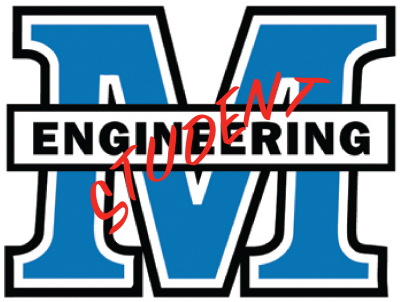

UMaine Dudes Engineering

Final Capstone Report

Project Title: Waldoboro Intersection Redesigns

Prepared For:
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Executive Summary

The project consists of three separate intersections, Rt. 1 & W. Main St, Rt. 32 & West Main St, and Old Augusta Rd & Washington Rd. Each of these intersections are all separate from each other, but they all have one thing in common; poor sight distances. These poor sight distances raise safety concerns about the visibility of approaching vehicles when entering the intersections. While there was more that was desired at each intersection, the poor sight distances were our primary concern.

Rt. 1 & W. Main St

When approaching the intersection of Rt. 1 and W. Main St from the east, it's common for drivers to completely miss the intersection because of a crest on the approach partially obstructing the sightline to the intersection, along with the lack of signage and lighting at the intersection. There is also a park and ride that provides parking for the city forest and for people that drive together to work. Because of the small size of the parking lot, and the large number of people that leave their vehicles there so they can commute together, there often isn't enough space for people to park if they want to access the city forest trails.

To combat these issues requests at the intersection we have created three design options. The first is a minimalistic design that includes increasing the island size and increasing striping around the intersection. While this design is the least expensive option it doesn't fix all of the challenges. The second design option is a realigned W. Main St. to increase the turning radius for right turning vehicles. The radius increase was requested of us by our client and shifting the alignment increased the sight distances for the intersection. However this design features the new roadway over where the existing park and ride is. To address that we made a third design option which includes the same realigned roadway as the second option but also includes a separate park and ride. This new park and ride is located on the Waldoboro town forest land off of Rt. 1 and increases the capacity from 17 spaces to 32.

Rt. 32 & W. Main St

At the intersection of Rt. 32 & W. Main St, there is a vertical crest curve that obstructs vehicles on the eastbound approach from vehicles stopped at the intersection. People stopped at the intersection are unable to determine if vehicles are approaching in the eastbound direction. This creates a high crash location with 45 intersection movement crashes occurring in the past 18 yearsIt was also desired that there be a sidewalk and crosswalk added to our designs. This sidewalk would run along West Main St. from the intersection to the recreational fields on Percy Moody Rd.

Our design solutions for these issues was to one, to redesign the road profile of the eastbound intersection approach, and a second option of adding a stop sign to the eastbound approach leg. Both of these solutions will address the sightline concerns at the intersection, by making the sight distance longer or taking away the need for sight distance. We have also designed a sidewalk and crosswalk per the client's request along W. Main St. and across Rt. 32 to tie into the existing crosswalk along Rt. 32.

Old Augusta Rd & Washington Rd

At the intersection of Old Augusta Rd & Washington Rd, there is a vertical sag curve that prevents vehicles on the southbound approach of Washington Rd from being seen by vehicles stopped on Old Augusta Rd until they're right at the intersection. Currently the sight distance at the intersection is a quarter of what the standards say it should be. Along with a speed limit through the intersection of 45 mph, this creates major safety concerns for vehicles entering the intersection. Plus, our client noted that people often have to listen for approaching vehicles because the sightline distance isn't long enough.

With this intersection being in a more rural location there were less added design factors other than increasing the sight distances to improve safety. To do this we decided that the best solution to improve sight distance is to redesign the road profile. We have made two separate road profiles that will increase the sight distance to meet the required standards. The first is a pure elevation change of the roadway that consists of a large cut and a small fill to increase the sight distance to 500 ft. Our second design option for this intersection is to reduce the speed from 45 mph to 35 mph. This will decrease the required sight distances so we can design a less intrusive cut to the roadway profile.

Acknowledgements

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- Dr. Edwin Nagy, Ph.D., P.E., S.E. - University of Maine Civil Engineering Dept.
- Derek Nener-Plante, M.S., P.E. - University of Maine Civil Engineering Dept.

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1 Safety and Level of Service for Current Intersections

1.1 Introduction

The UMaine Dudes capstone group has been working on a project in the town of Waldoboro, Maine. This project features three intersections that will be redesigned to improve safety and add new infrastructure requested by the client. In preparation for future work, the safety and level of service of the current intersections was assessed first. Based on the current state of the intersections, our group determined if new traffic infrastructure was needed.

1.2 Safety Analysis

1.2.1 W. Main St. / Rt. 32

Currently, both W. Main St. and Rt. 32 have a speed limit of 35 mph. According to the Maine Department of Transportation (MDOT) Crash Query Tool, since 2003 there have been 46 vehicle crashes, an average of just under 3 per year. Based on the 2019 Annual Average Daily Traffic (AADT) data from the MDOT public map viewer, the daily traffic volumes for this intersection are the following:

- W. Main E = 1340
- W. Main W = 2610
- Rt. 32 N = 2220
- Rt. 32 S = 2460

1.2.2 W. Main St. / Rt. 1

Currently, W. Main St. has a speed limit of 45 mph and Rt. 1 has a speed limit of 55 mph. According to the MDOT Crash Query Tool, since 2003 there have been 21 vehicle crashes, an average of about 1 per year. Based on the 2019 AADT data from the MDOT public map viewer, the daily traffic volumes for this intersection are the following:

- W. Main NB = 580
- W. Main SB = 831
- Rt. 1 E = 10320
- Rt. 1 W = 11250

1.2.3 Old Augusta Rd. / Washington Rd.

Currently, Old Augusta Rd. has a speed limit of 35 mph and Washington Rd. has a speed limit of 45 mph. According to the MDOT Crash Query Tool, since 2003 there have been 9 vehicle crashes, which is an average of 0.5 per year. Based on the 2019 AADT data from the MaineDOT public map viewer, the daily traffic volumes for this intersection are the following:

- Washington Rd. N = 1410
- Washington Rd. S = 1350
- Old Augusta Rd. = 640
- Old Augusta Rd. = 910

See **Appendix 1.B** for more in depth traffic volume data including hourly traffic volume for all roads in the intersections.

1.3 Two-Way Stop Control Delay Calculation

Some of the roads in the intersections do not have an approach delay because there is not currently a stoplight or stop sign to delay the traffic. These calculations are helpful because they helped us determine how our intersection designs will affect approach delay in the intersections.

1.3.1 W. Main St. / Rt. 1

It has been determined that the Main St. approach has an approach delay of approximately 9.30 seconds.

1.3.2 W. Main St. / Rt. 32

It has been determined that the northbound route 32 approach has an approach delay of approximately 8.80 seconds and the southbound route 32 approach has an approach delay of approximately 9 seconds

1.3.3 Old Augusta Rd. / Washington Rd.

It has been determined that the eastbound Augusta Road approach has an approach delay of approximately 8.80 seconds and the westbound Augusta Road approach has an approach delay of approximately 8.80 seconds.

1.4 Proposed Traffic Infrastructure

According to the MDOT study at W. Main St. / Rt. 32, (WALTM06 07/16/04)
The intersecting roads have similar volumes.

- Rt 32 NB - 1234 AADT
- Rt 32 SB - 1263 AADT
- W Main St EB - 637 AADT
- W Main St WB - 1105 AADT

Rt 32 is the major road with West Main St being the minor. An additional stop sign on W Main St EB is being proposed as a potential option to create a 3-way stop in order to stop the direction that has obscured vision, dips, or bumps that already require drivers to use lower operating speeds. A stop sign on West Main St WB is not being proposed due to an approximately 9% uphill grade that could be hazardous in severe winter conditions. In accordance with MUTCD chapter 2, section 2B.07 the intersection meets the following requirements B, C1, and C2 for a multiway stop:

- B. 5 intersection movement crashes in 2019.
- C1. Figure 3 and 4, Traffic Volume Report.
- C2. Figure 1 and 2, Traffic Volume Report. Delay time N/A (queue length required)

It continues:

A. Where traffic control signals are justified, the multiway stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.

B. A crash problem, as indicated by 5 or more reported crashes in a 12-month period that are susceptible to correction by a multiway stop installation. Such crashes include right- and left-turn collisions as well as right-angle collisions.

C. Minimum volumes:
1. The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour for any 8 hours of an average day, and
2. The combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same 8 hours, with an average delay to minor-street vehicular traffic of at least 30 seconds per vehicle during the highest hour, but
3. If the 85th-percentile approach speed of the major-street traffic exceeds 65 km/h (40 mph), the minimum vehicular volume warrants are 70 percent of the above values.

D. Where no single criterion is satisfied, but where Criteria B, C.1, and C.2 are all satisfied to 80 percent of the minimum values. Criterion C.3 is excluded from this condition.

1.5 Signalization Requirement Check

MUTCD Section 4C Warrants have been used to determine if signalization is appropriate. If satisfied, traffic signalization is an option. If multiple warrants are satisfied, evidence for signalization is stronger. However, signalization is not mandated by these warrants, and engineering studies should be done before installing any traffic control devices.

1.5.1 Old Augusta Rd. and Washington Rd.

- Warrant 4C.02 – 8 Hour Vehicular Volume: *Not Satisfied*
    - Neither major or minor road hourly volumes meet the requirements
- Warrant 4C.03 – 4 Hour Vehicular Volume: *Not Satisfied*
    - Neither major or minor road hourly volumes meet the requirements

1.5.2 Rt. 32 and West Main St.

- Warrant 4C.02 – 8 Hour Vehicular Volume: *Satisfied (Condition A)*
    - Since an isolated town of 10,000 or less residents, major road meets the minimum of 350 VPH both ways, and minor road meets the minimum of 105 VPH in any direction.
- Warrant 4C.03 – 4 Hour Vehicular Volume: *Satisfied*
    - Since an isolated town of 10,000 or less residents, the major road and minor road have at least 4 hours a day where it goes over the necessary threshold of Figure 4C-2. Any data that goes over that threshold satisfies this warrant's condition.
- Warrant 4C.05 – School Crossing: *Possibly Satisfied*
    - Our Client has tasked us with the installation of a crosswalk at this intersection. The primary purpose of this crosswalk is to allow school children to cross the road and get to the recreation complex down the road. Considering all the sports teams, it's feasible that more than 20 students an hour at peak time will use this crosswalk, which is a minimum requirement for this warrant.

1.5.3 Rt. 1 and West Main St.

- Warrant 4C.02 – 8 Hour Vehicular Volume: *Satisfied (Condition B)*
    - Since the speed limit of the major road is greater than 40 mph (55 mph), the major road meets the minimum of 525 VPH in both directions, and the minor road meets the minimum of 53 VPH in any direction.

- Warrant 4C.03 – 4 Hour Vehicular Volume: *Satisfied*
    - Since the speed limit of the major road is greater than 40 mph, the major road meets the minimum of 800 VPH in both directions, and the minor road meets the minimum of 60 VPH in any direction.

1.6 Conclusion

In conclusion, Old Augusta Rd. and Washington Rd. do not need new traffic signalization. Both Rt. 32 and West Main St. and Rt. 1 and West Main St. should have traffic studies conducted for further inquiry on necessary traffic signalization. In light of being unable to actually perform these studies, we have not added new traffic signals as part of our designs.

2 Permitting, Ordinances, and Property Lines

2.1 Permitting Introduction

The permitting requirements for this project are fairly straight forward. There is minimal permitting required prior to the start of the project. The only permits that will need to be filed are excavation permits and they are the same for each of the three intersections. These two permits need to be filed prior to any work being done on the roads and intersections.

2.1.2 Required Permits

The first is a Maine DOT Highway Opening Permit. This permit is required by the state of Maine to allow an excavation within the limits of a state or state-aid Highway. The second required permit is the Dig Safe Permit. This permit falls under the same heading of an excavation permit, but is filed with the non-profit dig safe.

- Highway Opening Permit

  A person, entity or Utility may not perform an Excavation within the limits of a state or state-aid Highway without applying for and obtaining a Highway Opening Permit.

- Dig Safe Permit

  Dig Safe is a not-for-profit clearinghouse that notifies participating utility companies of your plans to dig. In turn, these utilities (or their contract locating companies) respond to mark out the location of their underground facilities.

2.2 Pertinent Laws and Ordinances:

The following ordinances are based on zoning. Each ordinance describes the purpose and uses for each zone. During our design process we used the zones and ordinances to fit our designs to the wants and needs of the town at each location. A zoning map for the town of Waldoboro can be found in **Appendix 2.A**.

2.2.1 Rt. 1 and W. Main St. Zoning Ordinances

The Rt. 1 and W. Main St. intersection is zoned as Rural, Route 1 Commercial A, and Route 1 Commercial B zones (see **Appendix 2.A** for details). The zoning ordinances that pertain to our work are as follows:

- "6.6.7 Rural District. The purpose of the Rural District is to retain the rural character of Waldoboro by allowing agricultural, forestry, aquaculture, home occupations and light industrial uses…. The Rural District encompasses most of the land area in the Town and is intended for non-intensive uses and traditional
- "6.6.5 Route One Commercial A District. The purpose of the Route One Commercial A District, which applies to portions of Route One, is to replace the strip development with well-planned, attractive, well-landscaped development, to encourage a uniform street-scape along the corridor, to minimize roadway openings onto Route One, and to provide vehicle connections between lots. The district is designated for a mix of residential/commercial uses, commercial uses, light industry/manufacturing, agriculture and forestry."

- "6.6.6 Route One Commercial B District. The purpose of the Route One Comercial B District is to allow business and light industry/manufacturing development along Route One with fewer restrictions than in the Route One Commercial A district."

2.2.2 W. Main St. and Rt. 32 St. Zoning Ordinances

The W. Main St. and Rt. 32 intersection is classified as a village zone. The zoning ordinances that pertain to our work are as follows:

- "6.6.9 Village District. The purpose of the Village District is to retain and protect the character of Waldoboro Village and to provide for future growth consistent with existing land development patterns."

2.2.3 Old Augusta Rd. and Washington Rd. Zoning Ordinances

The Old Augusta Rd. and Washington Rd. intersection is classified as a rural village business district. The zoning ordinances that pertain to our work are as follows:

- "6.6.8 Rural Village Business District. The purpose of the Rural Village Business District is to encourage small scale residentially-compatible business activities in Waldoboro's historic rural crossroad neighborhoods."

2.3 Property Lines:

The property line maps for each intersection are shown in **Appendix 2.C**.

2.3.1 Rt. 1 and W. Main St. Property Lines

The majority of the property is privately owned land, with the exception of the town forest that is located southwest of the intersection of Rt. 1 and W. Main St. (plot R-22). This may possibly give us the option to use part of that plot to relocate the existing park and ride to set it further back from the roadway. The plot just west of the intersection (R-12) is privately owned, so buying out the plot or requesting the owner's permission is required if clearing is to be done in order to improve the site line for turning traffic.

2.3.2 W. Main St. and Rt. 32 Property Lines

The focus on this intersection for property lines is the north side of W. Main St. This is where we were requested to add in a sidewalk going from the west side of the intersection, along the road to the town's athletic fields. The right of way provides enough room for the addition of a sidewalk along Main St. All other work should stay well within the right of way. The other property line constraint that we considered was when matching the grade of the designed road profile to the driveways coming out of private property lines.

2.3.3 Washington Rd. and Old Augusta Rd. Property Lines

At this intersection our design for the change in elevation is contained within the right of way because we are only making changes to the road in the vertical direction in order to increase the sightlines. As with W. Main St and Rt. 32, we considered the property line constraints, and they were not applied on this intersection because we decided to change the grade where there were no driveways.

3 Design Sightline Fixes

3.1 Introduction

For this work package, our team has evaluated and created fixes for the horizontal and vertical sightline issues concerning the three intersections in Waldoboro Maine. It is critical that drivers have adequate awareness of the roadway, and other cars around them. For this reason, it is imperative to give drivers as much information as possible by increasing sightline distance. Based on the current state of the intersections, our group has found solutions for the horizontal sightline issue at Rt. 1/West Main St., and the vertical sightline issues at both Rt. 32/West Main St. and Old Augusta Rd./Washington Rd.

3.2 Current Sightline Issues

3.2.1 Rt. 32 and West Main St.

Figure 3.1 Shows the crest vertical curve from SB approach

Figure 3.2 Shows the Vertical Sag Curve from WB approach

Figure 3.3 Shows the Crest Vertical Curve from EB approach

The primary sightline issue at this intersection is from **Figure 3.3.** Traffic on West Main Street does not stop and the road slopes on the western side. As a result, it is difficult for the stopped cars on route 32 to see the approaching traffic on West Main Street (seen in **Figure 3.1**). During the site visit (a rainy day), cars were observed turning onto West Main at such a high speed due to the poor sightline, that they were hydroplaning. This sightline issue presents a safety risk, and has the potential to cause accidents. When cars approach from the West (**Figure 3.2)**, they have a hard time seeing over the crest in **Figure 3.3.** All of the sightline issues from the three figures revolve around the vertical crest curve in **Figure 3.3**. By fixing this one vertical sightline, we can alleviate all of this intersection's vertical sightline problems.

Another potential sightline issue at this intersection has to do with the sidewalk that our project will add to West Main Street. As part of the sidewalk design, a crosswalk across the northern section of route 32 will be added. This crosswalk will set cars further back, reducing sight distance. If crosswalk indicator fixtures are added, they could also reduce or block sight distance.

3.2.2 Old Augusta Rd/Washington Rd

Figure 3.4 Shows the Vertical Sag Curve on Old Augusta Road, SB approach

The main sightline issue at this intersection is the grade of Old Augusta Road. At this intersection, a 45 mph road (Old Augusta) meets a 25 mph road (Washington). Washington Road has a stop sign while Old Augusta Road does not. Cars stopped at this stop sign have difficulty seeing the cars traveling up the steep hill on the eastern section of Old Augusta Road. This is due to the sag vertical curve of the road, seen in **Figure 3.4**. The significantly higher rate of speed and potential speeding (mentioned by client) make this sightline issue even worse.

3.2.3 Rt 1 and W. Main St

Figure 3.5 Shows Horizontal Sightline obstructions at the Rt. 1 and West Main St. Intersection looking East (right from turning vehicle perspective)

The Sightline issues for this intersection are less severe. However, there could still be improvement. There is not a clear and open horizontal sightline until very close to Rt 1, as seen in **Figure 3.5**. There is a utility pole obstruction as well as the tree line that could be cut back to improve the sightlines and provide a clear line of sight farther back from the intersection. The issue with the tree line is that it is privately owned and would need some way to work around

that issue to get approval to cut the trees back farther. Another solution would be to move the intersection altogether, which we've done in a couple of our designs.

