
Conceptual Design Report

North Road Intersections at Chelmsford Road and Pine Hill Road



Prepared for

Town of Bedford

December 2016

Prepared by



GREEN INTERNATIONAL AFFILIATES, INC.
Civil and Structural Engineers

Green No. 16065

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 1

2.0 NORTH ROAD AT CHELMSFORD ROAD INTERSECTION 2

2.1 Existing Conditions 2

2.1.1 Overview..... 2

2.1.2 Geometric Considerations..... 2

2.1.3 Traffic Count Program 3

2.1.4 Future Traffic Volume Projections..... 4

2.1.5 Safety Analysis 7

2.1.6 Signal Warrant Analysis 10

2.1.7 Level of Service (LOS)..... 10

2.2 Design Alternatives 11

2.2.1 No Build Traffic Analysis 11

2.2.2 Alternative 1 14

2.2.3 Alternative 2 18

2.2.4 Alternative 3 21

2.3 Environmental Consideration 22

2.4 Other Considerations 23

2.5 Preferred Alternative 24

3.0 NORTH ROAD AT PINE HILL ROAD INTERSECTION 25

3.1 Existing Conditions 25

3.1.1 Overview..... 25

3.1.2 Geometric Considerations..... 25

3.1.3 Traffic Count Program 25

3.1.4 Future Traffic Volume Projections..... 27

3.1.5 Safety Analysis 30

3.1.6 Signal Warrant Analysis 33

3.2 Design Alternatives 33

3.2.1 Pine Hill Road..... 33

3.2.2 No Build Traffic Analysis 34

3.2.3 Alternative 1 36

3.2.4 Alternative 2 39

3.2.5 Alternative 3 42

3.3 Environmental Consideration 43
3.4 Other Considerations 43
3.5 Preferred Alternative 44

TABLES

Table 2.01 - Summary of Observed ATR Traffic Data: North Road, North of Homestead Circle 3
Table 2.02 - Summary of Observed ATR Traffic Data: Chelmsford Road (Route 4), North of North Road... 4
Table 2.03 - Summary of Observed ATR Traffic Data: North Road (Route 4), North of Minuteman Drive .. 4
Table 2.04 – Summary of Intersection Crash Data 8
Table 2.05 - Level of Service Criteria for Signalized Intersections 11
Table 2.06 - Level of Service Criteria for Unsignalized Intersections..... 11
Table 2.07 – Summary of No Build Capacity Analysis..... 12
Table 2.08 – Summary of Alternative 1 Capacity Analysis..... 15
Table 2.09 – Summary of Alternative 2 Capacity Analysis..... 19
Table 2.10 – Summary of Alternative 3 Capacity Analysis..... 22
Table 3.01 - Summary of Observed ATR Traffic Data: North Road (Route 4), North of Minuteman Drive 26
Table 3.02 - Summary of Observed ATR Traffic Data: North Road (Route 4), South of Pine Hill Road 26
Table 3.03 - Summary of Observed ATR Traffic Data: Pine Hill Road, East of North Road (Route 4)..... 27
Table 3.04 – Summary of Intersection Crash Data 31
Table 3.05 – Summary of No Build Capacity Analysis..... 34
Table 3.06 – Summary of Alternative 1 Capacity Analysis..... 37
Table 3.07 – Summary of Alternative 2 Capacity Analysis..... 40
Table 3.08 – Summary of Alternative 3 Capacity Analysis..... 42

FIGURES

Figure 1: North Road at Chelmsford Road 2016 Existing Traffic Volumes 5
Figure 2: North Road at Chelmsford Road 2026 Future Traffic Volumes 6
Figure 3: North Road at Chelmsford Road Crash Diagram 9
Figure 4: North Road at Chelmsford Road Alternative 1 Conceptual Design 13
Figure 5: North Road at Chelmsford Road Alternative 2 Conceptual Design 17
Figure 6: North Road at Chelmsford Road Alternative 3 Conceptual Design 20
Figure 7: North Road at Pine Hill Road 2016 Existing Traffic Volumes..... 28
Figure 8: North Road at Pine Hill Road 2026 Future Traffic Volumes..... 29
Figure 9: North Road at Pine Hill Road Crash Diagram..... 32
Figure 10: North Road at Pine Hill Road Alternative 1 Conceptual Design..... 35
Figure 11: North Road at Pine Hill Road Alternative 2 Conceptual Design..... 38
Figure 12: North Road at Pine Hill Road Alternative 3 Conceptual Design..... 41

APPENDICES

- Appendix A ATR/TMC Data
- Appendix B Crash Rate Worksheets
- Appendix C Synchro Reports
- Appendix D Count Station Data
- Appendix E Signal Warrant Analysis Worksheets

1.0 EXECUTIVE SUMMARY

The Town of Bedford has requested conceptual design services for intersection improvements at the following two locations along North Road, a vital transportation link within the Town:

- North Road at Chelmsford Road Intersection
- North Road at Pine Hill Road Intersection

At the North Road at Chelmsford Road intersection, the Town has expressed the desire for several improvements to geometry, pedestrian accommodations, and bicycle accommodations that will benefit safety for vehicles, pedestrians, and bicyclists. Geometric improvements will aim to mitigate safety issues caused by sight obstructions, the confusing intersection layout, and the ambiguous existing traffic control. The Town would like to provide a sidewalk on at least one side of each road and bicycle lanes on both sides of the roadways. These pedestrian and bicycle accommodations will provide connectivity to key points such as the Minuteman Rail Trail, both to the north and south of the intersection.

At the North Road at Pine Hill Road intersection, The Town has expressed the desire for several improvements to mitigate issues with deficient traffic operations, safety, and absent pedestrian amenities. The Town would like to complete a connection between the existing sidewalk on North Road easterly to the existing sidewalk on Heritage Drive along Pine Hill Road. The Town would also like to improve the intersection in a way that would promote safety and reduce cut-through traffic in adjacent residential neighborhoods.

The Town has requested that three conceptual level design alternatives be prepared for each of the intersections. A preferred alternative will then be selected through coordination with Town officials and community meetings. The purpose of this report is to present the alternatives, summarize our findings, evaluations, and engineering recommendations.

The following indicates the preferred alternative at each intersection based on Green’s engineering evaluations and findings as well as several key features of the respective alternative.

North Road at Chelmsford Road – Alternative 2 is preferred

- Realigns North Road to form a “T” intersection configuration and signalizes the intersection.
- Improves sight lines and safety for the intersection
- Improves pedestrian and bicycle accommodations
- Better defining the northbound slip lane to North Road which also allow for future landscape opportunities.
- Requires several land takings and/or permanent easements.
- Signalization results in long queues along Chelmsford Road during the morning peak period as a trade-off for improved overall traffic operations and safety.
- Order of magnitude construction estimate of \$850,000. This cost does not include utility pole relocations or right-of-way acquisitions or easements.

North Road at Pine Hill – Alternative 2 is preferred

- Realigns Pine Hill Road to form a “T” intersection configuration and signalizes the intersection.
- Improve sight lines and safety for the intersection.
- Widen North Road to add a dedicated left-turn lane for the North Road southbound approach.

- Widen North Road shoulders to improve bicycle accommodations.
- Permanent Right-of-Way impacts are not anticipated.
- Signalization results in long queues along North Road northbound during the afternoon peak period as a trade-off for improved overall traffic operations and safety.
- Provides new sidewalk connection between North Road and Heritage Drive along Pine Hill Road.
- Order of magnitude construction estimate of \$400,000. This cost does not include utility pole relocations or temporary construction easements.

2.0 NORTH ROAD AT CHELMSFORD ROAD INTERSECTION

2.1 Existing Conditions

2.1.1 Overview

North Road at Chelmsford Road is an unsignalized three-legged intersection. North Road serves as the northeastern and southern legs of the intersection, while Chelmsford Road serves as the northern leg. North Road functions as an important connection to Route 3 which is located approximately 1.5 miles northeast of the intersection. South of the intersection, North Road becomes Route 4 and functions as the primary route to and from the center of Bedford. Chelmsford Road is Route 4 north of the intersection and provides access to Chelmsford Center. The land use in the area of the intersection is mainly comprised of residential homes, along with one business and undeveloped wooded land. Environmentally sensitive areas adjacent to the intersection include the Minnie Reid Conservation Area to the west and wetlands to the southeast. Both roadways are non-NHS, urban minor arterial roadways under the Town of Bedford jurisdiction.

2.1.2 Geometric Considerations

North of the intersection, North Road is a two-way, two-lane roadway approximately 28 feet in width. The roadway consists of two approximately 12-foot wide travel lanes and 2-foot shoulders. South of the intersection, North Road is a two-way, two-lane roadway approximately 32 feet in width. The roadway consists of two approximately 12-foot-wide travel lanes and 4-foot wide shoulders. The roadway has bituminous berm on the east side with no curbing along the west side. There are no existing defined bicycle or pedestrian accommodations along either side of the roadway. The right-of-way in this area along North Road is approximately 50 feet.

Chelmsford Road is a two-way, two-lane roadway approximately 32 feet in width. The roadway consists of two approximately 12-foot wide travel lanes and 4-foot wide shoulders. The roadway has no curbing or berm on either side of the road. There are no bicycle or pedestrian accommodations along either side of the roadway. The right-of-way for Chelmsford Road in this area is approximately 50 feet.

At the intersection, the North Road southbound approach intersects Route 4 at a skewed angle of approximately 30 degrees; this approach is controlled by stop signs. The approach also takes a sharp turn to meet Chelmsford Road forming a T intersection layout at the intersection opening. The Route 4 northbound approach is excessively wide such that right turning



North Road at Chelmsford Road looking north.

vehicles are channelized by a painted island to separate the northbound through movements and right-turning movements. The main conflict point at the intersection is between the southbound left turn from North Road and the through traffic on Chelmsford Road. There is a secondary conflict point between the southbound left-turn from Chelmsford Road and northbound right-turn movement; as it is unclear which movement has the responsibility to yield. There are existing flashing warning beacons present at the intersection to help increase awareness of the intersection with multiple stop signs for the North Street approach.

2.1.3 Traffic Count Program

As part of the development of the conceptual design alternatives, traffic volume data were collected and used to form the basis of the traffic analysis. Manual turning movement counts (TMC) were collected from Wednesday and Thursday September 28-29, 2016 during the peak periods (7:00-9:00 A.M. and 4:00-6:00 P.M.). The traffic count program also included a 7-day Automatic Traffic Recorder (ATR) vehicle count from Wednesday, September 28th, 2016 to Tuesday, October 4th, 2016 at the following locations:

- North Road north of Homestead Circle
- Chelmsford Road (Route 4) north of North Road
- North Road (Route 4) north of Minuteman Drive

Tables 2.01 through 2.03 summarize the ATR data that were collected as part of this study. Figure 1 summarizes the existing peak hour TMC data. The complete ATR and TMC data are included in the attached Appendix A.

Table 2.01 - Summary of Observed ATR Traffic Data: North Road, North of Homestead Circle

	NORTH ROAD, NORTH OF HOMESTEAD CIRCLE		
	WEEKDAY AVERAGE	AM PEAK HOUR	PM PEAK HOUR
Time Period	Daily	7:30 – 8:30	4:45 – 5:45
Traffic Volume ¹	7,381 vpd	638 vph	621 vph
K-Factor ²	-	8.6%	8.4%
Directional Distribution	55% NB / 45% SB	57% NB / 43% SB	56% NB / 44% SB
Heavy Vehicle Percentage	3.8% NB / 4.4% SB	1.8% NB / 2.4% SB	1.2% NB / 1.3% SB
Average Speed	36 mph NB / 36 mph SB		
85 th Percentile Speed	40 mph NB / 40 mph SB		
¹ vpd = vehicles per day, vph = vehicles per hour			
² percent of daily traffic that occurs during the peak hour			

Note: Data have been averaged over five weekdays and rounded. September to October (ATR) data.

Table 2.02 - Summary of Observed ATR Traffic Data: Chelmsford Road (Route 4), North of North Road

	CHELMSFORD ROAD (ROUTE 4), NORTH OF NORTH ROAD		
	WEEKDAY AVERAGE	AM PEAK HOUR	PM PEAK HOUR
Time Period	Daily	6:45 – 7:45	4:15 – 5:15
Traffic Volume ¹	8,019 vpd	1,026 vph	1,014 vph
K-Factor ²	-	12.8%	12.6%
Directional Distribution	50% NB / 50% SB	3% NB / 97% SB	91% NB / 9% SB
Heavy Vehicle Percentage	4.5% NB / 3.0% SB	0.2% NB / 2.6% SB	3.4% NB / 0.2% SB
Average Speed	40 mph NB / 35 mph SB		
85 th Percentile Speed	43 mph NB / 41 mph SB		
¹ vpd = vehicles per day, vph = vehicles per hour			
² percent of daily traffic that occurs during the peak hour			

Note: Data have been averaged over five weekdays and rounded. September to October (ATR) data.

Table 2.03 - Summary of Observed ATR Traffic Data: North Road (Route 4), North of Minuteman Drive

	NORTH ROAD (ROUTE 4), NORTH OF MINUTEMAN DRIVE		
	WEEKDAY AVERAGE	AM PEAK HOUR	PM PEAK HOUR
Time Period	Daily	6:45-7:45	5:00 – 6:00
Traffic Volume ¹	14,357 vpd	1,374 vph	1,507 vph
K-Factor ²	-	9.6%	10.5%
Directional Distribution	53% NB / 47% SB	15% NB / 85% SB	82% NB / 18% SB
Heavy Vehicle Percentage	3.2% NB / 4.6% SB	0.8% NB / 3.3% SB	1.1% NB / 0.8% SB
Average Speed	39 mph NB / 36 mph SB		
85 th Percentile Speed	42 mph NB / 43 mph SB		
¹ vpd = vehicles per day, vph = vehicles per hour			
² percent of daily traffic that occurs during the peak hour			

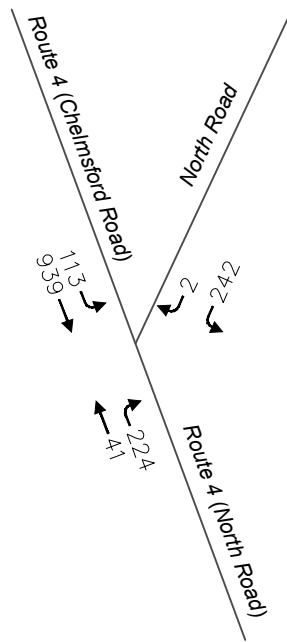
Note: Data have been averaged over five weekdays and rounded. September to October (ATR) data.

