB 1	SB 1
Volume Total	20	41	611	1134
Volume Left	20	0	30	0
Volume Right	0	41	0	12
cSH	54	251	616	1700
Volume to Capacity	0.37	0.16	0.05	0.67
Queue Length 95th (ft)	33	14	4	0
Control Delay (s)	106.8	22.1	1.3	0.0
Lane LOS	F	C	A	
Approach Delay (s)	49.4		1.3	0.0
Approach LOS	E			

Intersection Summary			
Average Delay	2.1		
Intersection Capacity Utilization	65.0%	ICU Level of Service	C
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Volume (veh/h)	10	4	29	15	5	78	13	476	9	115	1005	6
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	11	4	32	16	5	85	14	517	10	125	1092	7
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	1984	1901	1096	1930	1899	522	1099			527		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	1984	1901	1096	1930	1899	522	1099			527		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	67	93	88	57	91	85	98			88		
cM capacity (veh/h)	33	60	262	38	60	558	635			1040		

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	SB 1
Volume Total	11	36	22	85	541	1224
Volume Left	11	0	16	0	14	125
Volume Right	0	32	0	85	10	7
cSH	33	186	42	558	635	1040
Volume to Capacity	0.33	0.19	0.52	0.15	0.02	0.12
Queue Length 95th (ft)	27	17	47	13	2	10
Control Delay (s)	162.0	28.9	163.1	12.6	0.6	3.6
Lane LOS	F	D	F	B	A	A
Approach Delay (s)	59.8		43.3		0.6	3.6
Approach LOS	F		E			

Intersection Summary			
Average Delay	6.4		
Intersection Capacity Utilization	103.7%	ICU Level of Service	G
Analysis Period (min)	15		

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Volume (veh/h)	19	46	40	534	1027	13
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	21	50	43	580	1116	14
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None					
Median storage veh)						
Upstream signal (ft)				576		
pX, platoon unblocked	0.80					
vC, conflicting volume	1791	1123	1130			
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1990	1123	1130			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)						
tF (s)	3.5	3.3	2.2			
p0 queue free %	58	80	93			
cM capacity (veh/h)	50	250	618			

Direction, Lane #	EB 1	EB 2	NB 1	SB 1
Volume Total	21	50	624	1130
Volume Left	21	0	43	0
Volume Right	0	50	0	14
cSH	50	250	618	1700
Volume to Capacity	0.42	0.20	0.07	0.66
Queue Length 95th (ft)	38	18	6	0
Control Delay (s)	121.8	23.0	1.9	0.0
Lane LOS	F	C	A	
Approach Delay (s)	51.8		1.9	0.0
Approach LOS	F			

Intersection Summary			
Average Delay	2.7		
Intersection Capacity Utilization	71.0%	ICU Level of Service	C
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Volume (veh/h)	19	6	29	15	5	78	11	460	9	115	1012	5
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	21	7	32	16	5	85	12	500	10	125	1100	5
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	1969	1886	1103	1916	1884	505	1105			510		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	1969	1886	1103	1916	1884	505	1105			510		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	39	89	88	57	91	85	98			88		
cM capacity (veh/h)	34	62	260	38	62	571	632			1055		

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	SB 1
Volume Total	21	38	22	85	522	1230
Volume Left	21	0	16	0	12	125
Volume Right	0	32	0	85	10	5
cSH	34	167	42	571	632	1055
Volume to Capacity	0.61	0.23	0.52	0.15	0.02	0.12
Queue Length 95th (ft)	52	21	47	13	1	10
Control Delay (s)	215.2	32.7	162.3	12.4	0.5	3.6
Lane LOS	F	D	F	B	A	A
Approach Delay (s)	96.9		43.0		0.5	3.6
Approach LOS	F		E			

Intersection Summary			
Average Delay	7.8		
Intersection Capacity Utilization	103.0%	ICU Level of Service	G
Analysis Period (min)	15		