3.3 Current/Redesigned Road Profiles

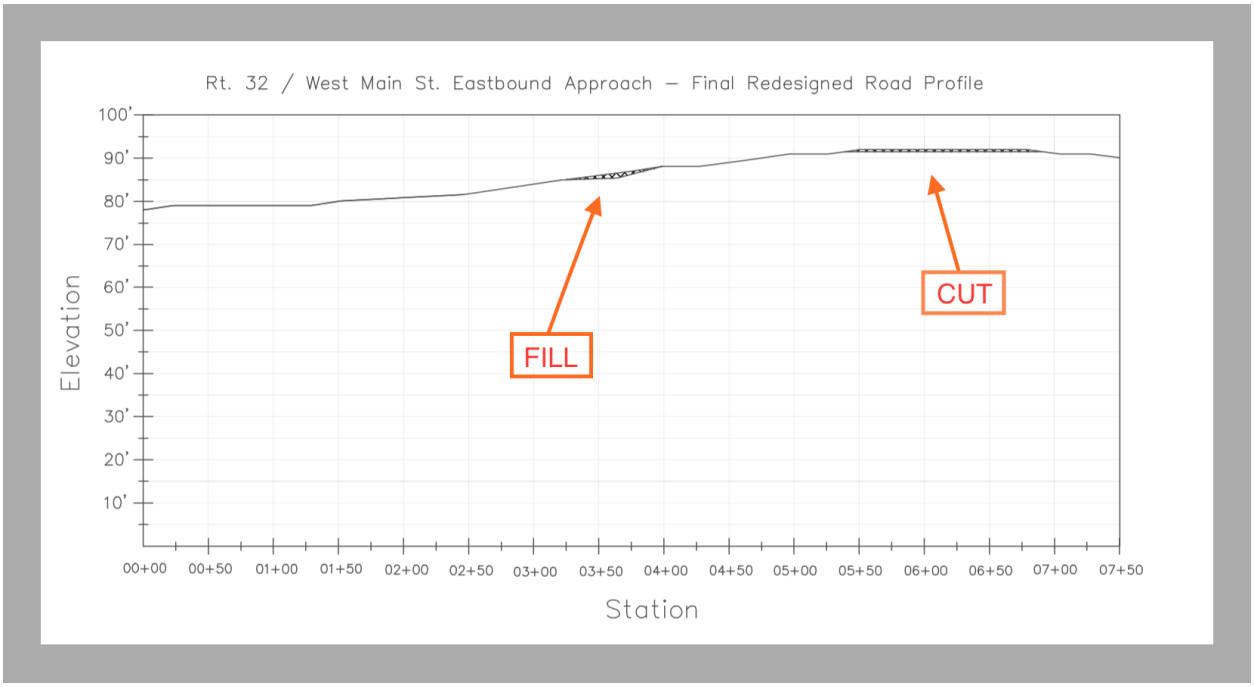

Figure 3.6 Rt. 32 / West Main St. Eastbound Approach -- Current Vs. Redesigned Road Profile

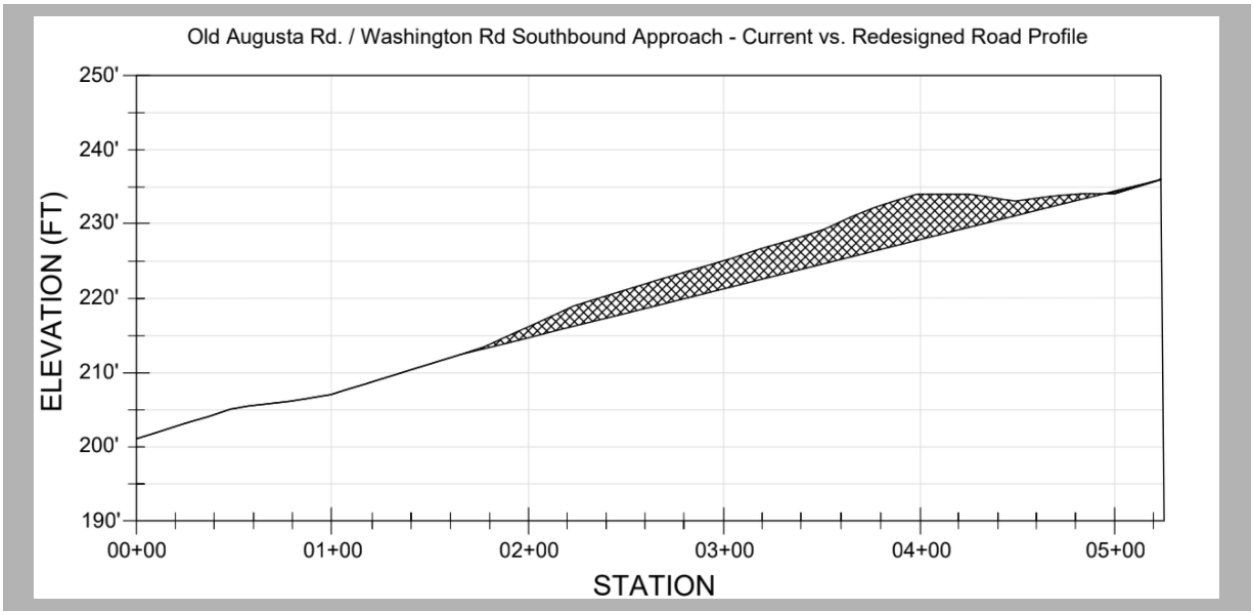

Figure 3.7 Old Augusta Rd. / Washington Rd. Southbound Approach -- Current vs. Redesigned Road Profile

3.4 Vertical Sightline Solutions

There were 2 primary solutions calculated for vertical sightlines. The first one being from Rt. 32/West Main St. As shown in **Figure 3.6**, the higher profile will be cut and reduced to the lower profile. The higher profile is the current road profile, and the lower profile is the new calculated road profile. The current road profile is uneven, with steep/abrupt grade changes, leading to a crest at the top of the intersection. In our redesigned model, we have found the ideal grade in order to alleviate the vertical crest at the top of our intersection. Our new design has a gentler slope throughout, creating a smoother ride and meets the necessary sightline standards to be discussed in **Chapter 7**. Removing the vertical crest will also allow cars from the other three intersection approaches to have much improved sightlines.

The second solution is for Old Augusta/Washington Rds. As shown in **Figure 3.7**, the higher profile will be cut and reduced to the lower profile, and a small amount of filling will be required at station 05+00. The higher profile is the current road profile, and the lower profile is the new calculated road profile. The current road profile is fairly smooth, but has an abrupt leveling that results in an unnecessary vertical crest. By changing the grade to be more gentle throughout, the crest will be eliminated and the intersections level will be maintained. The three other intersection approaches will now have adequate sightlines after removing the vertical crest curve here.

A couple caveats/assumptions were made in order to calculate these new road profiles. The first caveat is that our group was unable to acquire elevations for driveways along our road profiles. When cutting or filling the road, the driveways along the road have to follow suit. Therefore, driveways are a limiting factor when changing the road elevation. Our team acknowledges that before actual work could be done, a full assessment on driveway elevations would need to be incorporated into the road profile calculations. The true road profile elevations for both **Figure 3.6** and **Figure 3.7** are most likely in between the current road profile, and our ideal calculated one. Another caveat is that instead of exact stationing data taken from a field study, our group was limited to Lidar obtained elevation data accurate to the nearest foot. Our team also acknowledges that because of our limited accuracy, a proper road profile study with stationing would need to occur before work should be done on this project. The primary source of calculations for vertical sightlines was from the AASHTO Green Book 2001 Edition. For further inquiry on calculations on vertical sightlines and road profile elevations, refer to **Appendices 3.C**, **3.D**, and **3.E**. **Appendix 3.C** is an excel data sheet, illustrating the elevation and station data for each intersection, along with a graph of the road profiles accurate to 0.5 feet. **Appendix 3.D** shows the raw road profile elevations put into AutoCAD. **Appendix 3.E** shows our calculated road profiles (current, redesigned, and both), created in AutoCAD.

3.5 Horizontal Sightline Solutions

There were no horizontal sightline issues at Rt. 32/West Main St. or Washington Rd/Old Augusta Rd. The only horizontal sightline issue is at Rt. 1/West Main St., as discussed in the Current Sightline Issues Section (3.2). The solution to the horizontal sightlines problem was calculated by using standards from the 2001 AASHTO green book. For further inquiry, refer to **Appendices 3.A**, **3.B**, and **3.C**. **Appendix 3.A** shows the three horizontal sight triangles for each intersection. **Appendix 3.B** explains the sightline standards used from the AASHTO Green Book for calculations. **Appendix 3.C** has excel data referring to the necessary sight distance calculated from the horizontal sightline triangles.

4 Intersection of Route 1 and West Main Street Designs

4.1 Introduction

Our minimal design focuses on minor changes that will improve the quality of the intersection. It is meant to be cost effective, yet still have a meaningful impact. Our moderate design takes it a step further to target more of the specific issues that the intersection has, while removing the park and ride. We physically alter the approach to the intersection from West Main St., along with moving/changing the intersection itself. Our creative design is the same as our moderate design, but has a newly designed park and ride along Route 1 approaching from the west.

4.2 Minimal Design

The first design choice was to increase the size of the island at the intersection. The width of the road turning from West Main St. onto Route 1 was about 85 ft before the widening of the island. The new road width is around 57 ft. Because of the steep radial curve to the right of this junction, the road width for the right turning lane needs to be greater than normal. Taking that into account, our final design has effective lane widths of 18 ft. This is more than the standard 12 ft, yet is small enough that cars will remain in single lanes, rather than trying to create an unintended second lane. An additional benefit of the island's increased size is that it will ensure cars do not accidentally turn into the intersection on the wrong side. While there is no evidence that cars turned improperly before, it is even less likely to happen now.

The second design choice was to add striping to this same junction. We have added a stop bar spanning both lanes, and a 30 ft median line splitting the lanes. These additions were added

in order to give drivers adequate information on where to stop and turn. In the current design, drivers are left to their own decision making, which increases confusion and potential for accidents/conflicts.

These designs are shown in **Appendix 4.A & 4.B**.

The option of removing the trees located on private property right next to the cars turning right onto Route 1 was considered, but ultimately the sightline issue at the intersection was caused by the crest curve and not the trees, so the designs listed above were selected instead.

4.3 Moderate Design

This design was created to account for the two of the major issues that were conveyed to us about this specific intersection. Those are the lack of sight distance to the right of the intersection, and a sharp radius on the intersection approach. The design incorporates moving the intersection westward along Route 1, shifting the approach alignment, adding a narrow center island, keeping the right turn and left turn lanes for stopped vehicles turning onto Route 1 described in the previous design, adding two lanes with an alternate merge for vehicles turning from Route 1 onto West Main St. By shifting the intersection westward we improved both horizontal and vertical sightlines. The vertical sightlines that we calculated at this intersection were not an issue. But it was brought to our attention that the vehicles traveling westbound on Route 1 often exceed the posted speed limit. So knowing that we chose to be conservative and allow for an increased vertical sight distance to account for faster moving vehicles. This impeded on our second goal to increase the approach turning radius. By shifting the intersection west we were limited on space to allow for a larger turning radius while still remaining within the right of way. We were able to slightly increase the turning radius by shifting the alignment of West Main St. south west to allow for a more gentle turning approach.

We were given the option to eliminate the park and ride all together or redesign it elsewhere onsite. This design eliminates the current park and ride since the new road alignment will run directly over it. Our next design option will explore the possibility of rebuilding the park and ride.

4.4 Creative Design

The most effective option is to rebuild the park and ride and still implement the alignment change from the moderate design. The new park and ride will be built west of the intersection on the south end of Route 1, connected to the eastbound lane. It will include 32 spaces which is an improvement from the 17 parking spaces of the current park and ride, or 22 if users park parallel along the grass.

The new park and ride will be built on lot R-22, which is the town forest and is owned by the Town of Waldoboro. The option to increase the size of the existing park and ride was not chosen because doing so would infringe on lot R-11, which is privately owned.

This option would include the benefits of the realigned road in the moderate option, which would solve the horizontal sightline issues as well. In summation, this design would improve all drivers' sightlines to the intersection and it would improve the park and ride capacity. Also, it will require the new parking lot be built on the town forest and the West Main St. approach to the intersection be realigned to allow for a larger turn radius.

5 Intersection of Rt. 32 and West Main St. Designs

The intersection of Rt. 1 and West Main St. and Waldoboro Maine has multiple issues and requirements that we have addressed. The first was the addition of a sidewalk and crosswalk. The new sidewalk that was requested extends from the intersection to the recreational field approximately 750 feet down the road. The crosswalk is to allow pedestrians to cross the street from the existing sidewalk. The design issue was sightlines. We have addressed the vertical crest heading Eastbound towards the intersection, by redesigning the road profile and performing cut and fill calculations.

5.1 Cut and Fill Design

The final designs below take into account real world factors, customized specifically for this road. The main factor we had to take into account for cut and fill design, was the driveways. In order to preserve the grade of the driveways, we were very limited with what we could cut and fill. From MaineDOT: "When Grading Drives which are flatter than the maximum profiles, the following rule of thumb should be used, do not exceed a grade % change of more than 9% in a 6 foot increment of driveway length, this applies to both up and down profiles."

Using google earth's street view, and our AutoCAD plan view, we were able to come up with a solution that fits both MaineDOT's driveway requirements and fulfills the necessary sightline distance requirements from the AASHTO design guide. **Table 5.1** below shows the exact sightline distance changes that were made. Passenger Cars were previously 19 feet short of the standard, and are now 27 feet above the standard (a 46 foot increase). Single Unit Trucks were previously 14 feet short of the standard, and are now only 3 feet short of the standard. With the redesigned road profile both passenger cars and single unit trucks will see an increase in sight distance. This will in turn increase the safety for the intersection as a whole. If the driveways grades weren't a problem, then we would have been able to perform more cuts and fills to meet and even exceed all standards, but as it stands, we were limited to the one cut and one fill that we have made.

To accompany the cut and fill that we have designed for the intersection approach we recommend there to be an investigation as to the exact depth of the water and sewer mains that

run through the street. The water main is approximately 4-5 ft deep and will need sufficient cover to prevent frost. The redesigned profile may affect the amount of cover over the pipe after the road elevation has been changed. This will require cutting out a section of the pipe and reinstalling it at a deep enough depth to have 5 ft of cover over the top of the pipe to our new designed elevation. This also may need to be done to the sewer main that runs along the centerline of the road. There would need to be more research done however since we do not have the exact depth of this main, the only information we have states that the depth varies. If the sewer line is deep enough through our cut section that it will remain lower than the elevation of the changed water line than it does not need to be relocated.

Table 5.1 -- Sightline Comparisons Before/After Cut and Fill

	Calculated Desired Sightline Distance (ft)	Current Sightline Distance (ft)	Redesigned Sightline Distance (ft)
Passenger Cars	386	365	413
Single Unit Truck	489	475	486

5.2 Second Design Option

There is a second design option that we have considered which consists of adding an additional stop sign on the eastbound approach of West Main St. This option will make the intersection three way stop controlled. While the positives of this option is that it is much less expensive and less intrusive and eliminates the sightline issues that are present. This is not our recommended option because of the significant drawbacks. While the sightline issues are solved the added stop sign may pose an additional safety risk. There could be confusion based on an assumption by drivers that it is a 4-way stop controlled intersection when in fact the westbound approach does not stop. While this risk could be mitigated by making the intersection 4-way stop controlled this was avoided by your request and the steep grade of the westbound approach. Because of these factors it is our recommendation to change the eastbound approach profile to meet the sightline standards.

5.3 Sidewalk Design

The sidewalk we have designed will go from intersection to the driveway of the athletic fields with a crosswalk across the northern section of Rt 32 that connects the existing sidewalk along Rt 32 to the proposed sidewalk along West Main St. We have also included an option for additional crossing lights for the crosswalk in our designs. The sidewalk and crosswalk were designed around ADA standards to suit all users. There will be ramps at all driveway and road

crossings with metal detectable warning panels at the road crossings according to figure 5.1. With our designs the existing sidewalk will need to be updated to meet ADA requirements stated previously. The final sidewalk design consists of a 3.5 ft wide sidewalk and a 6” wide curb that runs from the intersection to Percy Moody Road as requested. We have prepared two materials options for the sidewalk construction. The first and less expensive is an asphalt sidewalk with an asphalt curb. The second option is a concrete sidewalk with a granite curb.

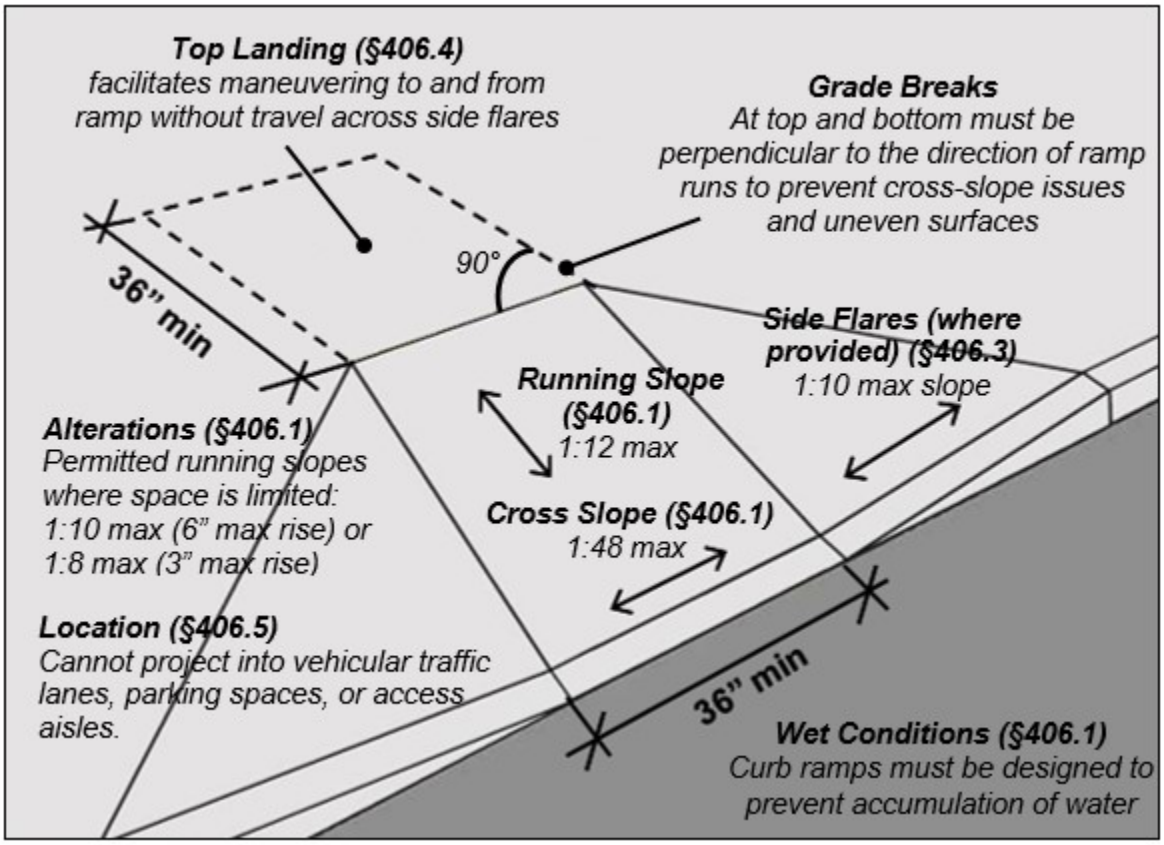

Figure 5.1: ADA sidewalk ramp requirements

5.4 Intersection Lighting Design

In order to increase visibility of the intersection at night, two 2,500 lumen light poles were designed to be placed at opposite corners of the intersection: one at the northwest corner and the other at the southeast corner. The light poles are to be oriented to face the cross street, West Main St., and will provide ample lighting to illuminate the crosswalk for pedestrians. The configuration for this design is shown in **Appendix 5.A**. These light poles are placed according to the AASHTO Green Book, and are designed according to the FHWA Lighting Handbook. In accordance with the FHWA Lighting Handbook, warrant analysis was conducted on this intersection using the recommended Transportation Association of Canada Guide for the Design of Roadway Lighting warranting form, which suggested delineated lighting - lighting that

illuminates vehicles on the cross street and marks the intersection for approaching vehicles. The FHWA Lighting Handbook laid out lighting intensity limitations based on the residential zoning that this intersection is in, with maximum illuminance on the ground at 3.0 lux, so the 2,500 lumen intensity recommended in this design is the maximum allowable given the geometry and zoning, and is still high enough to provide adequate safety to both drivers and pedestrians at the intersection.

6 Intersection Old Augusta Rd. and Washington Road Designs

6.1 Introduction

The primary focus of Old Augusta Rd and Washington Rd is to improve designed sightlines North of the intersection (Southbound). In order to improve the sightlines, we performed some cuts and fills of the roadway, based off centerline elevations. Sightlines were improved by 4 times in one case, achieved by a couple feet being cut off of a vertical crest.

6.2 Elevation Design

In this profile redesign, we improved the sight distance without making unnecessary elevation changes. Old Augusta Rd. is a local street, so we based the required sight distance on the AASHTO standards for passenger cars. Because passenger cars require the largest sight distance given that the driver sits lower to the ground than other vehicles, combination vehicles will also have an improved sight distance at the intersection.

To determine what areas needed to be cut or filled, a profile drawn to the scale of the section was designed. Using the to scale profile in accordance with AASHTO's sightline standards, we drew where the new road would need to be, basing it on the position of a driver in a passenger car 3' above the road. That sightline was then extended to the minimum required sight distance, 500', and all obstructions blocking a vehicle in that line were either cut or filled in. This design improved the sight distance from 125' to 500'

6.3 Cut and Fill Calculations

The cut and fill calculations in **Appendix 6.B** use the road profile shown in **Appendix 6.B**. From that profile we see that there will be a cut from stations 2+39 to 4+40, and a fill between stations 0+83 to 1+32. Using AutoCAD hatching we can calculate the areas on that profile drawing that will be cut or filled. Those areas multiplied by the width of the roadway that needs to be cut or filled returns the volume of earth that needs to be moved to accommodate our

design. Our major assumptions for these calculations were that we used a design specification of a 30” overall depth of the pavement structure (asphalt pavement and sub base gravel layers), as well as side slopes at 4h:1v. We deemed these as fair assumptions based on Maine DOT and AASHTO design codes. It is important to note that the volume of cut required does not include cutting back slopes to tie the base of the ditches in with the existing ground. This is because the slope of those back slopes is not standardized like the 4:1 side slopes off of the roadway. This is because the back slopes are determined by geotechnical slope stability requirements where the side slopes are determined by what is considered to be a safe slope for a vehicle that goes off the road to traverse. There would need to be a more in depth geotechnical study to determine the allowable slope for the native soil, at which point the volume of cut required for the back slopes can be calculated and added.

