23 November 2020

Nate Reisner, PE
Development Engineer
ADOT Northcentral District
Flagstaff, Arizona

Dear Mr. Reisner,

The attached report and plan set detail the process that BETR Engineering followed in the creation of a suitable roundabout design for implementation at the intersection of Pine Knoll and McConnell Dr. in Flagstaff, Arizona. This design consists of a combination single- and dual-lane roundabout at the intersection, with an added bypass lane to serve eastbound to southbound traffic and a median separating McConnell Dr. eastbound and westbound traffic. The presented design meets the identified goal of alleviating traffic congestion at the intersection, while ensuring accommodations for the I-17 exit ramp traffic and is designed to function at a Level of Service of C in the peak hour after 20 years of traffic growth. This design is estimated to cost $829,064.25 to construct.

We are confident that this design will suit the location and the needs of all stakeholders and the accompanying report thoroughly explains the design and decision process. However, if you or your party have any questions or concerns, please email Tessa Huettl at tnh68@nau.edu for clarification.

Sincerely,

BETR Engineering

Brian Carpenter
Emery Ellsworth
Tessa Huettl
Rose Voyles

Final Design Report

McConnell Dr. and Pine Knoll Dr. Roundabout Design

November 5, 2020

BETR Engineering

Brian Carpenter
Emery Ellsworth
Tessa Huettl
Rose Voyles

College of Engineering, Informatics, and Applied Sciences
Northern Arizona University

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Abbreviations

AADT	Annual Average Daily Traffic
AC	Asphalt Concrete
ADOT	Arizona Department of Transportation
BTB	Bituminous Treated Base
FHWA	Federal Highway Administration
LOS	Level of Service
MUTCD	Manual on Uniform Traffic Control Devices
NAIPTA	Northern Arizona Intergovernmental Public Transportation Authority
NAU	Northern Arizona University
SBS	Social and Behavioral Sciences
VCR	Vehicle Capacity Ratio

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Thank you to Ted Biggs for his assistance and advice in presentation creation and preparation.

Exclusions

This project does not include standard details and drawings, detour plans, construction plans, utility assessment and relocation, landscaping and lighting plans, pavement design, permitting, or geotechnical analysis. Justifications for each of these exclusions are provided in a list below.

- *Standard Details and Drawings* are part of a stage of project design that this project does not extend to.
- *Detour Plans* were not requested by the client and as such shall be completed by another entity.
- *Construction Plans* are part of a stage of project design that this project does not extend to.
- *Utility Assessment and Relocation* is part of a stage of project design that this project does not extend to.
- *Landscaping and Lighting Plans* are part of a stage of project design that this project does not extend to.
- *Pavement Design* is part of a stage of project design that this project does not extend to.
- *Permitting* is part of a stage of project design that this project does not extend to.
- *Geotechnical Analysis* is not necessary as the new design will be tied into the existing pavement.

1.0 Project Introduction

1.1 Project Background

This design report pertains to the design of a roundabout at an intersection on NAU's Flagstaff Mountain campus. As such, this project has been named NAU Roundabout. The project will be referred to by this name throughout this report as well as in all subsequent attachments.

The project intersection is located at the intersection of McConnell Dr. and Pine Knoll Dr. Currently, this intersection is a three-way stop-controlled intersection with the eastbound approach consisting of a through lane and a designated right turn lane, the northbound approach consisting of a left turn lane and a right turn lane, and the westbound approach consisting of a combination through and a left-turn lane. The intersection is approximately 150 feet east of the I-17 exit ramp and approximately 120 feet west of the bus pullout. The location of the project intersection within the Flagstaff network can be seen in Figure 1-1. A detailed aerial image of the intersection and the immediate area can be seen in Figure 1-2.

Figure 1-1: NAU Roundabout Location Map

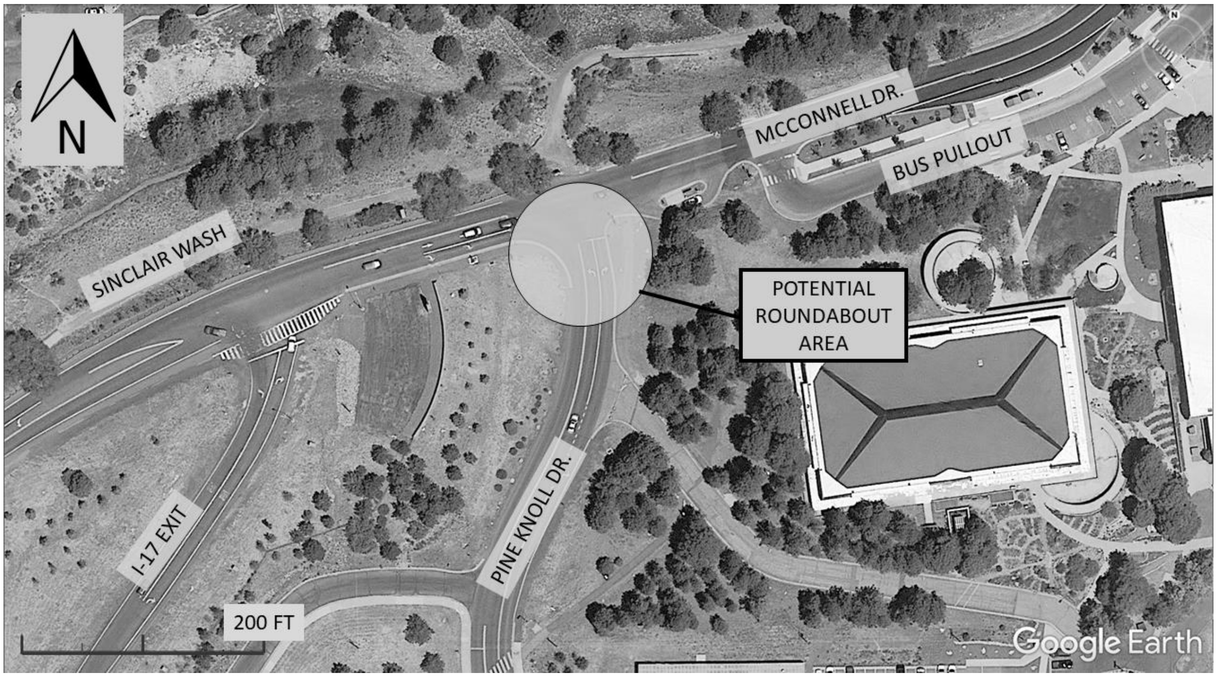

Figure 1-2: NAU Roundabout Vicinity Map Including Potential Roundabout Area

1.2 Constraints and Limitations

One of the main constraints of this project includes the proximity of the proposed site to Sinclair Wash. The wash cannot be encroached on and is a potential source of flooding. Any improvements must be configured to the available space and topography of the land. This includes navigating the slope south of the current intersection. Additionally, concerns of all stakeholders included within the project must be addressed, meaning congestion and safety of on-campus traffic must be ensured as well as congestion and safety immediately off-campus, namely at the adjacent I-17 freeway exit. Furthermore, the articulated busses frequently used by NAIPTA and routed directly through the intersection must be accommodated. Many of these challenges indicate the need to shift the intersection improvements south of the current intersection, which presents the challenge of re-aligning all approaches and assessing the grade of the south approach.

1.3 Major Objectives

The major objective of the design of the NAU Roundabout is to address and relieve congestion at this heavily trafficked intersection, while still maintaining adequate safety for all users. The intersection accommodates pedestrians, bicyclists, passenger vehicles, medium-duty box trucks, and standard and articulated buses. As such, the roundabout must be designed to convey every one of these user types through the intersection in a safe and efficient manner. Additionally, the client has requested the incorporation of the I-17 exit ramp into the functionality of the whole project area.

2.0 Review of Existing Data

2.1 Traffic Data

The Roundabout Team obtained traffic data from multiple sources, with varying recording methods and reviewed all data to determine what data to use for design of the intersection and how best to use it. The chosen course was to utilize turning movement data from the McConnell Dr. and Pine Knoll Dr. intersection and between Pine Knoll Dr. and the I-17 exit ramp that was recorded by the City of Flagstaff. The McConnell Dr. and Pine Knoll Dr. intersection data is from April 2019 and includes two-hour windows during the morning, mid-day, and afternoon traffic peaks, with counts for different vehicle types, and alternative users (pedestrians and bicyclists). The data recorded from the I-17 exit ramp includes turning movements off of the exit ramp and vehicle volumes on McConnell Dr. between the exit ramp and Pine Knoll Dr. as total hourly volumes per movement. Of all acquired data, these two sets provide the most complete and accurate depiction of the current project area functionality.

2.2 Site Features

The Roundabout Team obtained existing site surveys and topographical maps from the City of Flagstaff and Northern Arizona University. Each source's data was reviewed to determine the most applicable features and were then combined into a single site map. This necessitated the manipulation of coordinate systems in order to align two differing survey methods but resulted in a usable existing site map with contour data and site features. However, due to survey limits occurring before the end of the design limits, additional linework was added based on an aligned aerial. Since existing surface data for the roadway and any existing curb and gutter data is available, the lack of accurate elevation data for the added features was not a concern to the following design process.

2.3 Right-of-Way Investigation

A right-of-way investigation was completed to assess the existing property boundaries and right-of-way's that out project might conflict with. This investigation was completed using the parcel viewer from the Coconino County Assessor's Office [1]. The investigation revealed that the roundabout project will be mostly on NAU property with a possible conflict with the right-of-way of the I-17 exit ramp which belongs to the State of Arizona.

3.0 Field Work

3.1 Existing Site Conditions

An in-person site investigation was completed to assess the current condition of the proposed roundabout area. Photos were taken of new roadway elements that did not appear on the aerial map, such as a new sidewalk on the north side of McConnell Dr. and a new crosswalk on the East side of the intersection of McConnell Dr. and Pine Knoll Dr. These new elements were added to the AutoCAD drawings to easily view how they will fit into the roundabout design. An exhibit of these new elements can be seen in Exhibit A.

3.2 Existing Drainage Area

Through an investigation of the site during a rainstorm, the BETR Engineering team was able to determine how the existing site manages stormwater. From this investigation, the team determined that the majority of the surrounding area is configured to convey stormwater directly into Sinclair Wash, without interacting with the intersection. The area that interacts with the intersection, and as such is pertinent to this roundabout design, can be seen in Exhibit B.

4.0 Existing Traffic Analysis

4.1 Data Formatting

From the acquired turning movement data, the peak AM, mid-day, and PM hours were retrieved, as calculated by the utilized traffic count program. This provided corresponding turning movement counts for all Pine Knoll Dr. and McConnell Dr. intersection approaches and the I-17 exit ramp and McConnell Dr. approaches. In order to address the objective of serving the I-17 exit ramp traffic, the I-17 exit ramp movements were manipulated into the total intersection movements as U-turns, under the presumption that all I-17 exit traffic may be routed through a McConnell Dr. and Pine Knoll Dr. roundabout. To be best utilized for design of a piece of infrastructure expected to perform well for many years, the data needed to be grown to better model expected future traffic flows.

In order to grow the data for expected future conditions, a change rate was needed. This required that a current and past AADT be retrieved to be used in Equation 4-1. These AADTs were found on the ADOT traffic counts map from the years 2019 and 2007 and were located on McConnell Dr. between the I-17 exit ramp and Pine Knoll Dr. Generally, an AADT from the current year would be used but given the current circumstances resulting in abnormal traffic flow conditions at the site, the previous year's AADT is a better reflection of typical traffic. These AADTs produced a 12-year change rate which, when taken for a single year, produced an annual change rate of 0.8%. Additionally, a typical traffic growth rate of 2.0% was used to capture all possible future volumes. These growth rates were input into Equation 4-2 along with a 20-year growth period and individual turning movements in order to produce future turning movement volumes.

Equation 4-1: Change Rate

$$Change\ Rate = AADT_{current}/AADT_{Previous}\ [1]$$

Equation 4-2: Future Volume

$$Future\ Volume = Current\ Volume * (1 + Change\ Rate)^{n}\ [1]$$

Table 4-1 below shows the results of these growth calculations.

Table 4-1: Turning Movement Volumes Growth

Approach	Movement	AM Peak Volume			Mid-Day Peak Volume			PM Peak Volume		
		Current	20 Year Growth		Current	20 Year Growth		Current	20 Year Growth	
			0.8%	*2%*		*0.8%*	*2%*		*0.8%*	*2%*
WB McConnell	Left	70	83	105	90	106	134	89	105	133
	Thru	70	83	105	209	246	311	287	337	427
EB McConnell	Thru	244	287	363	202	237	301	236	277	351
	Right	343	403	510	242	284	360	222	261	330
	U-Turn	195	229	290	208	244	310	458	538	681
Pine Knoll	Left	108	127	161	299	351	445	416	488	619
	Right	38	45	57	97	114	145	130	153	194

4.2 Software Use

The grown turning movements were entered into Rodel, a roundabout modeling software which allows for manipulation of roundabout geometry features in the determination of total functionality. Several preliminary models were run in order to determine the feasibility of basic roundabout at the McConnell Dr. and Pine Knoll Dr. intersection. Models run include AM, Mid-day, and PM peak turning volumes at an 0.8% and 2.0% growth rate over 20 years, and both with and without the added I-17 U-turn movements. The resulting outputs can be seen in Appendix A through L, with a range of LOS grades that indicate which movements are functioning well (LOS A, B, and C) and which are functioning poorly (LOS D, E, and F) in a basic single-lane roundabout. This provided a beginning point for developing and analyzing possible alternative solutions for the project area. Tables 4-2, 4-3, and 4-4 summarize the software outputs by peak hour.

Table 4-2: AM Peak Output Summary

AM Peak							
Growth Rate		0.8% Growth			2.0% Growth		
Approach Leg		McConnell (WB)	McConnell (EB)	Pine Knoll (NB)	McConnell (WB)	McConnell (EB)	Pine Knoll (NB)
No U-turns	LOS	A	A	A	A	B	A
	Capacity	1090	1144	919	1052	1117	847
	VCR	0.15	0.602	0.187	0.198	0.781	0.256
With U-turns	LOS	A	C	A	A	F	A
	Capacity	853	1143	719	770	1116	620
	VCR	0.195	0.804	0.239	0.273	1.042	0.352

Table 4-3: Mid-Day Peak Output Summary

Mid-Day Peak							
Growth Rate		0.8% Growth			2.0% Growth		
Approach Leg		McConnell (WB)	McConnell (EB)	Pine Knoll (NB)	McConnell (WB)	McConnell (EB)	Pine Knoll (NB)
No U-turns	LOS	A	A	A	B	A	B
	Capacity	857	1115	969	776	1081	905
	VCR	0.41	0.467	0.48	0.573	0.61	0.649
With U-turns	LOS	B	B	B	D	D	E
	Capacity	660	1115	746	556	1081	649
	VCR	0.533	0.686	0.623	0.8	0.896	0.91

Table 4-4: PM Peak Output Summary

PM Peak							
Growth Rate		0.8% Growth			2.0% Growth		
Approach Leg		McConnell (WB)	McConnell (EB)	Pine Knoll (NB)	McConnell (WB)	McConnell (EB)	Pine Knoll (NB)
No U-turns	LOS	B	A	B	E	A	F
	Capacity	741	1117	928	644	1084	857
	VCR	0.595	0.481	0.69	0.866	0.629	0.946
With U-turns	LOS	F	F	F	F	F	F
	Capacity	416	1116	521	310	1082	413
	VCR	1.062	0.964	1.229	1.805	1.258	1.967

5.0 Preliminary Geometry

5.1 Inscribed Circle Diameter

While the Roundabout Team later developed several alternative design solutions for the project area, it was necessary to first determine the potential infrastructure area to help inform placement and alignment decisions. The inscribed circle diameters for the alternative designs were based on the design vehicle of the intersection and the number of lanes required to serve the expected traffic flow. The design vehicle, which is the largest vehicle expected to utilize the intersection with some frequency is a WB-67 which have design turning radii of 45-feet [2]. For a single lane roundabout, this vehicle's turn radius suggests an inscribed circle diameter between 100 and 130 feet but requires a path with at least a 45-foot radius, plus at least two feet of clearance between the edge of the vehicle's tire track and the roadway curb [4]. For a double-lane roundabout, an inscribed circle of 150 feet is recommended, with lane widths of 32 feet and a center island with radius 86 feet. This means that the minimum intersection area required for this project is about 8,000 square feet for a single-lane roundabout and a minimum of 18,000 square feet for a double-lane roundabout. A map of the project location with these areas depicted can be seen in Exhibit C.

6.0 Alternatives Development

Due to the growth limitations of the area and the results of modeling a 2.0% growth rate over 20 years, as well as feedback from technical advisors, a growth rate of 0.8% for the 20-year growth period was used for the development of alternatives. Per discussions with City of Flagstaff official, traffic growth is limited at NAU Mountain Campus, Flagstaff greater, and overall parking potential has limited further growth options, making the 0.8% traffic growth rate through this intersection a more likely model.

Alternatives concepts were developed by considering different methods of managing the traffic flows at both the Pine Knoll and McConnell Dr. intersection and the I-17 exit ramp. Given the nature of a roundabout in creating near-constant flows of traffic through its exits, I-17 exist ramp left-turn traffic would be impeded. The two options for ensuring flow from the exit ramp was to route it through the roundabout at Pine Koll and McConnell Dr. or to add infrastructure allowing the ramp traffic to adequately exit. These options led to the alternatives outlined in the following sub-sections.

It is important to note that a similar problem as would occur with the I-17 exit ramp would occur with the bus pullout on McConnell Dr. A potential option would have been to add the bus pullout as a fourth leg to the roundabout. This was initially considered in an early starting design. However, this design highlighted that such a design would feature geometry likely to lead to increases vehicle collisions. Both the Rodel software used to model the intersection design and the FHWA roundabout design guide indicate that angles between an entrance and subsequent exit that are less than 90 degrees, lead to more vehicle collisions [4] [5]. Additionally, introducing a fourth, one-way leg to a roundabout in an area where roundabouts are not common is liable to increase confusion among users.

For these reasons, BETR Engineering recommends altering the current bus pullout configuration to alleviate the issues of exiting busses crossing traffic to make necessary maneuvers. One way of doing this and the method that BETR Engineering recommends at this stage is to adjust the alignment of McConnell Dr. to skew slightly to the south, allowing for the construction of twin bus pullouts on the north and south side of McConnell Dr., serving westbound and eastbound busses, respectively. This eliminated the need for busses to turn left, crossing traffic, in order to reenter the stream of traffic. This recommendation is depicted in each of the alternatives presented below.

6.1 Single-Lane Alternative

This alternative consists of a single lane roundabout at Pine Knoll Dr. and McConnell Dr., a single-lane roundabout is only possible by choosing an I-17 exit ramp treatment that keeps the ramp traffic out of the Pine Knoll Dr. and McConnell Dr. roundabout. To accomplish this while also not impeding movements exiting the I-17 ramp another single lane roundabout was added at the ramp exit. This alternative produced a LOS of A and has an inscribed circle diameter of 131 feet. This alternative can be seen in Exhibit D with corresponding Rodel outputs seen in Appendix M.

6.2 Double-Lane Alternative

This alternative employs a median to direct all traffic off the I-17 exit ramp to the east and through the Pine Knoll Dr. and McConnell Dr. roundabout. This increases the traffic through the roundabout as all users that would make left turns from the exit ramp, now make a U-turn through the roundabout. In order to meet capacity for this increase in traffic, the single-lane roundabout was transformed into a double-lane roundabout. This alternative produced a LOS of A and requires an inscribed circle diameter of 131 feet. This alternative can be seen in Exhibit E with corresponding Rodel outputs seen in Appendix N.