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Volume (veh/h)	3	46	42	532	1027	12
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	3	50	46	578	1116	13
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None					
Median storage veh)						
Upstream signal (ft)				576		
pX, platoon unblocked	0.80					
vC, conflicting volume	1792	1123	1129			
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1992	1123	1129			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)						
tF (s)	3.5	3.3	2.2			
p0 queue free %	93	80	93			
cM capacity (veh/h)	49	250	619			

Direction, Lane #	EB 1	EB 2	NB 1	SB 1
Volume Total	3	50	624	1129
Volume Left	3	0	46	0
Volume Right	0	50	0	13
cSH	49	250	619	1700
Volume to Capacity	0.07	0.20	0.07	0.66
Queue Length 95th (ft)	5	18	6	0
Control Delay (s)	83.1	22.9	2.0	0.0
Lane LOS	F	C	A	
Approach Delay (s)	26.6		2.0	0.0
Approach LOS	D			

Intersection Summary			
Average Delay	1.5		
Intersection Capacity Utilization	72.6%	ICU Level of Service	C
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Volume (veh/h)	20	5	26	18	5	102	34	1096	21	87	676	16
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	22	5	28	20	5	111	37	1191	23	95	735	17
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	2323	2221	743	2240	2218	1203	752			1214		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2323	2221	743	2240	2218	1203	752			1214		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	85	93	8	85	51	96			84		
cM capacity (veh/h)	10	35	418	21	35	227	858			574		

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	SB 1
Volume Total	22	34	25	111	1251	847
Volume Left	22	0	20	0	37	95
Volume Right	0	28	0	111	23	17
cSH	10	152	23	227	858	574
Volume to Capacity	2.14	0.22	1.07	0.49	0.04	0.16
Queue Length 95th (ft)	92	20	79	61	3	15
Control Delay (s)	1250.7	35.4	450.2	35.1	1.7	4.7
Lane LOS	F	E	F	E	A	A
Approach Delay (s)	512.0		111.5		1.7	4.7
Approach LOS	F		F			

Intersection Summary			
Average Delay	21.6		
Intersection Capacity Utilization	91.9%	ICU Level of Service	F
Analysis Period (min)	15		

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Volume (veh/h)	17	29	47	1224	742	22
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	18	32	51	1330	807	24
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None					
Median storage veh)						
Upstream signal (ft)				576		
pX, platoon unblocked	0.36					
vC, conflicting volume	2251	818	830			
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	4492	818	830			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)						
tF (s)	3.5	3.3	2.2			
p0 queue free %	0	92	94			
cM capacity (veh/h)	1	379	802			

Direction, Lane #	EB 1	EB 2	NB 1	SB 1
Volume Total	18	32	1382	830
Volume Left	18	0	51	0
Volume Right	0	32	0	24
cSH	1	379	802	1700
Volume to Capacity	35.55	0.08	0.06	0.49
Queue Length 95th (ft)	Err	7	5	0
Control Delay (s)	Err	15.4	3.1	0.0
Lane LOS	F	C	A	
Approach Delay (s)	3705.0		3.1	0.0
Approach LOS	F			

Intersection Summary			
Average Delay	83.8		
Intersection Capacity Utilization	112.5%	ICU Level of Service	H
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Volume (veh/h)	20	5	23	17	7	102	34	1127	20	87	672	23
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	22	5	25	18	8	111	37	1225	22	95	730	25
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	2357	2253	743	2270	2254	1236	755			1247		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2357	2253	743	2270	2254	1236	755			1247		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	84	94	9	77	49	96			83		
cM capacity (veh/h)	9	33	418	20	33	217	855			558		

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	SB 1
Volume Total	22	30	26	111	1284	850
Volume Left	22	0	18	0	37	95
Volume Right	0	25	0	111	22	25
cSH	9	137	23	217	855	558
Volume to Capacity	2.53	0.22	1.14	0.51	0.04	0.17
Queue Length 95th (ft)	95	20	83	65	3	15
Control Delay (s)	1541.3	38.7	481.7	37.7	1.8	4.9
Lane LOS	F	E	F	E	A	A
Approach Delay (s)	664.8		122.3		1.8	4.9
Approach LOS	F		F			