6.4 Signage and Utilities

Unfortunately, after reaching out to our Client and MaineDOT, we were unable to obtain data on underground utilities at this facility. Before any further planning can be done, DigSafe should be contacted in order for them to mark underground utilities, such as gas lines, and wastewater tunnels. After these spots are marked, they should be incorporated into the plan view drawing.

For the location of telephone poles, their overhead wires, and any other visible utility, Google Earth was used to estimate their approximate location. Google Earth was also used to determine the existing signage and their approximate locations.

7 Level of Service and Safety Analysis for New Designs

The primary focus of this project has been to improve the safety of all three intersections. Back in **Chapter 1**, we assessed the safety and level of service for the current intersections. Now that the new designs for all three intersections have been completed, the safety and level of service of the new intersection designs must be assessed.

7.1 Level of Service Analysis

The calculations and values for each intersection level of service can be seen in **Appendix 7.B** with an example calculation in **Appendix 7.A**. The current levels of service have not changed since our initial assessment in **Chapter 1**. The reason for this is that there was no reason that we found a need to change the traffic control device (the main contributing factor to delay) at the intersections based on level of service and traffic volumes. We have however added in a future expected delay and level of service at the end of a 30 year design life. We

approximated the annual traffic growth by using the Waldoboro population growth rate to find future traffic volumes for our calculations. We found that all of the intersection approaches still remain at an A rating for level of service which is defined as an average approach delay of less than 10 seconds.

For the 2nd design on Rt. 32 and W. Main St., adding a stop sign on the eastbound approach of W. Main St, there is no information on calculating the level of service for a 3-way stop. From observations of 3-way stops, the level of service is typically expected to decrease in peak AM and peak PM hours, causing longer delay times.

7.2 Safety Analysis

To determine if the new designs for the intersections increased the safety, we used Crash Modification Factors (CMF's) to predict the future crashes. CMF's are taken from studies of the before and after performance of multiple intersections with each of the intersections having a similar countermeasure installed.

7.2.1 Route 32 and West Main St.

At this intersection, the largest contributing factor to crashes is the vertical crest curve on the eastbound approach of West Main St that conceals approaching vehicles from the stopped vehicles on Route 32.

7.2.1.1 Design 1: Road Grade Redesign

Shown in **Figure 7.1** is a map of conflict zones on a 4-leg intersection. With the current grade design, vehicles approaching the intersection on the eastbound approach are concealed from crossing or turning vehicles that are entering the conflict zones. By redesigning the grade on the eastbound approach in accordance with AASHTO standards, vehicles entering the intersection from Route 32 will be able to see approaching vehicles on West Main St., and have the time needed to make a decision, thus removing the uncertainty when entering the conflict zones.

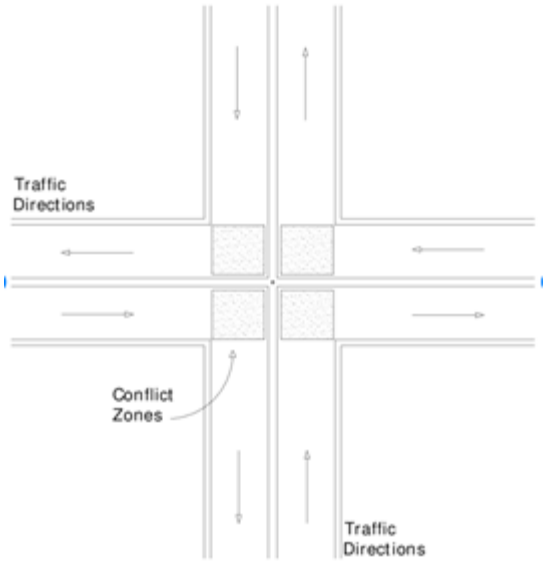

Figure 7.1 – Intersection Conflict Zones

Table 7.1 -- Crashes from 2005-2020 at Rt. 32/W. Main St

Route 32 and West Main St		
Crash Type	Time	
	Day	Night
Intersection Movement	40	5
Rear End/Sideswipe	1	1

Table 7.2 -- Predicted Crashes at Rt. 32/W. Main St

Predicted crashes		
Design	Crashes Next 15 Years	Crashes Per Year
1	44.0	3
2	NA	NA

The first design, extending the sight distance reduces the expected number of crashes by 3 over the course of 15 years.

7.2.1.2 Design 2: Proposed Stop Sign on W. Main St.

This design proposal is for a 3-way stop intersection with no grade change on the eastbound approach. The purpose of this design is to increase safety at the intersection by stopping vehicles on the eastbound approach.

By adding an additional stop sign, vehicles on the eastbound approach of West Main St will need to slow down before the crest and stop at the intersection. This makes it so that there are no hidden vehicles when entering the conflict zones on the intersection, reducing the number of intersection movement crashes.

On this design however, we were not able to estimate the number of predicted crashes due to how uncommon 3-way stops are. It is assumed that this design will reduce intersection movement crashes because the sightline issue is removed. It's also possible that rear end crashes will increase, due to an added stop sign and the vertical crest curve that could block stopped vehicles at the new stop sign from vehicles approaching from behind them, on the eastbound approach of W. Main St.

7.2.2 Old Augusta Rd and Washington Rd

At this intersection, the largest contributing factor to crashes is the vertical sag curve on the southbound approach of Washington Rd that conceals the approaching southbound vehicles from the vehicles entering the intersection on Old Augusta Rd and the turning vehicles on the northbound approach of Washington Rd.

Even though this intersection has had fewer crashes over the past 15 years than the other ones we've been working with, the majority of them have been crashes that involve injuries, including one fatal crash. Both our designs increase the sightlines, so both of them will reduce the number of injury accidents because approaching vehicles will be able to slow down considerably more if a collision is to happen.

7.2.2.1 Washington Rd Grade Redesign Option 1

To increase the level of safety at the intersection, our design is based on the sight distance that's required to locate approaching cars and turn safely. In **Figure 7.1**, there are two areas of conflict that are currently hazardous because vehicles on the southbound approach are not always visible. In accordance with the AASHTO sight distance standards, our designs reduce the sag curve, increasing the sight distance so that approaching southbound vehicles are visible at all points of the intersection.

Table 7.3 -- Sightline Comparisons Before/After Cut and Fill

Design	Current Sightline Distance (ft)	Calculated Desired Sightline Distance (ft)	Redesigned Sightline Distance (ft)
1	125	496	500

Table 7.4 -- Crashes from 2005-2020 at Old Augusta Rd and Washington Rd

Old Augusta Rd and Washington Rd		
Crash Type	Time	
	Day	Night
Intersection Movement	8	-
Rear End/Sideswipe	1	-
Went Off Road	1	-

Table 7.5 -- Predicted Crashes at Old Augusta Rd and Washington Rd

Predicted crashes		
Design	Crashes Next 15 Years	Crashes Per Year
1	6	0.37
2	9	0.57

As seen in **Table 7.5**, our first design, keeping the existing speed limit and increasing the sightline to the AASHTO standard reduces the amount of crashes by 4 over the next 15 years.

7.2.2.2 Washington Rd Grade Redesign Option 2

Option 2 which is calculated in **Appendix 7.C** for a grade redesign of Washington Rd combines a reduction in the speed limit of Washington Rd from 45 mph to 35 mph with cutting the vertical curve. This reduces the required sight distances for vehicles to turn out onto Washington Rd from 500 ft to 385 ft. Because of the reduced sight distance requirement this option will require less cutting of the road. This makes the option almost as safe as option 1 while reducing the cost to implement. This option relies on the ability to be approved by the town to get a speed limit reduction on Washington Rd from 45 to 35 mph.

As seen in **Table 7.5**, our second design option, reducing the speed limit and increasing the sightline to the standard of that speed limit is expected to decrease the amount of crashes by 1 over the next 15 years.

7.2.3 Route 1 and West Main St.

7.2.3.1 Minimal Design Specific Safety Improvements

For the minimal design, it is important to keep costs low, while providing a meaningful improvement to the intersection. Our solution is to increase the size of the intersection's island, by extending its width by about 25 feet to the right. By doing this, we'll increase safety in two ways. The first way we'll increase safety is to extend the width of the island. By extending the island's width, it'll be much more difficult to accidentally turn down the wrong side of the island. It's unknown how often people do that, but our assumption is that it probably happens rarely. With this new addition, we're confident that it should never happen again. The second way we'll increase safety, is by creating a 90 degree turning angle when turning left at the intersection. Previously, cars were at an approximate 67 degree angle when turning, which created two problems: difficulty seeing both directions of oncoming traffic and having a non-orthogonal turn onto Rt. 1 from the intersection. Both of these issues are alleviated or improved upon by changing the turning angle to 90 degrees.

Another important aspect of increased safety, is the addition of a stop bar and median line, separating the right and left turn lanes. Because the intersection is much wider than a normal two lane road, cars will now have more structure heading towards the intersection. The stop bar has another benefit. The stop bar improves the horizontal sightlines, by allowing cars to pull up far enough that the trees on the right of the intersection do not impede upon the driver's sightline.

7.2.3.2 Moderate/Creative Specific Safety Improvements

In our new designs, we moved the intersection over to the left approximately 120 feet centerline to centerline. By moving the intersection, we've achieved the maximum necessary sight distance.

Table 7.6 -- Sightline Distances Before/After Redesigns

	Current Sightline Distance (ft)	Calculated Desired Sightline Distance (ft)	Redesigned Sightline Distance (ft)
Passenger Car	821	606	884
Single Unit Truck	903	768	1006
Combination Truck	903	930	1006

From **Table 7.6,** Passenger Cars, and Single Unit Trucks meet the required sightline distance before and after redesigned sightlines. The issue with the current sightlines is Combination Trucks, which fall 27 feet short of the required sight distance. However, after redesigns, we've increased the sightline distance to 76 feet above the required sight distance. This extra buffer is important, as people typically speed about 0-5 mph above the speed limit on highways such as these, causing the true necessary sight distance to be slightly higher than the standard required.

We also reduce the amount of conflicts when turning left out of the intersection. As seen in **Appendix 4.C** when approaching the intersection from the west, the second lane on the right will end before the intersection. Currently, there is no true end to the second lane, and cars are expected to merge or exit without being told to do so. Now when turning left at the intersection, the driver will only have to look for 2 lanes in either direction, instead of 3 lanes, reducing the amount of factors to think about before turning.

Another conflict that we are reducing, is when turning left onto West Main St. from Rt. 1. (approaching from the East). Instead of having to turn through 2 active lanes of traffic, the right lane ends before the turning point, causing the driver turning to only have to wait for 1 active lane of traffic. After turning, the drivers will have adequate distance to come to a yield for the other lane of traffic. Effectively, we've moved the conflict from the intersection to a safer area just outside of the intersection.

The most expensive design for this intersection also features a new park and ride to replace the old one. The new park and ride has significantly more spaces and is further west down route 1 then the current one. Because of its location on the road, the new park and ride has clear sightlines in both directions.

7.2.2.3 Rt. 1 and W. Main St. Design Overview

Table 7.7 -- Crashes from 2005-2020 at Rt. 1/W. Main St

Route 1 and West Main St		
Crash Type	Time	
	Day	Night
Intersection Movement	4	1
Rear End/Sideswipe	4	-
Went Off Road	1	1
Bicycle	1	-

Table 7.8 -- Predicted Crashes at Rt. 1/W. Main St

Predicted Crashes		
Design	Crashes Next 15 Years	Crashes Per Year
1	10	0.65
2	4	0.29

Over the course of the next 15 years, we would expect to see a drop in crashes for both designs. The 1st design which is the minimal design reduces crashes from 11 crashes in 15 years to 10 crashes in 15 years as shown in **Table 7.7** and **Table 7.8**. The 2nd design is the creative/moderate design and in **Table 7.7** and **Table 7.8** we see a larger reduction in crashes. 4 crashes over 15 predicted years compared to 11 crashes in the past 15 years.

7.3 Lighting Plan

Warrant analysis was conducted for each intersection using the FHWA Roadway Lighting Handbook method. The warrant analysis, shown in **Appendix 7.D.**, determined that there should be delineated lighting fixtures installed at the Rt. 32 and West Main St. intersection only. The results were largely based on the current day-to-night crash ratio and the general geometry and thus they should be accurate regardless of the design solution. The lighting fixtures should be placed as shown in **Appendix 7.E.** in order to provide adequate lighting for pedestrians crossing the crosswalk as well as cars on the cross street. The fixtures should be 20 ft tall, which is standard according to the handbook, and are placed and oriented in order to reduce the amount of light going into the residential areas. Further analysis as to which type of light fixture and its cost will be determined in the next chapter.

8 Cost Analysis

8.1 Introduction

One of the primary objectives that our team had when beginning this project was to create many options based on the client's budget. In order to do this effectively, we've created multiple design options for each intersection. These different designs range from inexpensive minor changes, to more costly creative designs with major changes. The intersection of Rt. 1 and West Main St. has 3 major design options. The intersection of Rt. 32 and West Main St. has 2 major design options. The intersection of Old Augusta and Washington Rds. also has 2 major design options. Within each of these major designs, there are a few minor options that we've produced. All of these options were created in hopes that the client will be able to mix and match to their liking, depending on their desired scope, schedule, and budget. It is important to note that the costs only account for direct costs, including materials and labor. The cost estimates for the materials were based off of the average item bid prices on MaineDOT contracts from March of 2014 to March of 2017.

8.2 Old Augusta Rd. and Washington Rd.

At Old Augusta Rd. and Washington Rd., there are two major design options, and zero minor design options. This intersection required the least amount of changes, which is why there are only two design options. Both of these options include changing the road elevation to increase sightline distance. Option 1 includes a greater amount of cut to achieve the desired sight distance. Option 2 has less amount of cut, but reduces speed limit from 45 mph to 35 mph in order to achieve the desired sight distance. Below, **Table 8.1** compares a couple key factors the client will need to understand when considering which option to choose.

Table 8.1 -- Old Augusta and Washington Rds. Key Factors

	Direct Cost	Meets Sightline Standard?	Intersection Speed Limit
Option 1	$92,100	Yes	45 mph
Option 2	$77,150	Yes	35 mph

There are a few important things to note about the values in **Table 8.1** above. The first, is that Option 2 costs approximately $15,000 less than Option 1. Both of these options achieve the desired sightline standards calculated by our team. The most complicated factor to analyze is the difference of the speed limits. With the 45 mph speed limit, vehicles can travel faster through the intersection, which causes a higher chance of a fatal crash. With the 35 mph speed limit, vehicles will travel slightly slower through the intersection. After evaluating these key factors, our group concludes that the most economical and safe option would be Option 2.

8.3 Rt. 1 and West Main St.

At Rt. 1 and West Main St. there are three major design options. These three options are named: Minimal, Moderate, and Creative. For the Minimal option, the major focuses are on expanding the median island and the addition of street lights. For the Moderate option, the main focus is moving the intersection approximately 120 feet to the left. The two major changes are the realignment of the road, and the complete removal of the Park and Ride. The Creative option is the same as the Moderate option, however it replaces the Park and Ride with a new one on Rt. 1. Below, **Table 8.2** compares some of the key aspects to consider when analyzing the three options. It is important to note that the three options are not easily comparable, and are ultimately up to the client's scope and budget.

Table 8.2 -- Rt. 1 and West Main St. Key Factors

	Cost	Meets Sightline Standard?	Has a Park and Ride?
Minimal	$45,000	No	Yes
Moderate	$181,000	Yes	No
Creative	$380,000	Yes	Yes (Improved)

The Minimal design's sightline distance is 27 feet below the calculated standard for combination trucks. It meets the standards for passenger cars and single unit trucks. The Park and Ride would remain unchanged. There are minor safety improvements with the lighting system and slight realignment of intersection. This is the most economical option by far at $45,000.

The Moderate design meets all required sightline distances, going over the required amounts by a minimum of 70 feet. The Park and Ride would be completely removed so the road can be realigned over it. An intersection with a new median island, and a lane for incoming traffic turning traffic off Rt. 1 will be added. There would be a reduction of potential turning

conflicts at the intersection with this new design. This option costs about 4x as much as the Minimal option, totaling $181,000.

The Creative design includes everything that the Moderate design entails, but it also adds the Park and Ride onto a new site a few hundred feet to the left of the intersection. The Park and Ride has been improved, with full 2-way traffic support and 32 spaces (17 currently). This option costs 8x as much as the Minimal option, and 2x as much as the Moderate option, totaling $380,000.

There is no one option that is objectively better. Each has its own pros and cons. The Minimal design is the most economical, but doesn't meet all the safety standards. The Moderate design meets all the safety standards, is relatively affordable, but removes the Park and Ride. The Creative design meets the safety standards and improves the Park and Ride, but is relatively expensive compared to the other options. It is our recommendation that the client uses this data to pick the best option for them.

8.4 Rt. 32 and West Main St.

At Rt. 32 and West Main St. there are two major design options and two minor design options. The major options are named Option 1 and Option 2. Option 1 includes cutting and filling of the roadway, a sidewalk and crosswalk, and a pedestrian lighting system. Option 2 is a more economical option, keeps the road as it is, adds a sidewalk and crosswalk, and a pedestrian lighting system. The special aspect of Option 2, is that it adds a stop sign to create a 3-way stop with 1 lane that doesn't stop (coming from the East). The minor options are for the sidewalk design. Asphalt paving with asphalt curbing is the first option. Concrete paving with granite curbing is the second option. These options will be classified as 'Asphalt' and 'Concrete' from now on. Below, **Table 8.3** illustrates the key factors for the major options.

Table 8.3 -- Rt. 32 and West Main St. Key Factors for Major Options

	Cost	Meets Sightline Standard?
Option 1	$110,000	Yes
Option 2	$7,500	Yes

Option 1 alleviates the issues of the current intersection with proper road design and no added delays. Having a greater sightline decreases driver hesitation and increases decision making when at an intersection. It is relatively expensive compared to Option 2, costing about 15x as much at $110,000. Option 2 is the more economical option. Making the intersection a 3-way stop instead of a 2-way will fix the sightline issue. Turning vehicles will no longer have to check to

make sure cars aren't coming from the direction of the vertical crest, therefore the sightline no longer matters. However, adding a 3-way stop will create longer queue times. Longer queue times are bad for a couple of reasons: drivers dislike them, and traffic can back up. If the budget allows, our group recommends Option 1, as it makes the road more safe and efficient, while Option 2 makes the road safe but less efficient.

For the minor sidewalk options it will mainly come down to preference and aesthetic choice. The total cost of the Asphalt sidewalk is $32,500. The total cost of the Concrete sidewalk is $50,000. When considering which sidewalk design to choose, it is important to think about the long term effects. Concrete sidewalks are built for longevity, which is why sidewalks are usually made of concrete. While Asphalt sidewalks are initially cheaper, they require maintenance and repairs more frequently. The long term economical choice would be a Concrete sidewalk. The short term economical choice would be an Asphalt sidewalk. Another reason Concrete may be superior to Asphalt is the aesthetics. Concrete with granite curbing is aesthetically pleasing compared to asphalt pavement and curbing. Because of these factors, our group recommends using Concrete with granite curbing as the sidewalk design.

9 Drainage

9.1 Introduction

Our drainage plan is limited in scope. We initially did not intend to design drainage, but at the request of the Client, we designed a basic road grading system. Since we do not have access to the water utility plans, we were unable to design sophisticated drainage systems.

9.2 Drainage Discussion And Recommendations

Appendix 9.A and 9.B give an overview of the drainage system for the intersection of Rt. 1/West Main St. and the Park and Ride respectively. **Appendices 9.C, 9.D, 9.E** show the general road profile views of each intersection. Roadway and sidewalk grades are all set to 2%, with shoulders being 4%. These values are within MDOT recommended standards. Our recommendation is that actual drainage systems be set up with the intersection of Rt. 32/West Main St. in accordance with the existing water utility's. All other drainage systems should be efficient.