6.3 Bypass Lane Alternative

This alternative is very similar to the Double-Lane option but includes a bypass lane to direct traffic turning onto Pine Knoll Dr. from eastbound McConnell Dr. without routing through the roundabout itself. This is an added capacity feature that allowed for some reduction in lanes in some portions of the roundabout. This alternative produced a LOS of C and has an inscribed circle diameter of 131 feet. This alternative can be seen in Exhibit F with corresponding Rodel outputs seen in Appendix O.

7.0 Analysis of Alternatives

7.1 Analysis Criteria

The alternatives described above were evaluated based on relative cost, pedestrian safety, relative likelihood of accidents, level of service, and user interaction. Each of these criteria was used in a decision matrix to produce a score for each alternative in order to determine the overall best design option. The criterion listed are described below along with an explanation of the weight associated with each. For each of these criteria, the alternatives received a score on a scale of 1 to 5, with a score of 5 being the most desirable score and a score of 1 being the least desirable.

The first criteria analyzed was the relative cost estimation. This item was weighted 25%, which is the largest assigned weight due to the importance it plays in the final decision. The relative cost for each alternative is dependent on comparisons of the anticipated construction needed, which includes demolition area, new paved area, and fill volume.

Pedestrian safety was the next criteria analyzed. Pedestrian safety is an important factor when designing the roundabout. This portion of the decision matrix was weighted 20%. This roundabout will serve many different users, but since this project lies on a college campus, pedestrians will be one of the main users of this intersection. Pedestrian safety was analyzed on the basis of the number of lanes pedestrians would have to cross in order to cross the street. Pedestrian-vehicle collisions increase with the number of lanes pedestrians need to traverse and, since all designs feature only one crosswalk, the number of lanes to cross is an accepted accurate measurement of pedestrian safety within these alternative designs [6].

The next criteria analyzed was the relative likelihood of accidents. This was assigned a weight of 15%. Accidents are an important consideration in choosing a design to move forward with. The ideal design will be able to efficiently allow users to navigate through the intersection without compromising the safety of those users. Factors such as multiple lanes or confusing movements in a roundabout can lead to a greater likelihood that accidents will occur and can be represented by the number of vehicle conflict points in the intersection. Appendix P includes examples of vehicle conflict points in roundabouts.

Level of service was the next criteria being analyzed. Level of service is a ranking (A-F) based on speed, travel time, delay, safety, and maneuverability [4]. The level of service was outputted from the Rodel Software according to these different factors and these outputs can be found in Table 7-1. Regarding the decision matrix, this portion was weighted at 10%.

Table 7-1: Rodel Alternative LOS Outputs

Alternative Efficiency	
Alternative	LOS
Single	A
Double	A
Bypass	C

The last criteria analyzed was the user interaction. User interaction includes items the user may experience while navigating through the intersection such as complexity, discomfort, and predictability. Each of these experiences were weighted individually to account of the user's overall experience. Complexity was weighted at 15%, and accounts for the confusion and unfamiliarity the user could experience when navigating through the roundabout. Discomfort was weighted at 5%, and accounts for how the user feels with driving in a roundabout, especially a double-lane roundabout. Predictability was weighted at 10%, and accounts for the user, and their comfort level with driving through the roundabout with possibly inexperienced drivers.

7.2 Application of Criteria to Alternatives

The 1st alternative evaluated was the Single Lane alternative, and this alternative received a 2 for relative cost as it is expected to be the most expensive alternative due to the cost of constructing two full roundabouts and the amount of fill necessary to allow for the construction of the I-17 exit ramp roundabout. However, it would still cost less than more extensive intersection construction. This alternative received a 4 for pedestrian safety as this alternative is the simplest designed alternative, and will have designated crosswalks for pedestrians, as well as a sidewalk on the north side of the intersection, running the length of McConnell Dr. Regarding relative likelihood of accidents, this alternative received a 4, as the simple roundabout design allows for speed control and optimal entry and exit angles, with 6 points of vehicle conflict (relatively few points compared to other intersection options). A point was lost due to the expected transition from one roundabout into another. For Level of Service, this alternative received a 5 because it can navigate users through the intersection well. For user interaction, complexity received a 2, discomfort received a 3, and predictability received a 3. The overall user interaction for this alternative is a positive experience, mainly due to the simplicity of this design but points were lost due to need for most users to travel through two roundabouts, one after another.

The 2nd alternative evaluated was the Median alternative, which would entail a double-lane roundabout, as well as a median placed in front of the exit ramp of the I-17 ramp. This design received a 3 for relative cost as it has a lower expected construction area and fill requirement than the single lane, but more than the bypass option. This median would prevent users from turning left when exiting the ramp, and routes them through the roundabout. Regarding pedestrian safety, this alternative received a 3 due to the width of the road, and the amount of traffic completing U-Turns in the roundabout. For relative likelihood of accidents, this alternative received a 2 due to the number of potential collision points (18 points) caused by the merging and crossing maneuvers that are possible with this design. For user interaction, complexity was ranked a 2, discomfort was ranked a 3, and predictability was ranked a 2. This design as stated before, could cause confusion with the inclusion of an inner circulating lane. This design may be new to some users, and other users may not feel comfortable when navigating through this alternative.

The 3rd alternative evaluated was the Bypass Lane, and this alternative has a single lane roundabout, along with a bypass lane for vehicles exiting off the I-17 ramp entering campus. Relative cost was rated a 4 as the expected cheapest alternative due to a lesser quantity of required fill and a lower expected paved area compared to the other two options but is still more expensive than leaving the intersection as is. Regarding pedestrians, this alternative received a 4 and would have designated crosswalks for pedestrians, as well as a sidewalk on the north side of the intersection, running the length of McConnell Dr. For relative likelihood of accidents, this alternative received a 4 due to the number of vehicle conflict points (7, relatively few points compared to other intersection options). For level of service, this alternative received a 3 because it received an output level of service C. Regarding user interaction, complexity received a 4, discomfort received a 4, and predictability received a 3. The overall user interaction for this alternative is positive but may cause some discomfort when utilizing the bypass lane from the exit ramp.

A summary of the quantitative evidence to support the team's decision matrix scoring is seen in Table 7-2. The final decision matrix can be seen in Table 7-3, showing the winning alternative.

Table 7-2: Support Data for Alternative Analysis

Criterion		Weight	Alternatives		
			Single	Double	Bypass
Relative Cost		25%	Fill =21,863 cu ft, Construction = 5759 sq ft	Fill = 11,948 cu ft, Construction = 7790 sq ft	Fill = 11,711 cu ft, Construction = 5759 sq ft
Ped. Safety		20%	2 lanes to cross	3 lanes to cross	2 lanes to cross
Likelihood of accidents		15%	6 points of conflict	18 points of conflict	7 points of conflict
LOS		10%	A	A	C
User Interaction	Complexity	15%	2 roundabouts with 1 lane	1 roundabout with 2 lanes	1 roundabout with 1-2lanes
	Discomfort	5%	100% of vehicles enter a roundabout	100% of vehicles enter a roundabout	88% of vehicles enter a roundabout
	Predictability	10%	3 drivers entering roundabout at once	5 drivers entering roundabout at once	3 drivers entering roundabout at once

Table 7-3: Alternatives Decision Matrix

Criterion		Weight	Alternatives		
			Single	*Double*	*Bypass*
Relative Cost		25%	2	3	4
Ped. Safety		20%	4	3	4
Likelihood of accidents		15%	4	1	4
LOS		10%	5	5	3
User Interaction	*Complexity*	15%	2	2	4
	Discomfort	5%	3	3	4
	Predictability	10%	3	2	3
	Total	**100%**	**3.2**	**2.7**	**3.8**

7.3 Alternative Selection

Based on the results of the decision matrix, the Bypass Lane alternative was selected. This alternative had the best overall score due to its performance in the categories of relative cost, pedestrian safety, relative likelihood of accidents, and overall user interaction.

8.0 Pre-Development Drainage Analysis

8.1 Pre-Development Time of Concentration

The time of concentration was determined for the drainage area that drains through the intersection. Time of concentration is the time required for runoff water to travel from the most hydraulically remote point of the drainage area to the outlet of that drainage area [7]. To determine time of concentration for our drainage area, five different drainage paths were analyzed following the guidelines in the City of Flagstaff Stormwater Management Design Manual [7]. These paths can be seen in Exhibit B. The calculation of time of concentration for each flow type can be seen in Table 8-1 and the total time of concentration for each path can be seen in Table 8-2. The time of concentration for our drainage area was rounded to 5 minutes for all future design, as per the City of Flagstaff Stormwater Management Design Manual.

Table 8-1: Time of Concentration by Flow Type

Time of Concentration by Flow Type					
Path	Sheet				
	Roughness	Length	Δ Elevation	Slope	Time
2	0.014	66.0	22.02	0.3333	0.433
Path	Shallow Concentrated Unpaved				
	Length	Elevation 1	Elevation 2	Slope	Time
2	257.9	6882.5	6867.25	0.0591	0.869
3	277.2	6884.25	6869	0.0550	0.969
Path	Shallow Concentrated Paved				
	Length	Elevation 1	Elevation 2	Slope	Time
1	35.5	6887	6886.67	0.0093	0.381
2	29.4	6864.75	6862.5	0.0765	0.110
3	29.4	6864.75	6862.5	0.0765	0.110
4	18.8	6906	6905.75	0.0133	0.169
	29.4	6864.75	6862.5	0.0765	0.110
5	18.8	6906	6905	0.0531	0.084
	29.4	6864.75	6862.5	0.0765	0.110
Path	Gutter				
	Length	Elevation 1	Elevation 2	Slope	Time
1	1377.2	6886.67	6862.5	0.0176	3.208
2	135.8	6867.25	6864.75	0.0184	0.309
3	209.3	6869	6864.75	0.0203	0.453
4	1250.5	6905.75	6864.75	0.0328	2.131
5	1323.6	6905	6864.75	0.0304	2.343

Table 8-2: Total Time of Concentration

Total Time of Concentration						
Path	Sheet	Shallow Concentrated		Gutter	Total Time	Total Length
		Unpaved	Paved			
1	0.00	0.00	0.38	3.21	3.59	1412.7
2	0.43	0.87	0.11	0.31	1.72	323.9
3	0.00	0.97	0.11	0.45	1.53	486.5
4	0.00	0.00	0.28	2.13	2.41	1269.3
5	0.00	0.00	0.19	2.34	2.54	1342.4

8.2 Pre-Development Weighted Runoff Coefficient

A weighted runoff coefficient was calculated for the area that will drain directly through the McConnell/Pine Knoll intersection. This runoff coefficient considers the different surface types in the drainage area. Each different surface type has a different runoff coefficient which was found in the City of Flagstaff Stormwater Management Design Manual. A total weighted runoff coefficient was calculated as shown in Table 8-3 by determining using Equation 8-1.

Equation 8-1: Total Weighted Runoff Coefficient

$$C_w = \frac{\sum C_i A_i}{A_{tot}}$$

$$C_w \rightarrow weighted\ runoff\ coefficient$$
$$C_i \rightarrow runoff\ coefficient\ of\ surface\ type$$
$$A_i \rightarrow area\ of\ surface\ type$$
$$A_{tot} \rightarrow total\ area$$

Table 8-3: Pre-Development Weighted Runoff Coefficient

Pre-Development Weighted Runoff Coefficient					
Surface Type		Grass	Roof	Paved	Total
Area	sqft	51191	9062	95517	155769
Weight	%	32.86%	5.82%	61.32%	100.00%
Runoff Coefficient		0.15	0.95	0.95	0.69

8.3 Pre-Development Runoff

The total pre-development runoff through the intersection was calculated using the rational method, as seen in Equation 8-2. The values used to calculate the pre-development runoff values as well as the pre-development runoff values can be seen in Table 8-4.

Equation 8-2: Rational Equation

$$Q = C_f CIA \text{ [7]}$$

$$Q \rightarrow rate\ of\ runoff\ (cfs)$$
$$C_f \rightarrow antecedent\ precipitation\ factor$$
$$C \rightarrow runoff\ coefficient$$
$$I \rightarrow rainfall\ intensity\ (in/hr)$$
$$A \rightarrow total\ drainage\ area\ (acres)$$

Table 8-4: Pre-Development Drainage Flow Rate

Pre-Development Flow Rate					
Storm Event	Antecedent Precipitation Factor	Weighted Runoff Coefficient	Intensity	Area	Flow Rate
			in/min	*acre*	*cfs*
10-yr	1.00	0.69	5.76	3.58	14.2
100-yr	1.25	0.69	8.52	3.58	26.2

9.0 Redesign and Check

With the Bypass alternative selected, finalization of the design needed to occur which was accomplished by performing a three-part analysis process. First, a safety test called Fastest Route, detailed by the FHWA roundabout guide, was performed on the initial alternative design to ensure vehicle speeds through the roundabout remained within an acceptable range. Then, the geometry was modified slightly to adjust Fastest Route outcomes, while maintaining appropriate entry and exit angles and lane widths as well as the original lane arrangement and major features of the design. Finally, the design was input into Rodel to ensure the capacity of the roundabout and LOS remained acceptable (LOS of C or greater).

The Fastest Route analysis is performed to determine the greatest possible speed a vehicle could reach while traveling through a roundabout. This path is the smoothest route, ignoring lane markings, and entering through an entry, maneuvering around the center island, and exiting through an exit. From this path, three different radii are taken: the entry path radius, circulating path radius, and exit path radius [4]. These are used in conjunction with velocity equations, as seen below in Equation 9-1 and 9-2 to determine the speed associated with each part of the path. These are then compared to the allowable range for each part of the path, as depicted in Table 9-1.

Equation 9-1: Fastest Route Speed for Entry and Circulating Radius

$$V = 3.4415R^{0.3861}$$

$$V \rightarrow predicted\ speed\ (mph)$$
$$R \rightarrow radius\ of\ curve$$

Equation 9-2: Fastest Route Speed for Exit Radius

$$V_3 = \frac{((1.47V_2)^2 + 13.8d_{23})^{\frac{1}{2}}}{1.47}\ [4]$$

$$V_3 \rightarrow actual\ exit\ speed\ (mph)$$
$$V_2 \rightarrow circulatory\ speed\ for\ through\ vehicles\ based\ on\ R2\ path\ radius\ (mph)$$
$$d_{23} \rightarrow distance\ along\ vehicle\ path\ bewtween\ midpoint\ of\ R2\ path\ and\ point\ of\ interest\ on\ exit\ path\ (mph)$$

Table 9-1: Fastest Route Path Speed Ranges [4]

Radius (R_x)	Description	Range of Speeds (Vx)
Entry Path Radius, R1	The minimum radius on the fastest through path prior to the yield line. This is not the same as Entry Radius.	20 to 25 mph
Circulating Path Radius, R2	The minimum radius on the fastest through path around the central island.	15 to 25 mph
Exit Path Radius, R3	The minimum radius on the fastest through path to the exit.	N/A

The first iteration and final iteration of geometry, with corresponding Fastest Route, can be seen in Exhibit G and H, respectively. This final iteration shall function as the base geometry for the final design. The Rodel software output showing LOS, capacity, and additional performance outputs for this base geometry can be seen in Appendix Q. Table 9-2 below summarizes the Fastest Route data for the initial and final geometry for the Bypass alternative, showing that the final geometric design meets the described safety and efficiency checks.

Table 9-2: Fastest Route Path Speeds

Location	Speed (mph)	
	Initial Geometry	Final Geometry
Entry	17.7	18.8
Circulating	25.7	24.1
Exit	31.8	31.4

10.0 Post-Development Drainage Analysis

10.1 Post-Development Time of Concentration

As the chosen roundabout design did not add any new elements that would increase the time of concentration, the post-development time of concentration was also rounded to 5 minutes for future design. An exhibit of the drainage area used for this analysis can be seen in Exhibit I.

10.2 Post-Development Weighted Runoff Coefficient

Using the same process as was used to determine the pre-development weighted runoff coefficient, a post-development total weighted runoff coefficient was calculated as shown in Table 10-1.

Table 10-1: Post-Development Weighted Runoff Coefficient

Post-Development Weighted Runoff Coefficient					
Surface Type		Grass	Roof	Paved	Total
Area	sqft	49516	10642	100606	160764
Weight	%	30.80%	6.62%	62.58%	100.00%
Runoff Coefficient		0.15	0.95	0.95	0.70

10.3 Post-Development Runoff

As with the pre-development runoff, the post-development runoff was calculated using the rational method. The values used to calculate the pre-development runoff values as well as the pre-development runoff values can be seen in Table 10-2.

Table 10-2: Post- Development Drainage Flow Rate

Post-Development Flow Rate					
Storm Event	Antecedent Precipitation Factor	Weighted Runoff Coefficient	Intensity	Area	Flow Rate
			in/min	*acre*	*cfs*
10-yr	1.00	0.70	5.76	3.69	15.0
100-yr	1.25	0.70	8.52	3.69	27.7

10.4 New Drainage Structures

New drainage structures are required if the post-development runoff of a design is significantly larger than the pre-development runoff. With the chosen design, the post-development runoff was about 6% larger than the pre-development runoff. This relatively small increase in runoff does not necessitate the need for additional drainage infrastructure, when considering the timing of peak flows entering Sinclair wash. The project site's proximity to Sinclair Wash allows for runoff from the site to immediately enter the channel, meaning any additional runoff will have moved downstream long before the peak runoff from Sinclair Wash watershed reaches the limits of the site. Given that the proposed increase in drainage corresponds to a pre-peak condition, the only recommended drainage infrastructure consists of typical street drainage facilities: curb and gutter, curb cuts, and scuppers.

11.0 Final Traffic Analysis

A final traffic analysis was completed in order to verify the final geometry determined for the roundabout. This final traffic analysis utilized the PM peak turning volume for the 0.8% growth rate data, as well as the determined geometry for the bypass alternative. This information was inputted into the Rodel software and the LOS for each leg, and overall LOS were outputted. These LOS determined would be functioning during the peak hour. Regarding the various legs of the intersection, McConnell WB received a LOS B, McConnell EB received a LOS B, and Pine Knoll Dr. received a LOS D. The overall LOS for the roundabout functioning during the peak hour would be a LOS C. The Rodel outputs can been seen in Appendix R.

12.0 Signing and Striping

The signing and striping requirements for the roundabout at McConnell Dr. and Pine Knoll Dr. were referenced from the standards, guidelines and requirements of the City of Flagstaff Engineering Design Standards, [10] the FHWA roundabout guide [4] and the MUTCD [9]. The MUTCD is a document created by the FHWA and is a compilation of standards, guidance and options for all types of traffic control devices, which includes road markings, highway signs, and traffic signals.

The signing and striping sheets in the plan set for this project were created following the guidance outlined in the City of Flagstaff Engineering Design Standards section 13-16-002, which states that the sheets shall detail the type, size and placement location of all temporary and permanent signs and pavement markings [10]. All signs shall be on one-eight-gauge aluminum and be installed on posts made of square tubing to comply with ADOT Signing and Marking Standard Drawings Detail S-1. Any existing signs that must be removed during the construction of this project shall be replaced with new signs and the old one will be salvaged to the City of Flagstaff [10]. Signs shall me installed to the minimum height requirements outlined in the Arizona Supplement to the MUTCD [11]. For our project area this minimum height shall be 7 feet from the bottom of the sign to the top of the curb. If a sign is installed where no curbing is present, then the 7 feet minimum shall be measured from the bottom of the sign to the elevation of the near edge of the traveled way [11].

All pavement markings shall be either dual component epoxy or preformed markings and shall be installed according to the guidance provided in the ADOT standard specifications 705,708 and 709 [10][12].