Intersection Summary			
Average Delay	24.9		
Intersection Capacity Utilization	92.7%	ICU Level of Service	F
Analysis Period (min)	15		

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Volume (veh/h)	47	41	53	1224	739	17
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	51	45	58	1330	803	18
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None					
Median storage veh)						
Upstream signal (ft)				576		
pX, platoon unblocked	0.36					
vC, conflicting volume	2258	812	822			
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	4519	812	822			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)						
tF (s)	3.5	3.3	2.2			
p0 queue free %	0	88	93			
cM capacity (veh/h)	0	382	808			

Direction, Lane #	EB 1	EB 2	NB 1	SB 1
Volume Total	51	45	1388	822
Volume Left	51	0	58	0
Volume Right	0	45	0	18
cSH	0	382	808	1700
Volume to Capacity	103.61	0.12	0.07	0.48
Queue Length 95th (ft)	Err	10	6	0
Control Delay (s)	Err	15.7	3.5	0.0
Lane LOS	F	C	A	
Approach Delay (s)	5347.7		3.5	0.0
Approach LOS	F			

Intersection Summary			
Average Delay	224.0		
Intersection Capacity Utilization	117.4%	ICU Level of Service	H
Analysis Period (min)	15		

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0%	
Volume (veh/h)	24	6	23	16	6	102	28	1093	20	87	664	25
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	26	7	25	17	7	111	30	1188	22	95	722	27
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	2298	2195	735	2212	2198	1199	749			1210		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2298	2195	735	2212	2198	1199	749			1210		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	82	94	22	82	51	96			84		
cM capacity (veh/h)	11	37	423	22	37	228	860			577		

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	NB 1	SB 1
Volume Total	26	32	24	111	1240	843
Volume Left	26	0	17	0	30	95
Volume Right	0	25	0	111	22	27
cSH	11	133	25	228	860	577
Volume to Capacity	2.48	0.24	0.96	0.49	0.04	0.16
Queue Length 95th (ft)	106	22	73	61	3	15
Control Delay (s)	1385.1	40.1	391.9	34.9	1.3	4.6
Lane LOS	F	E	F	D	A	A
Approach Delay (s)	649.2		98.2		1.3	4.6
Approach LOS	F		F			

Intersection Summary			
Average Delay	24.7		
Intersection Capacity Utilization	95.3%	ICU Level of Service	F
Analysis Period (min)	15		

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Sign Control	Stop			Free	Free	
Grade	0%			0%	0%	
Volume (veh/h)	13	41	59	1218	739	10
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	14	45	64	1324	803	11
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None					
Median storage veh)						
Upstream signal (ft)				576		
pX, platoon unblocked	0.36					
vC, conflicting volume	2261	809	814			
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	4526	809	814			
tC, single (s)	6.4	6.2	4.1			
tC, 2 stage (s)						
tF (s)	3.5	3.3	2.2			
p0 queue free %	0	88	92			
cM capacity (veh/h)	0	384	813			

Direction, Lane #	EB 1	EB 2	NB 1	SB 1
Volume Total	14	45	1388	814
Volume Left	14	0	64	0
Volume Right	0	45	0	11
cSH	0	384	813	1700
Volume to Capacity	29.24	0.12	0.08	0.48
Queue Length 95th (ft)	Err	10	6	0
Control Delay (s)	Err	15.6	3.8	0.0
Lane LOS	F	C	A	
Approach Delay (s)	2419.0		3.8	0.0
Approach LOS	F			

Intersection Summary			
Average Delay	65.1		
Intersection Capacity Utilization	120.2%	ICU Level of Service	H
Analysis Period (min)	15		