As shown in table 2.02 and 2.03, it appears that the distribution of traffic along the Route 4 corridor reflects that the majority of the traffic along the Route 4 corridor is commuter traffic using Route 4 as a means to avoid Route 3 traffic during peak hours.

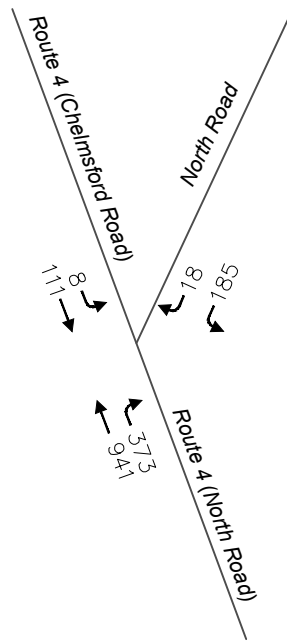
2.1.4 Future Traffic Volume Projections

A year 2026 traffic volume network was developed by identifying potential area-wide background traffic volume growth and known specific nearby development projects that could contribute to traffic flow on the 2026 study network. Figure 2 summarizes the future traffic volume peak hour TMC data.

Green reviewed traffic growth and historical traffic count trends for the project’s analysis area. Based upon our review of local count stations, an annual growth rate of one percent (1%) per year for ten years was used to forecast future roadway volumes. These rates would presumably account for some of the more remote growth in the region, as well as, potential nearby smaller residential and business growth that could result in added traffic through the study area. The count station data can be found in Appendix C.



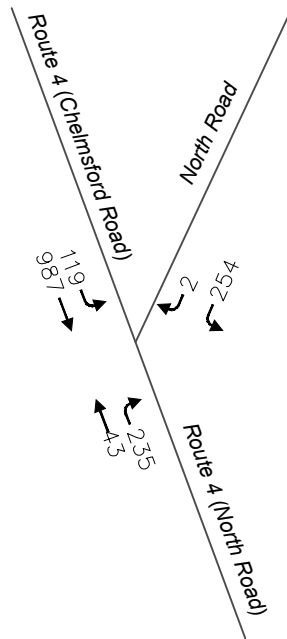
AM PEAK HOUR



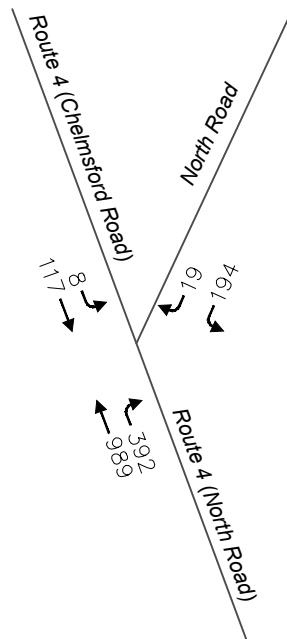
PM PEAK HOUR



Figure 1
2016 Existing Traffic Volumes
Route 4 and North Road Intersection
Bedford, MA



AM PEAK HOUR



PM PEAK HOUR

2.1.5 Safety Analysis

Crash data were obtained from the Town of Bedford and MassDOT for the three (3) year period between 2013 – 2015. The records indicate that there were ten (10) crashes reported at the intersection of North Road at Chelmsford Road during the three-year time frame. Eight (8) of the ten (10) crashes at the intersection involved property damage only. There were no fatalities, although there were two (2) crashes where injuries were reported. There were eight (8) crashes in three years that involved angle collisions during a turning movement. Seven (7) of these eight (8) crashes involved vehicles exiting North Road turning left onto Route 4. Two (2) crashes involved rear end collisions.

Table 2.04 provides a summary of the intersection crash data and Figure 3 shows the types of crashes in a diagram.

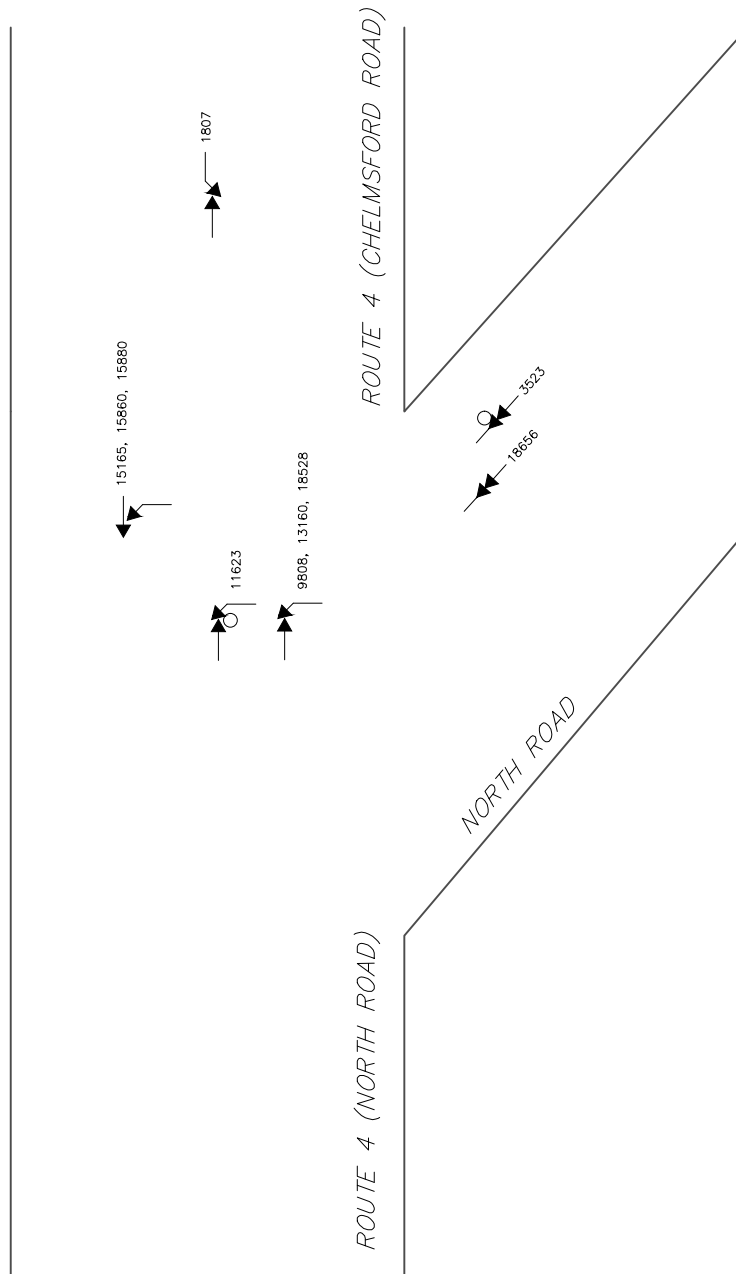
The MassDOT intersection Crash Rate Worksheet was used to calculate the crash rate at the study intersection which is included in Appendix B. It was determined that the intersection had a crash rate of 0.62 crashes per million entering vehicles (MEV) slightly above the 0.56 average crashes per MEV for MassDOT District 4 unsignalized intersections.

The North Road southbound approach creates a major conflict point at the intersection of Route 4. Due to the skew of the intersection and the tight radius on the northwestern corner, vehicles tend to not recognize the stop sign at the intersection and on occasions they fail to stop. Further provoking this movement is an old stop bar that is painted over approximately 40 feet north along North Road. This stop bar is commonly mistaken as the official stopping point for the intersection. In addition, poor sight lines create difficulties for motorists in the area and may have contributed to the angle collisions involving vehicles exiting North Road.

The standard MassDOT Crash Rate Worksheets are included in Appendix B

Table 2.04 – Summary of Intersection Crash Data

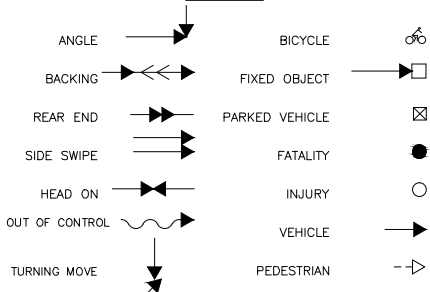
	North Road at Chelmsford Road		
	2013	2014	2015
Severity			
Property Damage	2	3	3
Injury	1	1	
Fatality			
Unknown			
Collision Type			
Rear End		1	1
Angle	3	3	2
Side Swipe			
Head On			
Single Vehicle			
Collision with Ped			
Collision with Bike			
Other/Unknown			
Time of Day			
6:01 AM – 10:00 AM		1	
10:01 AM – 4:00 PM	1	2	
4:01 PM – 7:00 PM	2		3
7:01 PM – 6:00 AM		1	
Roadway Conditions			
Dry	2	3	1
Wet			1
Snow/Ice	1	1	1
Other/Unknown			
Season			
Dec-Feb	1	3	2
Mar-May		1	
June-Aug			
Sept-Nov	2		1
Light Conditions			
Daylight	2	3	1
Dawn/Dusk	1	1	2
Dark (Unlit)			
Dark (Lit)			
Unknown			
Totals			
	3	4	3
Annual Average Crashes	3.33		
Intersection Crash Rate (MEV)			
MassDOT District 3 Average Crash Rate (MEV)	0.62		
	0.56		



2013-2015

	DATE	TIME	W	PD	I	F	L	R	V
9808	9/27/2013	4:13 PM	F	YES			1	1	3
11623	11/9/2013	6:59 PM	SA	YES	1		4	1	3
13160	12/20/2013	12:48 PM	F	YES			1	3	3
1807	2/18/2014	8:40 PM	TU	YES			4	1	
3523	4/2/2014	7:59 AM	W	YES	1		1	1	14
15165	12/1/2014	10:52 AM	M	YES			1	1	3
15860	12/16/2014	1:52 PM	TU	YES			1	1	3
15880	10/29/2015	4:37 PM	TH	YES			1	1	2
18528	12/15/2015	6:29 PM	TU	YES			4	4	3
18656	12/17/2015	6:16 PM	TH	YES			4	2	5

SYMBOLS



LIGHT CONDITIONS (L)

1. DAYLIGHT
2. DAWN
3. DUSK, UNLIT ROADWAY
4. DUSK, LIT ROADWAY
5. DARKNESS, UNLIT ROADWAY
6. DARKNESS, LIT ROADWAY
99. UNKNOWN

ROAD CONDITIONS (R)

1. DRY
2. WET
3. SNOW OR ICY
4. SLUSH
5. OTHER/ UNKNOWN

WEEDKAY (W)

- M = MONDAY F = FRIDAY
 TU = TUESDAY SA = SATURDAY
 W = WEDNESDAY SU = SUNDAY
 TH = THURSDAY

VIOLATIONS CITED (V)

1. SPEED TOO FAST
 2. FAILURE TO YIELD
 3. RAN STOP SIGN
 4. RAN TRAFFIC SIGNAL
 5. FOLLOWING TOO CLOSE
 6. IMPROPER PASSING
 7. WRONG SIDE OF ROAD
 8. IMPROPER TURNING
 9. IMPROPER BACKING
 10. HAD BEEN DRINKING
 11. PEDESTRIAN VIOLATION
 12. RECKLESS DRIVING
 13. IMPROPER LIGHT OR BRAKES
 14. CARE IN STARTING/STOPPING
- I = INJURY
 F = FATALITY

FIGURE 3

CONCEPTUAL ANALYSIS REPORT
 BEDFORD NORTH ROAD
 INTERSECTION OF CHELMSFORD ROAD AND
 NORTH ROAD
 BEDFORD, MA



GREEN INTERNATIONAL AFFILIATES, INC.
 CIVIL & STRUCTURAL ENGINEERS WESTFORD, MASSACHUSETTS

2.1.6 Signal Warrant Analysis

As part of this study, we completed traffic signal warrant analyses at the study intersection in compliance with the Manual on Uniform Traffic Control Devices (MUTCD) 2009 Edition using the existing traffic volumes. The study intersection meets the requirements for MUTCD Warrants 1 (Eight-Hour Vehicular Volume), 2 (Four-Hour Vehicular Volume), and 3 (Peak Hour). Therefore, traffic signal control is considered to be warranted at the study intersection using these three primary traffic signal warrants. The signal warrant analysis worksheets are included in Appendix E.

2.1.7 Level of Service (LOS)

To assess quality of traffic flow, intersection capacity analyses were conducted for the study intersections for the following three scenarios:

- 2016 Existing Conditions
- 2026 Future No-Build Conditions (Future Traffic Volumes with Existing roadway/intersection conditions)
- 2026 Future Build Conditions (Future Traffic Volumes with recommended improvements)

Within each scenario, analyses were conducted for the weekday morning and afternoon peak hours. The intersection capacity analyses determine vehicular delays, vehicular queuing, and intersection capacity based on the intersection geometry, traffic signal timing and phasing, and vehicular volumes.

“Level of Service” (LOS) is used to denote the different operating conditions for roadways and intersections under various traffic volume loads. LOS designations range from “A” at best with little or no delays to “F” at worst with long delays and forced flow conditions. LOS ratings for an intersection are based upon the average delay per approaching vehicle.

The following table summarizes the relationship between LOS and vehicle delay. It is noted that the delay thresholds in the table below correspond with a volume-to-capacity (v/c) ratio of less than 1.0. For any v/c ratio of greater than 1.0, a LOS “F” is assigned, regardless of the vehicular delay.

Table 2.05 - Level of Service Criteria for Signalized Intersections

LEVEL OF SERVICE	VEHICLE DELAY RANGE(SEC)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

Table 2.06 - Level of Service Criteria for Unsignalized Intersections

LEVEL OF SERVICE	VEHICLE DELAY RANGE (SEC)
A	≤ 10
B	> 10 and ≤ 15
C	> 15 and ≤ 25
D	> 25 and ≤ 35
E	> 35 and ≤ 50
F	> 50 or v/c > 1.00

Detailed traffic analysis networks for the weekday morning and afternoon peak hours were developed to perform the capacity analyses, utilizing the Synchro 9 software. This software implements the methodologies of the 2010 Highway Capacity Manual, and is approved for use by MassDOT. The complete capacity analysis worksheets for the intersection are provided in Appendix C.

2.2 Design Alternatives

Three (3) design alternatives are presented for the intersection of North Road at Chelmsford Road. All three options require alterations to the existing geometry of the intersection and right-of-way takings from the property of Renzo’s Salon. Each alternative will improve safety by providing a more intuitive intersection layout. In addition to the three alternatives, a no build condition with the projected traffic volumes is provided as a future base-line comparison. Conceptual designs for each alternative are shown in Figures 4 to 6.