13.0 Temporary Traffic Control

For any proposed construction, there must be a temporary traffic control plan. The temporary traffic control plan illustrates which streets and access points will be unavailable during construction and contains a basic plan for communicating these closures to the public. As such, a temporary traffic control plan was created for the project site, following the requirements of the City of Flagstaff Engineering Design Standards section 13-06-008 [10]. This section states that the traffic control plan should follow the guidance outlined in the MUTCD [9] and be approved by the city engineering manager before acquiring any permits that will be necessary to implement the plan. Additional guidance is provided in this section as to how the traffic control plan should be implemented. Permits should be obtained following the guidance outlined in section 13-15-001 of the City of Flagstaff Engineering Design Standards [10].

14.0 Plan Set Production

A plan set was produced in order to accurately portray BETR Engineering's design for the project site. This plan set includes typical sections, removal, construction, vertical and horizontal geometry, and signing and striping plans for the design. The plan set is attached as Exhibit J.

14.1 Typical Sections

Typical roadway sections were created for each change in roadway components. This includes sections along both legs of McConnell Dr. and Pine Knoll Dr. and the I-17 exit ramp. For purposes of cross section illustration and cost estimate calculations, roadway materials and depths were assumed as follows: 1" asphalt concrete (AC), 7" bituminous treated base (BTB), and 13.5" Aggregate Base, Class 2.

14.2 Geometric Layout

A geometric layout of the edge of pavement was created for the extents of new construction. This layout includes linework showing the centerlines and edge of pavement of each roadway as well as table callouts of length and angle data for all straight-line segments and length, radius of curvature, and delta angle data for all curved segments.

14.3 Profiles

Profiles were created for the edge of pavement for westbound McConnell, eastbound McConnell Dr. to southbound Pine Knoll Dr., and northbound Pine Knoll Dr. to eastbound McConnell Dr. as well as the centerline of the I-17 exit ramp. These profiles include both the existing ground surface and proposed grade as well as the approximate location of important features.

14.4 Removal Plans

Removal plans were created to detail the existing elements that would have to be demolished in order to construct the final design. These plans include the removal pavement, concrete elements, trees, signs, and some small structures.

14.5 Construction Plans

The construction plans created detail the materials and areas necessary to create the final design. This includes new full depth and partial depth pavement, new concrete areas, and new landscaped areas. These plans illustrate key elements of the design, such as bike and pedestrian accommodations, in the form of ramps for both user type.

15.0 Final Design Recommendations

15.1 Social Impacts

Roundabouts can elicit strong feelings from the community there are implemented in. As such, one of the main social impacts of this design has to do with public acceptance of the design. This would not be the first roundabout in the Flagstaff area (Paseo del Rio and O'Leary/Brannen Cir, Switzer Canyon and Turquoise, Arrowhead and West, Gemini and Pine Cliff), which means other instances of roundabouts have done the work of introducing the feature and assuaging many concerns about their use. However, this will be the first roundabout on campus, where traffic can become heavy and users may be relatively new drivers and also may be visitors unfamiliar with the area. As such, there is the potential for the social impact that simply inputting a roundabout can have on the general thoughts and feelings of users in the area that can then be connected to opinions of the NAU campus and Flagstaff experience.

Another social impact has to do with the general mobility of public due to the implementation of a roundabout. Roundabouts are a traffic calming device, used to slow and control vehicle flows. This has the greatest cost for motorized users that tend to drive more aggressively (as fast as possible) and the greatest benefits for those users already traveling at a slower pace (pedestrians, cyclists, transit). This helps to create a more equitable travel experience for all users.

Roundabouts, and their associated infrastructure, have the added effect of making the roadways more approachable for other users such as cyclists and pedestrians. Pedestrians are given their own walking areas and traffic slows down. This particular design has the potential to tie into the FUTS trail, includes new and improved transit bays, and safer pedestrian accommodations. For an area that already has a high number of non-motorized users, a roundabout can create a more suitable street environment, making pedestrian and bicycle travel more enjoyable.

An additional social impact is the effect the design will have on the aesthetics of the intersection area. These are how the design will appeal to the five sense. The design proposed has the ability to integrate additional greenspace, pedestrian accommodations, make bicycle travel safer and easier, and decrease vehicular congestion, but will result in a larger intersection area overall and will necessitate the removal of certain site features. In general, due to these changes, this design will aid in visual appeal by creating a more comprehensive intersection design, incorporating greenspace and reducing vehicular congestion. General air quality will improve due to reduced vehicle emissions. Vehicle noise may be reduced due to decreased vehicular congestion. Overall, thought the intersection area will increase, this design will benefit the area by creating a more approachable, usable intersection, with features for all users.

15.2 Economic Impacts

Implementation of this design has several associated costs. These include the initial capital costs of design, acquiring right of way, and construction. Essentially, no right of way would need to be purchased for this project as all area is either owned by NAU, or ADOT, which eliminates that cost. Other capital costs are included in the cost of implementing the design.

Other costs include operational and maintenance costs. Virtually no operational costs are required with a roundabout and maintenance costs in addition to the existing four-way stop intersection are mainly due to landscaping. A conservative estimate of $700/per year has been assumed. All other maintenance costs (repaving, lighting, signage and stripping) are assumed consistent with the original design and ignored for this cost-benefit analysis.

Next, there are costs to society in the form of fuel costs, cost of delay, and cost of crashes. Fuel cost tend to decrease with the implementation of a roundabout as vehicle are able to travel through an intersection without stopping, idling, and re-accelerating. Vehicles that do come to a complete stop seldom wait more than seconds before entering the roundabout. Cost of delay is defined as a loss of productivity due to time spent in traffic and can be quantified as monetary value given an associated average vehicle-hour cost as a representation of lost wages and/or worker productivity. Roundabouts generally improve delay times and, as the final Rodel model shows, a maximum delay, during peak conditions and after 20 years of traffic growth, is 30 seconds. This would result in monetary savings for individual users and the community as a whole.

Cost of crashes is the monetary value associated with collisions at the intersection. This includes the property damage of one or more vehicles and anything at the site, but also includes the cost of medical bills, emergency services, loss of productivity due to injury and declined quality of life due to injury. Though crash predictions could not be quantified due to lack of preliminary crash data, roundabout are shown to decrease overall vehicular collisions by 37 percent, with injury collisions dropping 75 percent, fatal crashes dropping 90 percent, and pedestrian collisions dropping 40 percent, as compared to stop or signal controlled intersections [8]. This results in a cost benefit for the community with the implementation of the roundabout design.

15.3 Environmental Impacts

Environmental impacts of the design include the impact of fuel consumption, pollution, and removal of vegetation. With the implementation of this design, which will ensure continual flow of traffic with little need to stop on the intersection approach, fuel consumption will decrease, which is a positive environmental impact. This leads into the environmental impact of pollution. With decreased fuel consumption due to this intersection design, vehicle emissions will also decrease, reducing NO_x and CO. This will positively impact humans, plants, and animals. However, as with any construction project, there is the likelihood of pollution due to fuel spillage, construction equipment emissions, and construction waste and materials, which would overall be a negative impact for the site.

The design ensures little to no change in impermeable area from the initial design, meaning there will be no further impact on the drainage and infiltration of the site. Additionally, the design does not impact the Sinclair wash, ensuring the functionality of this channel is not impeded upon. Construction of this design will necessitate the removal of at least five large pine trees and some additional smaller trees, which is an overall negative but, the design does allow new unpaved area that can be used to plant new trees. Additionally, the central greenspace on the roundabout allows for a landscaping opportunity to increase vegetation and aesthetic appeal.

15.4 Cost of Implementing Design

The estimated cost of implementing the design presented is $829,064.25. Appendix S shows a breakdown of this cost by pay item.

15.5 Additional Recommendations

The scope of this project and project constraints limited the extents of work in and around the project site. While the design presented meets the project goals, there are additional recommendations the BETR Engineering team would make to improve aspects of the site outside of the project scope. These are summarized below:

Bus bay: The current design includes two added bus bays which will eliminate the need for buses to turn across traffic to re-enter the roadway. It is recommended that the current bus bay area be changed to one way, eastbound, and a curb cut be added for the entrance.

Regrade parking lot entrance: The presented design maintains the required less than 4% approach grade on all legs. Ensuring the Pine Knoll Dr. leg met this requirement resulted in lower elevation of roadway at the north P62 parking lot entrance. As such, it is recommended that the lot entrance be regrading to accommodate this adjustment.

As an aesthetic recommendation, the team purposes using green space of the central roundabout island for a new university welcome sign, highlighting the new entrance to the campus.

16.0 Summary of Engineering Work

16.1 Original Gantt chart

The original Gantt chart was created before knowledge of governmental health restrictions due to COVID-19. The start of the school year, August 31, was moved up to August 12, causing an early start to our project work. An updated Gantt chart was produced with dates aligned and slightly changed to fit the new project start and end dates. This is the schedule that will be referred to in future discussion. This Gantt Chart can be seen in Exhibit K.

16.2 Updated Gantt chart

The updated Gantt chart shows the actual progression of work through our project. It can be seen that several tasks at the start of the project were accomplished in less time than originally anticipated. This was largely due the cut of surveying tasks from project work. Later on, several tasks took longer than expected due to conflicts with other time requirements. The final Gantt Chart can be seen in Exhibit L with a superimposed final Gantt chart over the original Gantt Chart seen in Exhibit M.

17.0 Summary of Engineering Costs

17.1 Original Staffing Costs

The original estimate for staffing costs for the design of this project totaled $135,760. Table 17-1 shows the original staffing estimates.

Table 17-1: Original Staffing Cost

Staffing Breakdown				
	Classification	**Hours**	**Rate ($/hr)**	**Cost**
Personnel	SE	299	180	$53,820
	PM	144	160	$23,040
	DT	131	95	$12,445
	EIT	337	105	$35,385
	ST	47	110	$5,170
Supplies	**Classification**	**Days**	**Rate ($/day)**	**Cost**
	Survey equip.	3	100	$300
	Computers	56	100	$5,600
			Total	$135,760

17.2 Updated Staffing Costs

The team's final staffing costs can be seen in Table 17-2, and total $65,655. This value is lower than expected due to the elimination of a few early tasks such as surveying and the condensing of the project schedule.

Table 17-2: Original Staffing Cost

Staffing Breakdown				
	Classification	**Hours**	**Rate ($/hr)**	**Cost**
Personnel	SE	142	180	$25,560
	PM	83.5	160	$13,360
	DT	49.5	95	$4,703
	EIT	156.5	105	$16,433
Supplies	**Classification**	**Days**	**Rate ($/day)**	**Cost**
	Computers	56	100	$5,600
			Total	$65,655

17.3 Time Spent

In total, 431.5 hours were spent by the team in completing this project. The total hours for each position can be seen in Table 9-2 above.

18.0 Conclusion

In conclusion, BETR Engineering has designed and presented a roundabout based intersection solution to the vehicular congestion at the Pine Knoll and McConnell Dr. intersection, with consideration given for the I-17 exit ramp. The design presented features a two-lane roundabout with an added bypass lane, through which all McConnell Dr. and Pine Knoll Dr. intersection traffic and all I-17 exit ramp traffic will be conveyed. The intersection was designed to a Level of Service of C for the expected 20-year traffic growth. The presented solution is a workable design that meets the objective described above.

19.0 References

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20.0 Appendices

Appendix A: Rodel Outputs – AM Peak, 0.8% Growth

2040 AM Peak
50% Confidence Level
Nighttime conditions

Project: AM Peak 0.8% Growth
Scheme: AM Peak 0.8% Growth
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 AM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	82	82	0	5.0	1.00	0.900
2	McConnell (EB)	0	286	402	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	127	45	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 AM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		164		127			1090			0.150	
2	McConnell (EB)		688		82			1144			0.602	
3	Pine Knoll Dr. (NB)		172		286			919			0.187	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		3.9		3.9		0.5			A		A
2	McConnell (EB)		7.9		7.9		4.4			A		A
3	Pine Knoll Dr. (NB)		4.8		4.8		0.7			A		A

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Appendix B: Rodel Outputs – AM Peak, 2.0% Growth

2040 AM Peak
50% Confidence Level
Nighttime conditions

Project: AM Peak 2% Growth
Scheme: AM Peak 2% Growth
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 AM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	104	104	0	5.0	1.00	0.900
2	McConnell (EB)	0	363	510	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	160	57	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 AM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		208		160			1052			0.198	
2	McConnell (EB)		873		104			1117			0.781	
3	Pine Knoll Dr. (NB)		217		363			847			0.256	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		4.3		4.3		0.7			A		A
2	McConnell (EB)		14.4		14.4		9.9			B		B
3	Pine Knoll Dr. (NB)		5.7		5.7		1.0			A		A

Appendix C: Rodel Outputs – Mid-Day Peak, 0.8% Growth

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: Mid-Day Peak 0.8% Growth
Scheme: Mid-Day Peak 0.8% Growth
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes: Approach Lanes	Lanes: Entry Lanes	Lanes: Circulating Lanes	Lanes: Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows: U-Turn	Turning Flows: Exit-2	Turning Flows: Exit-1	Turning Flows: Bypass	Flow Modifiers: Trucks %	Flow Modifiers: Flow Factor	Flow Modifiers: Peak Hour Factor
1	McConnell (WB)	0	106	245	0	5.0	1.00	0.900
2	McConnell (EB)	0	237	284	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	351	114	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr) Arrival Flow: Left	Arrival Flow: Right	Arrival Flow: Bypass	Opposing Flow: Entry	Opposing Flow: Bypass	Capacity (veh/hr) Capacity: Left	Capacity: Right	Capacity: Bypass	Average VCR: Left	Average VCR: Right	Average VCR: Bypass
1	McConnell (WB)		351		351			857			0.410	
2	McConnell (EB)		521		106			1115			0.467	
3	Pine Knoll Dr. (NB)		465		237			969			0.480	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec): Left	Right	Bypass	Leg	95% Queue (veh): Left	Right	Bypass	Level of Service: Left	Right	Bypass	Leg
1	McConnell (WB)		7.1		7.1		2.1			A		A
2	McConnell (EB)		6.1		6.1		2.6			A		A
3	Pine Knoll Dr. (NB)		7.1		7.1		2.7			A		A

Appendix D: Rodel Outputs – Mid-Day Peak, 2.0% Growth

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: Mid-Day Peak 2% Growth
Scheme: Mid-Day Peak 2% Growth
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	134	311	0	5.0	1.00	0.900
2	McConnell (EB)	0	300	360	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	444	144	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		445		444			776			0.573	
2	McConnell (EB)		660		134			1081			0.610	
3	Pine Knoll Dr. (NB)		588		300			905			0.649	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		10.8		10.8		3.9			B		B
2	McConnell (EB)		8.5		8.5		4.6			A		A
3	Pine Knoll Dr. (NB)		11.3		11.3		5.4			B		B

Appendix E: Rodel Outputs – PM Peak, 0.8% Growth

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: PM Peak 0.8% Growth
Scheme: PM Peak 0.8% Growth
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	104	337	0	5.0	1.00	0.900
2	McConnell (EB)	0	277	260	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	488	152	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		441		488			741			0.595	
2	McConnell (EB)		537		104			1117			0.481	
3	Pine Knoll Dr. (NB)		640		277			928			0.690	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		11.9		11.9		4.3			B		B
2	McConnell (EB)		6.2		6.2		2.8			A		A
3	Pine Knoll Dr. (NB)		12.4		12.4		6.4			B		B

Report dated 3-Sep-2020
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Appendix F: Rodel Outputs – PM Peak, 2.0 % Growth

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: PM Peak 2% Growth
Scheme: PM Peak 2% Growth
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	132	426	0	5.0	1.00	0.900
2	McConnell (EB)	0	351	330	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	618	193	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		558		618			644			0.866	
2	McConnell (EB)		681		132			1084			0.629	
3	Pine Knoll Dr. (NB)		811		351			857			0.946	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		37.6		37.6		14.5			E		E
2	McConnell (EB)		8.9		8.9		5.0			A		A
3	Pine Knoll Dr. (NB)		53.3		53.3		25.2			F		F

Report dated 3-Sep-2020
Rodel Version 1.96 Run number 5

Appendix G: Rodel Outputs – AM Peak, 0.8% Growth, With U-turns

2040 AM Peak
50% Confidence Level
Nighttime conditions

Project: AM Peak 0.8% Growth U-Turns
Scheme: AM Peak 0.8% Growth U-Turns
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr.	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 AM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	83	83	0	5.0	1.00	0.900
2	McConnell (EB)	229	287	403	0	5.0	1.00	0.900
3	Pine Knoll Dr.	0	127	45	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 AM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		166		355			853			0.195	
2	McConnell (EB)		919		83			1143			0.804	
3	Pine Knoll Dr.		172		515			719			0.239	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		5.2		5.2		0.7			A		A
2	McConnell (EB)		15.7		15.7		11.2			C		C
3	Pine Knoll Dr.		6.6		6.6		0.9			A		A

Appendix H: Rodel Outputs – AM Peak, 2.0% Growth, with U-turns

2040 AM Peak
50% Confidence Level
Nighttime conditions

Project: AM Peak 2% Growth U-Turns
Scheme: AM Peak 2% Growth U-Turns
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 AM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	105	105	0	5.0	1.00	0.900
2	McConnell (EB)	290	363	510	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	161	57	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 AM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		210		451			770			0.273	
2	McConnell (EB)		1163		105			1116			1.042	
3	Pine Knoll Dr. (NB)		218		653			620			0.352	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		6.4		6.4		1.1			A		A
2	McConnell (EB)		127.6		127.6		55.1			F		F
3	Pine Knoll Dr. (NB)		8.9		8.9		1.6			A		A

Appendix I: Rodel Outputs – Mid-day Peak, 0.8% Growth, With U-turns

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: Mid-Day Peak 0.8% Growth U-Turns
Scheme: Mid-Day Peak 0.8% Growth U-Turns
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	106	246	0	5.0	1.00	0.900
2	McConnell (EB)	244	237	284	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	351	114	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		352		595			660			0.533	
2	McConnell (EB)		765		106			1115			0.686	
3	Pine Knoll Dr. (NB)		465		481			746			0.623	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		11.6		11.6		3.4			B		B
2	McConnell (EB)		10.2		10.2		6.3			B		B
3	Pine Knoll Dr. (NB)		12.7		12.7		4.8			B		B

Appendix J: Rodel Outputs – Mid-day Peak, 2.0% Growth, With U-turns

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: Mid-Day Peak 2% Growth U-Turns
Scheme: Mid-Day Peak 2% Growth U-Turns
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes: Approach Lanes	Lanes: Entry Lanes	Lanes: Circulating Lanes	Lanes: Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows: U-Turn	Turning Flows: Exit-2	Turning Flows: Exit-1	Turning Flows: Bypass	Flow Modifiers: Trucks %	Flow Modifiers: Flow Factor	Flow Modifiers: Peak Hour Factor
1	McConnell (WB)	0	134	311	0	5.0	1.00	0.900
2	McConnell (EB)	310	301	360	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	445	145	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr) Arrival Flow: Left	Arrival Flow: Right	Arrival Flow: Bypass	Opposing Flow: Entry	Opposing Flow: Bypass	Capacity (veh/hr) Capacity: Left	Capacity: Right	Capacity: Bypass	Average VCR: Left	Average VCR: Right	Average VCR: Bypass
1	McConnell (WB)		445		755			556			0.800	
2	McConnell (EB)		971		134			1081			0.898	
3	Pine Knoll Dr. (NB)		590		611			649			0.910	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec): Left	Right	Bypass	Leg	95% Queue (veh): Left	Right	Bypass	Level of Service: Left	Right	Bypass	Leg
1	McConnell (WB)		30.8		30.8		10.2			D		D
2	McConnell (EB)		29.0		29.0		19.5			D		D
3	Pine Knoll Dr. (NB)		49.5		49.5		18.5			E		E