10 Conclusion

In conclusion, we have presented a series of designs for all three intersections. These designs are all solutions to each intersection's problems, but have varying levels of cost and quality. While we have recommended certain designs over others in Section 8, we recommend that our client selects the design options that best fit their scope, schedule, and budget.

11 Disclaimer

The materials contained in this document and any supporting documentation were developed by us as students as part of our education in the College of Engineering in order to gain supervised engineering problem-solving experience. Therefore, information and recommendations, while useful for understanding a particular project's scope and possibilities for implementing solutions, should not be relied upon solely for the purposes of advancing a project beyond conceptual levels.

Furthermore, such material should not substitute for or replace the services of a design professional practicing in the areas of engineering or architecture, particularly for projects whose direct or indirect impact may affect the safety, health, or welfare of the public.

We students who prepared this information look forward to the opportunity to serve with fidelity the public, our future employers, and clients. In providing you with this information, our intention is to uphold and enhance the honor, integrity, and dignity of the engineering profession. We thank you for the opportunity to develop our skills through our work on this project.

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Stormwater Management Law, Maine Department of Environmental Protection, Jan. 2019, www.maine.gov/dep/land/stormwater/swapp1.pdf .

Structural Pavement Design Guidance, Maine DOT , 2019, file:///Users/seangeary/Downloads/DG%20-%20Structural%20Pavement%20Design.pdf.

Traffic Engineering, MaineDOT, www.maine.gov/mdot/traffic/index.shtml#permits.

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"Waldoboro, ME Property Tax Maps." *Waldoboro, ME Property Tax Maps* , Town of Waldoboro, 2020, www.waldoboromaine.org/departments/assessing/property_tax_maps.php#outer-15.

"What Is Dig Safe® ?" *Dig Safe System, Inc.* , www.digsafe.com/.

Appendix 1
Safety and Level of Service for Current Intersections

Rt 1 and Main St.
Count done in 2019

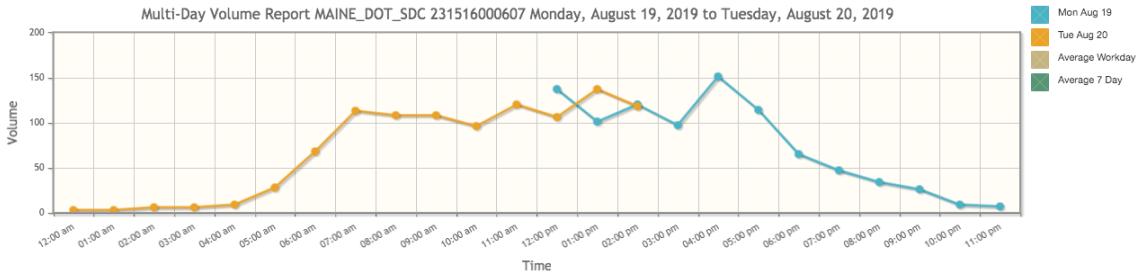
Rt 1 east of Main St:
AADT 10,320

Rt 1 west of Main St:
AADT 11,250

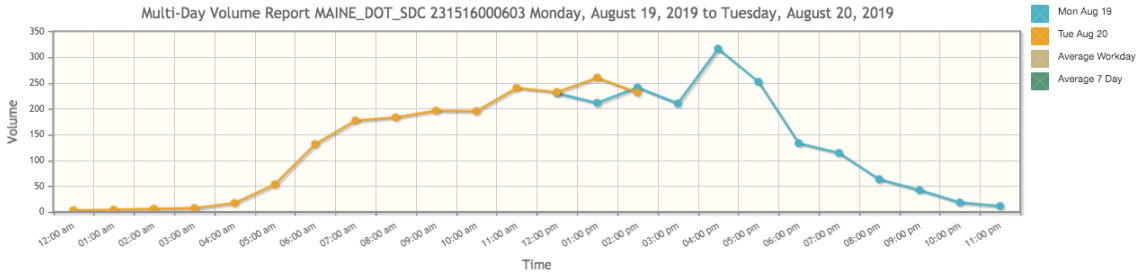
Main St. south of Rt 1:
AADT 1340
580 north bound (towards rt 1) turning from minor road to major road
831 south bound (away from rt 1) turning from major road to minor road

Main St. and Rt 32:
Count done Monday, Tuesday August 19, 20th 2019

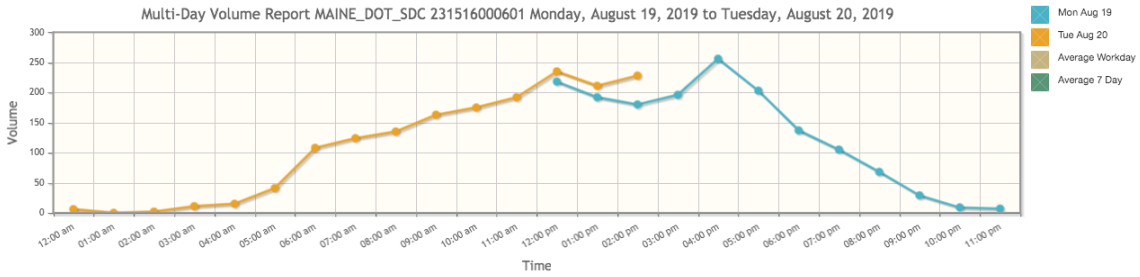
Main St. west of Rt 32
AADT 1340
11 AM peak: 120
4 PM peak: 151



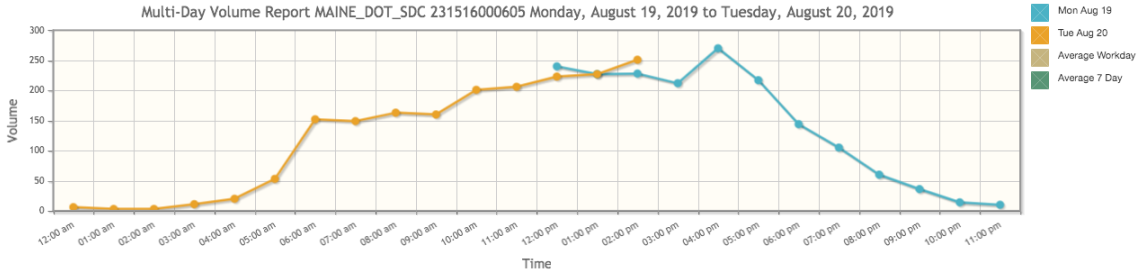
Main St. east of Rt 32
AADT 2610
11 AM peak: 240
4 PM peak: 316



Rt 32 north of Main St.
AADT 2220
11 AM peak: 192
4 PM peak: 256

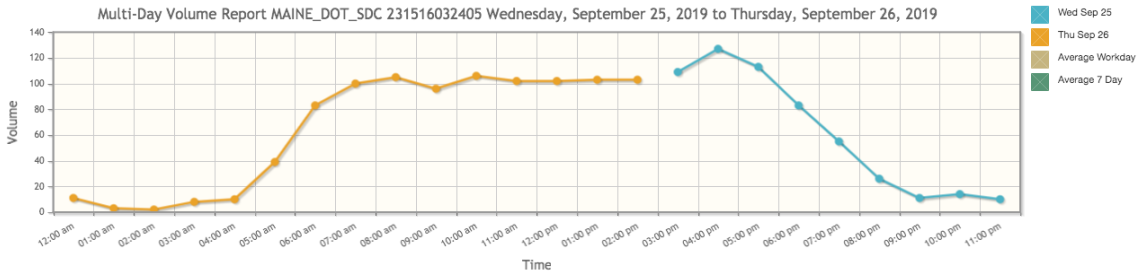


Rt 32 south of Main St.
AADT 2460
11 AM peak: 206
4 PM peak: 270

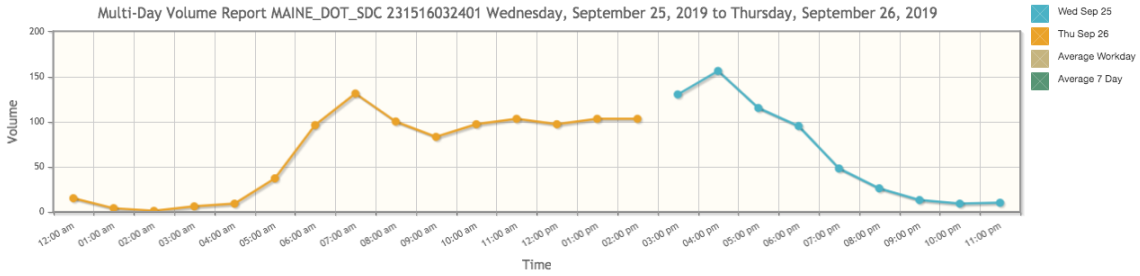


Washington Rd. and Old Augusta Rd.
Count done Wednesday, Thursday September 25, 26th 2019

Washington Rd. south of Augusta Rd.
AADT 1350
10 AM peak: 106
4 PM peak: 127

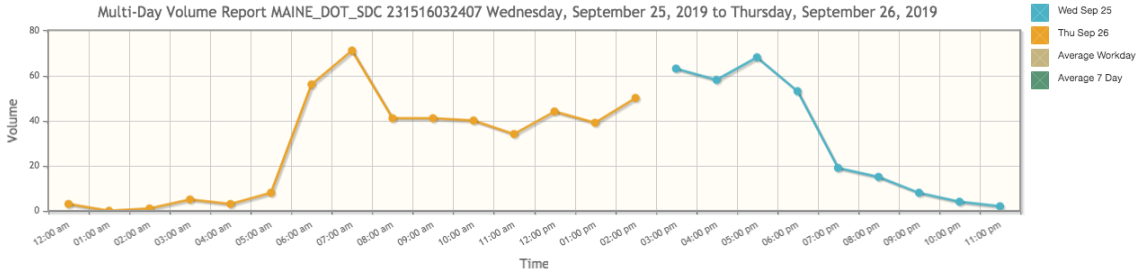


Washington Rd. north of Augusta Rd.
AADT 1410
7AM peak: 131
4PM peak: 156

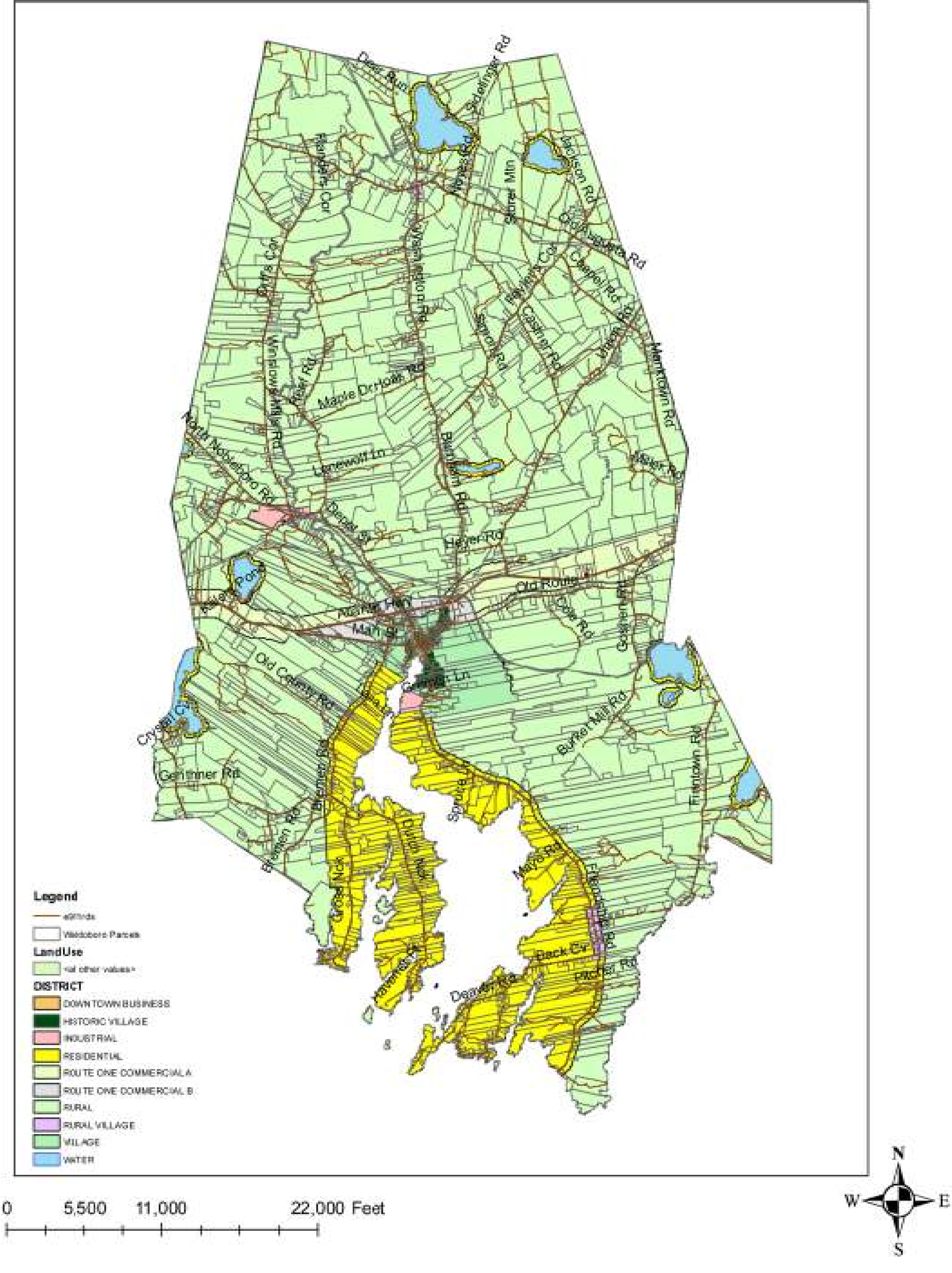


Augusta Rd. east of Washington Rd.
AADT 640
7 AM peak: 107
5 PM peak: 103

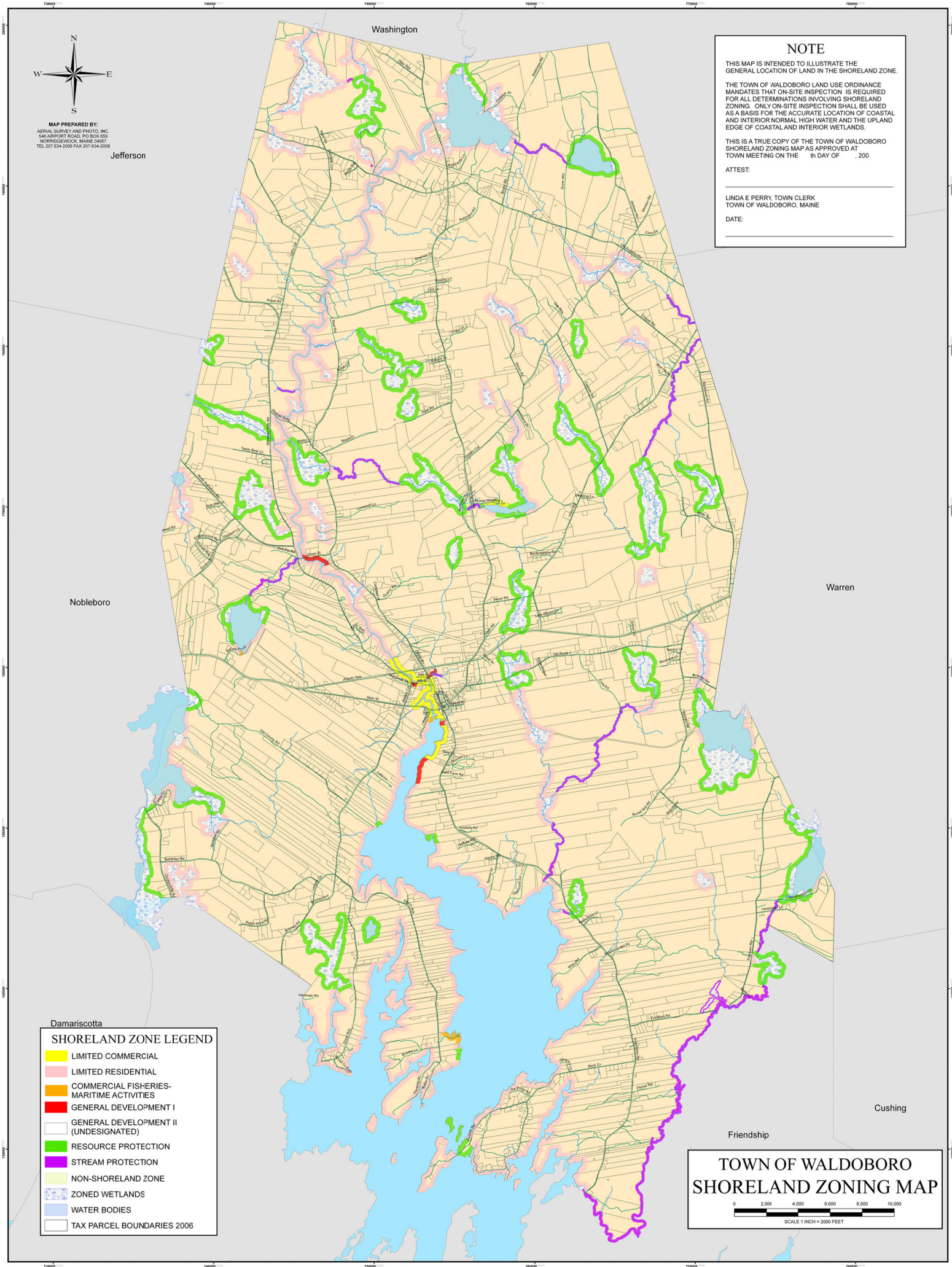
Augusta Rd. west of Washington Rd.
AADT 910
7 AM peak: 71
5 PM peak: 68



Appendix 2
Permitting, Ordinances, and Property Lines

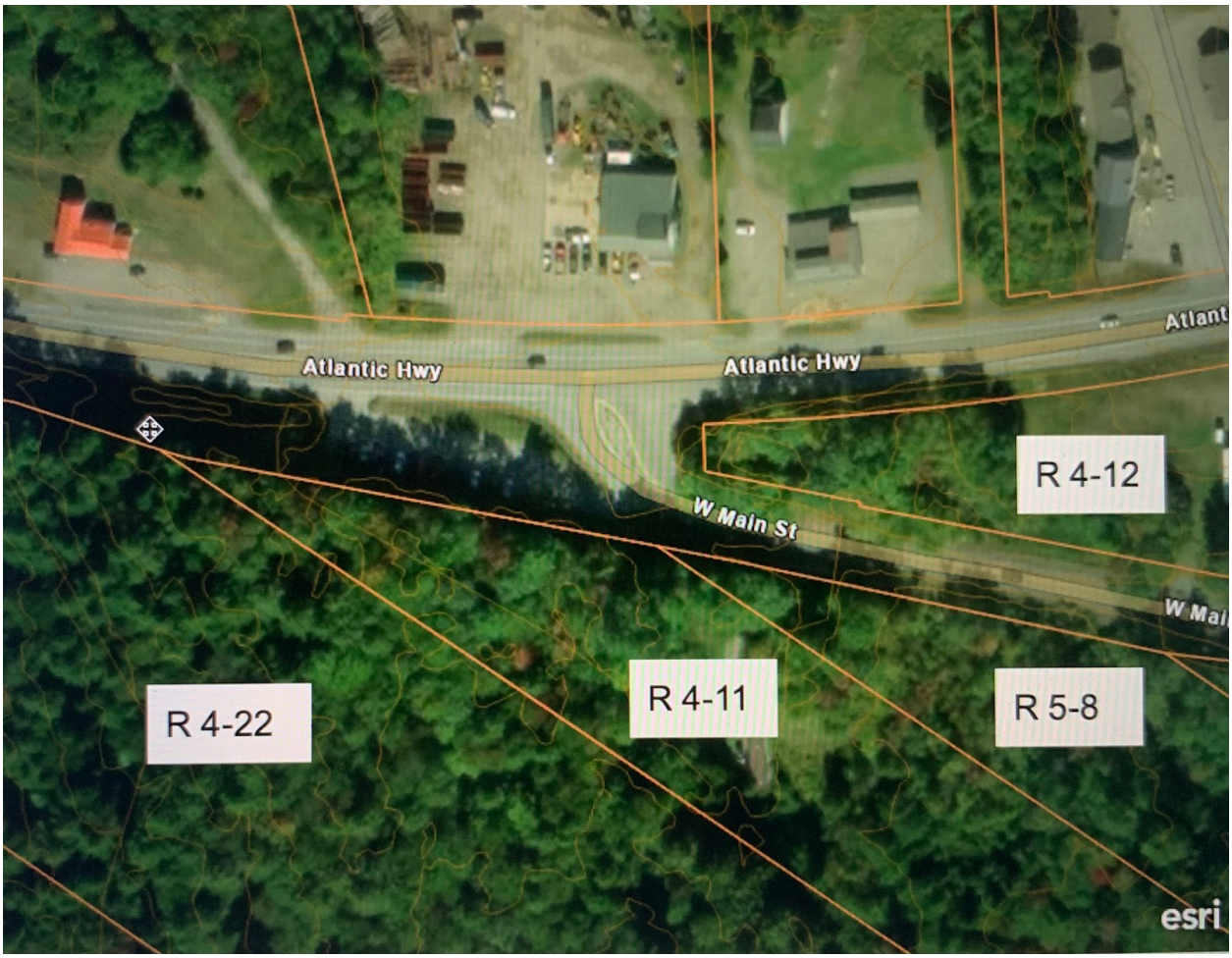


Legend
e911rds
Waldoboro Parcels
LandUse
<all other values>
DISTRICT
DOWNTOWN BUSINESS
HISTORIC VILLAGE
INDUSTRIAL
RESIDENTIAL
ROUTE ONE COMMERCIAL A
ROUTE ONE COMMERCIAL B
RURAL
RURAL VILLAGE
VILLAGE
WATER
0
5,500
11,000
22,000 Feet
N
S
E
W
Winslows Mills Rd
Maple Dr
Old Route
Main St
Old County Rd
Genthner Rd
Depot St
Heyer Rd
Butter Mill Rd
Friendly Rd
Mayo Rd
Back Cv
Pitcher Rd
Dutch Nck
Gross Nck
Mank Rd
Medomak Rd
Tannery Ln
Linewall Ln
Kaler Rd
North Nobleboro Rd
Crystal Cv
Jackson Rd
Chapel Rd
Spruce Rd
Flanders Rd
Burnham Rd
Bremen Rd
Manktown Rd
Finntown Rd