2.2.1 No Build Traffic Analysis

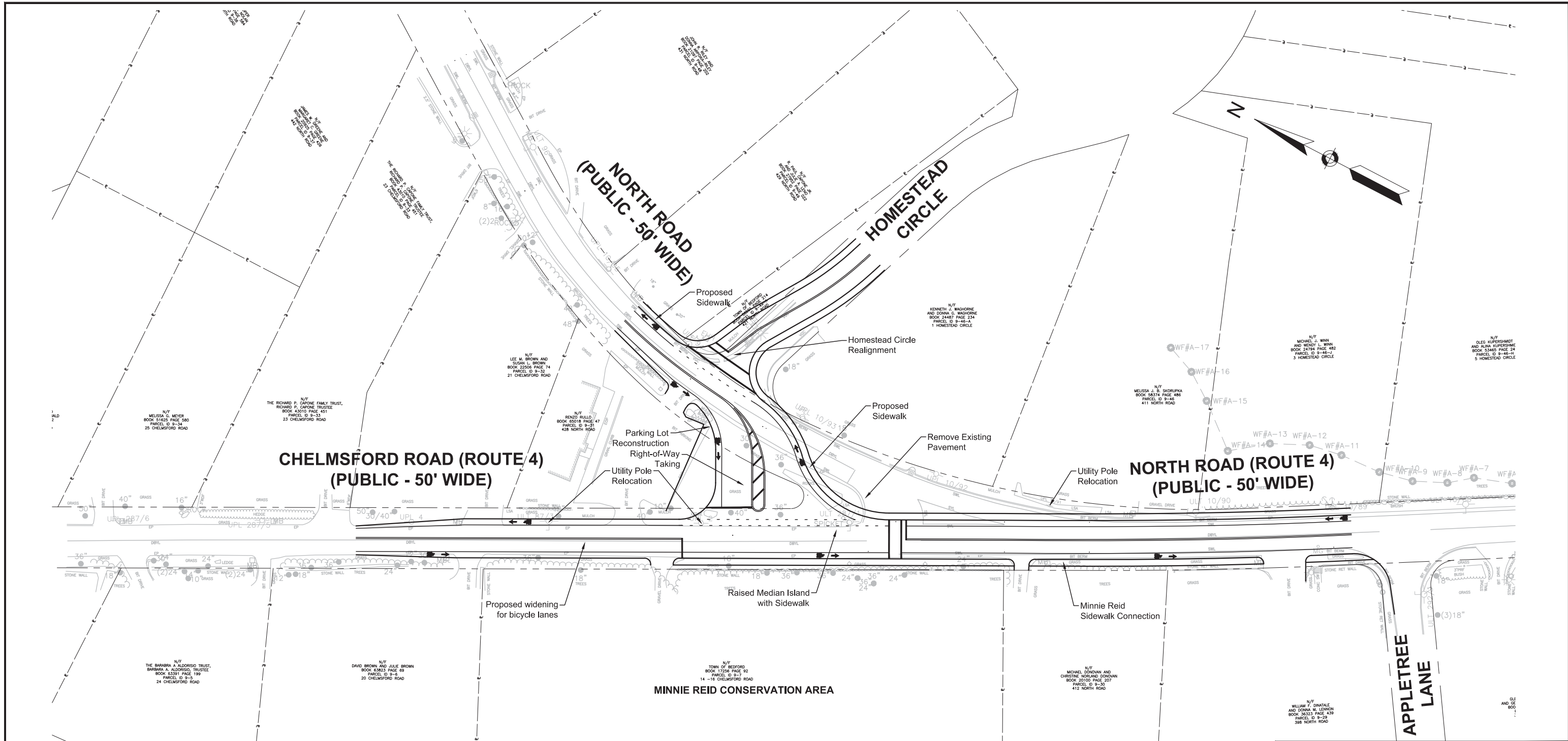
To assess existing conditions quality of traffic flow, Green conducted intersection capacity analyses for the study intersection for the condition where no improvements are done. Table 2.07 summarizes the results of the study for the no build condition. The intersection capacity analysis indicated the following:

- The North Road WB approach operates at a LOS F during all peak periods. The LOS F is worsened during 2026 projected future volumes. From this LOS F and the TMC, it can be deduced that the high level of traffic on Route 4 makes exiting movements from the North Road WB approach extremely difficult.

- The Route 4 traffic in both the northbound and southbound directions operate freely without delay.

Table 2.07 – Summary of No Build Capacity Analysis


	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2016 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road WB/SB	>120	F	1.84	-	502.5	111	F	1.01	-	232.5
Chelmsford Road SB	0.8	A	-	-	-	0.7	A	-	-	-
2026 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road WB/SB	>120	F	2.19	-	585	>120	F	1.14	-	282.5
Chelmsford Road SB	0.8	A	-	-	-	0.7	A	-	-	-
<i>Abbreviations:</i>										
EB = Eastbound L = Left LT = Left and Through Delay = Average delay per vehicle (measured in seconds) WB = Westbound T = Through LR = Left and Right LOS = Level of Service NB = Northbound R = Right TR = Through and Right v/c = Volume-to-Capacity ratio SB = Southbound LTR = Left, Through, and Right										



PROJECT **NORTH ROAD INTERSECTION IMPROVEMENTS**

DESIGN SUBMISSION: **CONCEPTUAL DESIGN**

DRAWING TITLE: **NORTH ROAD INT ALTERNATIVE 1**

PREPARED FOR:
 **TOWN OF BEDFORD**
 BEDFORD DPW
 10 MUDGE WAY
 BEDFORD, MASSACHUSETTS

PREPARED BY:
 **GREEN INTERNATIONAL AFFILIATES, INC.**
 Civil and Structural Engineers (978) 923-0400
 Westford, Massachusetts GreenIntl.com

SCALE: AS NOTED	DESIGNED BY: MPD	FIGURE 4
DATE: 12/16/2016	DRAWN BY: MPD	
PROJECT NO. 16065	CHECKED BY: WW	



NO.	DATE	REVISIONS

2.2.2 Alternative 1

Geometric Considerations

Alternative 1 transforms the existing skewed intersection into a traditional “T” intersection configuration where Route 4 is maintained as the main thoroughfare and North Road is realigned to be perpendicular to Route 4. This alternative provides 11-foot lanes and 5-foot shoulder/bike lanes on each approach. A sidewalk is provided along the east side of the intersection to provide important connections to the Minuteman Rail Trail both to the north and south. On the North Road southbound approach, the intersection widens to approximately 160 feet as it approaches Route 4. A painted gore area separates the eastbound and westbound lanes in order to better define the usable/intended travel lanes. In addition to the improvements at the intersection, Alternative 1 proposes to realign Homestead Circle to provide more separation from the Route 4 intersection and to provide a better alignment in relation to the driveway for Renzo’s Salon. The realignment of both Homestead Circle and North Road provide new areas for potential green space and landscaping within the project. This design proposes full depth construction to enable the major realignment proposed. The western edge of Route 4 is maintained to avoid impacts to the Mini Reid Conservation land.

The geometry of the intersection was designed to accommodate WB-67 tractor trailers without encroaching into adjacent lanes. Under existing conditions, it is impossible for WB-67 tractor trailers to make left turns from the North Road southbound approach while staying within the marked lanes. Through the realignment and widening of the intersection under Alternative 1, this movement is possible without encroachment. Other difficult movements under existing conditions included the left turn movements from Chelmsford Road to North Road and right turn movements from North Road onto Chelmsford Road. These movements require school busses and larger vehicles to encroach into adjacent lanes. Under Alternative 1, these movements were designed to be possible for busses and SU-40 trucks to make without encroachment. WB-67 tractor trailers are still unable to make these movements without full intersection encroachment.

In order to implement the proposed improvements, significant impacts to abutting land are required. These impacts include significant right-of-way takings from the property of Renzo’s Salon, which would require a minor realignment of the southeast corner of the parking lot. Several utility pole relocations would be required on Chelmsford Road due to widening for bicycle lanes and on North Road due to the addition of a proposed sidewalk. The intersection realignment would also require several mature trees to be removed, however, it would also provide an area for potential green space and landscaping at the southeastern corner to help compensate for the loss of trees.

Traffic Analysis

An intersection capacity analysis was done for Alternative 1 for two conditions. The first condition, the intersection remains unsignalized, the second condition signalizes the intersection. Table 2.08 summarizes the results of each analysis.

Unsignalized

The unsignalized approach will operate at a slightly worse LOS F for the North Road southbound approach than the 2026 no-build condition due to the elimination of the existing slip lane being removed for right turning movements for northbound traffic. There is no change for through movements northbound and southbound, which continue to move without delays.

Signalized

Under a signalized condition, the intersection operations under a two-phase condition. The Route 4 northbound and southbound movements are one phase and the North Road WB movement is the other. Performing the analysis with this phasing results in the following:

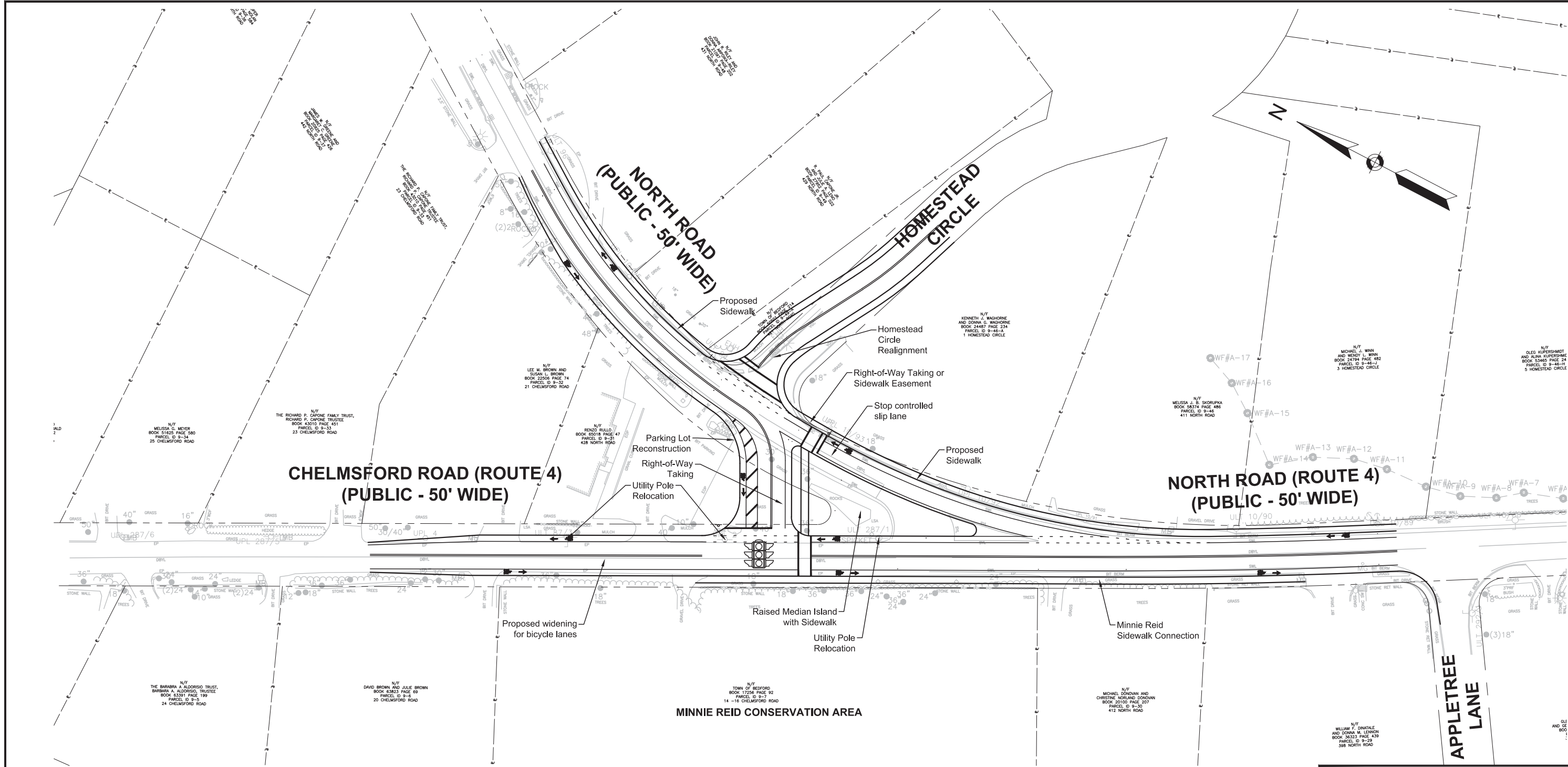
- In the AM peak the intersection operates at a LOS D. The southbound and westbound approaches both operate at a LOS D with 52 and 55 second delays, respectively.
- In the AM peak the 95th percentile queue in the southbound direction is projected to be 1,005 feet.
- In the PM peak, the intersection operates at a LOS E. The northbound and westbound approaches operate at a LOS F and LOS E with 86 and 71 second delays, respectively.
- In the PM peak, the 95th percentile queue in the northbound direction is project to be 1,392 feet (1/4 mile +/-).

Table 2.08 – Summary of Alternative 1 Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2026 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road WB/SB	>120	F	2.19	-	585	>120	F	1.14	-	282.5
Chelmsford Road SB	0.8	A	-	-	-	0.7	A	-	-	-
2026 Alternative 1 Unsignalized										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road WB/SB	>120	F	2.78	-	657.5	>120	F	1.55	-	395
Chelmsford Road SB	0.9	A	-	-	-	0.8	A	-	-	-
2026 Alternative 1 Signalized										
North Road NB	1.6	A	0.25	8	32	86.3	F	1.13	1134	1392
North Road WB	54.5	D	0.82	149	263	71.1	E	0.87	143	269
Chelmsford Road SB	52.0	D	1.03	760	1005	4.1	A	0.16	21	38
<i>Intersection LOS</i>	<i>43.8</i>	<i>D</i>	-	-	-	<i>78.4</i>	<i>E</i>	-	-	-
<i>Abbreviations:</i>										
EB = Eastbound	L = Left	LT = Left and Through	Delay = Average delay per vehicle (measured in seconds)							
WB = Westbound	T = Through	LR = Left and Right	LOS = Level of Service							
NB = Northbound	R = Right	TR = Through and Right	v/c = Volume-to-Capacity ratio							
SB = Southbound		LTR = Left, Through, and Right								

Conclusion


The improvements proposed for Alternative 1 improve safety at the intersection through improved sight lines and an improved intersection angle for the North Road approach. These improvements can be furthered through signalizing the intersection to better allow movements exiting North Road. However, the single lane configuration proposed for the Route 4 approaches do not fully capture the benefits that a signal could provide. Signalizing the intersection creates significant delays for the southbound approach during the morning peak period and the northbound approach during the afternoon peak period. Because of the significant increase in delay and queuing along Route 4, Alternative 1 is proposed to remain unsignalized thus improving safety through geometric improvements and maintaining similar traffic operations as the no build conditions. An order of magnitude estimate was prepared to determine that Alternative 1 would cost approximately \$600,000 to construct. This cost does not include the cost for utility pole relocations, right-of-way acquisitions, or temporary construction easements.