Appendix K: Rodel Outputs – PM Peak, 0.8% Growth, With U-turns

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: PM Peak 0.8% Growth U-Turns
Scheme: PM Peak 0.8% Growth U-Turns
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes: Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	105	337	0	5.0	1.00	0.900
2	McConnell (EB)	538	277	261	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	488	153	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		442		1026			416			1.062	
2	McConnell (EB)		1076		105			1116			0.964	
3	Pine Knoll Dr. (NB)		641		815			521			1.229	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		204.5		204.5		33.0			F		F
2	McConnell (EB)		52.4		52.4		31.4			F		F
3	Pine Knoll Dr. (NB)		453.7		453.7		72.9			F		F

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Appendix L: Rodel Outputs – PM Peak, 2.0% Growth, With U-turns

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: PM Peak 2% Growth U-Turns
Scheme: PM Peak 2% Growth U-Turns
HCM 2010 Model - Full Geometry

Operational Data

HCM Lanes and Headways

HCM 2016 Bearings and Lanes

Leg	Leg Names	Bearing (deg)	Lanes			
			Approach Lanes	Entry Lanes	Circulating Lanes	Exit Lanes
1	McConnell (WB)	270	1	1	1	1
2	McConnell (EB)	90	1	1	1	1
3	Pine Knoll Dr. (NB)	180	1	1	1	1

Traffic Flow Data (veh/hr)

2040 PM Peak Peak Hour Flows

Leg	Leg Names	Turning Flows				Flow Modifiers		
		U-Turn	Exit-2	Exit-1	Bypass	Trucks %	Flow Factor	Peak Hour Factor
1	McConnell (WB)	0	133	427	0	5.0	1.00	0.900
2	McConnell (EB)	681	351	330	0	5.0	1.00	0.900
3	Pine Knoll Dr. (NB)	0	619	194	0	5.0	1.00	0.900

Operational Results

HCM 2016 - 2040 PM Peak 60 minutes

Flows and Capacity

Leg	Leg Names	Flows (veh/hr)					Capacity (veh/hr)					
		Arrival Flow			Opposing Flow		Capacity			Average VCR		
		Left	Right	Bypass	Entry	Bypass	Left	Right	Bypass	Left	Right	Bypass
1	McConnell (WB)		560		1300			310			1.805	
2	McConnell (EB)		1362		133			1082			1.258	
3	Pine Knoll Dr. (NB)		813		1032			413			1.967	

Delays, Queues and Level of Service

Leg	Leg Names	Average Delay (sec)				95% Queue (veh)			Level of Service			
		Left	Right	Bypass	Leg	Left	Right	Bypass	Left	Right	Bypass	Leg
1	McConnell (WB)		1485.9		1485.9		131.3			F		F
2	McConnell (EB)		483.9		483.9		153.1			F		F
3	Pine Knoll Dr. (NB)		1767.4		1767.4		205.8			F		F

Appendix M: Rodel Outputs – Single-Lane

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	McConnell (WB)	270	0	12.00	1	15.00	1	33.00	66.00	30.00
2	McConnell (EB)	90	0	12.00	1	15.00	1	33.00	66.00	30.00
3	Pine Knoll Dr. (NB)	180	0	12.00	1	15.00	1	33.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	McConnell (WB)	131.00	16.00	1	16.50	1	12.00	1
2	McConnell (EB)	131.00	16.00	1	16.50	1	12.00	1
3	Pine Knoll Dr. (NB)	131.00	16.00	1	16.50	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	McConnell (WB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0
2	McConnell (EB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0
3	Pine Knoll Dr. (NB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	McConnell (WB)	None	441		487		429	793		0.5558	
2	McConnell (EB)	Yield	277	260	104	104	824	993	949	0.2791	0.2739
3	Pine Knoll Dr. (NB)	None	640		277		364	903		0.7090	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	McConnell (WB)	None	9.10		9.10	3.83		A		A
2	McConnell (EB)	Yield	4.65	5.16	4.90	1.10	1.14	A	A	A
3	Pine Knoll Dr. (NB)	None	11.63		11.63	7.35		B		B

Appendix N: Rodel Outputs – Double-Lane

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	McConnell (WB)	270	0	24.00	2	24.00	2	33.00	66.00	30.00
2	McConnell (EB)	90	0	24.00	2	24.00	2	33.00	66.00	30.00
3	Pine Knoll Dr. (NB)	180	0	24.00	2	24.00	2	33.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	McConnell (WB)	131.00	32.00	2	26.00	1	12.00	1
2	McConnell (EB)	131.00	32.00	2	26.00	2	12.00	1
3	Pine Knoll Dr. (NB)	131.00	32.00	2	26.00	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	McConnell (WB)	0	1.000	0	1.000	12.00	3584	0	12.00	1792	0
2	McConnell (EB)	0	1.000	0	1.000	12.00	3584	0	12.00	1792	0
3	Pine Knoll Dr. (NB)	0	1.000	0	1.000	12.00	3584	0	12.00	1792	0

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	McConnell (WB)	None	441		946		429	1240		0.3556	
2	McConnell (EB)	None	995		104		1283	1838		0.5414	
3	Pine Knoll Dr. (NB)	None	640		735		364	1390		0.4605	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	McConnell (WB)	None	5.44		5.44	2.23		A		A
2	McConnell (EB)	None	7.05		7.05	6.07		A		A
3	Pine Knoll Dr. (NB)	None	5.73		5.73	3.40		A		A

Appendix O: Rodel Outputs – Bypass Lane

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	McConnell (WB)	270	0	12.00	1	15.00	1	33.00	66.00	30.00
2	McConnell (EB)	90	0	12.00	1	15.00	1	33.00	66.00	30.00
3	Pine Knoll Dr. (NB)	180	0	12.00	1	15.00	1	33.00	66.00	30.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	McConnell (WB)	131.00	32.00	2	16.50	1	12.00	1
2	McConnell (EB)	131.00	16.00	1	26.00	2	11.50	1
3	Pine Knoll Dr. (NB)	131.00	16.00	1	16.50	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	McConnell (WB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0
2	McConnell (EB)	0	1.000	0	1.000	12.00	1792	0	11.50	1718	0
3	Pine Knoll Dr. (NB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Bypass Geometry

Bypass Approach Geometry (ft)

Leg	Leg Names	Bypass Type	Bypass Flows	V	nv	Vb	nvb	Vt	nvt
2	McConnell (EB)	Yield	260	12	1	12	1	12	1

Bypass Entry and Exit Geometry (ft)

Leg	Leg Names	Entry Geometry						Leg	Leg Names	Exit Lanes	
		Eb	neb	Lb	Lt	Rb	Phib			nex	Nmx
2	McConnell (EB)	12	1	0	130	66.0000 8026	30	3	Pine Knoll Dr. (NB)	1	2

Bypass Entry Capacity Modifiers and Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Calibration	
		Capacity + or -	Cross Walk Factor	Intercept + or -	Slope Factor
2	McConnell (EB)	0	1.000	0	1.000

Operational Results

2040 PM Peak - 60 minutes

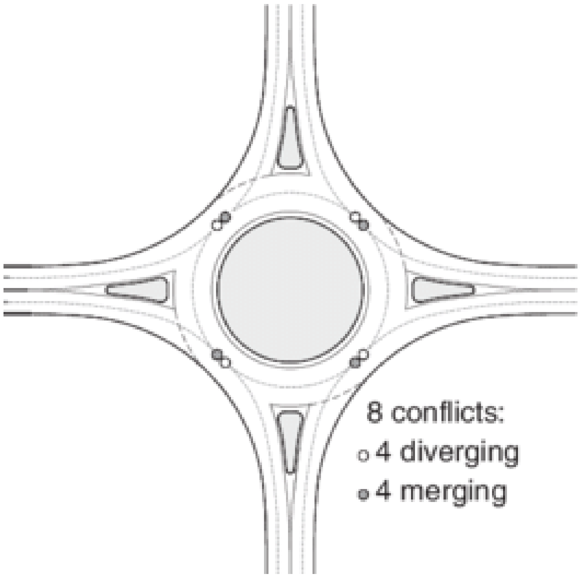
Flows and Capacity

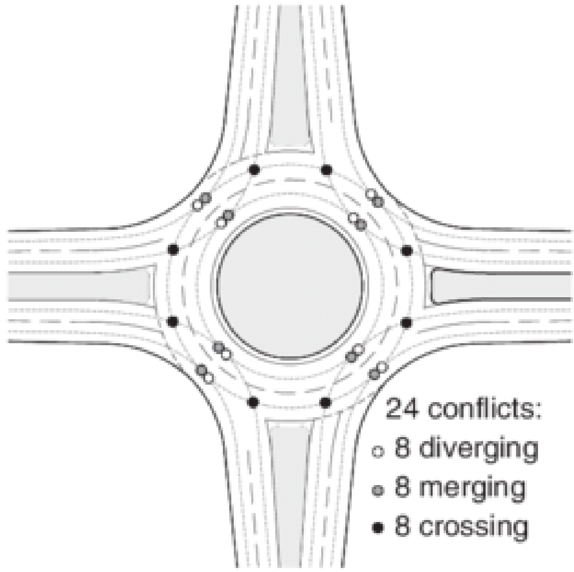
Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	McConnell (WB)	None	441		942		428	693		0.6362	
2	McConnell (EB)	Yield	735	260	104	104	1279	993	949	0.7405	0.2739
3	Pine Knoll Dr. (NB)	None	640		734		364	707		0.9052	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	McConnell (WB)	None	12.48		12.48	5.43		B		B
2	McConnell (EB)	Yield	11.62	5.16	9.93	8.32	1.14	B	A	A
3	Pine Knoll Dr. (NB)	None	41.64		41.64	34.79		E		E

Appendix P: Roundabout Conflict Point Examples





[13]

Appendix Q: Rodel Outputs – Base Geometry

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	McConnell (WB)	287	0	12.00	1	13.66	1	12.27	58.05	34.00
2	McConnell (EB)	90	0	12.00	1	11.00	1	11.65	47.68	21.00
3	Pine Knoll Dr. (NB)	191	0	12.00	1	15.00	1	26.24	61.28	10.00

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	McConnell (WB)	131.00	32.00	2	16.50	1	12.00	1
2	McConnell (EB)	131.00	16.00	1	26.00	2	11.50	1
3	Pine Knoll Dr. (NB)	131.00	16.00	1	16.50	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	McConnell (WB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0
2	McConnell (EB)	0	1.000	0	1.000	12.00	1792	0	11.50	1718	0
3	Pine Knoll Dr. (NB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Bypass Geometry

Bypass Approach Geometry (ft)

Leg	Leg Names	Bypass Type	Bypass Flows	V	nv	Vb	nvb	Vt	nvt
2	McConnell (EB)	Yield	260	12	1	12	1	12	1

Bypass Entry and Exit Geometry (ft)

Leg	Leg Names	Entry Geometry						Leg	Leg Names	Exit Lanes	
		Eb	neb	Lb	Lt	Rb	Phib			nex	Nmx
2	McConnell (EB)	12	1	0	130	66.0000 7603	30	3	Pine Knoll Dr. (NB)	1	2

Bypass Entry Capacity Modifiers and Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Calibration	
		Capacity + or -	Cross Walk Factor	Intercept + or -	Slope Factor
2	McConnell (EB)	0	1.000	0	1.000

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	McConnell (WB)	None	441		942		427	668		0.6604	
2	McConnell (EB)	Yield	735	260	104	104	1279	810	874	0.9079	0.2975
3	Pine Knoll Dr. (NB)	None	640		732		364	746		0.8581	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	McConnell (WB)	None	13.78		13.78	6.16		B		B
2	McConnell (EB)	Yield	29.89	5.79	23.59	24.21	1.29	D	A	C
3	Pine Knoll Dr. (NB)	None	30.17		30.17	23.16		D		D

Appendix R: Rodel Outputs – Final Design

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Operational Data

Main Geometry (ft)

Approach and Entry Geometry

Leg	Leg Names	Approach Bearing (deg)	Grade Separation G	Half Width V	Approach Lanes n	Entry Width E	Entry Lanes n	Flare Length L'	Entry Radius R	Entry Angle Phi
1	McConnell (WB)	287	0	12.00	1	13.93	1	12.27	58.05	35.40
2	McConnell (EB)	90	0	12.00	1	13.66	1	11.65	47.68	21.10
3	Pine Knoll Dr. (NB)	191	0	12.00	1	15.00	1	26.24	61.28	12.41

Circulating and Exit Geometry

Leg	Leg Names	Inscribed Diameter D	Circulating Width C	Circulating Lanes nc	Exit Width Ex	Exit Lanes nex	Exit Half Width Vx	Exit Half Width Lanes nvx
1	McConnell (WB)	131.00	32.00	2	14.00	1	12.00	1
2	McConnell (EB)	131.00	16.00	1	28.94	2	11.50	1
3	Pine Knoll Dr. (NB)	131.00	16.00	1	14.35	1	12.00	1

Capacity Modifiers and Capacity Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Entry Calibration		Approach Road			Exit Road		
		Capacity + or -	XWalk Factor	Intercept + or -	Slope Factor	V (ft)	Default Capacity	Calib Capacity	V (ft)	Default Capacity	Calib Capacity
1	McConnell (WB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0
2	McConnell (EB)	0	1.000	0	1.000	12.00	1792	0	11.50	1718	0
3	Pine Knoll Dr. (NB)	0	1.000	0	1.000	12.00	1792	0	12.00	1792	0

2040 PM Peak
50% Confidence Level
Nighttime conditions

Project: 2040 PM Peak 0.8% Growth U-Turns
Scheme: 2040 PM Peak 0.8% Growth U-Turns
Rodel-Win1 - Full Geometry

Bypass Geometry

Bypass Approach Geometry (ft)

Leg	Leg Names	Bypass Type	Bypass Flows	V	nv	Vb	nvb	Vt	nvt
2	McConnell (EB)	Yield	260	12	1	12	1	12	1

Bypass Entry and Exit Geometry (ft)

Leg	Leg Names	Entry Geometry						Leg	Leg Names	Exit Lanes	
		Eb	neb	Lb	Lt	Rb	Phib			nex	Nmx
2	McConnell (EB)	12	1	0	130	66.0001 0982	30	3	Pine Knoll Dr. (NB)	1	2

Bypass Entry Capacity Modifiers and Calibration (veh/hr)

Leg	Leg Names	Entry Capacity		Calibration	
		Capacity + or -	Cross Walk Factor	Intercept + or -	Slope Factor
2	McConnell (EB)	0	1.000	0	1.000

Operational Results

2040 PM Peak - 60 minutes

Flows and Capacity

Leg	Leg Names	Bypass Type	Flows (veh/hr)					Capacity (veh/hr)			
			Arrival Flow		Opposing Flow		Exit Flow	Capacity		Average VCR	
			Entry	Bypass	Entry	Bypass		Entry	Bypass	Entry	Bypass
1	McConnell (WB)	None	441		943		428	664		0.6641	
2	McConnell (EB)	Yield	735	260	104	104	1280	990	949	0.7428	0.2739
3	Pine Knoll Dr. (NB)	None	640		734		364	739		0.8664	

Delays, Queues and Level of Service

Leg	Leg Names	Bypass Type	Average Delay (sec)			95% Queue (veh)		Level of Service		
			Entry	Bypass	Leg	Entry	Bypass	Entry	Bypass	Leg
1	McConnell (WB)	None	14.02		14.02	6.34		B		B
2	McConnell (EB)	Yield	11.74	5.16	10.02	8.41	1.14	B	A	B
3	Pine Knoll Dr. (NB)	None	32.54		32.54	26.89		D		D

Appendix S: Cost of Implementing Design

60% Preliminary Cost Estimate					
November 2, 2020					
Item No.	Description	Quantity	Unit	Unit Price	Amount
9240170	CONTRACTOR QUALITY CONTROL	1	HOUR	$8,000.00	$8,000.00
7017025	TRAFFIC CONTROL	200	DAY	$1,100.00	$220,000.00
9240050	MISCELLANEOUS WORK (CONSTRUCTION CONFLICTS AND ADDITIONAL WORK)	1	LS	$200,000.00	$200,000.00
9010001	MOBILIZATION	1	LS	$23,000.00	$23,000.00
2010011	CLEARING AND GRUBBING	0	ACRE	$3,000.00	$0.00
2010020	TREE REMOVAL	6	EA	$750.00	$0.00
2020025	REMOVAL OF CONCRETE SIDEWALKS, DRIVEWAYS AND SLABS	3,920	SF	$3.00	$11,760.00
2020048	REMOVAL OF STRUCTURE (CMU WALL)	1	EA	$20.00	$20.00
2020021	REMOVE CURB AND GUTTER	1,320	LF	$3.00	$3,960.00
8080195	REMOVE AND SALVAGE EXISTING SIGN PANEL AND POST	4	EA	$75.00	$300.00
2030301	ROADWAY EXCAVATION	570	CY	$12.00	$6,840.00
2020081	REMOVE BITUMINOUS PAVEMENT (MILLING) (1”)	320	SY	$2.00	$640.00
3030022	AGGREGATE BASE, CLASS 2	760	CY	$70.00	$53,200.00
3080001	BITUMINOUS TREATED BASE	700	TON	$100.00	$70,000.00
4040002	1” ASPHALT CONCRETE	4,590	SY	$7.00	$32,130.00
9080101	CONCRETE CURB AND GUTTER, TYPE A (MAG DET. 220-1)	2,510	LF	$16.00	$40,160.00
9080201	CONCRETE SIDEWALK	10,090	SF	$8.00	$80,720.00
6080011	CAST IN PLACE DETECTABLE WARNING PANEL	2	EA	$50.00	$100.00
9080001	TYPE “A” ISLAND CURB	970	LF	$20.00	$19,400.00
9100201	CONCRETE MEDIAN ISLAND	500	SF	$8.00	$4,000.00
6080005	REGULATORY, WARNING, OR MARKER SIGN PANEL				
6080005.01	YIELD SIGN (R1-2, 36” X 36”)	3	EA	$225.00	$675.00
6080005.02	MERGE LEFT SIGN (W4-1, 36” X 36”)	1	EA	$225.00	$225.00
6080005.03	CONTINUE RIGHT (R6-4A, 36” X 30”)	3	EA	$200.00	$600.00
6080005.04	ROUNDABOUT SIGN (W2-6, 36” X 36”)	1	EA	$225.00	$225.00
6080005.05	SPEED LIMIT (R2-1, 30” X 36”)	5	EA	$225.00	$1,125.00
6080005.06	PROCEED THROUGH MEDIAN (W3-2, 36” X 36”)	2	EA	$225.00	$450.00
6080005.07	VEER AROUND MEDIAN (R4-7, 30” X 36”)	3	EA	$200.00	$600.00
6080005.08	RIGHT TURN ONLY (R3-5R, 30” X 36”)	2	EA	$200.00	$400.00
6080005.09	LANE GROUP RIGHT TURN (R3-8, 30” X 36”)	1	EA	$200.00	$200.00