Washington
Jefferson
Nobleboro
Warren
Damariscotta
Cushing
Friendship
N
W
E
S
MAP PREPARED BY:
AERIAL SURVEY AND PHOTO, INC.
546 AIRPORT ROAD, PO BOX 659
NORRIDGEWOCK, MAINE 04957
TEL 207 634-2006 FAX 207-634-2008
NOTE
THIS MAP IS INTENDED TO ILLUSTRATE THE GENERAL LOCATION OF LAND IN THE SHORELAND ZONE.
THE TOWN OF WALDOBORO LAND USE ORDINANCE MANDATES THAT ON-SITE INSPECTION IS REQUIRED FOR ALL DETERMINATIONS INVOLVING SHORELAND ZONING. ONLY ON-SITE INSPECTION SHALL BE USED AS A BASIS FOR THE ACCURATE LOCATION OF COASTAL AND INTERIOR NORMAL HIGH WATER AND THE UPLAND EDGE OF COASTAL AND INTERIOR WETLANDS.
THIS IS A TRUE COPY OF THE TOWN OF WALDOBORO SHORELAND ZONING MAP AS APPROVED AT TOWN MEETING ON THE th DAY OF , 200
ATTEST:
LINDA E PERRY, TOWN CLERK
TOWN OF WALDOBORO, MAINE
DATE:
SHORELAND ZONE LEGEND
LIMITED COMMERCIAL
LIMITED RESIDENTIAL
COMMERCIAL FISHERIES-MARITIME ACTIVITIES
GENERAL DEVELOPMENT I
GENERAL DEVELOPMENT II (UNDESIGNATED)
RESOURCE PROTECTION
STREAM PROTECTION
NON-SHORELAND ZONE
ZONED WETLANDS
WATER BODIES
TAX PARCEL BOUNDARIES 2006
TOWN OF WALDOBORO
SHORELAND ZONING MAP
0 2,000 4,000 6,000 8,000 10,000
SCALE 1 INCH = 2000 FEET

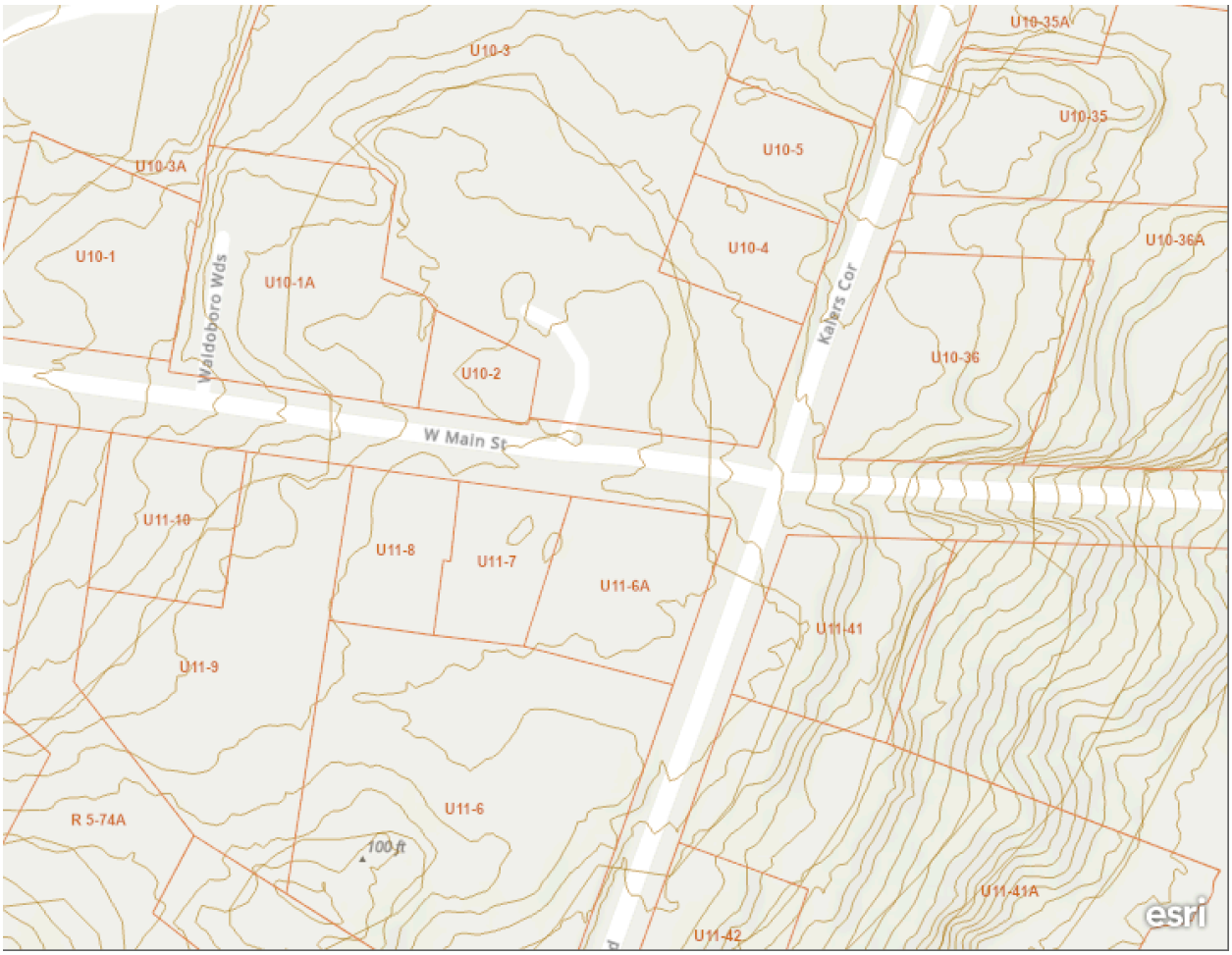
Appendix 2.C
Intersection Property Line Maps

Rt. 1 and W. Main St

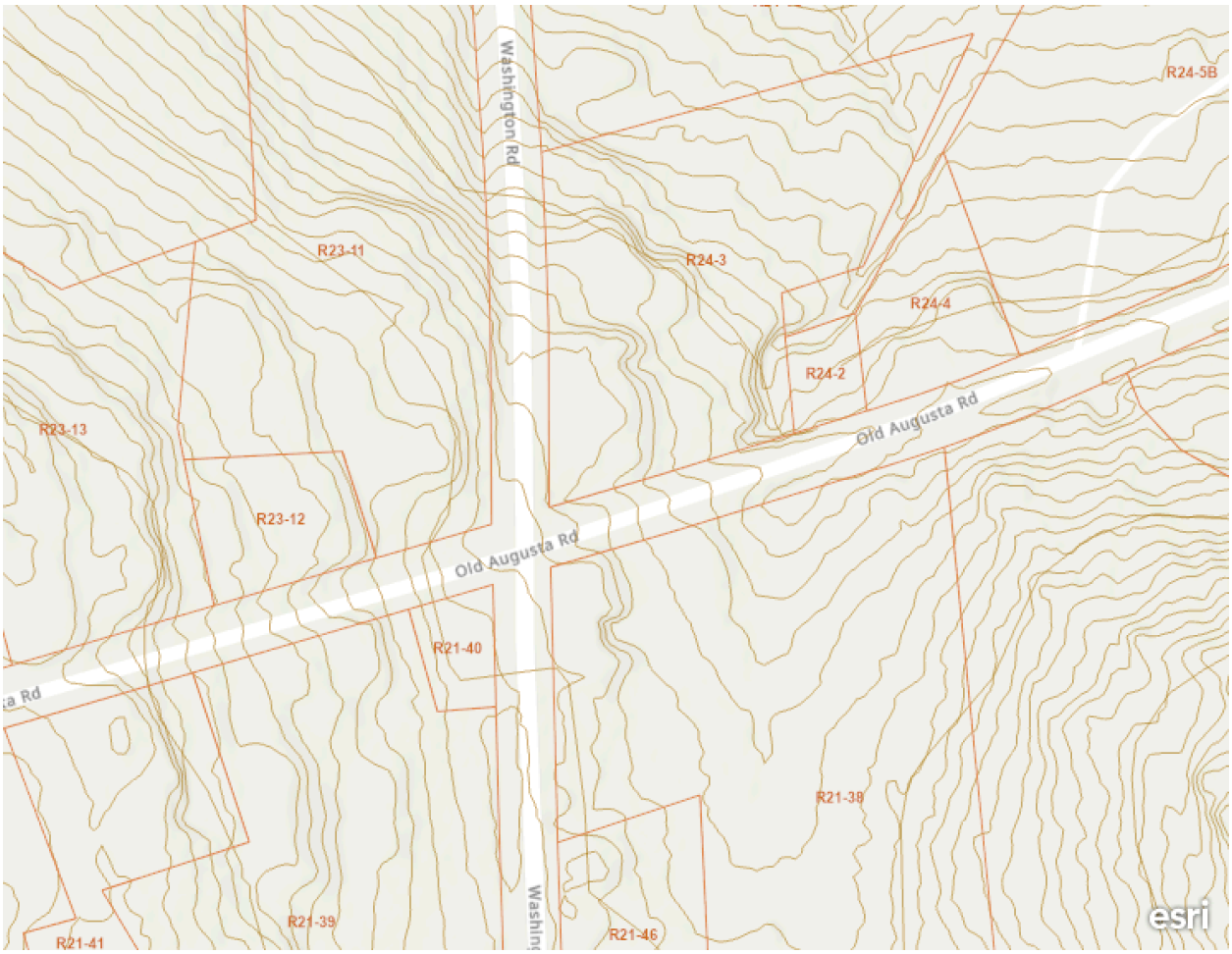



R 4-20
R 4-18
R 4-17
1
1
R 4-12
W Main St
R 4-11
R 5-8
R 4-22
R 5-8
esri

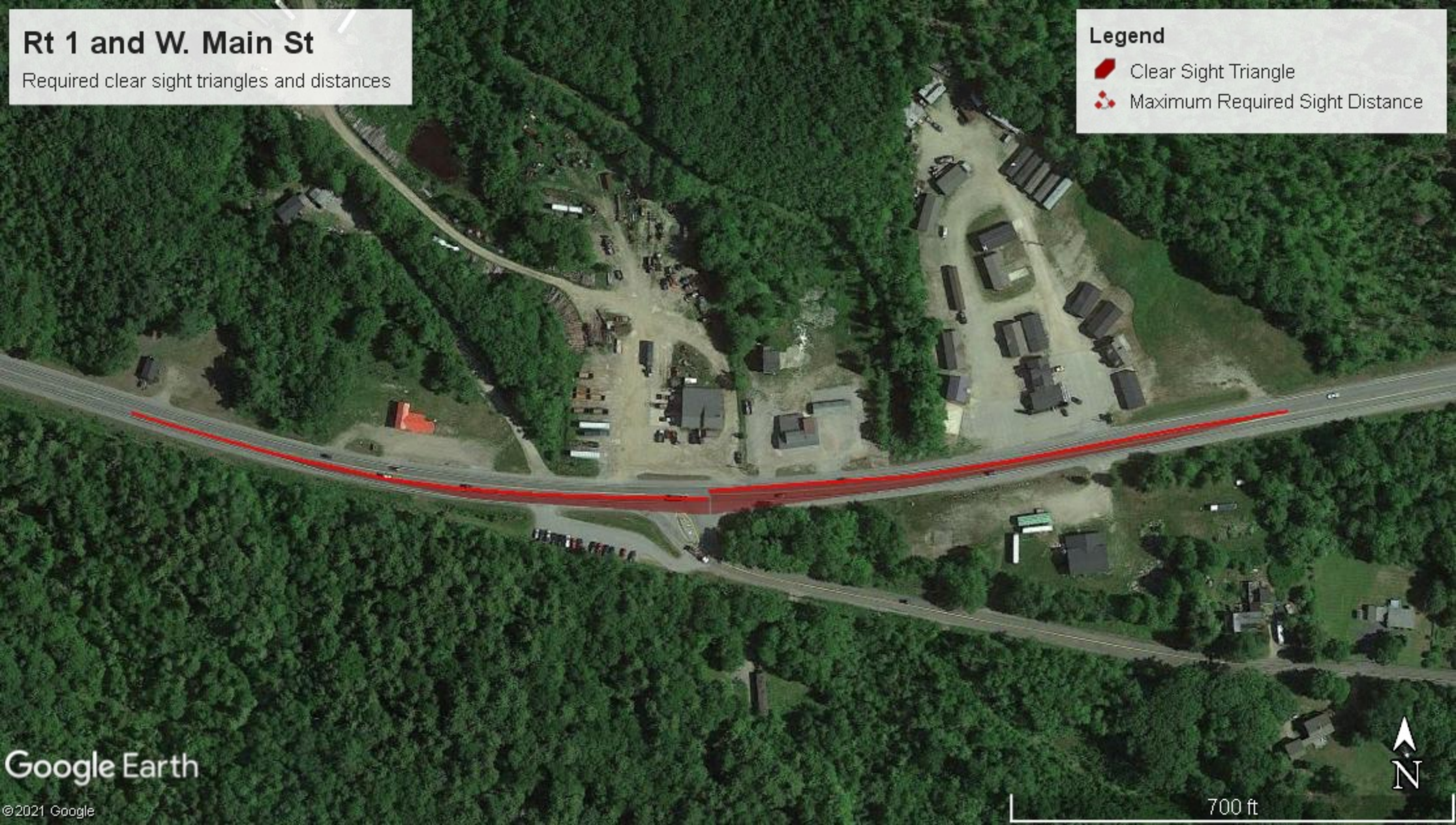
W. Main St. and Rt. 32

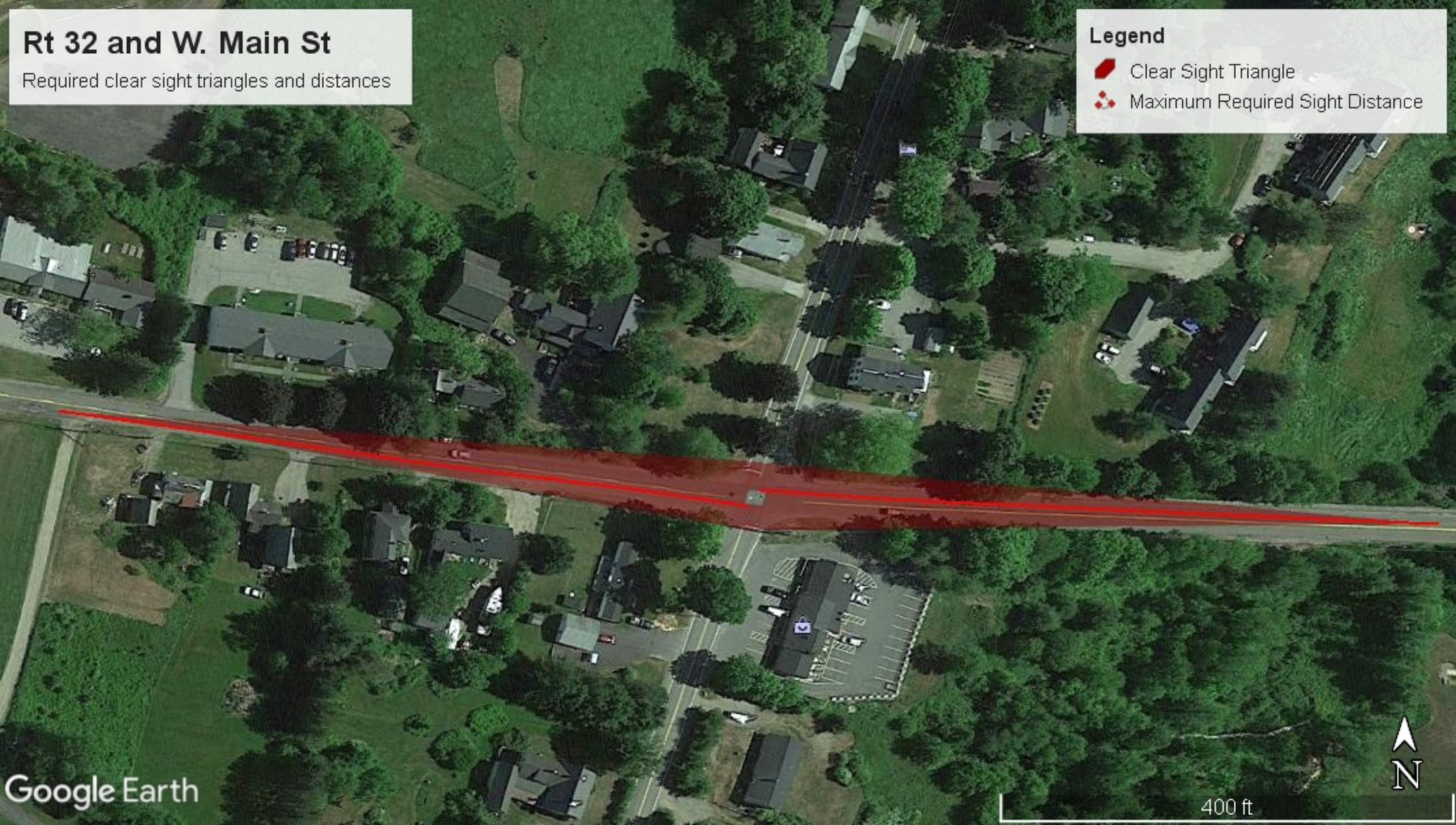

U10-3
U10-35A
U10-35
U10-3A
U10-5
U10-1
U10-4
U10-36A
Waldoboro Wds
U10-1A
Kalers Cor
U10-36
U10-2
W Main St
U11-10
U11-8
U11-7
U11-6A
U11-41
U11-9
U11-6
R 5-74A
100 ft
U11-41A
U11-42
esri

Washington Rd. and Old Augusta Rd.