PROJECT NORTH ROAD INTERSECTION IMPROVEMENTS

DESIGN SUBMISSION:
CONCEPTUAL DESIGN

DRAWING TITLE:
NORTH ROAD INT ALTERNATIVE 2

PREPARED FOR:

TOWN OF BEDFORD
 BEDFORD DPW
 10 MUDGE WAY
 BEDFORD, MASSACHUSETTS

PREPARED BY:

GREEN INTERNATIONAL AFFILIATES, INC.
 Civil and Structural Engineers
 Westford, Massachusetts (978) 923-0400
 GreenIntl.com

SCALE: AS NOTED
 DATE: 12/16/2016
 PROJECT NO. 16065
 DESIGNED BY: MPD
 DRAWN BY: MPD
 CHECKED BY: WW

FIGURE 5

NO.	DATE	REVISIONS

W:\Landscape\Projects\16065\16065.dwg - Green International - Concept Design - 12/20/2016 9:28 AM

2.2.3 Alternative 2

Geometric Considerations

Alternative 2 realigns the North Road approach to the intersection with Route 4 while maintaining the existing right-turn slip lane from Route 4 onto North Road. The North Road southbound approach is shifted to intersect Route 4 perpendicularly, which aims to provide better sightlines and a more defined and intuitive intersection layout. This alternative proposes 11-foot travel lanes and 5-foot shoulders/bicycle lanes on both North Road and Route 4. A sidewalk is proposed along the east side of North Road to provide a connection to the Minuteman Rail Trail both to the south and to the north. A curbed median island is proposed between the right-turning slip lane and the North Road northbound approach from Chelmsford Road, to separate these two movements. This separation will help vehicles exiting North Road better identify which vehicles approaching from the south are continuing onto Chelmsford Road and which vehicles are turning right onto North Road. The slip lane is stop controlled in order to lower speeds through this movement. The median island also provides a potential area for future landscaping and green space. Full depth pavement construction is proposed for the project due to the extensive realignment and widening.

The geometry of the intersection was designed to accommodate the same vehicles as Alternative 1. With the addition of the slip lane, the intersection point was able to be narrowed while still maintaining these vehicle accommodations.

In order to implement the proposed improvements, significant impacts to abutting land are required. These impacts include significant right-of-way takings from the property of Renzo's Salon, which would require a minor realignment of the southeast corner of the parking lot. Several utility pole relocations would be required on Chelmsford Road due to widening for bicycle lanes and on North Road due to the addition of a proposed sidewalk. The intersection realignment would also require several mature trees to be removed from the northeast corner of the existing intersection.

Traffic Analysis

An intersection capacity analysis was done for Alternative 2 for two conditions. The first condition, the intersection remains unsignalized, the second condition signalizes the intersection. Table 2.09 summarizes the results of each analysis.

Unsignalized

The unsignalized approach, will operate the same as a no build condition. The Route 4 northbound and southbound approaches still operate freely with the North Road southbound approach operating under a stop control. Both the existing condition and the proposed condition maintain a slip lane and although the proposed slip lane is stop controlled, no additional delays are expected from this.

Signalized

Under a signalized condition, the intersection operations under a two-phase condition. The Route 4 northbound and southbound movements are one phase and the North Road WB movement is the other. Performing the analysis with this phasing results in the following:

- In the AM peak the intersection operates at a LOS C. The westbound approach operates at a LOS D with a 51 second delay.
- In the AM peak the 95th percentile queue in the southbound direction projected to be 932 feet.

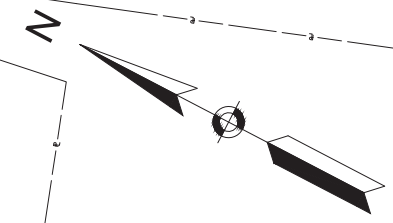
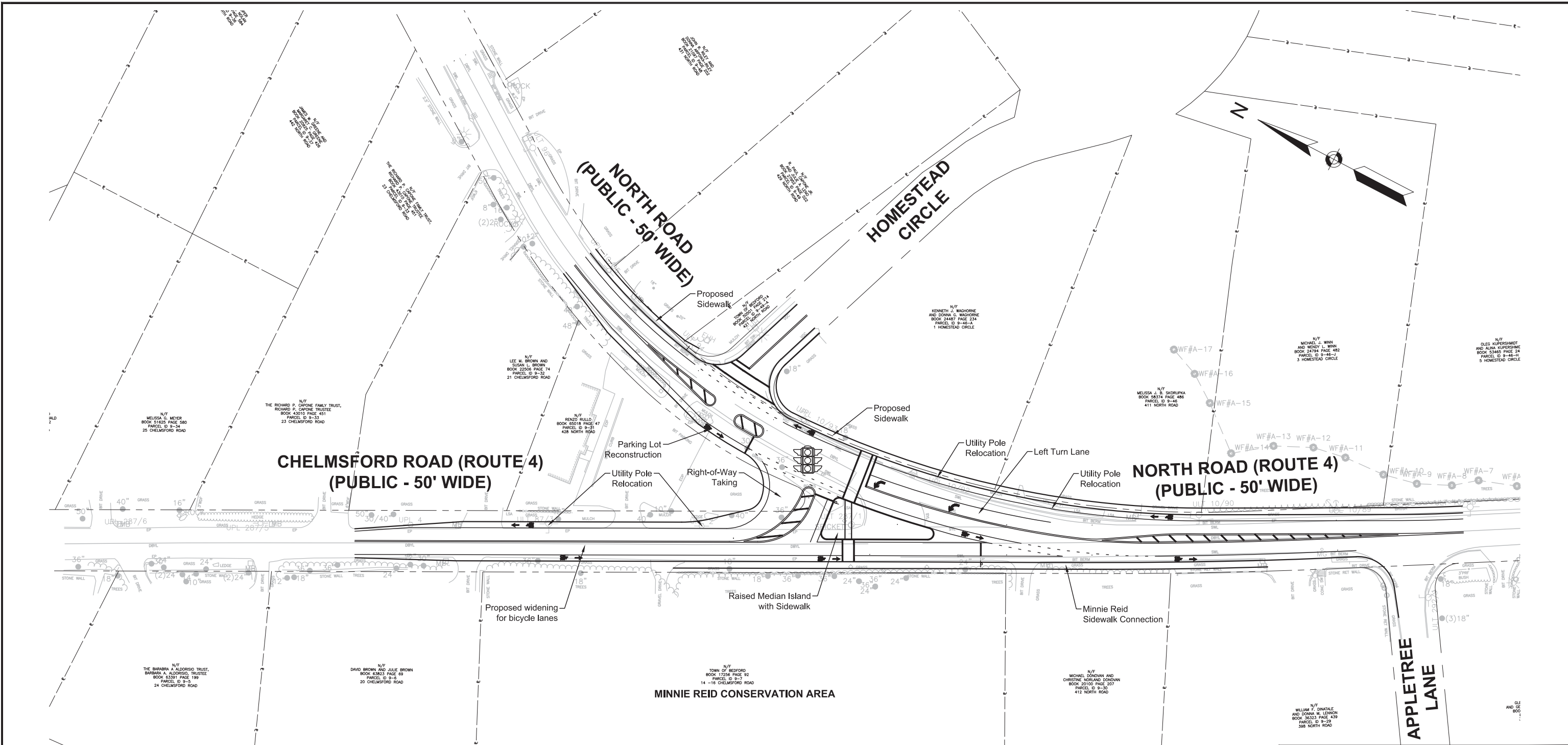
- In the PM peak, the intersection operates at a LOS B. The westbound approach operates at a LOS D with a 50 second delay.
- All approaches during the PM peak with the exception of the North Road WB, operate at LOS B or better with a maximum delay of 17 seconds for the North Road NB through movement.
- When Alternative 2 is signalized, traffic operations improve significantly compared to Alternative 1.



Table 2.09 – Summary of Alternative 2 Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2026 No Build/2026 Alternative 2 Unsignalized										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road WB/SB	>120	F	2.19	-	585	>120	F	1.14	-	282.5
Chelmsford Road SB	0.8	A	-	-	-	0.7	A	-	-	-
2026 Alternative 2 Signalized										
North Road NB	12.4	B	-	-	-	12.6	B	-	-	-
North Road NB T	31.4	C	0.15	22	52	17.1	B	0.84	382	626
North Road NB R	8.9	A	0.54	0	62	1.3	A	0.35	0	23
North Road WB/SB	51.3	D	0.80	149	263	49.7	D	0.74	122	245
Chelmsford Road SB	29.6	C	0.95	536	932	4.3	A	0.11	21	39
<i>Intersection LOS</i>	<i>30.1</i>	<i>C</i>	<i>-</i>	<i>-</i>	<i>-</i>	<i>16.6</i>	<i>B</i>	<i>-</i>	<i>-</i>	<i>-</i>
<i>Abbreviations:</i>										
EB = Eastbound L = Left LT = Left and Through Delay = Average delay per vehicle (measured in seconds) WB = Westbound T = Through LR = Left and Right LOS = Level of Service NB = Northbound R = Right TR = Through and Right v/c = Volume-to-Capacity ratio SB = Southbound LTR = Left, Through, and Right										

Conclusions

The improvements proposed for Alternative 2 improve safety at the intersection through improved sight lines and an improved intersection angle for the North Road approach. These improvements can be furthered through signalizing the intersection to better allow movements exiting North Road. The proposed extension of the northbound slip lane provides a right turning pocket that improves operations significantly during both peak periods. The increase in overall performance of the intersection with minor delays on all approaches warrants the signalization of the intersection. The drawbacks of this alternative include the resulting long queues along North Road and Chelmsford Road, and more frequent rear-end crashes that are typically associated with a signal. It is also worth noting that the slip lane is stop-controlled and while it provides the greatest safety benefits, vehicles will be required to stop even if there are no conflicting vehicles coming from Chelmsford Road. An order of magnitude estimate was prepared to determine that Alternative 2 would cost approximately \$850,000 to construct. This cost does not include the cost for utility pole relocations, right-of-way acquisitions, or temporary construction easements.



PROJECT NORTH ROAD INTERSECTION IMPROVEMENTS		
DESIGN SUBMISSION: CONCEPTUAL DESIGN		
DRAWING TITLE: NORTH ROAD INT ALTERNATIVE 3		
PREPARED FOR:  TOWN OF BEDFORD BEDFORD DPW 10 MUDGE WAY BEDFORD, MASSACHUSETTS		
PREPARED BY:  GREEN INTERNATIONAL AFFILIATES, INC. Civil and Structural Engineers Westford, Massachusetts (978) 923-0400 GreenIntl.com		
SCALE: AS NOTED	DESIGNED BY: MPD	FIGURE 6
DATE: 12/16/2016	DRAWN BY: MPD	
PROJECT NO. 16065	CHECKED BY: WW	

NO.	DATE	REVISIONS

M:\User\pauld\Projects\16065\16065.dwg; Current: Design; User: pauld; Date: 12/20/2016 9:48 AM

2.2.4 Alternative 3

Geometric Considerations

Alternative 3 realigns the intersection to make North Road the primary through way and Chelmsford Road the third leg of the intersection. Chelmsford Road is realigned to approach North Road perpendicularly while providing a signalized slip lane coordinated with the main intersection for traffic continuing southbound. The slip lane is separated from North Road by a curbed median island which could be used for future landscaping and green space. North Road is proposed to be widened to include a left turn lane on the northbound approach. Alternative 3 proposes 11-foot lanes and 5-foot shoulders/bicycle lanes on both North Road and Chelmsford Road. A sidewalk is proposed along the east side of North Road to provide connections to the Minuteman Rail Trail to the north and to the south.

The geometry of the intersection was designed to accommodate the same vehicles as Alternative 1. Although, the intersection has been realigned, each movement is designed to the same design vehicle as Alternative 1.

In order to implement the proposed improvements, impacts to abutting land are required. These impacts include right-of-way takings from the property of Renzo's Salon due to the realignment and along the east side of North Road due to proposed widening and the addition of a sidewalk. Several utility pole relocations would be required on Chelmsford Road due to widening for bicycle lanes and on North Road due to the addition of a proposed sidewalk. The intersection realignment would also require several mature trees to be removed from the northeast corner of the existing intersection.

Traffic Analysis

Based on preliminary evaluations, an unsignalized condition for this alternative would cause significant traffic performance deficiencies and safety concerns. As a result, an intersection capacity analysis was done for only for a signalized condition. Table 2.10 summarizes the results of each analysis.

Under a signalized condition, the intersection operations under a two-phase condition in both the morning and afternoon peak periods. The North Road northbound and southbound movements are one phase and the Chelmsford movement is the other. In the afternoon peak period, the left turning movement on the North Road northbound approach is given an advanced phase to better traffic operations. Performing the analysis with this phasing results in the following:

- In the AM Peak the intersection operates at an LOS E with an intersection delay of 60 seconds.
- The worst approach in the AM Peak, North Road WB, operates at a LOS E, with a 95th percentile queue of 310 feet.
- The Chelmsford Road southbound approach in the morning experiences excessive queues of 1,010 feet for the 95th percentile.
- In the PM Peak the northbound approach would operate as a protected/permitted left turn lane.
- In the PM Peak, the intersection operates at an LOS D with an intersection delay of 41.2 seconds.
- The worst approach in the PM Peak in terms of LOS is the North Road WB, which operates at an LOS E, with a 95th percentile queue of 272 feet.
- The North Road northbound left experiences long queues in the afternoon peak period of 953 feet for the 95th percentile.