6080005.1	CROSSWALK SIGN (R9-3bP, 24” X 18”)	1	EA	$120.00	$120.00
6080005.11	THROUGH ROUNDABOUT (R6-5P, 36” X 36”)	1	EA	$225.00	$225.00
6080005.12	PED/BIKE SIGN (W11-15a, 36” X 36”)	1	EA	$225.00	$225.00
6080005.13	SHARE THE ROAD (W16-1P, 18” X 24”)	3	EA	$120.00	$360.00
6080005.14	RIGHT LANE ENDING (W4-2R, 48” X 48”)	1	EA	$285.00	$285.00
6080005.15	STREET SIGN (D3-2, 48” X 42”)	1	EA	$275.00	$275.00
6080005.16	STREET SIGN (D3-2, 48” X 30”)	1	EA	$250.00	$250.00
6080005.17	STREET SIGN (D3-2, 48” X 30”)	1	EA	$250.00	$250.00
7090002	6” DOUBLE YELLOW, DUAL COMPONENT PAVEMENT MARKING (YELLOW EPOXY)	1,904	LF	$1.25	$2,380.00
7090002	4” YELLOW AROUND SPLITTER ISLAND, DUAL COMPONENT PAVEMENT MARKING (YELLOW EPOXY)	212	LF	$1.25	$265.00
7090010	WHITE PAVEMENT ARROW, DUAL COMPONENT PAVEMENT LEGEND	5	EA	$8.00	$40.00
7090010	YIELD BAR, DUAL COMPONENT PAVEMENT LEGEND	67	LF	$1.25	$83.25
7090001	6” WHITE, 2' STRIPE, 2' SPACING, DUAL COMPONENT PAVEMENT MARKING (WHITE EPOXY)	830	LF	$1.25	$1,037.50
7090001	6” WHITE, DUAL COMPONENT PAVEMENT MARKING (WHITE EPOXY)	3	LF	$1.25	$3.75
7090001	12” HIGH VISIBILITY CROSSWALK, 2' WHITE BAR, 2' SPACING PER COF, DUAL COMPONENT PAVEMENT MARKING (WHITE EPOXY)	28	LF	$1.25	$35.00
7090010	WHITE STRAIGHT PAVEMENT ARROW	1	EA	$8.00	$8.00
7090001	6” WHITE BROKEN CENTERLINE, DUAL COMPONENT PAVEMENT MARKING (WHITE EPOXY)	240	LF	$1.25	$300.00
7090010	RIGHT TURN ONLY PAVEMENT ARROW, DUAL COMPONENT PAVEMENT LEGEND	8	EA	$8.00	$64.00
7090010	WHITE MERGE ARROW, DUAL COMPONENT PAVEMENT LEGEND	8	EA	$8.00	$64.00
7090001	4” WHITE, DUAL COMPONENT PAVEMENT MARKING (WHITE EPOXY)	67	LF	$1.25	$83.75
	CONTINGENCY (5%)		LS	$39,260.00	$39,260.00
	TOTAL OF ITEMS				**$829,064.25**

Exhibit A: Site Area Map

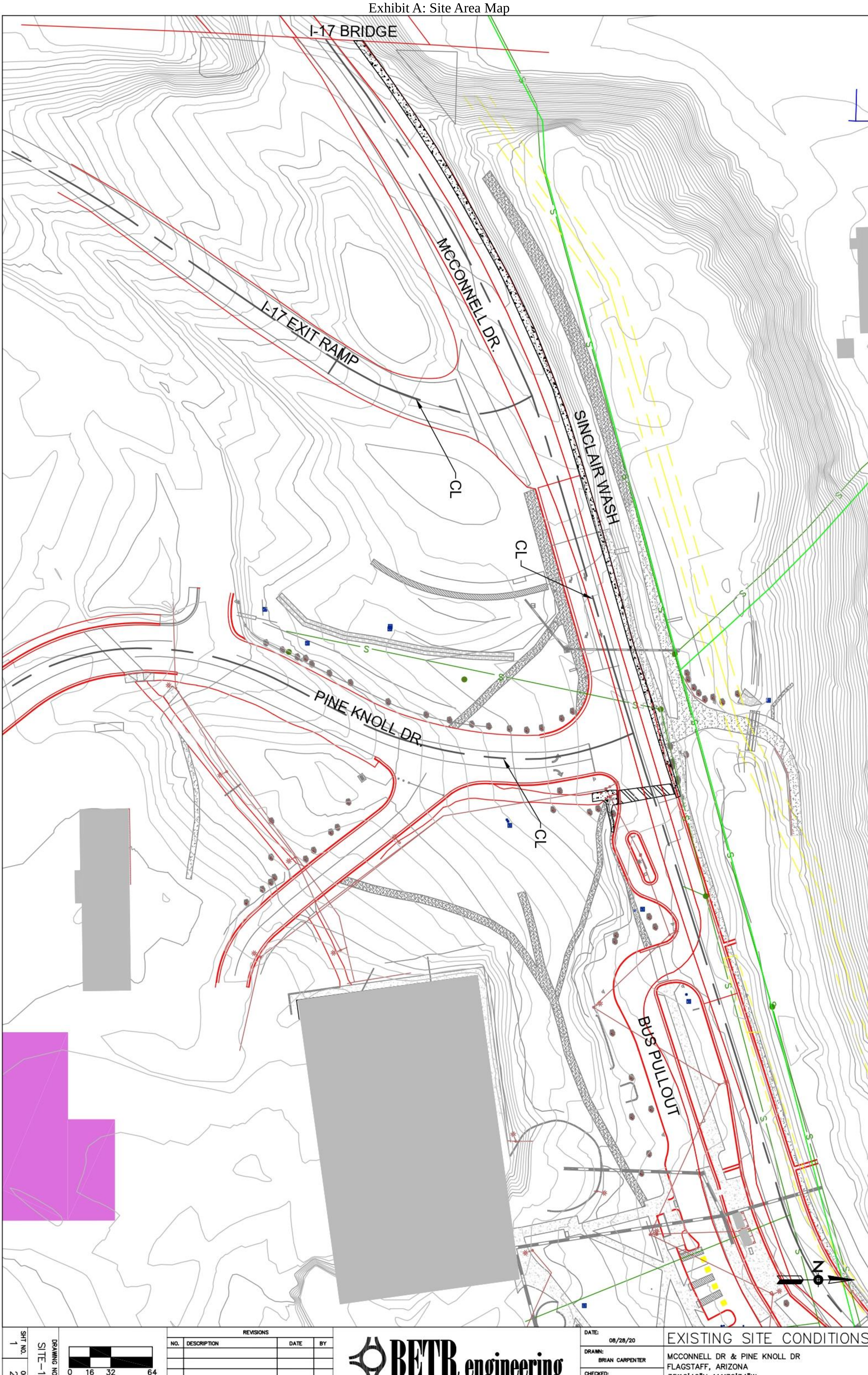


Exhibit B: Pre-Development Drainage Area

SHT NO.	DRAWING NO.		REVISIONS						
1 OF 2	DRN-1	0 37.5 75 150	NO.	DESCRIPTION	DATE	BY	BETR engineering	DATE: 09/28/2020 DRAWN: TESSA HUETTL CHECKED: BRIAN CARPENTER	PRE-DEV. DRAINAGE AREA MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N 111°39'34"W

Exhibit C: Minimum Intersection Areas

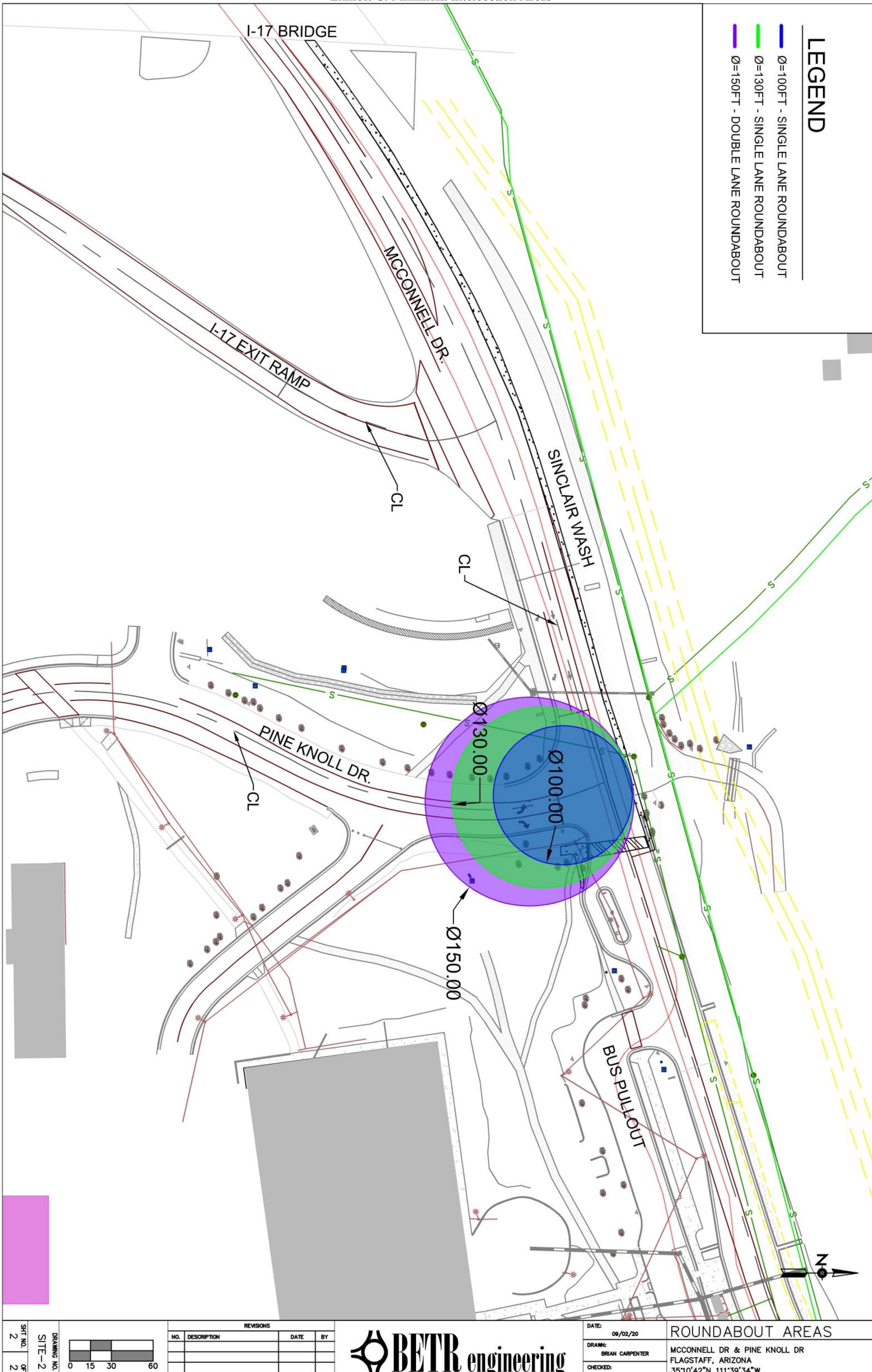
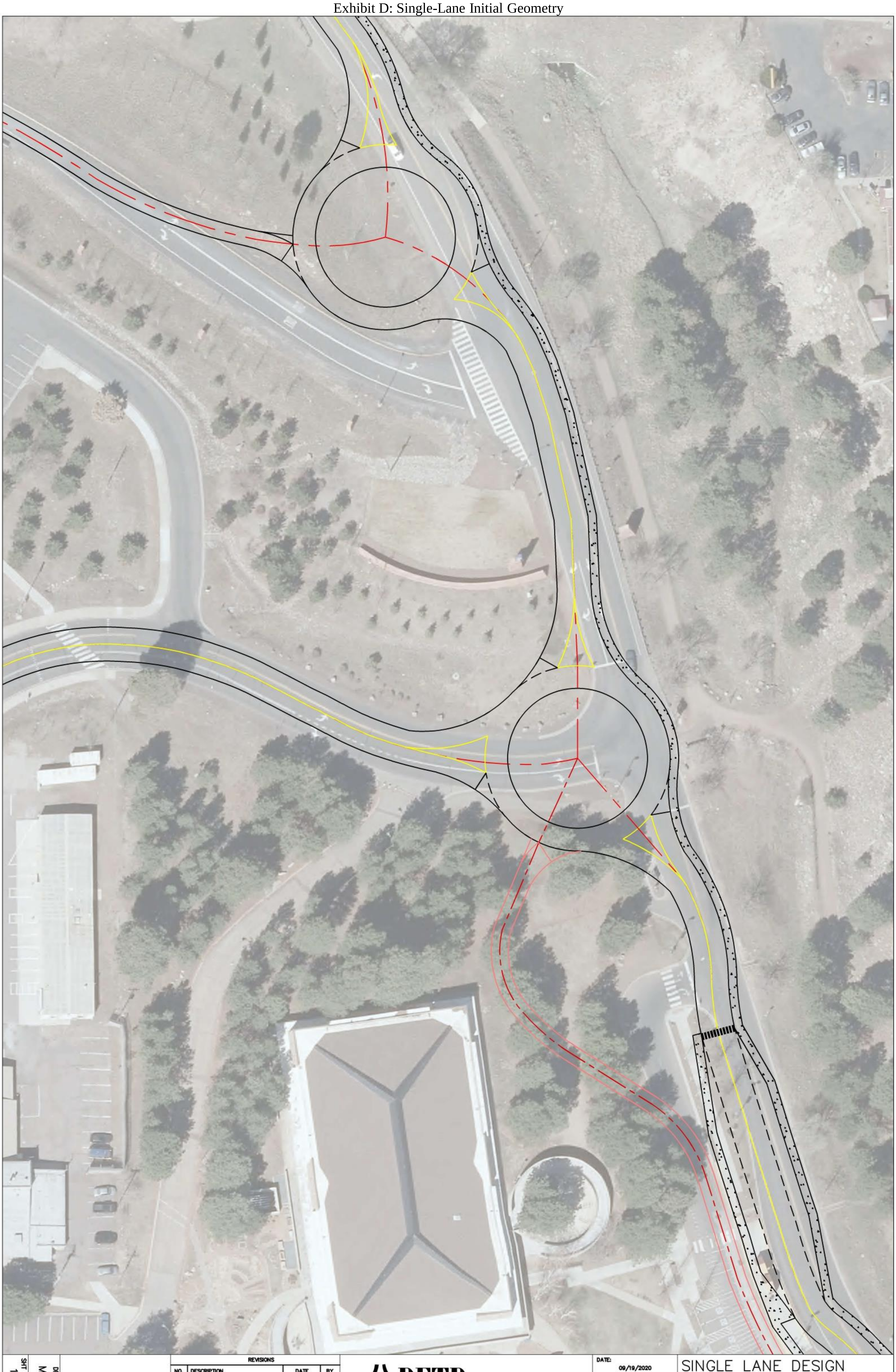


Exhibit D: Single-Lane Initial Geometry



SHT NO.	DRAWING NO.
1 OF 3	MOCK-1

0 15 30 60

REVISIONS

NO.	DESCRIPTION	DATE	BY

BETR engineering

DATE: 09/19/2020

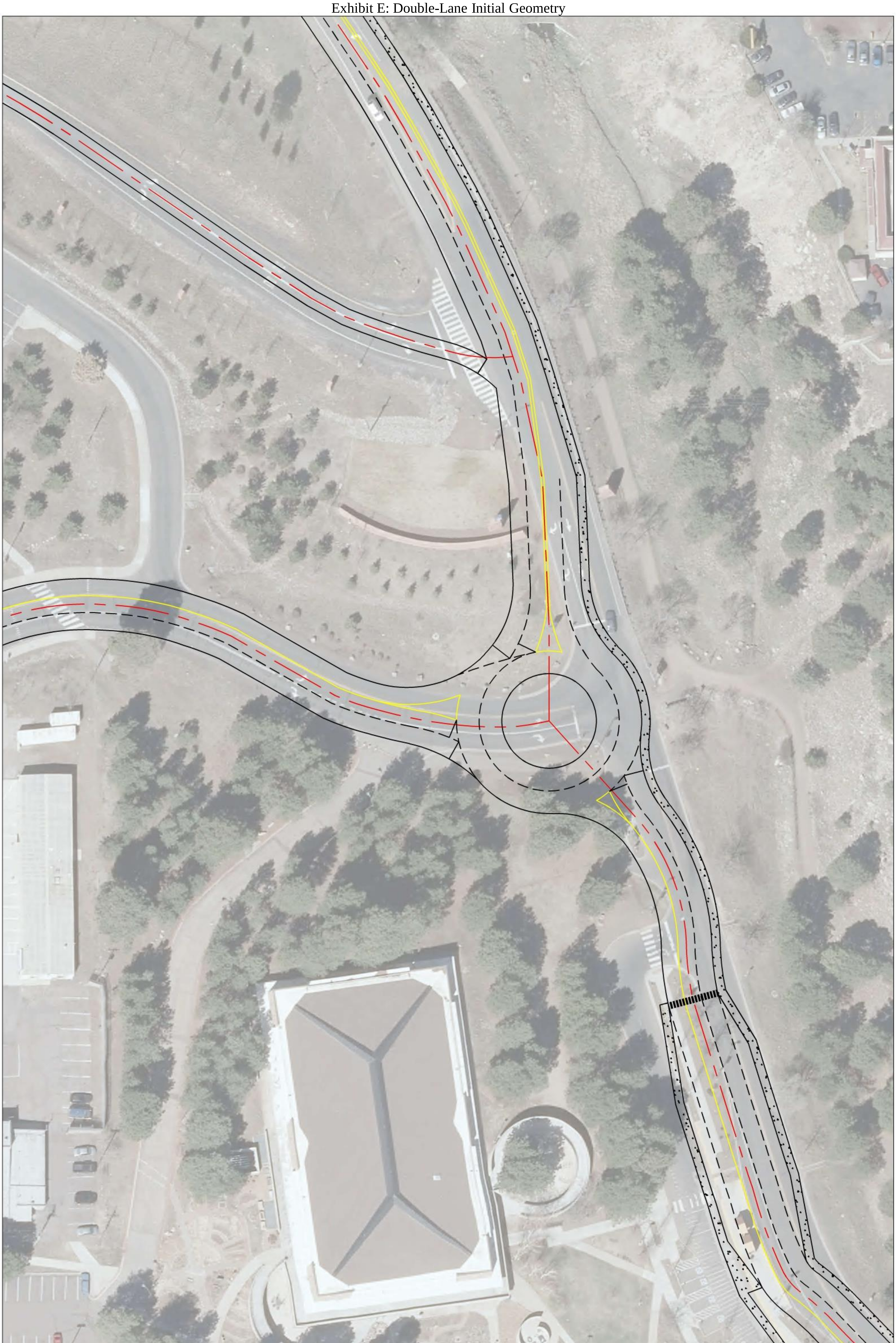
DRAWN: TESSA HUETTL

CHECKED: BRIAN CARPENTER

SINGLE LANE DESIGN

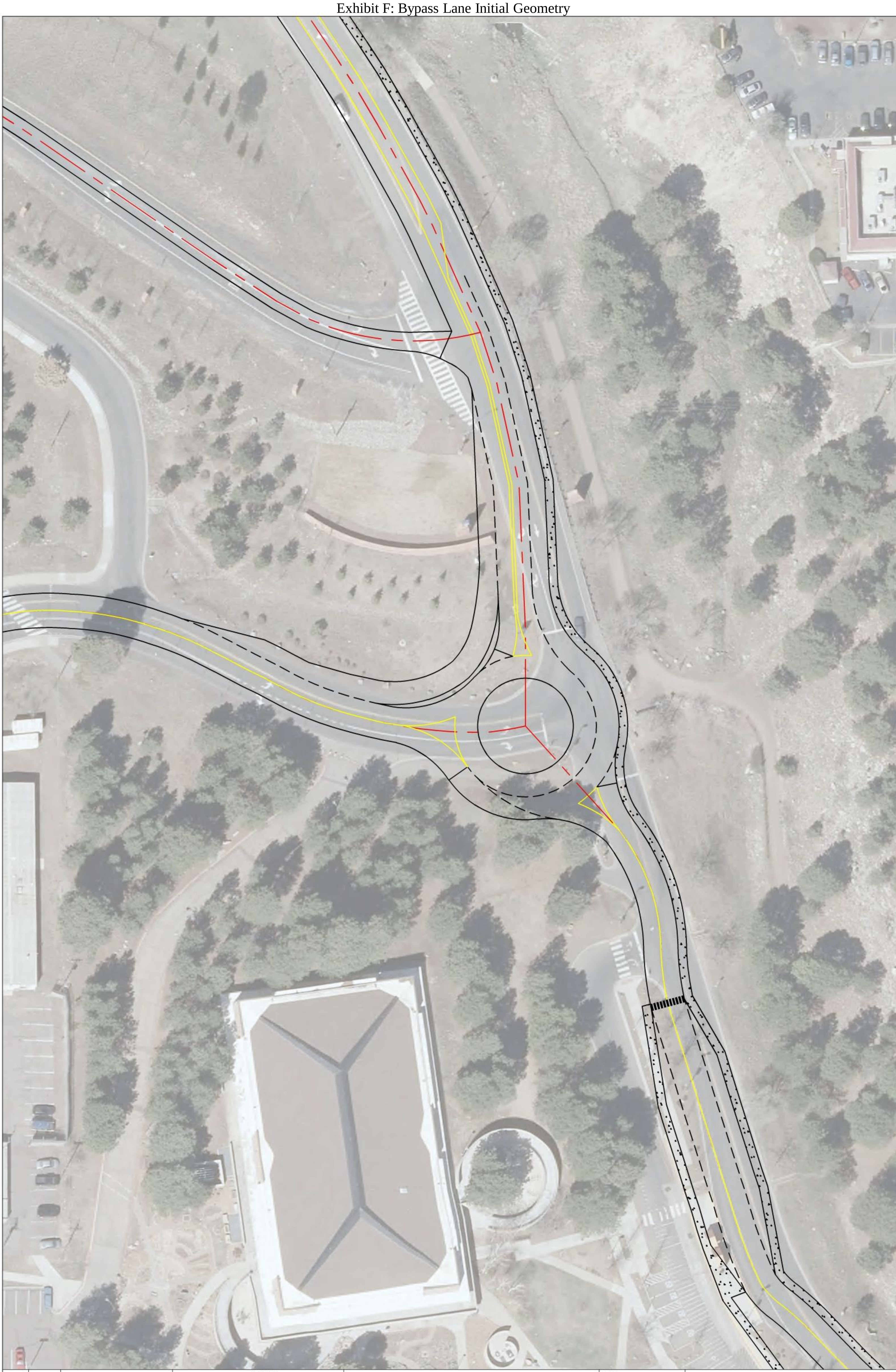
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W