Washington Rd
R24-5B
R23-11
R24-3
R24-4
R24-2
Old Augusta Rd
R23-13
R23-12
Old Augusta Rd
R21-40
R21-38
R21-39
R21-41
R21-46
esri

Appendix 3
Sightline Fixes


Rt 1 and W. Main St
Required clear sight triangles and distances
Legend
Clear Sight Triangle
Maximum Required Sight Distance
Google Earth
©2021 Google
N
700 ft

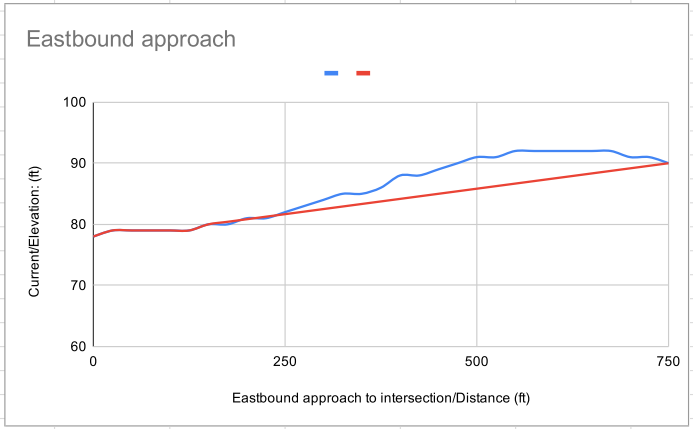

Rt 32 and W. Main St
Required clear sight triangles and distances
Legend
Clear Sight Triangle
Maximum Required Sight Distance
Google Earth
400 ft
N


Washington Rd and Old Augusta Rd
Required clear sight triangles and distances
Legend
Clear Sight Triangle
Maximum Required Sight Distance
Google Earth
©2021 Google
500 ft
N

Rt 32 and W. Main St				
Speed Limit	Design Vehicle	Time Gap for design vehicle	Necessary Sight Distance	1.47*V*tgap
35	Passenger Car	7.5	386	
	Single Unit Truck	9.5	489	
	Combination Truck	11.5	592	
Old Augusta Rd and Washington Rd.				
Speed Limit	Design Vehicle	Time Gap for design vehicle	Necessary Sight Distance	
45	Passenger Car	7.5	496	
	Single Unit Truck	9.5	628	
	Combination Truck	11.5	761	
Rt. 1 and W. Main St.				
Speed Limit	Design Vehicle	Time Gap for design vehicle	Necessary Sight Distance	
55	Passenger Car	7.5		
	Single Unit Truck	9.5	768	
	Combination Truck	11.5	930	

Rt. 32 and West Main St.

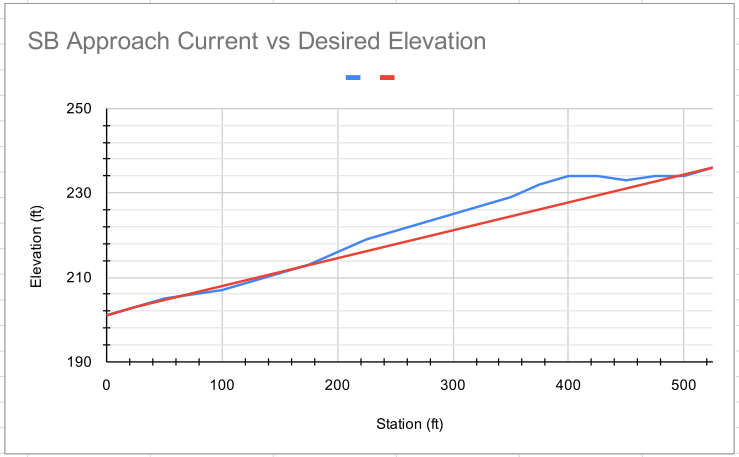
Eastbound approach to intersection					Westbound approach to intersection			
		Current	Desired	Rounded			Current	Desired
Station: (ft)	Distance (ft)	Elevation: (ft)	Elevation: (ft)	Elevation: (ft)	Station: (ft)	Distance (ft)	Elevation: (ft)	Elevation: (ft)
00+00	0	78	78	78	07+50	0	89	**No Change Necessary**
00+25	25	79	79	79	07+75	25	88	
00+50	50	79	79	79	08+00	50	87	
00+75	75	79	79	79	08+25	75	84	
01+00	100	79	79	79	08+50	100	82	
01+25	125	79	79	79	08+75	125	80	
01+50	150	80	80	80	09+00	150	78	
01+75	175	80	80.4166	80.5	09+25	175	75	
02+00	200	81	80.8332	81	09+50	200	73	
02+25	225	81	81.2498	81.5	09+75	225	70	
02+50	250	82	81.6664	82	10+00	250	67	
02+75	275	83	82.083	82	10+25	275	65	
03+00	300	84	82.4996	82.5	10+50	300	63	
03+25	325	85	82.9162	83	10+75	325	60	
03+50	350	85	83.3328	83.5	11+00	350	58	
03+75	375	86	83.7494	84	11+25	375	55	
04+00	400	88	84.166	84	11+50	400	53	
04+25	425	88	84.5826	84.5	11+75	425	50	
04+50	450	89	84.9992	85	12+00	450	48	
04+75	475	90	85.4158	85.5	12+25	475	46	
05+00	500	91	85.8324	86	12+50	500	45	
05+25	525	91	86.249	86.5	12+75	525	43	
05+50	550	92	86.6656	87	13+00	550	42	
05+75	575	92	87.0822	87	13+25	575	41	
06+00	600	92	87.4988	87.5	13+50	600	41	
06+25	625	92	87.9154	88	13+75	625	40	
06+50	650	92	88.332	88.5	14+00	650	40	
06+75	675	92	88.7486	89	14+25	675	40	
07+00	700	91	89.1652	89.5	14+50	700	41	
07+25	725	91	89.5818	89.5	14+75	725	41	
07+50	750	90	90	90	15+00	750	42	
					15+25	775	43	
					15+50	800	44	
					15+75	825	46	
					16+00	850	47	
					16+25	875	49	
					16+50	900	50	
					16+75	925	52	
					17+00	950	53	



Old Augusta and Washington Rds.

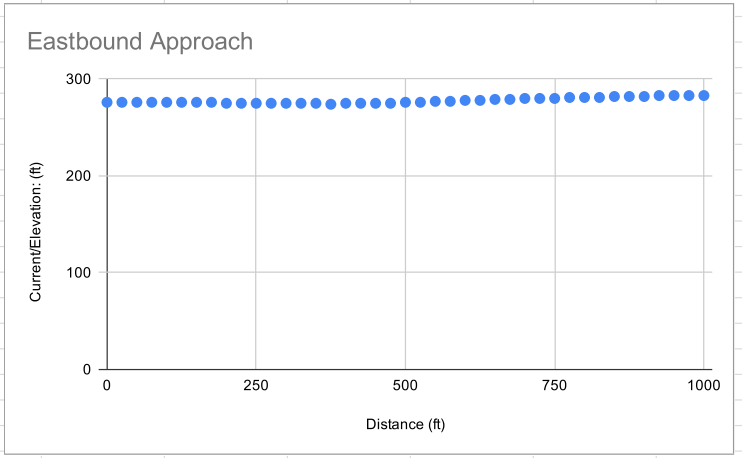
SB Approach			0.066
		Current	Desired
Station: (ft)	Distance (ft)	Elevation: (ft)	Elevation: (ft)
00+00	0	201	201
00+25	25	203	203
00+50	50	205	204.65
00+75	75	206	206.3
01+00	100	207	207.95
01+25	125	209	209.6
01+50	150	211	211.25
01+75	175	213	212.9
02+00	200	216	214.55
02+25	225	219	216.2
02+50	250	221	217.85
02+75	275	223	219.5
03+00	300	225	221.15
03+25	325	227	222.8
03+50	350	229	224.45
03+75	375	232	226.1
04+00	400	234	227.75
04+25	425	234	229.4
04+50	450	233	231.05
04+75	475	234	232.7
05+00	500	234	234.35
05+25	525	236	236

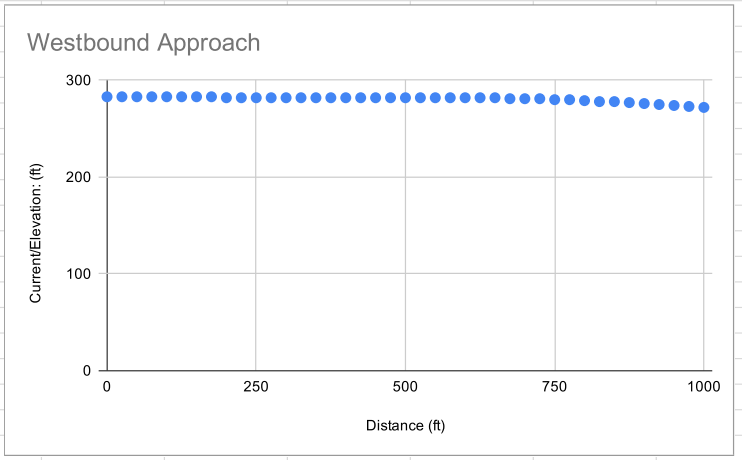
EB Approach			
		Current	Desired
Station: (ft)	Distance (ft)	Elevation: (ft)	Elevation: (ft)
00+00	0	259	**No Change Necessary**
00+25	25	259	
00+50	50	260	
00+75	75	261	
01+00	100	262	
01+25	125	263	
01+50	150	265	
01+75	175	267	
02+00	200	265	
02+25	225	262	
02+50	250	261	
02+75	275	260	
03+00	300	260	
03+25	325	259	
03+50	350	257	
03+75	375	256	
04+00	400	253	
04+25	425	250	
04+50	450	248	
04+75	475	246	
05+00	500	244	
05+25	525	242	
05+50	550	241	
05+75	575	238	
06+00	600	236	
06+25	625	236	

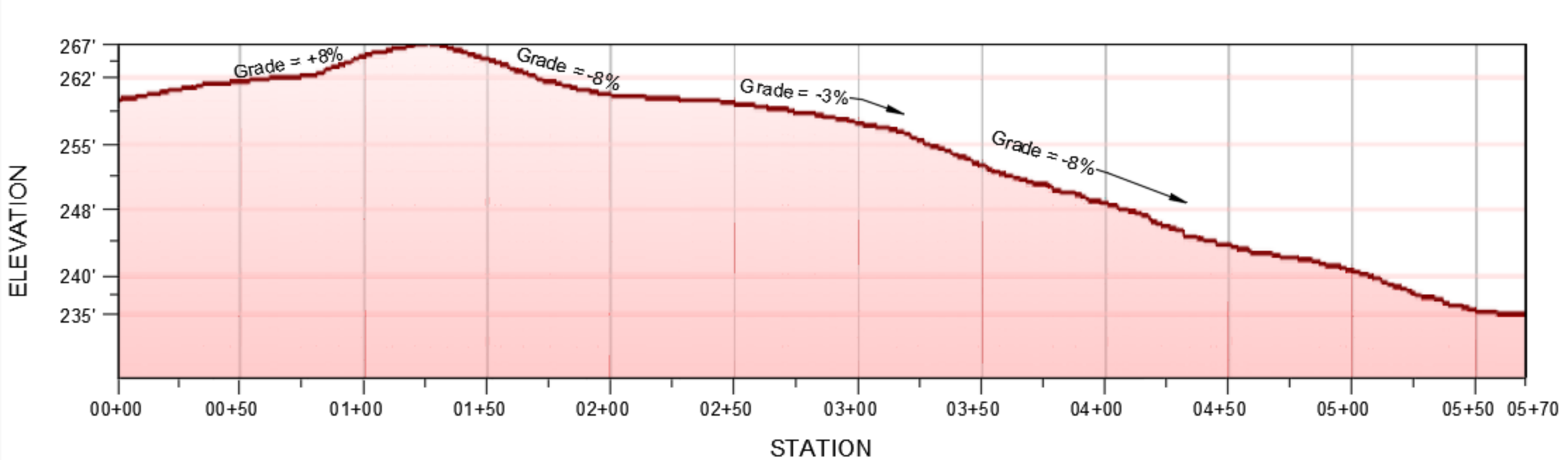


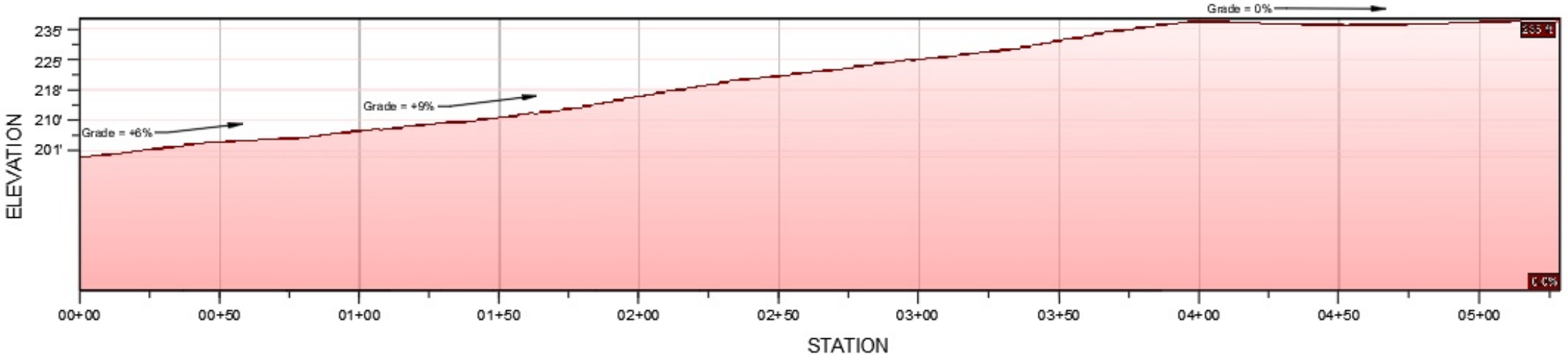
Rt.1 and West Main St.

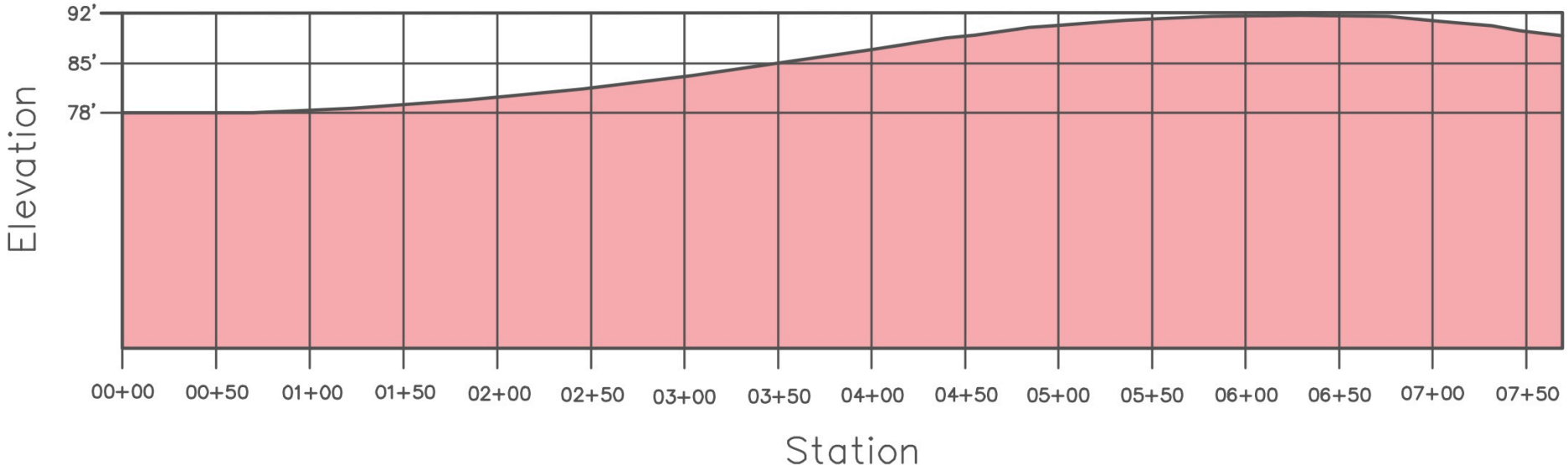
Eastbound approach to intersection				Westbound approach to intersection			
		Current	Desired			Current	Desired
Station: (ft)	Distance (ft)	Elevation: (ft)	Elevation: (ft)	Station: (ft)	Distance (ft)	Elevation: (ft)	Elevation: (ft)
00+00	0	276	**No Change Necessary**	10+00	0	283	**No Change Necessary**
00+25	25	276		10+25	25	283	
00+50	50	276		10+50	50	283	
00+75	75	276		10+75	75	283	
01+00	100	276		11+00	100	283	
01+25	125	276		11+25	125	283	
01+50	150	276		11+50	150	283	
01+75	175	276		11+75	175	283	
02+00	200	275		12+00	200	282	
02+25	225	275		12+25	225	282	
02+50	250	275		12+50	250	282	
02+75	275	275		12+75	275	282	
03+00	300	275		13+00	300	282	
03+25	325	275		13+25	325	282	
03+50	350	275		13+50	350	282	
03+75	375	274		13+75	375	282	
04+00	400	275		14+00	400	282	
04+25	425	275		14+25	425	282	
04+50	450	275		14+50	450	282	
04+75	475	275		14+75	475	282	
05+00	500	276		15+00	500	282	
05+25	525	276		15+25	525	282	
05+50	550	277		15+50	550	282	
05+75	575	277		15+75	575	282	
06+00	600	278		16+00	600	282	
06+25	625	278		16+25	625	282	
06+50	650	279		16+50	650	282	
06+75	675	279		16+75	675	281	
07+00	700	280		17+00	700	281	
07+25	725	280		17+25	725	281	
07+50	750	280		17+50	750	280	
07+75	775	281		17+75	775	280	
08+00	800	281		18+00	800	279	
08+25	825	281		18+25	825	278	
08+50	850	282		18+50	850	278	
08+75	875	282		18+75	875	277	
09+00	900	282		19+00	900	276	
09+25	925	283		19+25	925	275	
09+50	950	283		19+50	950	274	
09+75	975	283		19+75	975	273	
10+00	1000	283		20+00	1000	272	

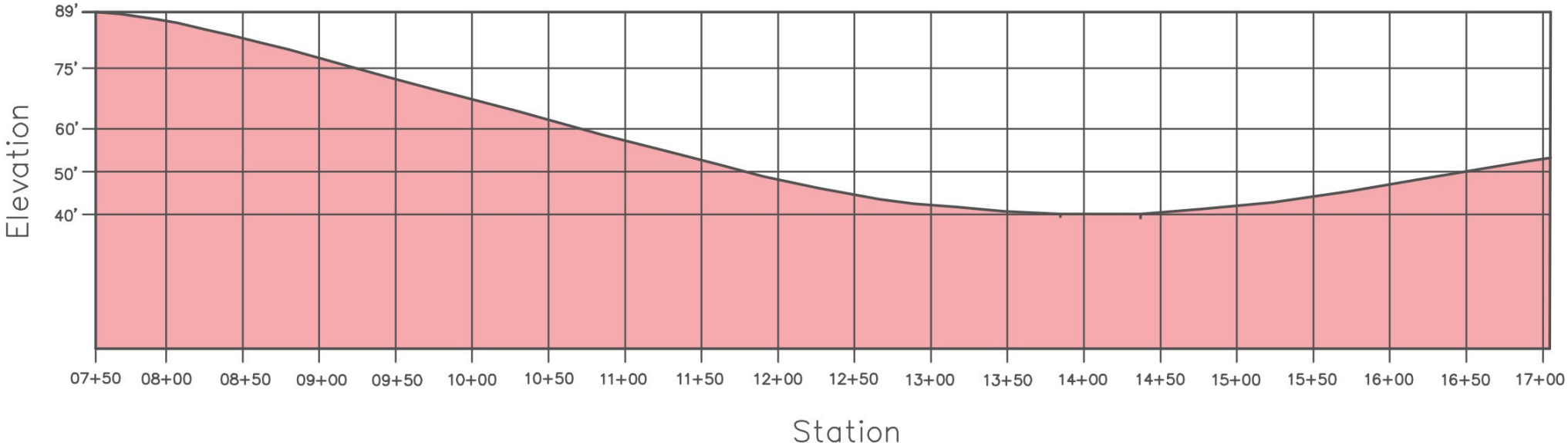




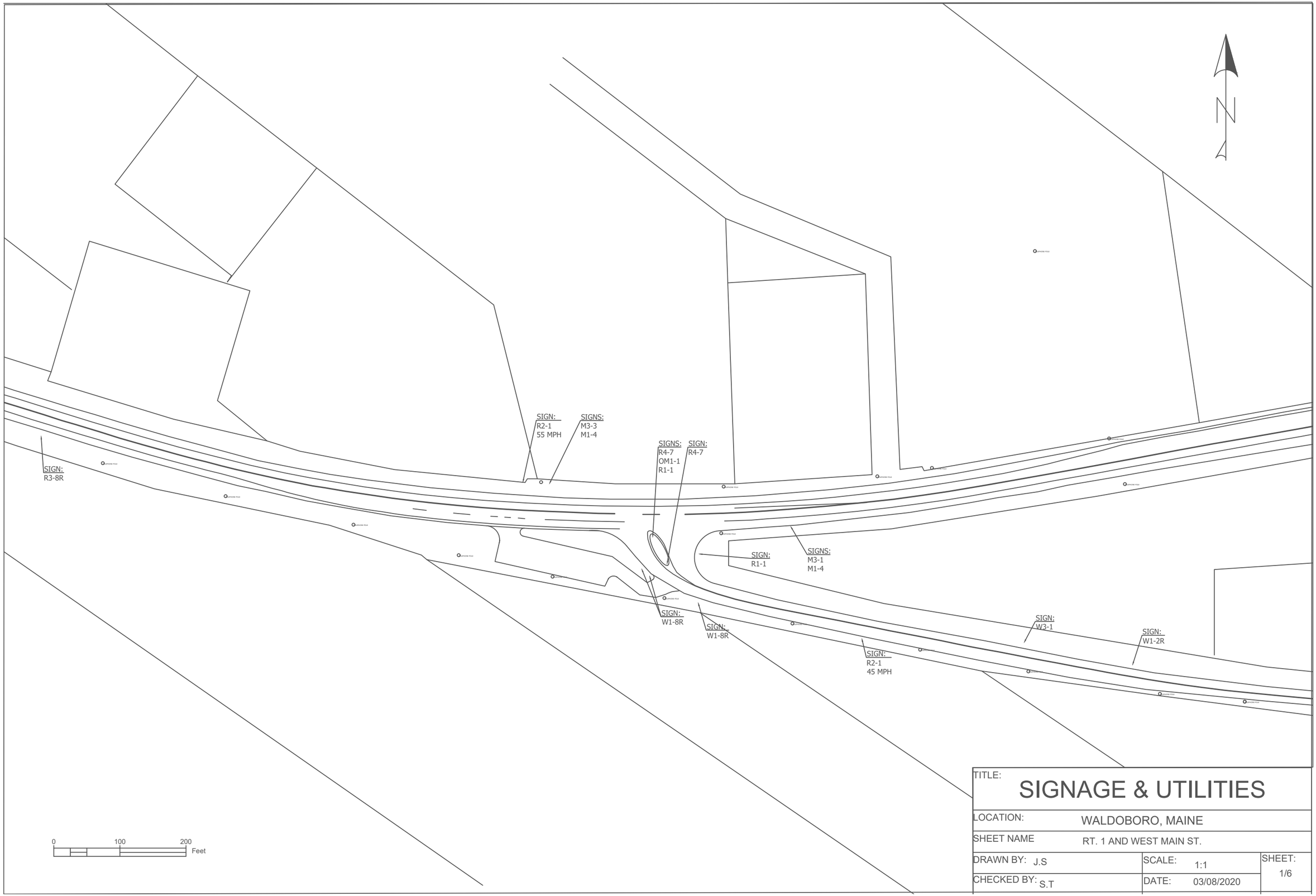

267'
262'
255'
248'
240'
235'
ELEVATION
Grade = +8%
Grade = -8%
Grade = -3%
Grade = -8%
00+00
00+50
01+00
01+50
02+00
02+50
03+00
03+50
04+00
04+50
05+00
05+50
05+70
STATION