Table 2.10 – Summary of Alternative 3 Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2026 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road WB/SB	>120	F	2.19	-	585	>120	F	1.14	-	282.5
Chelmsford Road SB	0.8	A	-	-	-	0.7	A	-	-	-
2026 Alternative 3 Signalized										
North Road NB	30.0	E	-	-	-	37.5	D	-	-	-
North Road NB L	70.6	E	0.60	28	85	50.7	D	1.02	598	953
North Road NB T	58.0	E	0.79	156	274	4.3	A	0.31	63	118
North Road WB/SB	66.5	E	0.87	172	310	59.3	E	0.79	135	272
Chelmsford Road SB	57.9	E	-	-	-	51.1	D	-	-	-
Chelmsford Road SB L	4.3	A	0.10	21	37	35.2	D	0.04	5	19
Chelmsford Road SB R	64.4	E	1.07	766	1010	52.3	D	0.62	74	132
<i>Intersection LOS</i>	<i>59.6</i>	<i>E</i>	<i>-</i>	<i>-</i>	<i>-</i>	<i>41.2</i>	<i>D</i>	<i>-</i>	<i>-</i>	<i>-</i>
<i>Abbreviations:</i>										
EB = Eastbound L = Left LT = Left and Through Delay = Average delay per vehicle WB = Westbound T = Through LR = Left and Right (measured in seconds) NB = Northbound R = Right TR = Through and Right LOS = Level of Service SB = Southbound LTR = Left, Through, and Right v/c = Volume-to-Capacity ratio										

Conclusion

The improvements proposed for Alternative 3 creates a more intuitive intersection which promotes safety. The intersection itself shifts the main through way from Route 4 to North Road eliminating the excessive skew of the intersection. This intersection configuration will potentially lessen cut-through traffic due to the shift of the through way. Due to the intersection realignment, the intersection must be signalized which creates significant queues in the morning peak period for the southbound approach. It also creates large queues in the afternoon peak period for the northbound left. Due to the large amount of left-turning vehicles, there is a potential that through vehicles will be blocked by the left-turn queues and experience longer delays than what the analysis predicted. An order of magnitude estimate was prepared to determine that Alternative 3 would cost approximately \$850,000 to construct. This cost does not include the cost for utility pole relocations, right-of-way acquisitions, or temporary construction easements.

2.3 Environmental Consideration

There is a wetland area on the east side of North Road (Route 4). In each alternative, work will likely occur within the 100-foot buffer zone, requiring a Notice of Intent submission to the Bedford Conservation Commission. There are no Priority or Estimated Habitat Areas in the vicinity of the project site, as defined by the Natural Heritage and Endangered Species Program (NHESP). The nearest Certified Vernal Pool is approximately 775 feet away from the project area. The intersection is not within a FEMA Flood Zone. As

part of the NOI submission, stormwater mitigation will be required. It is anticipated that the intersection will qualify as Redevelopment under the Massachusetts Stormwater Standards.

Per Article 55 of the Town of Bedford’s General Bylaws, any activity that disturbs one acre or greater of land in the Town requires a Stormwater Permit. Currently, all alternatives for the intersection of North Road and Chelmsford Road have limits of work that exceed one acre and will require a Stormwater Permit. An exemption may be sought under Section 6.B.8 of Article 55, which allows for the maintenance and improvement of existing public roadways when conducted in accordance with an approved Stormwater Pollution Prevention Plan. If an exemption is granted, the Town of Bedford encourages consistency with the Performance Standards set forth in Section 6.E of Article 55 as well as the Massachusetts Stormwater Management Standards.

For any alternatives that exceed one acre of land disturbance, compliance with the NPDES Construction General Permit will be required and preparation of a Stormwater Pollution Prevention Plan (SWPPP). Currently all three alternatives will require compliance with the NPDES CGP.

The North Road Area Local Historic District (LHD) and Upper North Road Area LHD are in the vicinity of the proposed intersection improvements. The North Road Area LHD has its northern limit approximately at the intersection of North Road and Appletree Lane, south of the proposed project area. The Upper North Road Area LHD begins at 431 North Road, approximately 150 feet northeast of the proposed work. None of the proposed alternatives will impact a property noted as historic within the Local Historic Districts.

If any alternative results in permanent impacts to the Minnie Reid Conservation Area, (conversion of that land held for natural resource purposes to any other purpose), Article 97 will be triggered which will result in a lengthy permitting process and will require state legislative approval. It is highly recommended that the improvements avoid permanent impacts to the conservation area.

As proposed, all three alternatives will include the widening of North Road by four feet or more for one-half mile or more, which exceeds a MEPA threshold for an ENF. If the project utilizes state funding, or if a state permit is required then an ENF will be required to be submitted to MEPA.

2.4 Other Considerations

In addition to the three alternatives, a roundabout alternative was also evaluated. The roundabout, although a great aid in traffic calming was deemed infeasible due to several reasons. The most prominent reason being impacts to the Minnie Reid Conservation Area. The roundabout would encroach in the conservation area in a way that would require takings. Takings of this land are not advised due to the extensive permitting process that would result.

In addition to vehicular accommodations, additional pedestrian accommodations have been requested by the Town along the west side of Route 4 to connect the Minnie Reid Conservation Area to the adjacent neighborhood south at Appletree Lane. This will provide a connection to the sidewalk network through the intersection and provide a safe connection across Route 4 while also providing access to the Minnie Reid Conservation Area. The existing grades in the area where this sidewalk is proposed are relatively steep in some sections and may require temporary impacts to the Minnie Reid conservation area.

2.5 Preferred Alternative

In comparing the three alternatives for North Road at Chelmsford Road intersection, safety and traffic operations are the two controlling criteria from an engineering perspective. With these two criteria in mind, the Alternative 2 signalized condition is the preferred option. The realignment of the “T” intersection between North Road and Route 4 improves sight lines and safety for the intersection. The extension of the northbound slip lane creates a right turn pocket and significantly improves operations during the afternoon period. This slip lane is also proposed to be stop controlled which will reduce the speed of vehicles making this movement. In addition to the safety and traffic operations improvements, the intersection provides the best pedestrian accommodations by minimizing crossing distances and providing visible crossings. Signalizing the intersection would also help provide gaps for entering vehicles at adjacent intersections and driveways.

3.0 NORTH ROAD AT PINE HILL ROAD INTERSECTION

3.1 Existing Conditions

3.1.1 Overview

North Road at Pine Hill Road is an unsignalized three-legged intersection. North Road is the northern and southern legs of the intersection while Pine Hill Road is the eastern leg. North Road functions as an important connection to Bedford Center to the south and Route 3 to the north. Pine Hill Road provides access to residential neighborhoods to the east of North Road. The land use in the area of the intersection is mainly comprised of residential homes and undeveloped wooded land. There are no environmentally sensitive areas directly within the project area. Pine Hill Road is designated as one of the Town's Scenic Roads in accordance with Article 45 of the Town of Bedford's General Bylaws. Article 45 requires a hearing (with the Planning Board and/or tree warden) for any stone wall or tree removal along a designated scenic road. Both roadways are non-NHS roadways under the Town of Bedford jurisdiction. North Road is an urban minor arterial roadway, while Pine Hill Road is an urban collector.

3.1.2 Geometric Considerations

North Road is a two-way, two-lane roadway approximately 30 feet in width. The roadway consists of two approximately 12-foot lanes and 2 to 4-foot shoulders with no curbing along either side. There are no existing defined bicycle accommodations along the roadway, but there is a newly constructed sidewalk south of the intersection along the east side. The right-of-way in this area along North Road is approximately 50 feet.

Pine Hill Road is a two-way, two-lane roadway approximately 22 feet wide. The roadway consists of two approximately 11-foot lanes with no striping for shoulders and no curbing. There are no pedestrian or bicycle accommodations along the roadway. The right-of-way in this area along Pine Hill Road is approximately 50 feet.



At the intersection, Pine Hill Road intersects North Road at an approximately 45 degrees to form a wye intersection layout; this approach is controlled by a stop sign. The Pine Hill Road approach widens at the intersection to provide separate dedicated left and right turn lanes. However, the turn lane pocket appears to accommodate no more than a one vehicle queue length. A residential driveway is located nearly directly across from Pine Hill Road. Utility poles line the entire east side of North Road and the north side of Pine Hill Road.

3.1.3 Traffic Count Program

As part of the development of the conceptual design alternatives, traffic volume data were collected and used to form the basis of the traffic analysis. The data were collected from Wednesday and Thursday September 28-29, 2016 and consisted of weekday peak period (7:00-9:00 A.M. and 4:00-6:00 P.M.) manual turning movement counts (TMC) at the intersection of North Road at Chelmsford Road. The traffic count program also included a 7-day Automatic Traffic Recorder (ATR) vehicle count from Wednesday, September 28th, 2016 to Tuesday, October 4th, 2016 at the following locations:

- North Road (Route 4) north of Minuteman Drive
- North Road (Route 4) south of Pine Hill Road
- Pine Hill Road east of North Road

Tables 3.01 through 3.03 summarize the ATR data that were collected as part of this study. Figure 7 summarizes the existing peak hour TMC data. The complete ATR and TMC data are included in the attached Appendix A.

Table 3.01 - Summary of Observed ATR Traffic Data: North Road (Route 4), North of Minuteman Drive

	NORTH ROAD (ROUTE 4), NORTH OF MINUTEMAN DRIVE		
	WEEKDAY AVERAGE	AM PEAK HOUR	PM PEAK HOUR
Time Period	Daily	6:45-7:45	5:00 – 6:00
Traffic Volume ¹	14,357 vpd	1,374 vph	1,507 vph
K-Factor ²	-	9.6%	10.5%
Directional Distribution	53% NB / 47% SB	15% NB / 85% SB	82% NB / 18% SB
Heavy Vehicle Percentage	3.2% NB / 4.6% SB	0.8% NB / 3.3% SB	1.1% NB / 0.8% SB
Average Speed	39 mph NB / 36 mph SB		
85 th Percentile Speed	42 mph NB / 43 mph SB		
¹ vpd = vehicles per day, vph = vehicles per hour			
² percent of daily traffic that occurs during the peak hour			

Note: Data have been averaged over five weekdays and rounded. September to October (ATR) data.

Table 3.02 - Summary of Observed ATR Traffic Data: North Road (Route 4), South of Pine Hill Road

	NORTH ROAD (ROUTE 4), SOUTH OF PINE HILL ROAD		
	WEEKDAY AVERAGE	AM PEAK HOUR	PM PEAK HOUR
Time Period	Daily	8:30 – 9:30	5:00 – 6:00
Traffic Volume ¹	8,726 vpd	756 vph	794 vph
K-Factor ²	-	8.6%	9.1%
Directional Distribution	53% NB / 47% SB	39% NB / 61% SB	72% NB / 28% SB
Heavy Vehicle Percentage	3.4% NB / 3.8% SB	2.9% NB / 4.4% SB	2.2% NB / 1.2% SB
Average Speed	37 mph NB / 37 mph SB		
85 th Percentile Speed	41 mph NB / 41 mph SB		
¹ vpd = vehicles per day, vph = vehicles per hour			
² percent of daily traffic that occurs during the peak hour			

Note: Data have been averaged over five weekdays and rounded. September to October (ATR) data.

Table 3.03 - Summary of Observed ATR Traffic Data: Pine Hill Road, East of North Road (Route 4)

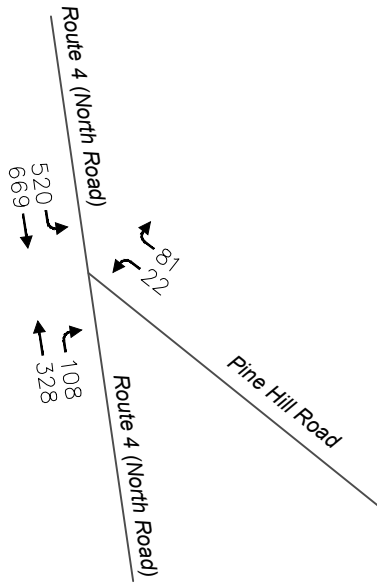
	PINE HILL ROAD, EAST OF NORTH ROAD (ROUTE 4)		
	WEEKDAY AVERAGE	AM PEAK HOUR	PM PEAK HOUR
Time Period	Daily	7:00 – 8:00	4:30 – 5:30
Traffic Volume ¹	5,069 vpd	654 vph	633 vph
K-Factor ²	-	12.9%	12.5%
Directional Distribution	47% EB / 53% WB	88% EB / 12% WB	10% EB / 90% WB
Heavy Vehicle Percentage	5.1% EB / 2.6% WB	3.5% EB / 0.6% WB	0.8% EB / 0.9% WB
Average Speed	33 mph EB / 32 mph WB		
85 th Percentile Speed	37 mph EB / 37 mph WB		
¹ vpd = vehicles per day, vph = vehicles per hour ² percent of daily traffic that occurs during the peak hour			

Note: Data have been averaged over five weekdays and rounded. September to October (ATR) data.

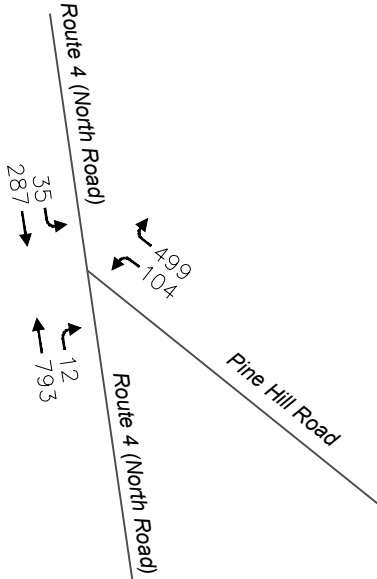
As shown in the above tables, it appears that the directional distributions indicate that Pine Hill Road is being used mainly by commuter traffic during the peak periods. Pine Hill Road, along with Route 4, may be used as an auxiliary route to Route 3 in order to avoid commuter traffic on Route 3. The Rogers VA Medical Center may also be a heavy traffic generator in this area.

3.1.4 Future Traffic Volume Projections

Similar to North Road at Chelmsford Road, a year 2026 traffic volume network was developed by identifying potential area-wide background traffic volume growth and known specific nearby development projects that could contribute to traffic flow on the 2026 study network. An annual growth rate of one percent (1%) per year for ten years was used to forecast future roadway volumes. Figure 8 summarizes the future traffic volume peak hour TMC data.

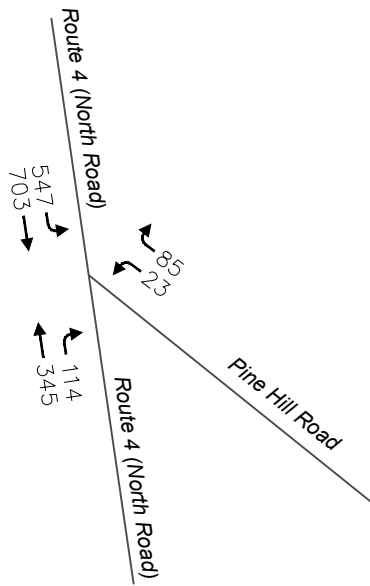


AM PEAK HOUR

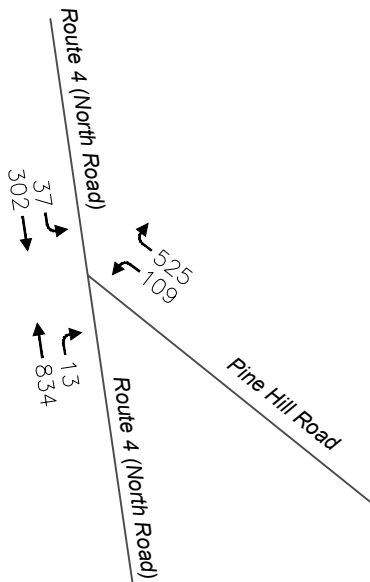


PM PEAK HOUR





AM PEAK HOUR



PM PEAK HOUR



Figure 8
2026 Future Traffic Volumes
Route 4 and Pine Hill Road Intersection
Bedford, MA

3.1.5 Safety Analysis

Crash data were obtained from the Town of Bedford and MassDOT for the years 2013 – 2015. The records indicate that there were nine (9) crashes reported at the intersection of North Road at Pine Hill Road during the three-year time frame. Six (6) of the nine (9) crashes at the intersection involved property damage only. There were no fatalities, although there were three (3) crashes where injuries were reported. There were four (4) crashes in three (3) years that involved rear end collisions and three (3) crashes that involved angle collisions during a turning movement.