Exhibit E: Double-Lane Initial Geometry



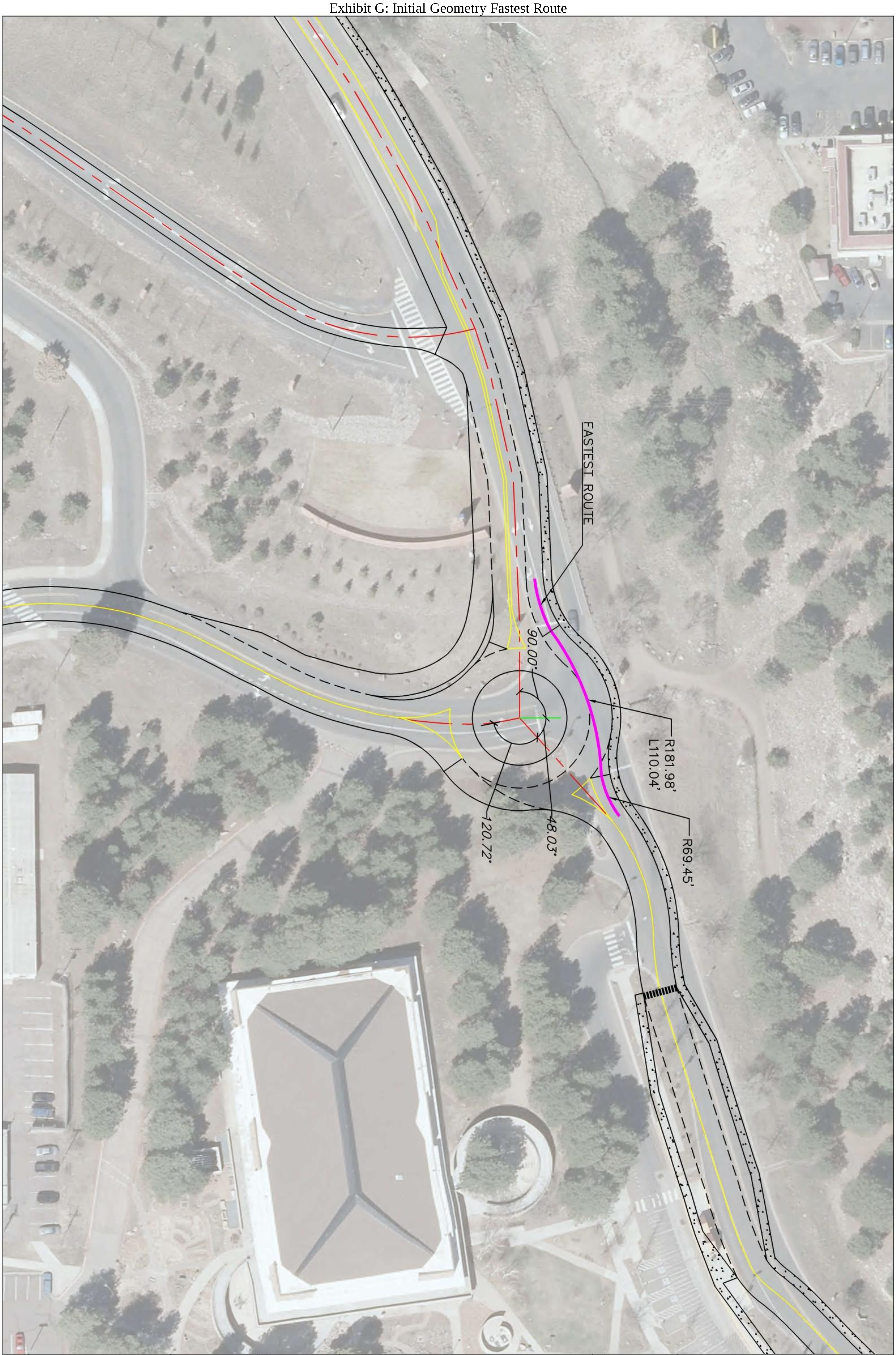
SHT NO.	DRAWING NO.		REVISIONS					DATE:	DOUBLE LANE DESIGN
2 OF 3	MOCK–2	0 15 30 60	NO.	DESCRIPTION	DATE	BY	BETR engineering	09/19/2020 DRAWN: TESSA HUETTL CHECKED: BRIAN CARPENTER	MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N 111°39'34"W

Exhibit F: Bypass Lane Initial Geometry



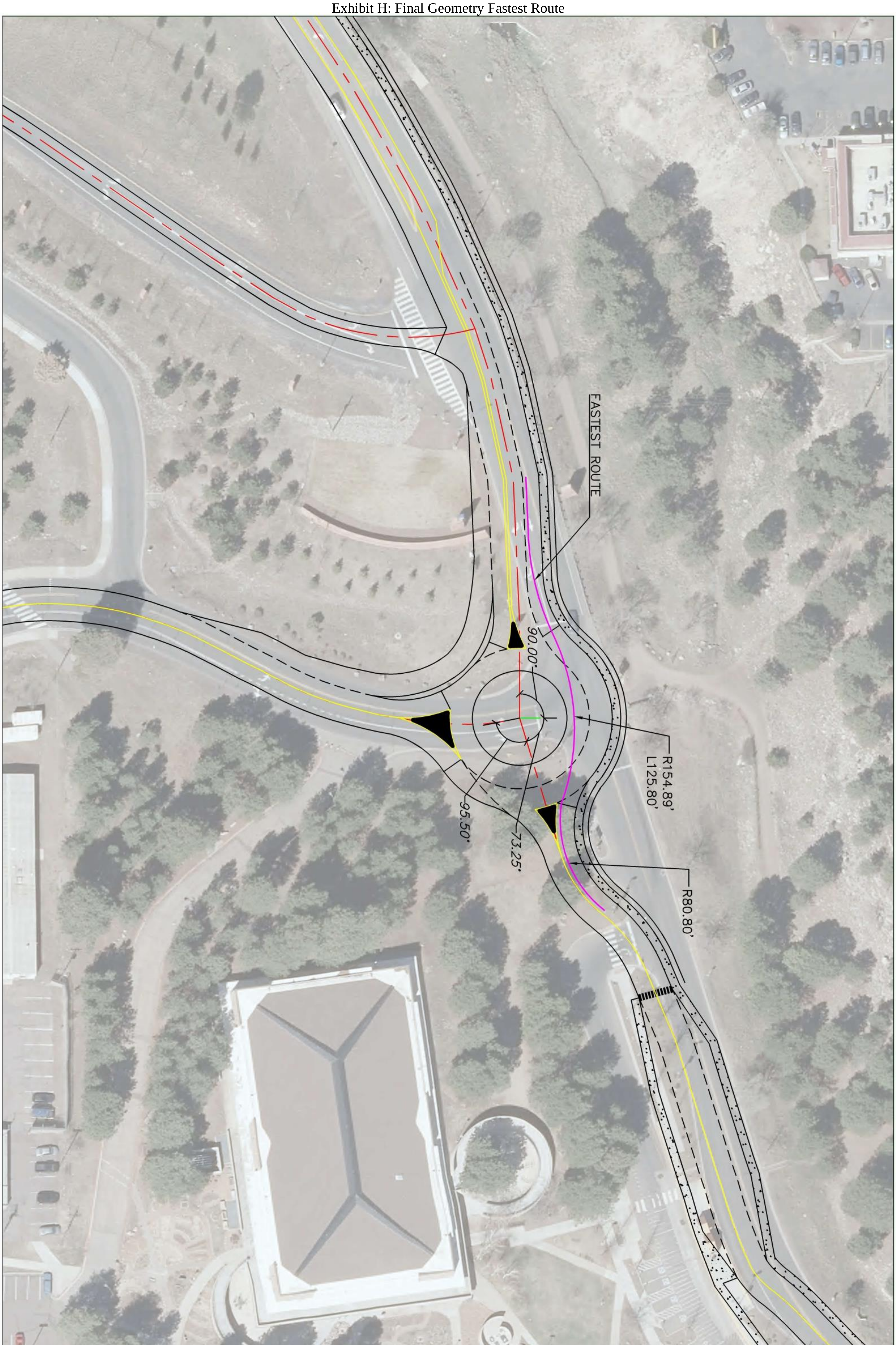
SHT NO. 3 OF 3	DRAWING NO. MOCK–3	0 15 30 60	REVISIONS	BETR engineering	DATE: 09/19/2020	BYPASS LANE DESIGN
			NO. / DESCRIPTION / DATE / BY		DRAWN: TESSA HUETTL	MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N 111°39'34"W
					CHECKED: BRIAN CARPENTER	

Exhibit G: Initial Geometry Fastest Route



SHT NO. 1 OF 2	DRAWING NO. FR-1	0 15 30 60	REVISIONS NO. DESCRIPTION DATE BY	BETR engineering	DATE: 09/19/2020 DRAWN: TESSA HUETTL CHECKED: BRIAN CARPENTER	INITIAL FASTEST ROUTE MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N 111°39'34"W

Exhibit H: Final Geometry Fastest Route



SHT NO. 2 OF 2

DRAWING NO. FR-2

0 15 30 60

REVISIONS			
NO.	DESCRIPTION	DATE	BY

BETR engineering

DATE: 09/19/2020

DRAWN: TESSA HUETTL

CHECKED: BRIAN CARPENTER

FINAL FASTEST ROUTE

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W

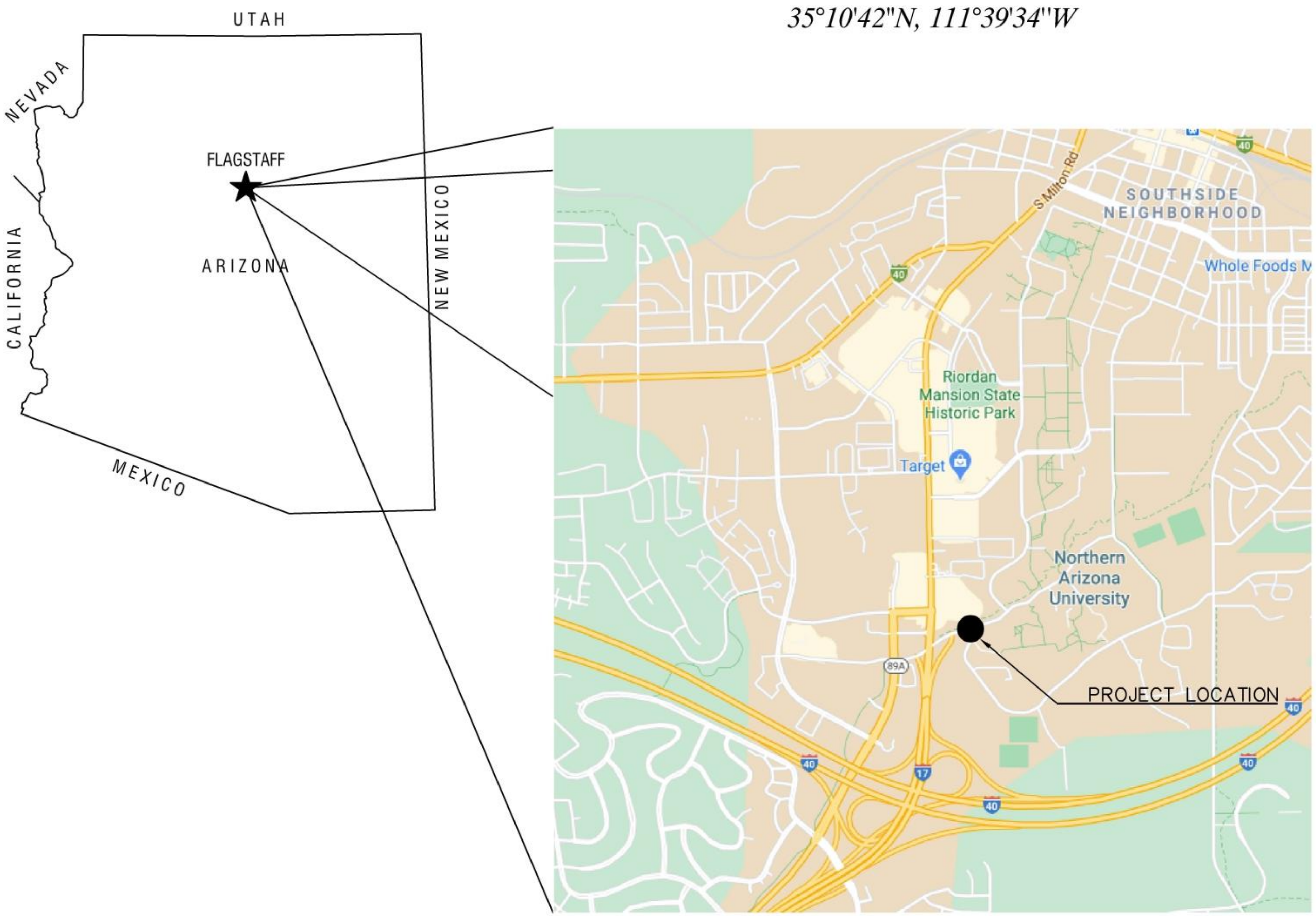
Exhibit I: Post-Development Drainage Area

SHT NO. 2 OF 2	DRAWING NO. DRN-2	0 37.5 75 150	REVISIONS				BETR engineering	DATE: 09/28/2020	POST-DEV. DRAINAGE AREA
			NO.	DESCRIPTION	DATE	BY		DRAWN: TESSA HUETTL	MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N 111°39'34"W
								CHECKED: BRIAN CARPENTER	

NAU ROUNDABOUT DESIGN

PROPOSED ROUNDABOUT AT THE INTERSECTION OF MCCONNELL DR AND PINE KNOLL DR IN FLAGSTAFF AZ

35°10'42"N, 111°39'34"W



INDEX OF SHEETS

SHEET	DRAWING	DESCRIPTION
1	CVR	COVER PAGE
2	TY-1	TYPICAL SECTIONS
3	TY-2	ROUNDABOUT SECTIONS
4	GEOM	GEOMETRIC LAYOUT
5 - 6	R-1 - R-2	REMOVAL SHEETS
7 - 10	C-1 - C-4	CONSTRUCTION SHEETS
11	PLN	PLAN SHEET
12 - 15	PRF-1 - PRF-4	WESTBOUND PROFILE
16	SGN	SIGNING PLAN
17 - 18	STP-1 - STP2	STRIPING PLAN SHEETS
19	TTC	TRAFFIC CONTROL PLAN

COVER PAGE

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

DATE: 09/19/2020
DRAWN: TESSA HUETTL
CHECKED: BRIAN CARPENTER

BETR engineering

REVISIONS

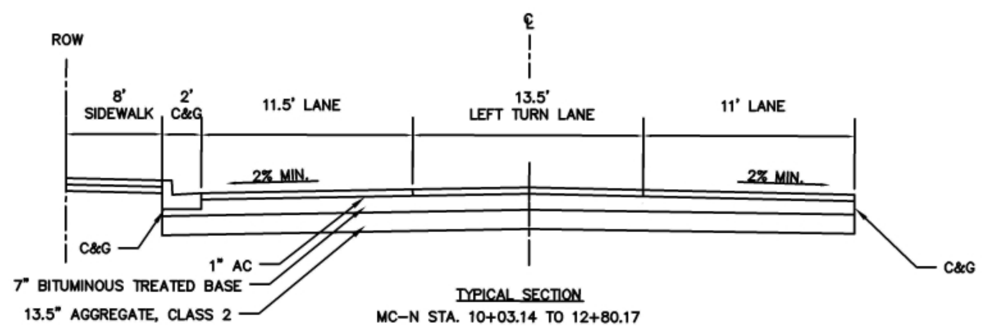
NO.	DESCRIPTION	DATE	BY

0 NTS

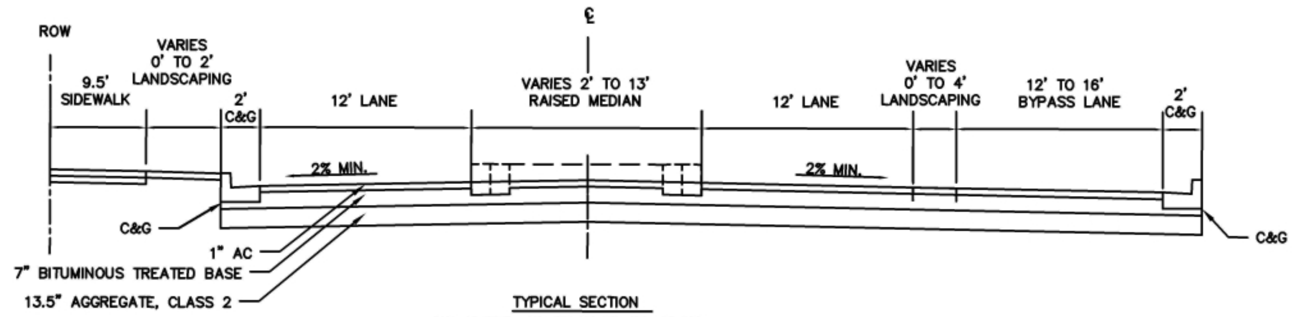
DRAWING NO. CVR

SHT NO. 1 OF 19

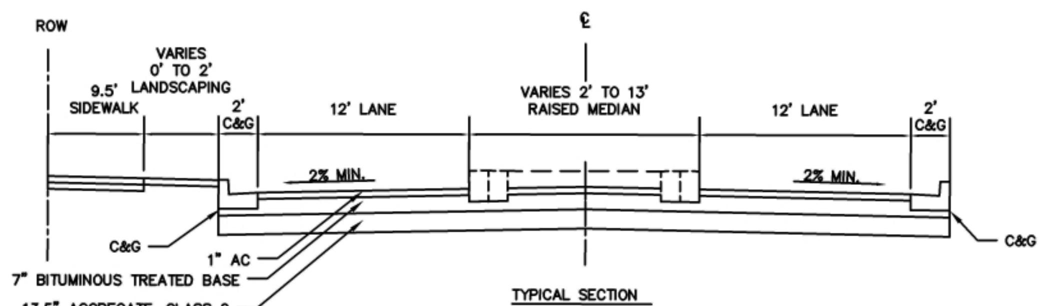
MCCONNELL DR. CROSS SECTIONS



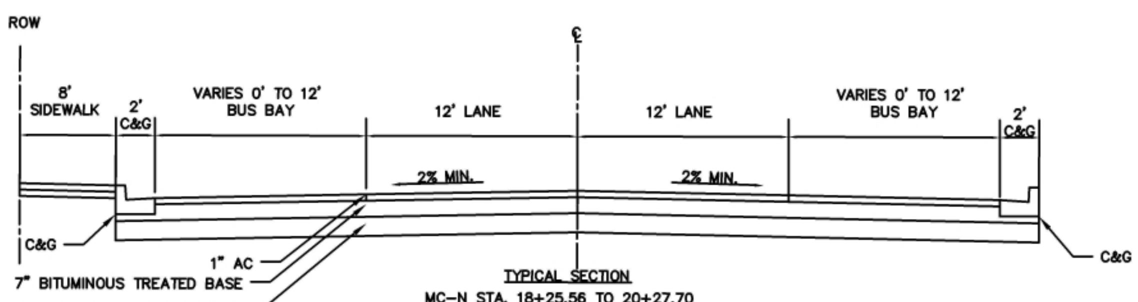
TYPICAL SECTION
MC-N STA. 10+03.14 TO 12+80.17