Grade = 0%
235'
225'
218'
210'
201'
ELEVATION
Grade = +6%
Grade = +9%
235'4
0 C%
00+00
00+50
01+00
01+50
02+00
02+50
03+00
03+50
04+00
04+50
05+00
STATION


92'
85'
78'
Elevation
00+00
00+50
01+00
01+50
02+00
02+50
03+00
03+50
04+00
04+50
05+00
05+50
06+00
06+50
07+00
07+50
Station


89'
75'
60'
50'
40'
Elevation
07+50
08+00
08+50
09+00
09+50
10+00
10+50
11+00
11+50
12+00
12+50
13+00
13+50
14+00
14+50
15+00
15+50
16+00
16+50
17+00
Station

Appendix 4
Intersection Rt. 1 and West Main St. Designs



TITLE:	SIGNAGE & UTILITIES		
LOCATION:	WALDOBORO, MAINE		
SHEET NAME	RT. 1 AND WEST MAIN ST.		
DRAWN BY: J.S		SCALE: 1:1	SHEET: 1/6
CHECKED BY: S.T		DATE: 03/08/2020	

N

SIGN:
R3-8A
(S-R)

SIGN:
Custom

SIGN:
R2-1
55 MPH

SIGNS:
M3-3
M1-4

SIGNS:
R4-7
OM1-1
R1-1

SIGN:
R4-7

SIGN:
R1-1

SIGN:
R1-1

SIGNS:
M3-1
M1-4

SIGN:
W1-8R

SIGN:
W1-8R

SIGN:
R2-1
45 MPH

SIGN:
W3-1

SIGN:
W1-2R

0 100 200 Feet

TITLE:	MINIMAL DESIGN		
LOCATION:	WALDOBORO, MAINE		
SHEET NAME	RT. 1 AND WEST MAIN ST.		
DRAWN BY: J.S , S.G		SCALE: 1:30	SHEET: 3/6
CHECKED BY: S.T		DATE: 03/07/2020	

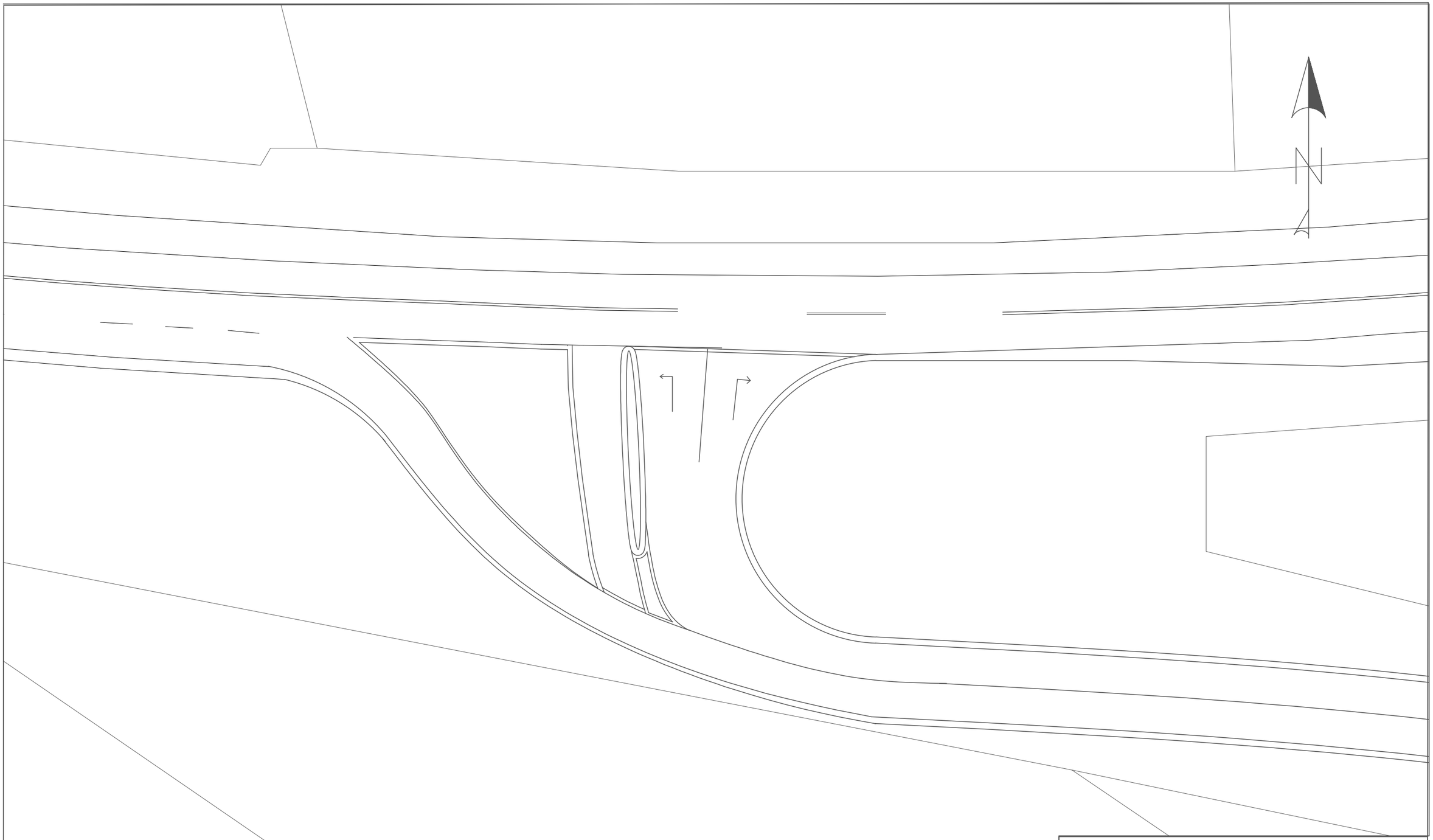
0 100 200 Feet

TITLE: MINIMAL DESIGN		
LOCATION: WALDOBORO, MAINE		
SHEET NAME: RT. 1 AND WEST MAIN ST.		
DRAWN BY: J.S , S.G	SCALE: 1:30	SHEET: 3/6
CHECKED BY: S.T	DATE: 03/07/2020	

N

0 100 200 Feet

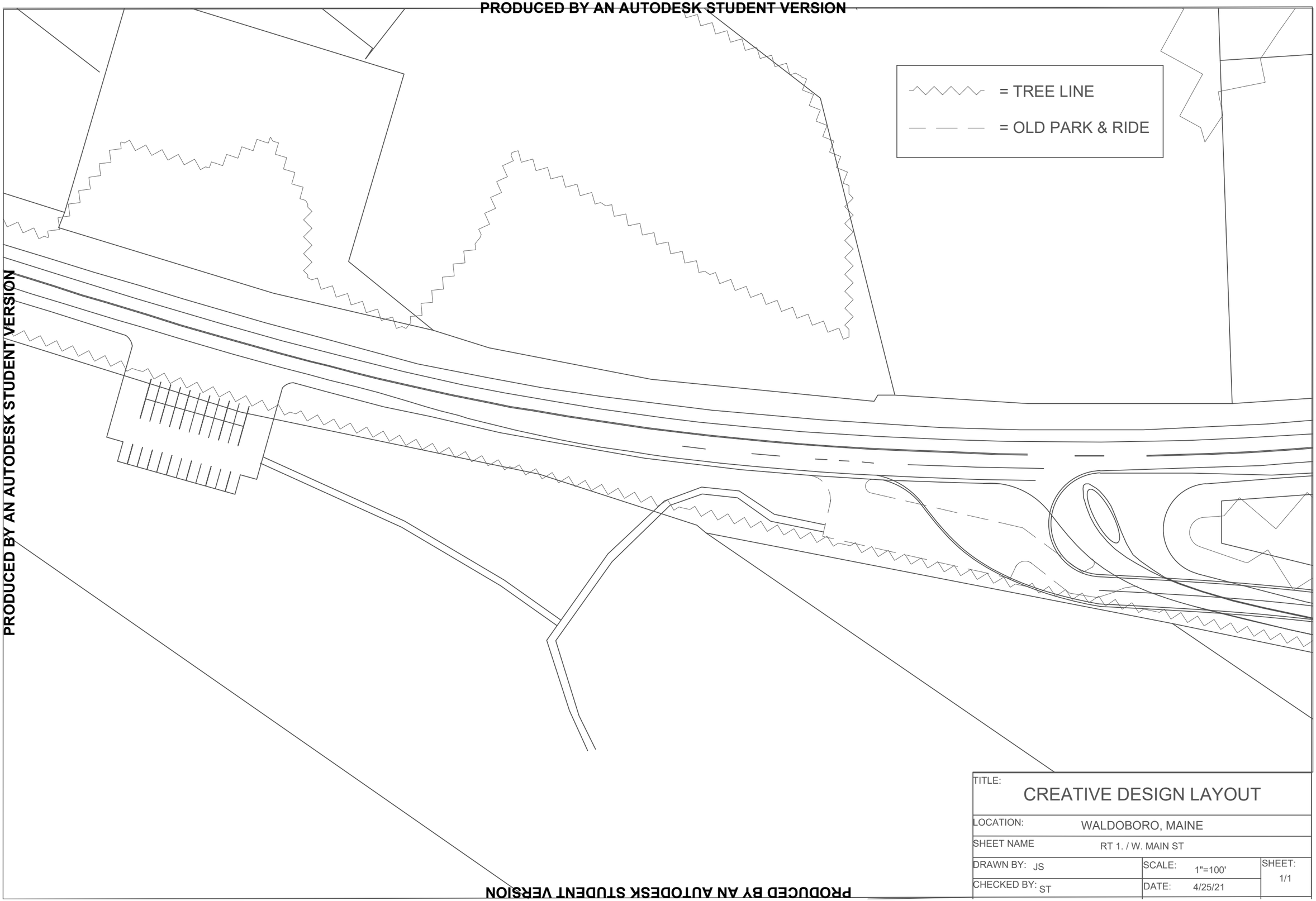
TITLE: MODERATE DESIGN		
LOCATION: WALDOBORO, MAINE		
SHEET NAME RT. 1 AND WEST MAIN ST.		
DRAWN BY: S.G.	SCALE: 1:1	SHEET: 4/6
CHECKED BY: S.T.	DATE: 02/10/18	



0 100 200 Feet

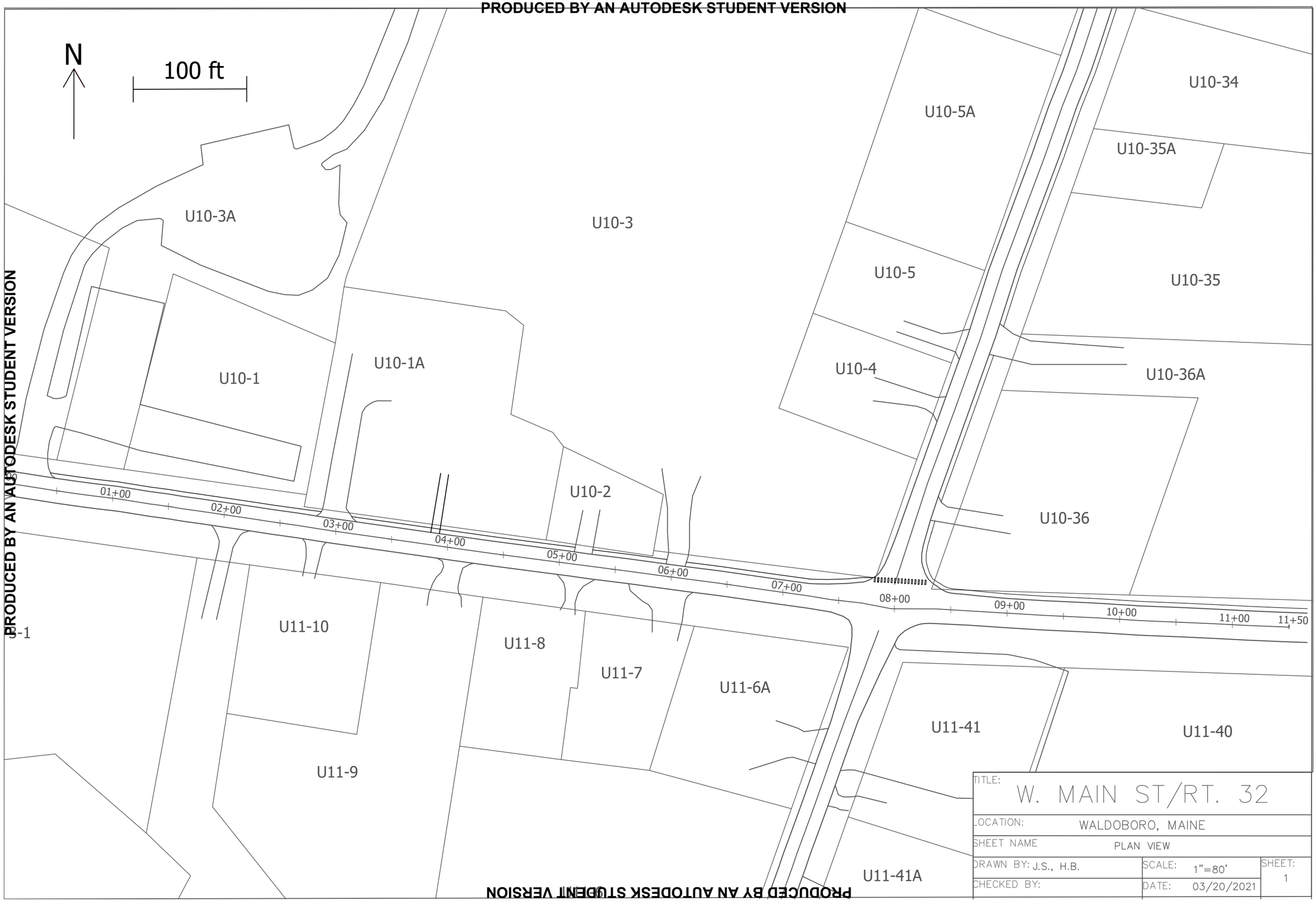
TITLE: MODERATE DESIGN		
LOCATION: WALDOBORO, MAINE		
SHEET NAME: RT. 1 AND WEST MAIN ST.		
DRAWN BY: S.G.	SCALE: 1:1	SHEET: 4/6
CHECKED BY: S.T.	DATE: 02/10/18	

TITLE:	PARKING LOT	
LOCATION:	WALDOBORO, MAINE	
SHEET NAME	RT. 1 AND WEST MAIN ST.	
DRAWN BY: J.S.	SCALE: 1:20	SHEET: 6/6
CHECKED BY: S.T.	DATE: 04/10/21	

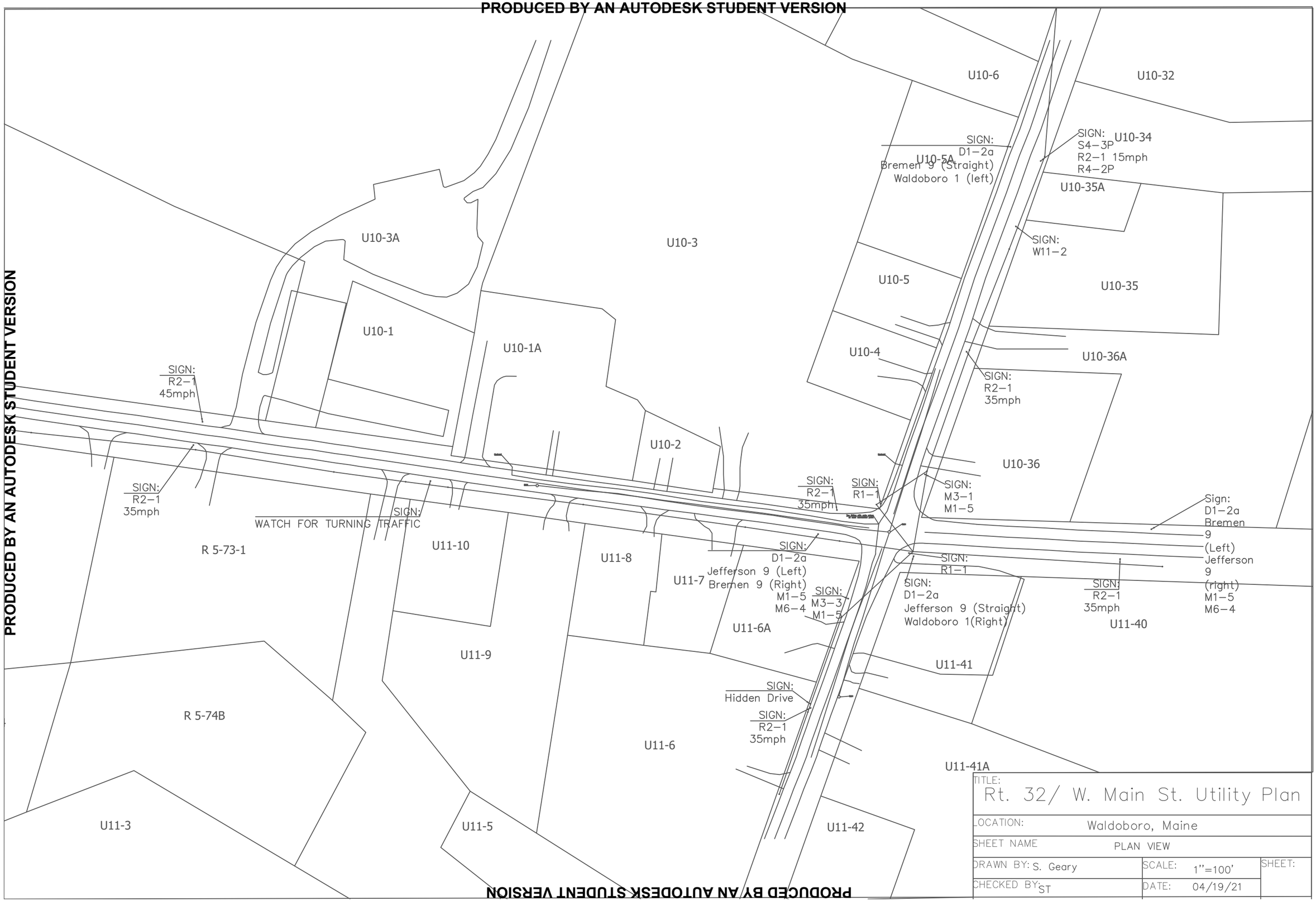


TITLE: CREATIVE DESIGN LAYOUT		
LOCATION: WALDOBORO, MAINE		
SHEET NAME: RT 1. / W. MAIN ST		
DRAWN BY: JS	SCALE: 1"=100'	SHEET: 1/1
CHECKED BY: ST	DATE: 4/25/21	