Table 3.04 provides a summary of the intersection crash data and Figure 9 shows the types of crashes in a diagram.

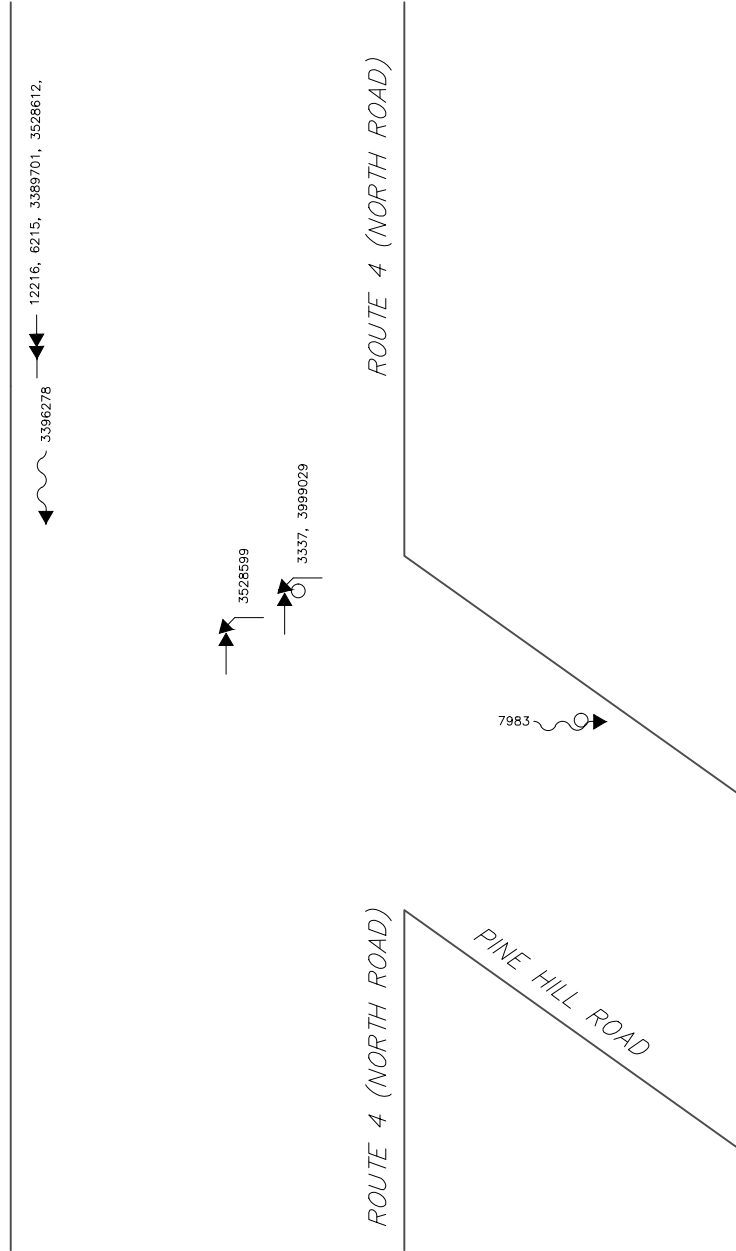
The MassDOT intersection Crash Rate Worksheet was used to calculate the crash rate at the study intersection. It was determined that the intersection had a crash rate of 0.51 crashes per million entering vehicles (MEV), slightly below the 0.56 crashes per MEV for MassDOT District 3 unsignalized intersections.

The Pine Hill Road approach creates a conflict point at the intersection of North Road (Route 4). Due to the skew of the intersection and the vast amount of vegetation at the southern corner, driver sightlines tend to be obstructed when exiting Pine Hill Road. Recently, the vegetation has been cut back improving sight lines. The heavy volume of North Road (Route 4) traffic further exacerbates this sight line issue by minimizing the number of available gaps for vehicles exiting Pine Hill Road. These issues create difficulties for drivers at the study intersection.

The standard MassDOT Crash Rate Work Sheets are included in Appendix B

Table 3.04 – Summary of Intersection Crash Data

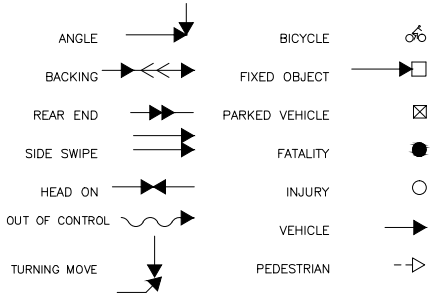
	<i>North Road at Pine Hill Road</i>		
	2013	2014	2015
Severity			
Property Damage	5	1	
Injury	1	2	
Fatality			
Unknown			
Collision Type			
Rear End	3	1	
Angle	1	2	
Side Swipe			
Head On			
Single Vehicle	2		
Collision with Ped			
Collision with Bike			
Other/Unknown			
Time of Day			
6:01 AM – 10:00 AM	4	2	
10:01 AM – 4:00 PM	1		
4:01 PM – 7:00 PM	1	1	
7:01 PM – 6:00 AM			
Roadway Conditions			
Dry	4	3	
Wet	1		
Snow/Ice	1		
Other/Unknown			
Season			
Dec-Feb	1	1	
Mar-May	2	1	
June-Aug	2	1	
Sept-Nov	1		
Light Conditions			
Daylight	6	3	
Dawn/Dusk			
Dark (Unlit)			
Dark (Lit)			
Unknown			
Totals			
	6	3	
Annual Average Crashes	3.00		
Intersection Crash Rate (MEV)			
	0.51		
MassDOT District 3 Average Crash Rate (MEV)	0.56		



2013-2015

	DATE	TIME	W	PD	I	F	L	R	V
3389701	1/24/2013	9:40 AM	TH	YES			1	1	
3396278	3/8/2013	7:29 AM	F	YES			1	3	
3528599	5/29/2013	5:28 PM	W	YES			1	1	
3528612	7/10/2013	8:41 AM	W	YES			1	2	
7983	8/19/2013	10:28 AM	M	YES	1		1	1	
12216	11/26/2013	8:19 AM	TU	YES			1	1	14
3337	3/28/2014	9:02 AM	F	YES	1		1	1	2
6215	6/3/2014	7:13 AM	TU	YES			1	1	14
3999029	12/4/2014	4:02 PM	TH	YES	2		1	1	

SYMBOLS



LIGHT CONDITIONS (L)

1. DAYLIGHT
2. DAWN
3. DUSK, UNLIT ROADWAY
4. DUSK, LIT ROADWAY
5. DARKNESS, UNLIT ROADWAY
6. DARKNESS, LIT ROADWAY
99. UNKNOWN

ROAD CONDITIONS (R)

1. DRY
2. WET
3. SNOW OR ICY
4. SLUSH
5. OTHER/ UNKNOWN

WEEDKAY (W)

M = MONDAY F = FRIDAY
 TU = TUESDAY SA = SATURDAY
 W = WEDNESDAY SU = SUNDAY
 TH = THURSDAY

VIOLATIONS CITED (V)

1. SPEED TOO FAST
 2. FAILURE TO YIELD
 3. RAN STOP SIGN
 4. RAN TRAFFIC SIGNAL
 5. FOLLOWING TOO CLOSE
 6. IMPROPER PASSING
 7. WRONG SIDE OF ROAD
 8. IMPROPER TURNING
 9. IMPROPER BACKING
 10. HAD BEEN DRINKING
 11. PEDESTRIAN VIOLATION
 12. RECKLESS DRIVING
 13. IMPROPER LIGHT OR BRAKES
 14. CARE IN STARTING/STOPPING
- I = INJURY
 F = FATALITY

FIGURE 9

CONCEPTUAL DESIGN REPORT
 BEDFORD NORTH ROAD
 INTERSECTION OF CHELMSFORD ROAD AND
 NORTH ROAD
 BEDFORD, MA



GREEN INTERNATIONAL AFFILIATES, INC.
 CIVIL & STRUCTURAL ENGINEERS WESTFORD, MASSACHUSETTS

3.1.6 Signal Warrant Analysis

As part of this study, Green completed a traffic signal warrant analysis at the study intersection in compliance with the Manual on Uniform Traffic Control Devices (MUTCD) 2009 Edition using existing traffic volumes. The study intersection meets the requirements for MUTCD Warrant 2 (Four-Hour Vehicular Volume) and Warrant 3 (Peak Hour). The study intersection does not meet the requirements for MUTCD Warrant 1 (Eight-Hour Vehicular Volume) under either Condition A or Condition B. Therefore, traffic signal control is not warranted at the study intersection using these three primary traffic signal warrants. Traditionally, MassDOT does not approve the installation of a signal if MUTCD Warrant 1 (Eight-Hour Vehicular Volume) is not met. The Town will need to consider future funding sources for this project as the signal option may be eliminated if the Town will be seeking MassDOT funding. The signal warrant analysis worksheets are included in Appendix E.

3.2 Design Alternatives

Three (3) design alternatives are presented for the intersection of North Road and Pine Hill Road and an analysis of Pine Hill Road sidewalk extension is presented. All three options require alterations to the existing geometry of the intersection. Conceptual designs for each alternative are shown in Figures 10 to 12.

3.2.1 Pine Hill Road

Sidewalk Design

The Town has requested that that sidewalk on the east side of North Road be continued onto Pine Hill Road to the intersection with Heritage Drive. This sidewalk continuation would be installed on the south side of Pine Hill Road in order to provide the best connection between North Road and Heritage Drive. The location on the south side of the road would allow for the existing roadway width to be maintained. The sidewalk, proposed with a grass buffer, would require impacts to the existing tree screening along the south side of the roadway and most likely require replacement of landscaping that requires removal.

Truck Exclusion

In each of the following alternatives, Green is recommending that a truck exclusion request be submitted to MassDOT for Pine Hill Road as the roadway is a town designated scenic route and fairly narrow. Truck exclusions can be requested from MassDOT Highway Division if warrants are met and a proper study has been done, according to *The Massachusetts Amendments to the Manual on Uniform Traffic Control*. One or more of the following warrants must be met in order to apply for a truck exclusion:

1. A volume of heavy commercial vehicles, which usually is in the range of five (5) to eight (8) percent, reduces the utilization of the facility and is cause for a substantial reduction in capacity or safety.
2. The condition of the pavement structure of the route to be excluded indicates that further repeated heavy wheel loads will result in severe deterioration of the roadway. (subject to Department review)
3. Notwithstanding the foregoing, in certain instances where land use is primarily residential in nature and a municipality has requested exclusion only during hours of darkness, a specific night exclusion may be granted.

Pine Hill Road, with proper documentation, should meet warrant 3. The roadway is narrow in width, it is a scenic route, and the land use is primarily residential. Green can assist in requesting this exclusion if desired

in the future. Although the Rogers VA Medical Center is a generator for trucks, we believe that there are other viable routes for trucks to access the medical facility.

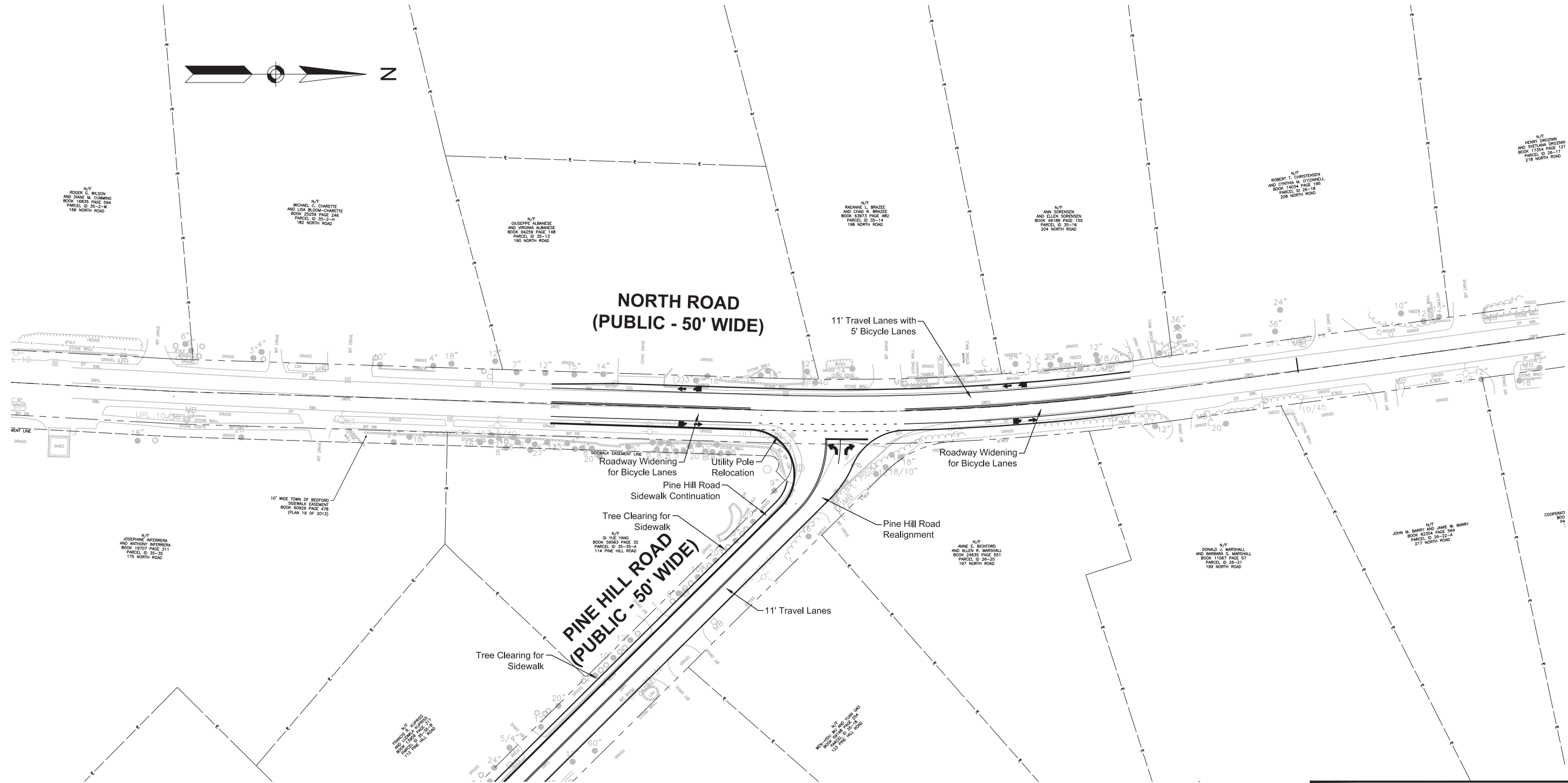
3.2.2 No Build Traffic Analysis

To assess existing conditions quality of traffic flow, Green conducted intersection capacity analyses for the study intersection for the condition where no improvements are done. Table 3.05 summarizes the results of the study for the no build condition. The intersection capacity analysis indicated the following:

- The Pine Hill Road WB approach operates at a LOS F during all peak periods. The LOS F is worsened during 2026 projected future volumes. From this LOS F and the TMC, it can be deduced that the high level of traffic on North Road (Route 4) makes exiting Pine Hill Road extremely difficult.
- The North Road (Route 4) traffic in both the northbound and southbound directions operate freely without delay.