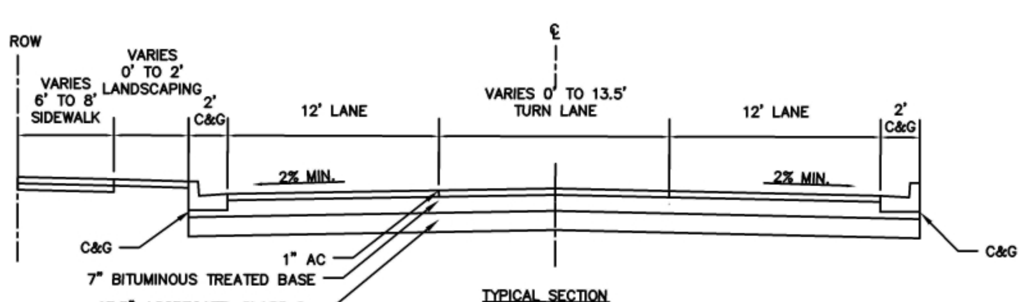
TYPICAL SECTION
MC-N STA. 12+80.17 TO 15+49.97



TYPICAL SECTION
MC-N STA. 16+63.29 TO 18+25.56

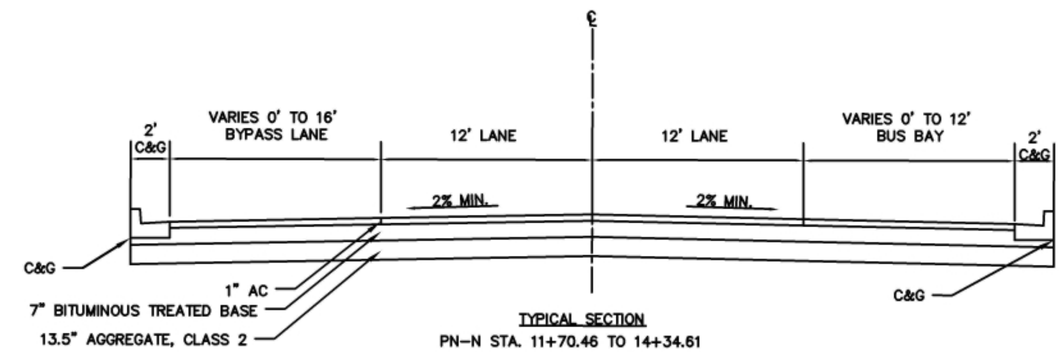


TYPICAL SECTION
MC-N STA. 18+25.56 TO 20+27.70

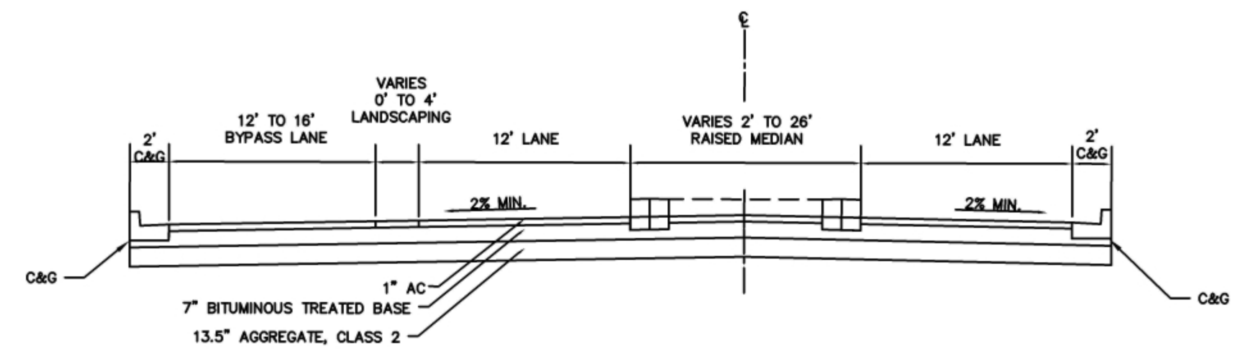


TYPICAL SECTION
MC-N STA. 20+27.70 TO 21+70.36

PINE KNOLL DR. CROSS SECTIONS

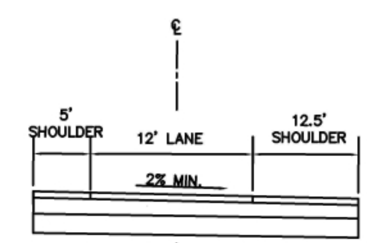


TYPICAL SECTION
PN-N STA. 11+70.46 TO 14+34.61



TYPICAL SECTION
MC-N STA. 14+34.61 TO 15+88.14

I-17 EXIT RAMP CROSS SECTIONS



TYPICAL SECTION
I-17-N STA. 14+76.51 TO 18+32.63

NOTE: PAVEMENT MATERIALS AND DEPTHS ARE ASSUMED

TYPICAL SECTIONS

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL

BETR engineering

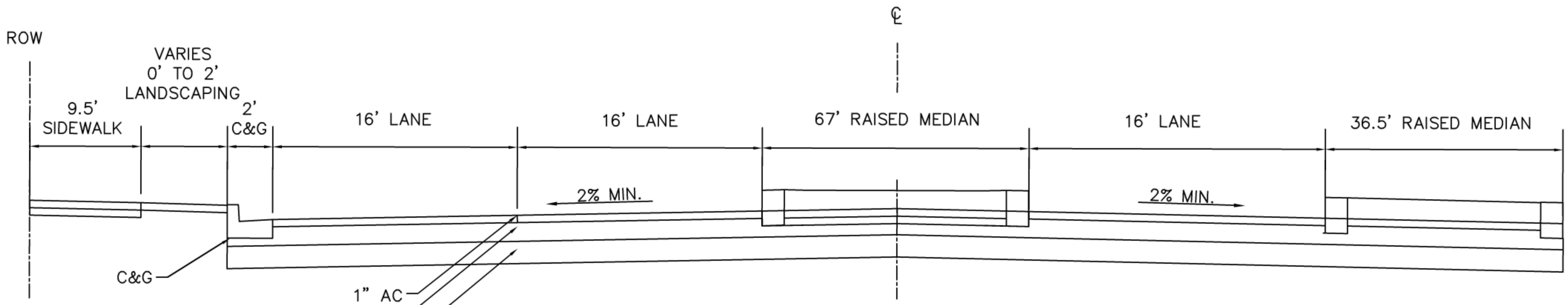
NO.	DESCRIPTION	DATE	BY

REVISIONS

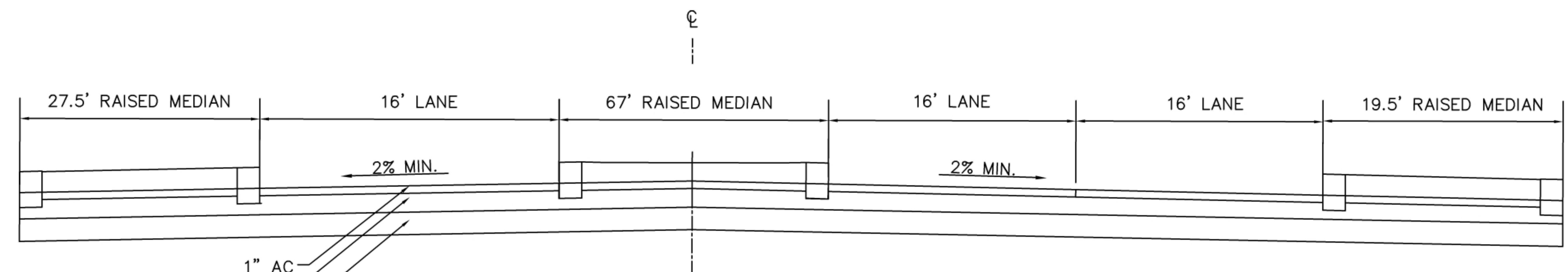
0 N/A N/A N/A

DRAWING NO. TY-1

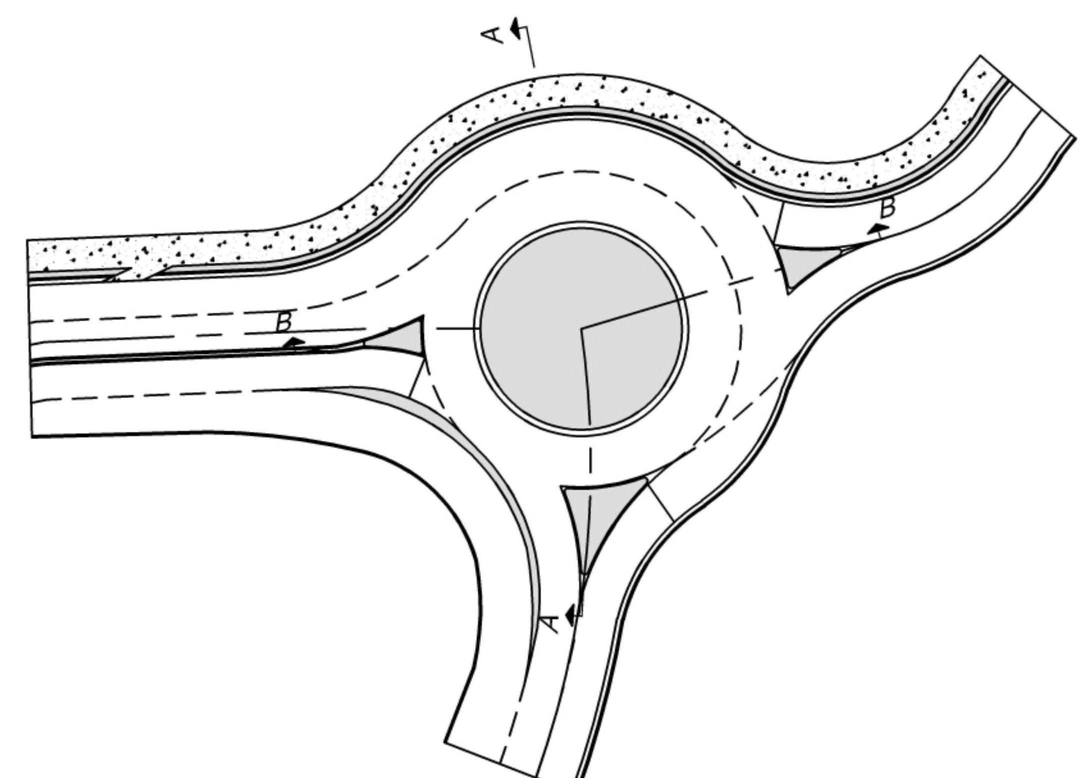
SHT NO. 2 OF 19



SECTION A–A
ROUNDABOUT CROSS SECTION



SECTION B–B
ROUNDABOUT CROSS SECTION



NOTE: PAVEMENT MATERIALS AND DEPTHS ARE ASSUMED

ROUNDABOUT SECTIONS
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL

BETR engineering

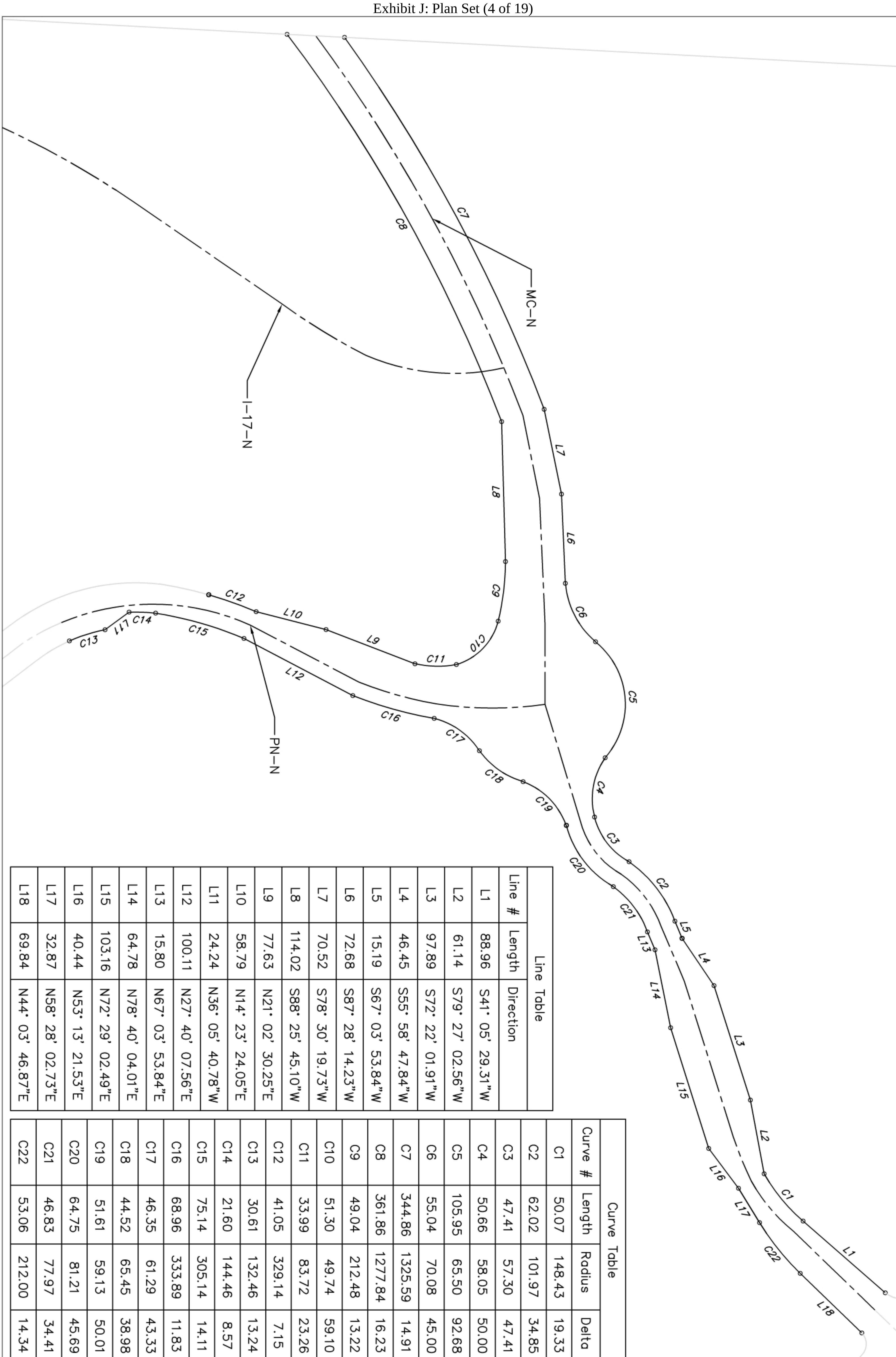
NO.	DESCRIPTION	DATE	BY

REVISIONS

0 N/A N/A N/A

DRAWING NO. TY–2

SHT NO. 3 OF 19



Line Table

Line #	Length	Direction
L1	88.96	S41° 05' 29.31"W
L2	61.14	S79° 27' 02.56"W
L3	97.89	S72° 22' 01.91"W
L4	46.45	S55° 58' 47.84"W
L5	15.19	S67° 03' 53.84"W
L6	72.68	S87° 28' 14.23"W
L7	70.52	S78° 30' 19.73"W
L8	114.02	S88° 25' 45.10"W
L9	77.63	N21° 02' 30.25"E
L10	58.79	N14° 23' 24.05"E
L11	24.24	N36° 05' 40.78"W
L12	100.11	N27° 40' 07.56"E
L13	15.80	N67° 03' 53.84"E
L14	64.78	N78° 40' 04.01"E
L15	103.16	N72° 29' 02.49"E
L16	40.44	N53° 13' 21.53"E
L17	32.87	N58° 28' 02.73"E
L18	69.84	N44° 03' 46.87"E

Curve Table

Curve #	Length	Radius	Delta
C1	50.07	148.43	19.33
C2	62.02	101.97	34.85
C3	47.41	57.30	47.41
C4	50.66	58.05	50.00
C5	105.95	65.50	92.68
C6	55.04	70.08	45.00
C7	344.86	1325.59	14.91
C8	361.86	1277.84	16.23
C9	49.04	212.48	13.22
C10	51.30	49.74	59.10
C11	33.99	83.72	23.26
C12	41.05	329.14	7.15
C13	30.61	132.46	13.24
C14	21.60	144.46	8.57
C15	75.14	305.14	14.11
C16	68.96	333.89	11.83
C17	46.35	61.29	43.33
C18	44.52	65.45	38.98
C19	51.61	59.13	50.01
C20	64.75	81.21	45.69
C21	46.83	77.97	34.41
C22	53.06	212.00	14.34