Appendix 5
Intersection Rt. 32 and West Main St. Designs

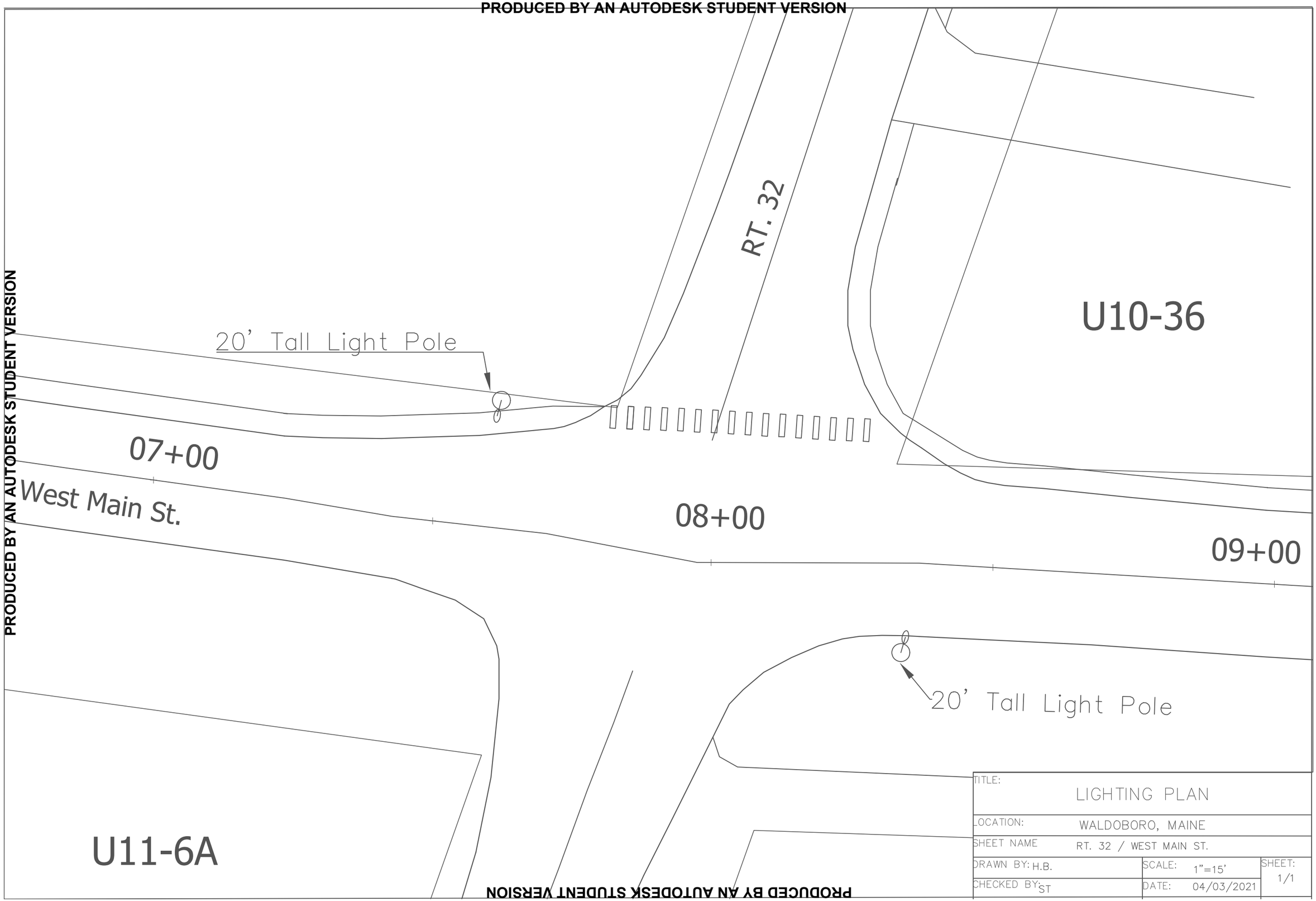


TITLE:	W. MAIN ST/RT. 32		
LOCATION:	WALDOBORO, MAINE		
SHEET NAME	PLAN VIEW		
DRAWN BY: J.S., H.B.		SCALE: 1"=80'	SHEET: 1
CHECKED BY:		DATE: 03/20/2021	



TITLE: Rt. 32/ W. Main St. Utility Plan

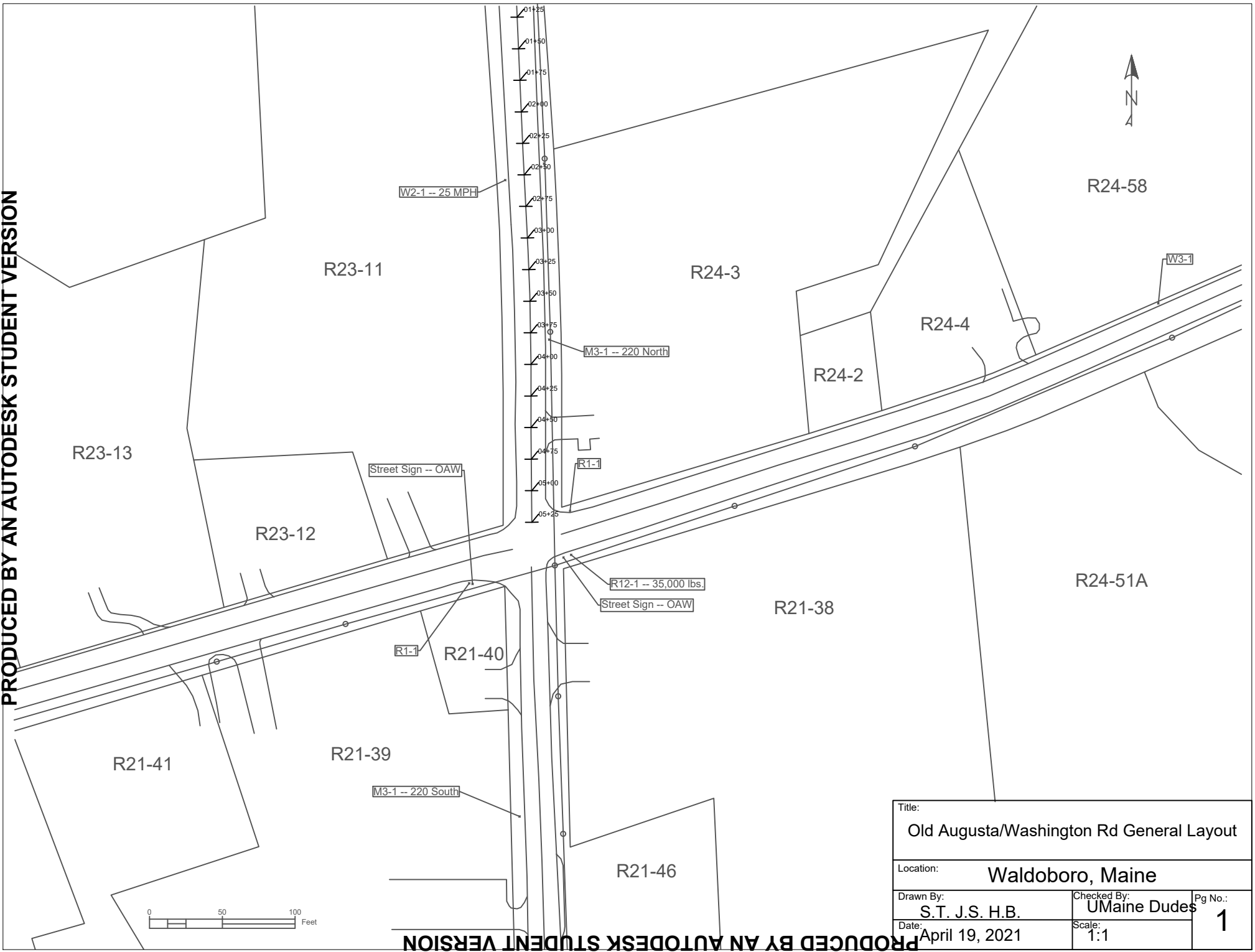
LOCATION:	Waldoboro, Maine		
SHEET NAME	PLAN VIEW		
DRAWN BY: S. Geary		SCALE: 1''=100'	SHEET:
CHECKED BY: ST		DATE: 04/19/21	



TITLE:	LIGHTING PLAN		
LOCATION:	WALDOBORO, MAINE		
SHEET NAME	RT. 32 / WEST MAIN ST.		
DRAWN BY: H.B.		SCALE: 1”=15’	SHEET: 1/1
CHECKED BY: ST		DATE: 04/03/2021	

PRODUCED BY AN AUTODESK STUDENT VERSION

Appendix 6
Intersection Old Augusta Rd. and Washington Rd. Designs



Title: Old Augusta/Washington Rd General Layout

Location: Waldoboro, Maine

Drawn By: S.T. J.S. H.B.

Checked By: UMaine Dudes

Pg No.: 1

Date: April 19, 2021

Scale: 1:1

PRODUCED BY AN AUTODESK STUDENT VERSION

Appendix 9
Drainage

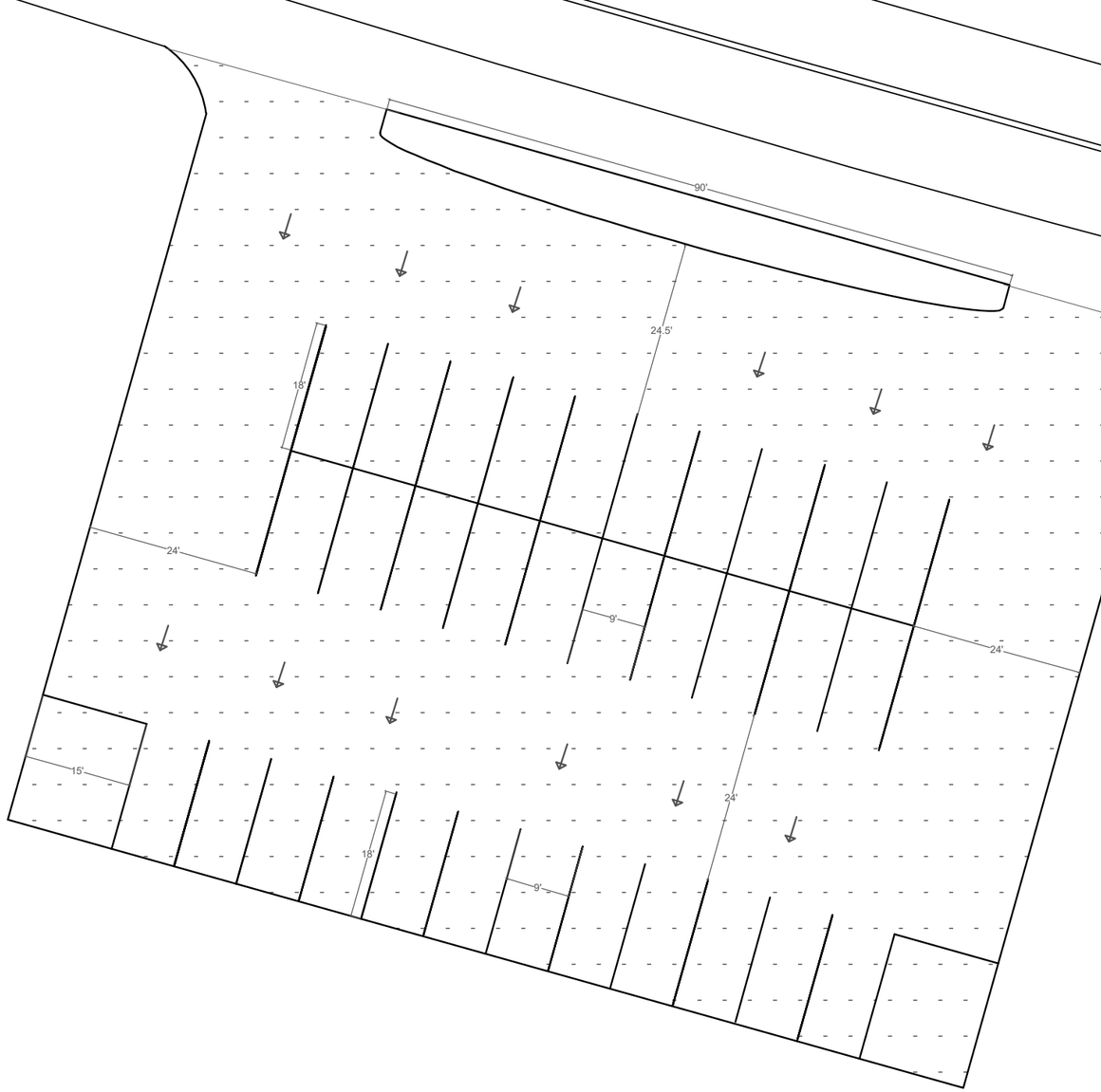
N

= 2% Cross-Slope for Drainage. Direction Indicated by Arrows. Separated by Edge of Pavement

0 30 60 Feet

INTERSECTION DRAINAGE

LOCATION:	WALDOBORO, MAINE		
SHEET NAME	RT. 1 AND WEST MAIN ST.		
DRAWN BY: S.G.		SCALE: 1:20	SHEET: 1/1
CHECKED BY: S.T.		DATE: 04/10/21	

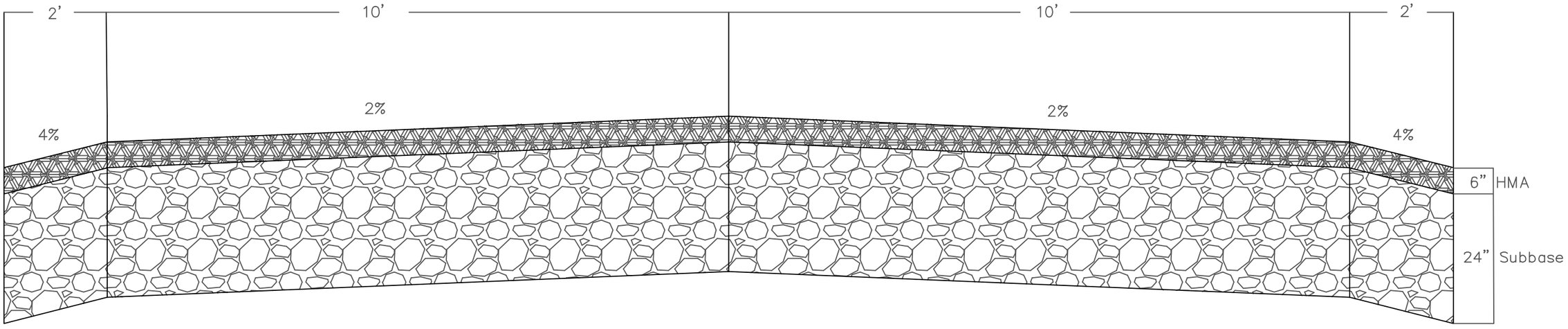


= 2% Cross-Slope for Drainage. Direction Indicated by Arrows.

0 20 40 Feet

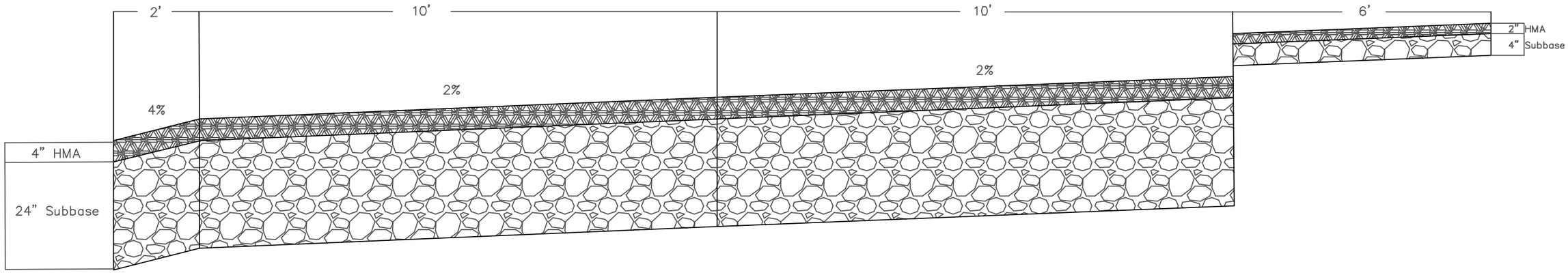
TITLE: PARKING LOT DRAINAGE		
LOCATION: WALDOBORO, MAINE		
SHEET NAME RT. 1 AND WEST MAIN ST.		
DRAWN BY: J.S.	SCALE: 1:20	SHEET: 1/1
CHECKED BY: S.T.	DATE: 04/10/21	

RT. 1 AND WEST MAIN ST. PROFILE VIEW



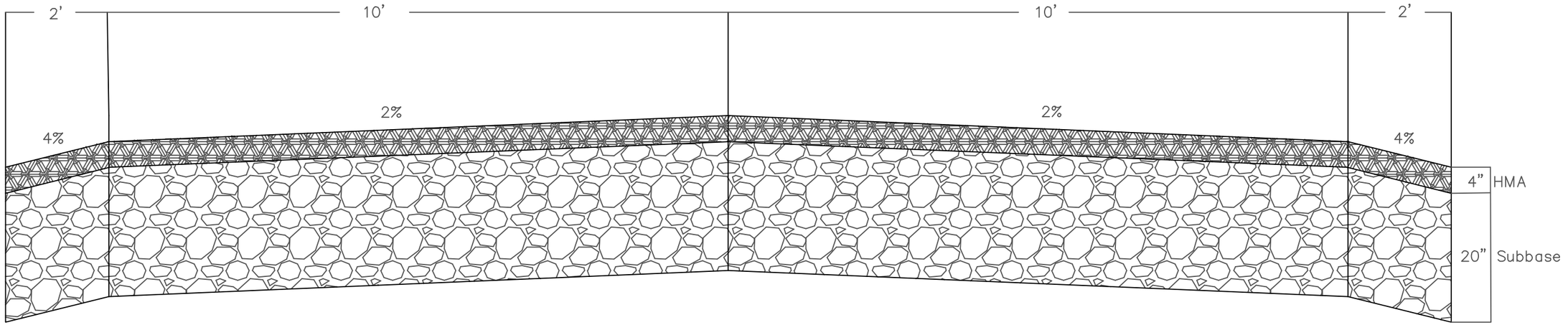
TITLE:	PROFILE VIEW		
LOCATION:	WALDOBORO, MAINE		
SHEET NAME	RT. 1 AND WEST MAIN ST.		
DRAWN BY: S.T.		SCALE: FULL	SHEET: 1/1
CHECKED BY: S.G.		DATE: 04/20/2021	

RT. 32 AND WEST MAIN ST. PROFILE VIEW



TITLE: PROFILE VIEW			
LOCATION: WALDOBORO, MAINE			
SHEET NAME RT. 32 AND WEST MAIN ST.			
DRAWN BY: S.T.	SCALE: FULL	SHEET: 1/1	
CHECKED BY: S.G.	DATE: 04/20/2021		

Old Augusta Rd. Washington Rd. Profile View



TITLE: PROFILE VIEW			
LOCATION: WALDOBORO, MAINE			
SHEET NAME OLD AUGUSTA AND WASHINGTON RD.			
DRAWN BY: S.T.	SCALE: FULL	SHEET: 1/1	
CHECKED BY: S.G.	DATE: 04/20/2021		