Table 3.05 – Summary of No Build Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2016 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road SB	5.2	A	-	-	-	1.1	A	-	-	-
Pine Hill Road WB	>120	F	3.99	-	107.5	>120	F	1.54	-	762.5
2026 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road SB	5.5	A	-	-	-	1.1	A	-	-	-
Pine Hill Road WB	>120	F	25	-	122.5	>120	F	1.72	-	897.5
<u>Abbreviations:</u>										
EB = Eastbound	L = Left	LT = Left and Through	Delay = Average delay per vehicle (measured in seconds)							
WB = Westbound	T = Through	LR = Left and Right	LOS = Level of Service							
NB = Northbound	R = Right	TR = Through and Right	v/c = Volume-to-Capacity ratio							
SB = Southbound		LTR = Left, Through, and Right								





PROJECT: NORTH ROAD INTERSECTION IMPROVEMENTS	
DESIGN SUBMISSION: CONCEPTUAL DESIGN	
DRAWING TITLE: PINE HILL INT ALTERNATIVE 1	
PREPARED FOR:  TOWN OF BEDFORD BEDFORD DPW 10 MUDGE WAY BEDFORD, MASSACHUSETTS	
PREPARED BY:  GREEN INTERNATIONAL AFFILIATES, INC. Civil and Structural Engineers Westford, Massachusetts (978) 923-0400 GreenIntl.com	
SCALE: AS NOTED	DESIGNED BY: MPD
DATE: 12/16/2016	DRAWN BY: MPD
PROJECT NO. 16065	CHECKED BY: WW

FIGURE 10

NO.	DATE	REVISIONS

W:\Landscape\Projects\16065\16065.dwg:Current Design 04/14/2016 10:58:48 AM Printed: 12/28/2016 9:58 AM

3.2.3 Alternative 1

Geometric Considerations

Alternative 1 transforms the existing skewed intersection into a traditional “T” intersection where North Road is maintained as the continuous movement and Pine Hill Road is shifted slightly to approach North Road perpendicularly. This alternative provides 11-foot lanes and 5-foot shoulders/bicycle lanes on North Road, while providing 10-foot lanes and 1-foot shoulders within the existing pavement width on Pine Hill Road. The Pine Hill Road approach maintains the existing approach configuration with one receiving lane, one left turn lane, and one right turn lane. This realignment shifts the intersection as much to the south as possible while avoiding right-of-way impacts. This achieves better sight lines for vehicles exiting Pine Hill Road, which in turn creates a safer intersection. There is an opportunity to expand sidewalk accommodations along the west side of North Road, if desired, as the space and right-of-way allow for this. In addition, the realignment of the intersection creates an area for additional green space and landscaping at the northeast corner. Due to the minor widening required, it is proposed that widening be achieved through box widening with the majority of the project to be milling and overlay.

The Alternative 1 realignment requires minimal impacts to abutting land in order to obtain a better intersection alignment. These impacts include minor widening on North Road to accommodate bicycle lanes. This widening would impact the drainage in the area and require relocation of existing drainage structures. One utility pole on the southeast corner of the intersection will require relocation.

Traffic Analysis

An intersection capacity analysis was done for Alternative 1 for two conditions. The first condition, the intersection remains unsignalized, the second condition signalizes the intersection. Table 3.06 summarizes the results of each analysis.

Unsignalized

The unsignalized approach, will operate the same as a no build condition. The North Road northbound and southbound approaches still operate freely with the Pine Hill Road westbound approach operating under a stop control.

Signalized

Under a signalized condition, the intersection operations under a two-phase condition. The North Road northbound and southbound movements are one phase and the Pine Hill Road westbound movement is the other. There is no advanced phase for the major peak hour movement during either peak hour as this increases delays for the opposing approaches significantly. Performing the analysis with this phasing results in the following:

- In the AM Peak the intersection operates at an LOS F due to large delays and queues in the southbound direction.
- In the PM Peak, the intersection operates at an LOS C. Delays on all approaches are below 50 seconds with the westbound approach operating at a delay of 47.9 seconds.

Table 3.06 – Summary of Alternative 1 Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2026 No Build/2026 Alternative 1 Unsignalized										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road SB	5.5	A	-	-	-	1.1	A	-	-	-
Pine Hill Road WB	>120	F	25	-	-	>120	F	1.72	-	-
2026 Alternative 1 Signalized (No Advanced Phase)										
North Road NB	2.0	A	0.33	45	85	32.8	C	0.92	413	705
North Road SB	>120	F	1.37	1618	1958	20.2	C	0.67	128	231
Pine Hill Road WB	33.4	C	-	-	-	43.7	D	-	-	-
Pine Hill Road WB L	69.8	E	0.26	22	54	23.1	C	0.21	49	91
Pine Hill Road WB R	23.5	C	0.53	0	57	47.9	D	0.94	255	479
<i>Intersection LOS</i>	<i>131.6</i>	<i>F</i>	-	-	-	<i>34.2</i>	<i>C</i>	-	-	-
<i>Abbreviations:</i>										
EB = Eastbound L = Left LT = Left and Through Delay = Average delay per vehicle WB = Westbound T = Through LR = Left and Right (measured in seconds) NB = Northbound R = Right TR = Through and Right LOS = Level of Service SB = Southbound LTR = Left, Through, and Right v/c = Volume-to-Capacity ratio										

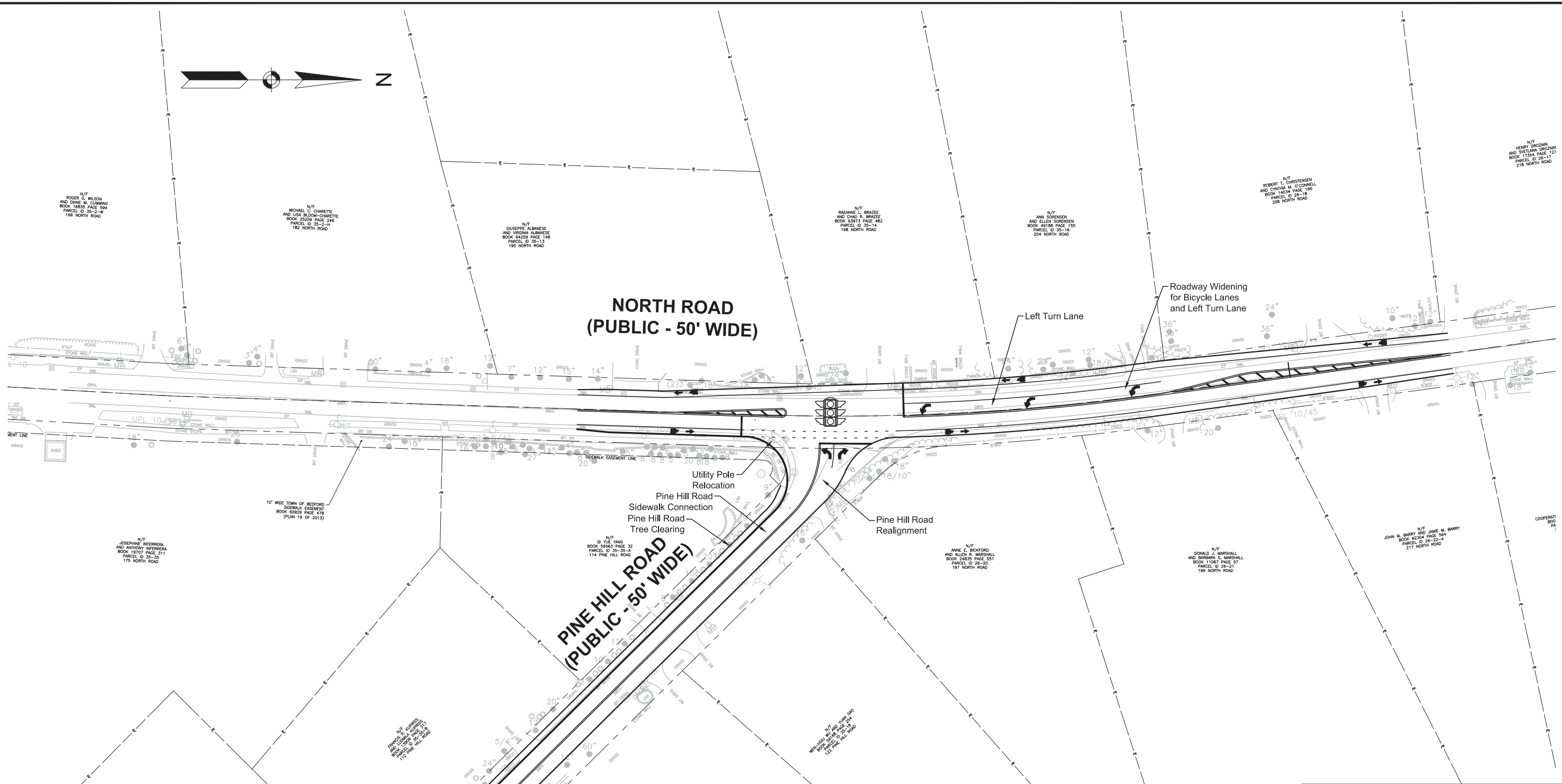
Conclusions

The improvements proposed for Alternative 1 improve safety at the intersection through improved sight lines for the Pine Hill Road approach. These safety improvements can be furthered through signaling the intersection to improve movements exiting Pine Hill Road. However, the single lane configuration proposed for the North Road (Route 4) approaches do not fully capture the benefits that a signal could provide. Signalizing the intersection creates significant delays and queuing for the southbound approach during the AM peak period. Because of these delays, the Alternative 1 is proposed to remain unsignalized thus improving safety through geometric improvements and maintaining existing traffic operations. An order of magnitude estimate was performed to determine that Alternative 2 would cost approximately \$200,000 to construct. This cost does not include the cost for utility pole relocations, right-of-way acquisitions, or temporary construction easements.



**NORTH ROAD
(PUBLIC - 50' WIDE)**

**PINE HILL ROAD
(PUBLIC - 50' WIDE)**



10' WIDE TOWN OF BEDFORD SIDEWALK EASEMENT BOOK 60929 PAGE 478 (PLAN 19 OF 2013)





PROJECT NORTH ROAD INTERSECTION IMPROVEMENTS	
DESIGN SUBMISSION: CONCEPTUAL DESIGN	
DRAWING TITLE: PINE HILL INT ALTERNATIVE 2	
PREPARED FOR:  TOWN OF BEDFORD BEDFORD DPW 10 MUDGE WAY BEDFORD, MASSACHUSETTS	
PREPARED BY:  GREEN INTERNATIONAL AFFILIATES, INC. Civil and Structural Engineers Westford, Massachusetts (978) 923-0400 GreenIntl.com	
SCALE: AS NOTED	DESIGNED BY: MPD
DATE: 12/16/2016	DRAWN BY: MPD
PROJECT NO. 16065	CHECKED BY: WW

FIGURE 11

NO.	DATE	REVISIONS

M:\Landscape\Projects\16065\16065.dwg:Current Design 04/16/2016 10:54:48 AM: 12/28/2016 9:58 AM

3.2.4 Alternative 2

Geometric Considerations

Alternative 2 retains the same realignment of Pine Hill Road as Alternative 1. The alternative also proposes also adding an 11-foot left turn lane on North Road for the southbound approach. With this left turn lane, North Road maintains two 11-foot through lanes along with an 11-foot left turn lane and 5-foot shoulders/bicycle lanes. Pine Hill Road maintains the exiting configuration similar to Alternative 1. There is no longer an option for a sidewalk on the west side of roadway. Pine Hill Road maintains the existing lane configuration while slightly realigning to improve sightlines.

Alternative 2 realignment requires significant impacts to abutting land. Major widening along the west side of North Road through the intersection would be required while minor widening along the east side of the road will be required. On the west side of North Road, several mature trees would need to be removed and several stone walls would need to be rebuilt. The proposed edge of pavement would abut the existing right-of-way and although this layout show's no permanent right-of-way impacts, right-of-way impacts may result from further design revisions. One utility pole at the southeast corner of the intersection will require relocation and other utility poles along the east side of the North Road will need to be looked at to determine if relocation is necessary. Drainage through the intersection will need to be reconstructed to accommodate the new pavement widths and widening proposed.

Traffic Analysis

Based on preliminary evaluations, an unsignalized condition for this alternative would cause significant traffic performance deficiencies and safety concerns. As a result, an intersection capacity analysis was done for only for a signalized condition. Table 3.07 summarizes the results of each analysis.

Under a signalized condition, the intersection operations under a two-phase condition in both the morning and afternoon peak periods. The North Road northbound and southbound movements are one phase and the Pine Hill Road movement is the other. In the morning peak period, the left turning movement on the North Road southbound approach is given an advanced phase to better traffic operations. Performing the analysis with this phasing results in the following:

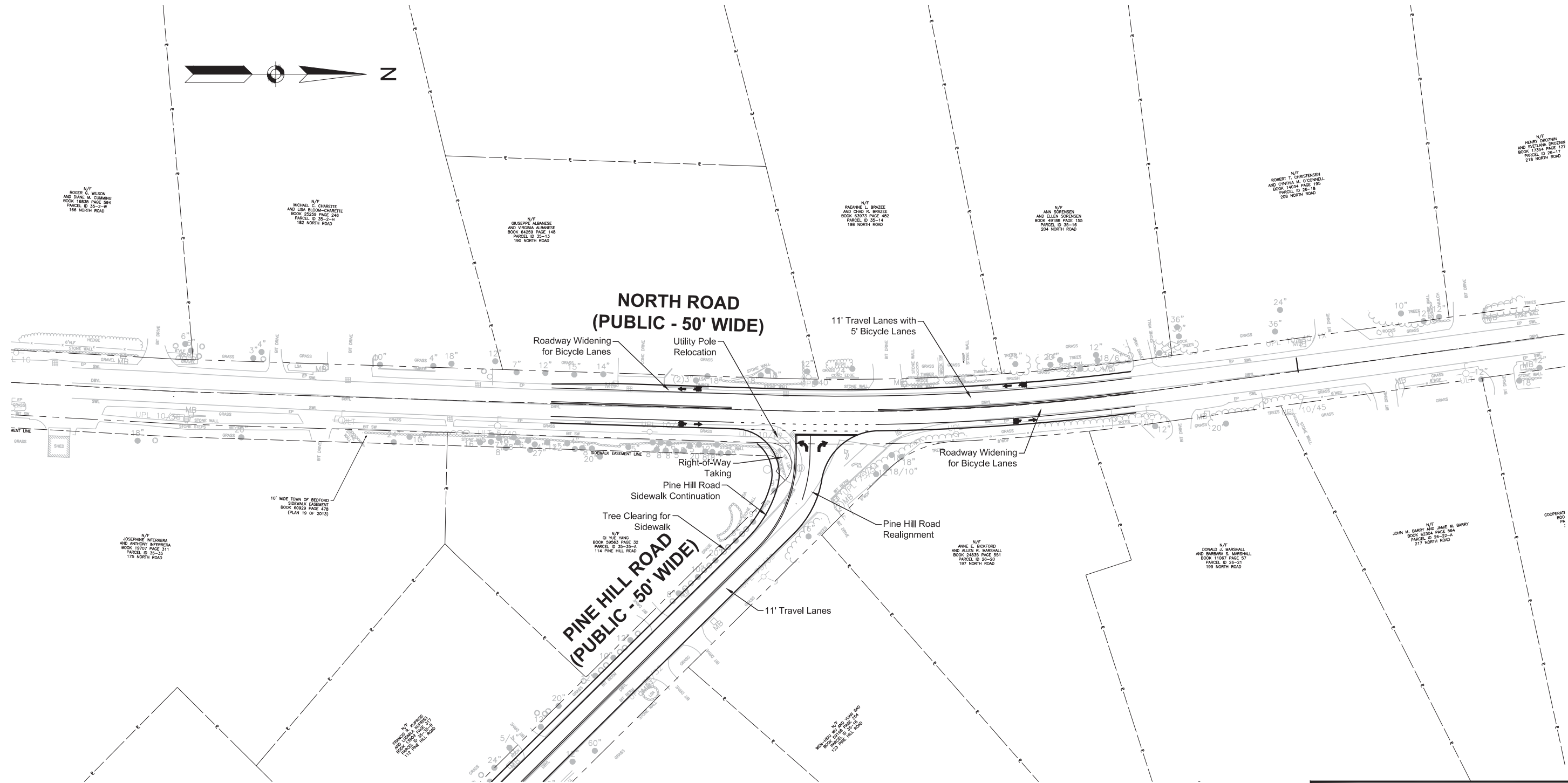
- In the AM peak hour, the North Road southbound approach operates with an advanced protected left-turn phase to accommodate the high volume of left-turning vehicles along the approach during the AM peak hour.
- In the PM peak hour, the southbound approach would operate as a permitted left turn lane with no protected phase. This is done to minimize delay and queues in the northbound direction.
- In the AM Peak the intersection operates at an LOS B with an intersection delay of 15.8 seconds.
- The worst approach in the AM Peak, Pine Hill Road WB L, operates at a LOS D, but this approach only encounters a 95th percentile queue of 35 feet; less than 2 car lengths.
- In the PM Peak, the intersection operates at an LOS C with an intersection delay of 34.9 seconds.
- The worst approach in the PM Peak, Pine Hill Road WB R, operates at an LOS D and has a queue of 435 feet.

Table 3.07 – Summary of Alternative 2 Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2026 No Build										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road SB	5.5	A	-	-	-	1.1	A	-	-	-
Pine Hill Road WB	>120	F	25	-	-	>120	F	1.72	-	-
2026 Alternative 2 Signalized										
North Road NB	31.7	C	0.78	207	382	37.5	D	0.95	400	681
North Road SB	9.8	A	-	-	-	13.2	B	-	-	-
North Road SB L	16.9	B	0.81	143	301	28.3	C	0.43	11	55
North Road SB T	4.2	A	0.51	89	182	11.3	B	0.34	85	137
Pine Hill Road WB	18.1	B	-	-	-	43.0	D	-	-	-
Pine Hill Road WB L	35.4	D	0.14	12	35	19.6	B	0.20	41	79
Pine Hill Road WB R	13.4	B	0.38	0	42	47.8	D	0.95	225	435
<i>Intersection LOS</i>	<i>15.8</i>	<i>B</i>	<i>-</i>	<i>-</i>	<i>-</i>	<i>34.9</i>	<i>C</i>	<i>-</i>	<i>-</i>	<i>-</i>
<i>Abbreviations:</i>										
EB = Eastbound			L = Left		LT = Left and Through		Delay = Average delay per vehicle (measured in seconds)			
WB = Westbound			T = Through		LR = Left and Right		LOS = Level of Service			
NB = Northbound			R = Right		TR = Through and Right		v/c = Volume-to-Capacity ratio			
SB = Southbound					LTR = Left, Through, and Right					

Conclusion

Alternative 2 introduces a left turn lane on the southbound approach in order to accommodate the significant number of left turning vehicles during the morning peak hour. With the left turn lane, the intersection would need to be signalized to better define the right-of-way for turning vehicles and due to safety concerns for vehicles exiting Pine Hill Road. The signalization of the intersections significantly improves operations during both peak periods and creates a safer intersection for all turning movements.. In addition to signalizing the intersection, the Pine Hill Road approach is realigned to form a traditional “T” intersection. This improves sight lines for vehicles exiting Pine Hill Road. An order of magnitude estimate was done to determine that Alternative 2 would cost approximately \$400,000. This cost does not include utility pole relocations or right-of-way acquisitions or easements.





PROJECT: NORTH ROAD INTERSECTION IMPROVEMENTS	
DESIGN SUBMISSION: CONCEPTUAL DESIGN	
DRAWING TITLE: PINE HILL INT ALTERNATIVE 3	
PREPARED FOR:  TOWN OF BEDFORD BEDFORD DPW 10 MUDGE WAY BEDFORD, MASSACHUSETTS	
PREPARED BY:  GREEN INTERNATIONAL AFFILIATES, INC. Civil and Structural Engineers Westford, Massachusetts (978) 923-0400 GreenIntl.com	
SCALE: AS NOTED	DESIGNED BY: MPD
DATE: 12/16/2016	DRAWN BY: MPD
PROJECT NO. 16065	CHECKED BY: WW

FIGURE 12

NO.	DATE	REVISIONS

W:\Landscape\Projects\16065\16065.dwg:Current Design 04/14/2016 12:28:08 PM Printed: 12/28/2016 9:48 AM

3.2.5 Alternative 3

Geometric Considerations

Alternative 3 realigns the Pine Hill Road approach to form a traditional T intersection with North Road. The intersection maintains the same configuration and accommodations as Alternative 1 in terms of lane configuration and bicycle and pedestrian accommodations. The main difference between Alternative 3 and Alternative 1 is the degree to which the intersection is a realigned. Alternative 3 takes a more drastic approach and pulls the intersection further south in order to lengthen the queues on Pine Hill Road and provide even better sight lines for vehicles exiting Pine Hill Road.

This alternative encounters similar impacts to Alternative 1 in terms of utility poles, widening, drainage, and the rebuild of stone walls. In addition to these impacts, Alternative 3 will also require right-of-way takings and extensive tree removal from the property on the southeast corner of the intersection.

Traffic Analysis

The intersection capacity analysis done for Alternative 3 mimics Alternative 1’s results as there is only changes in geometric design, not in traffic patterns. These results are shown below in Table 3.08

Table 3.08 – Summary of Alternative 3 Capacity Analysis

	AM PEAK					PM PEAK				
	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)	DELAY (s)	LOS	v/c	50 TH % Q (FT)	95 TH % Q (FT)
2026 No Build/2026 Alternative 1 Unsignalized										
North Road NB	0	A	-	-	-	0	A	-	-	-
North Road SB	5.5	A	-	-	-	1.1	A	-	-	-
Pine Hill Road WB	>120	F	25	-	-	>120	F	1.72	-	-
2026 Alternative 1 Signalized (No Advanced Phase)										
North Road NB	2.0	A	0.33	45	85	32.8	C	0.92	413	705
North Road SB	>120	F	1.37	1618	1958	20.2	C	0.67	128	231
Pine Hill Road WB	33.4	C	-	-	-	43.7	D	-	-	-
Pine Hill Road WB L	69.8	E	0.26	22	54	23.1	C	0.21	49	91
Pine Hill Road WB R	23.5	C	0.53	0	57	47.9	D	.94	255	479
<i>Intersection LOS</i>	<i>131.6</i>	<i>F</i>	<i>-</i>	<i>-</i>	<i>-</i>	<i>34.2</i>	<i>C</i>	<i>-</i>	<i>-</i>	<i>-</i>
Abbreviations:										
EB = Eastbound	L = Left	LT = Left and Through	Delay = Average delay per vehicle (measured in seconds)							
WB = Westbound	T = Through	LR = Left and Right	LOS = Level of Service							
NB = Northbound	R = Right	TR = Through and Right	v/c = Volume-to-Capacity ratio							
SB = Southbound		LTR = Left, Through, and Right								

Conclusion

Alternative 3 improves safety at the intersection while lengthening queues on the Pine Hill Road approach. Signalizing the intersection will improve safety through creating a safer environment for vehicles exiting Pine

Hill Road. However, similar to Alternative 1, the minor improvement to the Pine Hill Road approach does not warrant the installation of a signal. An order of magnitude estimate was done to determine that Alternative 2 would cost approximately \$200,000. This cost does not include utility pole relocations or right-of-way acquisitions or easements.

3.3 Environmental Consideration

There are no protected resource areas within the project limits for any of the alternatives for the intersection of North Road and Pine Hill Road. There is a wetland area east of the intersection approximately 320 feet away. Work will not take place in the buffer zone. The intersection is not within a FEMA Flood Zone. It is anticipated that the intersection will qualify as Redevelopment under the Massachusetts Stormwater Standards. However, since the intersection is not within any jurisdictional areas under the Wetlands Protection Act, a Notice of Intent is not required or anticipated.

Article 55 of the Town of Bedford General Bylaws regulates stormwater management in the Town. Any activity that disturbs one acre or more of land in the Town is subject to the Bylaw. Currently, Alternative Two exceeds one acre of disturbance for the intersection of North Road and Pine Hill Road and will require a Stormwater Permit. An exemption may be sought under Section 6.B.8 of Article 55, which allows for the maintenance and improvement of existing public roadways when conducted in accordance with an approved Stormwater Pollution Prevention Plan. If an exemption is granted, the Town of Bedford encourages consistency with the Performance Standards set forth in Section 6.E of Article 55 as well as the Massachusetts Stormwater Management Standards.

For any alternatives that exceed one acre of land disturbance, compliance with the NPDES Construction General Permit will be required and preparation of a Stormwater Pollution Prevention Plan (SWPPP). Currently Alternative Two will require compliance with the NPDES CGP.

There are no Priority or Estimated Habitat Areas in the vicinity of the project site, as defined by the Natural Heritage and Endangered Species Program (NHESP). The nearest Certified Vernal Pool is approximately 1,610 feet away from the project location.

The North Road Area Local Historic District (LHD) is in the vicinity of the proposed intersection improvements. Within the LHD, two properties in the area of the project site are noted as historic based on the MACRIS website. 197 North Road and 198 North Road abut the work area, but no impacts are anticipated to either property.

Pine Hill Road is one of Bedford's Scenic Roads as provided for under Article 45 of the Town General Bylaws. Article 45 is intended to regulate the tear-down of stone walls or removal of trees along any designated Scenic Road; if these activities are undertaken along Pine Hill Road, approval will be required by the Planning Board. As noted above, any removal of stone walls will also be evaluated to identify if MEPA thresholds will be triggered requiring a submission to MEPA. In addition, any tree removal that may be required will be evaluated to determine if a joint hearing with the Town Tree Warden and the Planning Board is required.

3.4 Other Considerations

In addition to the three alternatives developed for the Pine Hill Road intersection, Green considered other improvements. For Pine Hill Road, Green analyzed shifting Pine Hill Road three feet to the North at the intersection in order to avoid significant clearing along the south side of the road. This shift would require that a few mature trees along the north side of Pine Hill Road would need to be removed, but it would

minimize the amount of clearing required on the south side of the road. After discussion with the Town, it was determined that the removal of these trees was not preferred and realigning the roadway was determined to not be a preferred alternative.

After discussion with locals at the local concerns hearing that Green presented at, the property owner opposite Pine Hill Road mentioned that vehicles frequently encroach on her property to go around left turning vehicles at the intersection. Green has considered an option to propose curbing along this portion of North Road in order to restrict vehicles from encroaching on this property.

3.5 Preferred Alternative

In comparing the three alternatives for North Road at Pine Hill Road, safety and traffic operations are the two controlling criteria. With these two criteria in mind, Alternative 2 signalized is the best option out of the three. The realignment of the “T” intersection between North Road (Route 4) and Pine Hill Road improves sight lines and safety for the intersection, while the addition of a left turn lane on the North Road southbound approach significantly improves traffic operations. The signalized control of the intersection optimizes efficiency and promotes safety by creating phases for each approach. Overall, this option best solves the issue of vehicles having a difficult time exiting Pine Hill Road. Signalizing the intersection would also help provide gaps for entering vehicles at adjacent intersections and driveways. There is a potential that the signal could generate additional cut-through traffic. However, based on discussions with the Town, it is our understanding that it could alleviate cut-through traffic that are currently using other adjacent side streets and result in an overall safety benefit to the area. An order of magnitude estimate was done to determine that Alternative 2 would cost approximately \$400,000. This cost does not include utility pole relocations or right-of-way acquisitions or easements.

F:\Projects\2016\16065\Documents\Conceptual Analysis Report\Conceptual Analysis Report_ver04.docx