SHT NO. 4 OF 19

DRAWING NO. GEOM

0 17.5 35 70

REVISIONS

NO.	DESCRIPTION	DATE	BY

BETR engineering

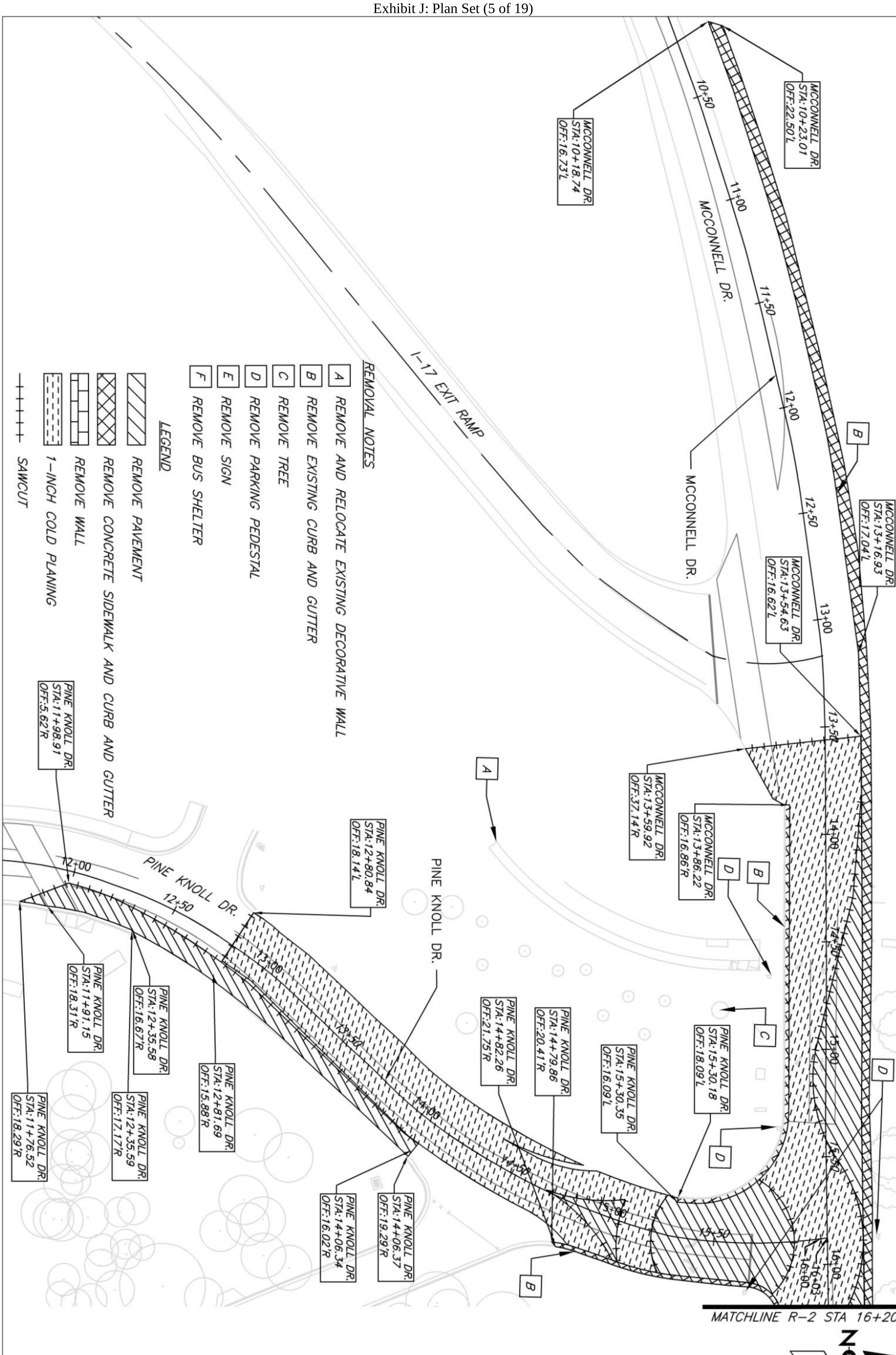
DATE: 11/05/2020

DRAWN: TESSA HUETTL

CHECKED: BRIAN CARPENTER

GEOMETRIC LAYOUT

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W



DATE: 10/26/2020	REMOVAL PLAN	
DRAWN: BRIAN CARPENTER	MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N 111°39'34"W	
CHECKED: TESSA HUETTL		

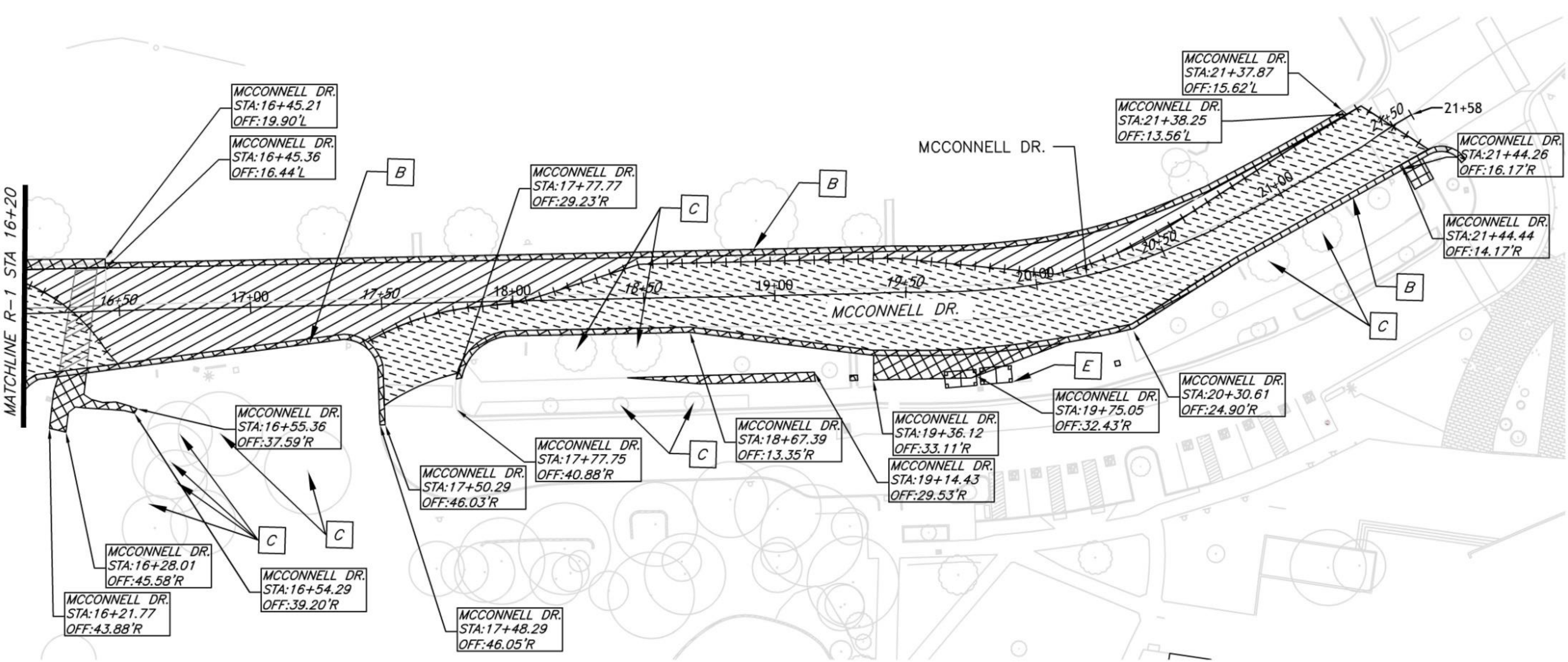
BETR engineering

REVISIONS			
NO.	DESCRIPTION	DATE	BY

0 10 20 40

DRAWING NO. R-1

SHT NO. 5 OF 19



REMOVAL NOTES

- A REMOVE AND RELOCATE EXISTING DECORATIVE WALL
- B REMOVE EXISTING CURB AND GUTTER
- C REMOVE TREE
- D REMOVE PARKING PEDESTAL
- E REMOVE SIGN
- F REMOVE BUS SHELTER

LEGEND

- REMOVE PAVEMENT
- REMOVE CONCRETE SIDEWALK AND CURB AND GUTTER
- REMOVE WALL
- 1-INCH COLD PLANING
- SAWCUT

REMOVAL PLAN
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W

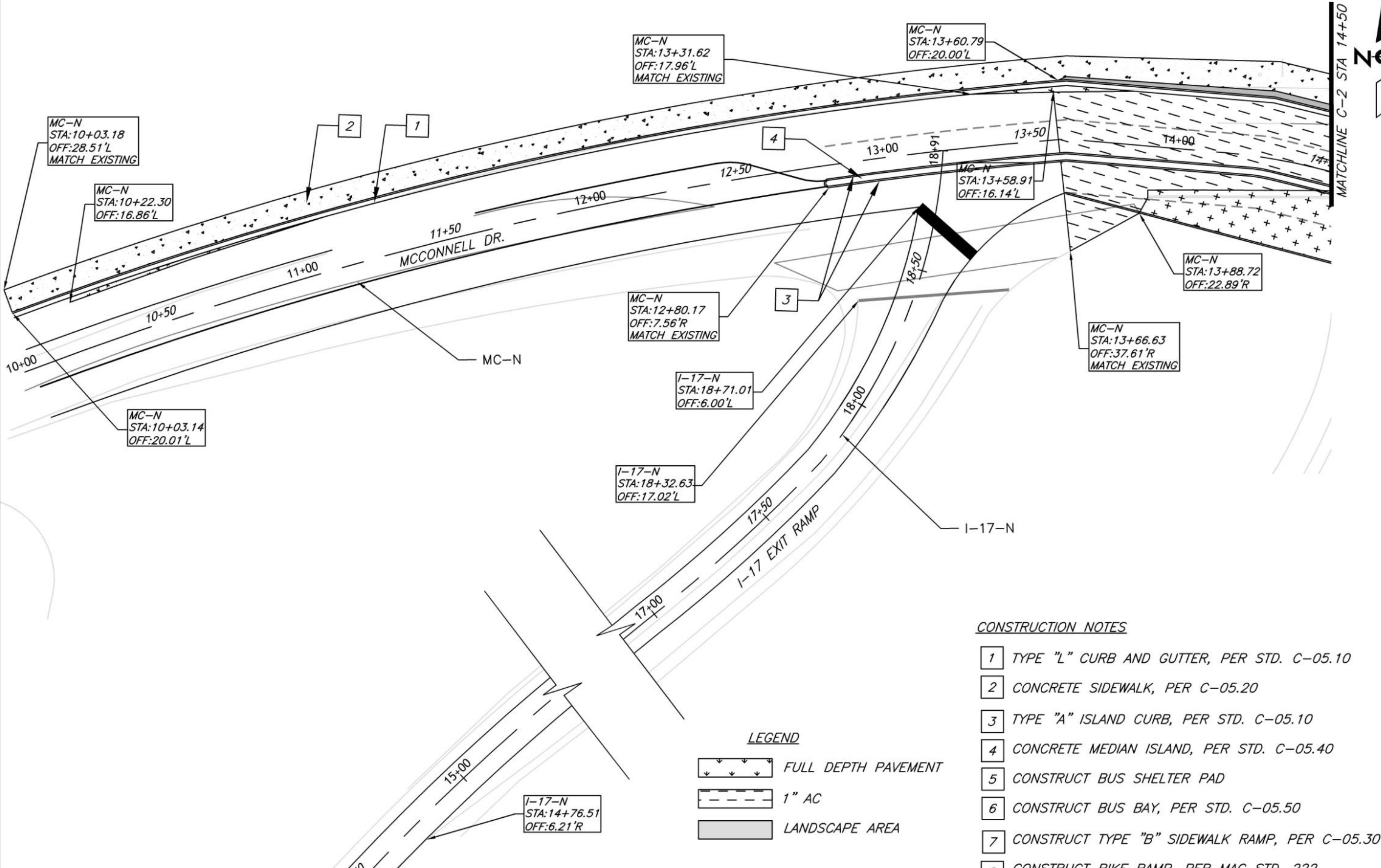
DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL

BETR engineering

REVISIONS			
NO.	DESCRIPTION	DATE	BY

0 10 20 40

DRAWING NO. R-2
SHT NO. 6 OF 19



CONSTRUCTION NOTES

1. TYPE "L" CURB AND GUTTER, PER STD. C–05.10
2. CONCRETE SIDEWALK, PER C–05.20
3. TYPE "A" ISLAND CURB, PER STD. C–05.10
4. CONCRETE MEDIAN ISLAND, PER STD. C–05.40
5. CONSTRUCT BUS SHELTER PAD
6. CONSTRUCT BUS BAY, PER STD. C–05.50
7. CONSTRUCT TYPE "B" SIDEWALK RAMP, PER C–05.30
8. CONSTRUCT BIKE RAMP, PER MAG STD. 222

LEGEND

- FULL DEPTH PAVEMENT
- 1" AC
- LANDSCAPE AREA

REVISIONS			
NO.	DESCRIPTION	DATE	BY

0 7.5 15 30

BETR engineering

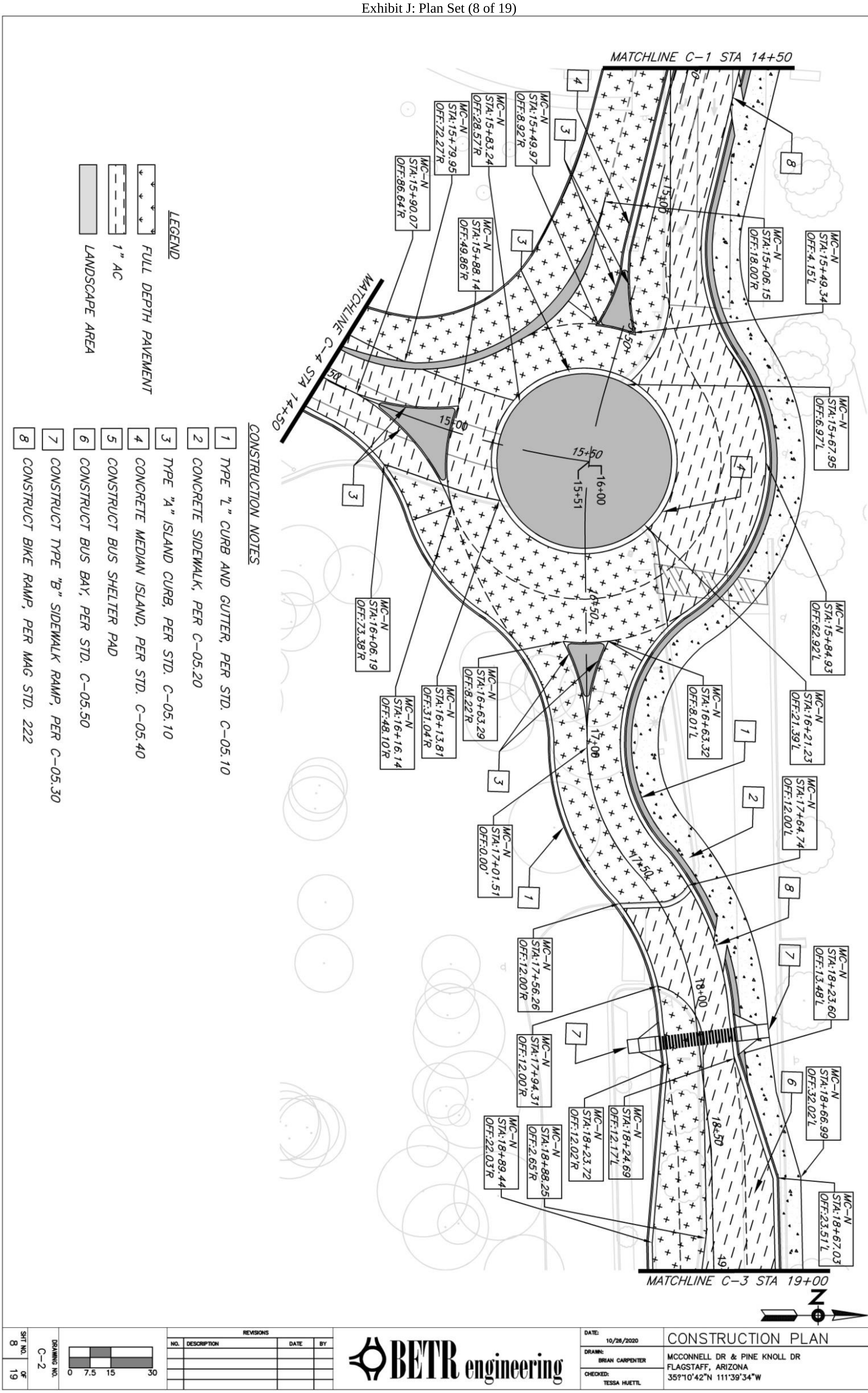
DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL

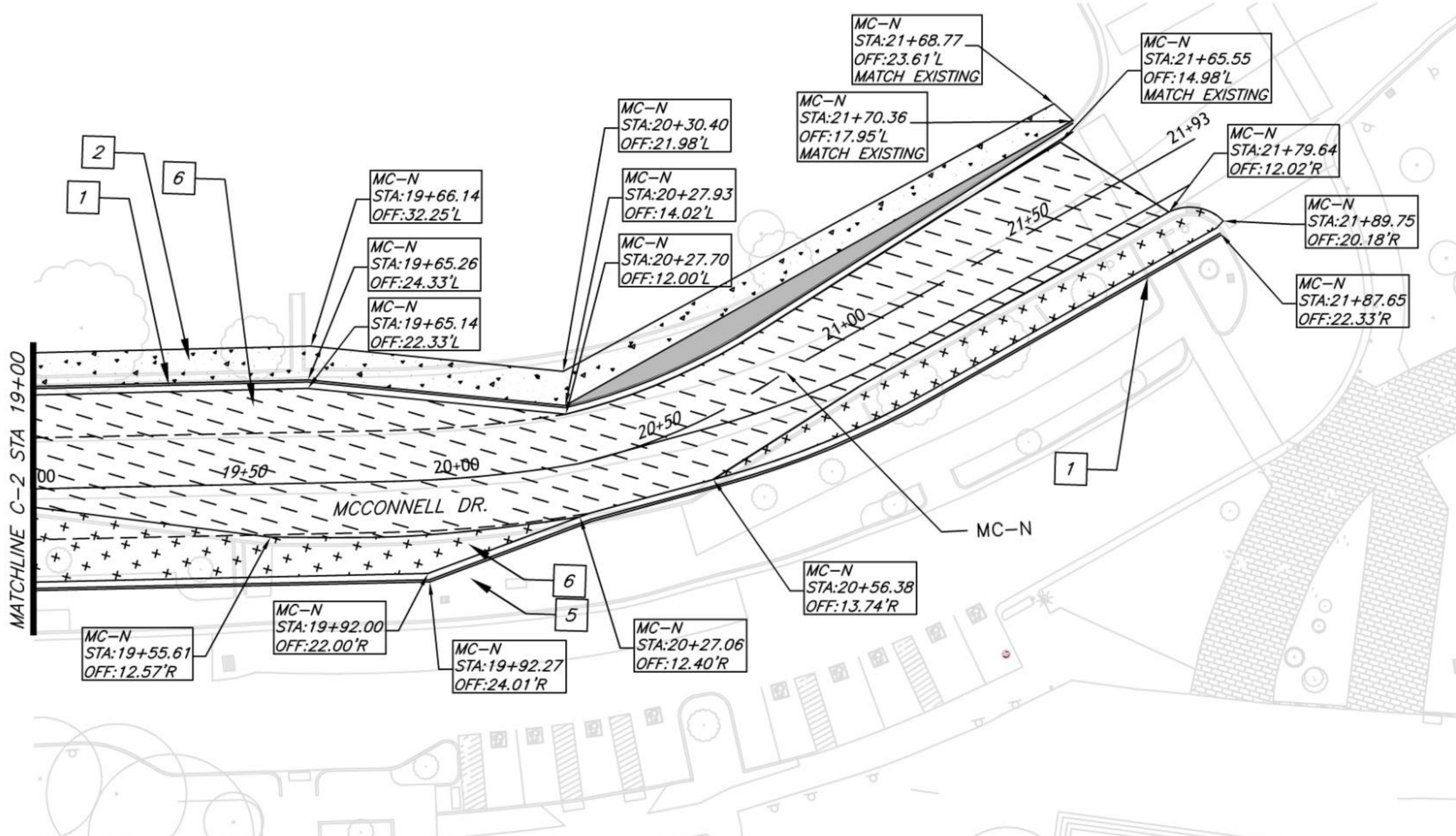
CONSTRUCTION PLAN

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W

DRAWING NO. C–1

SHT NO. 7 OF 19


MATCHLINE C-1 STA 14+50
MATCHLINE C-4 STA 14+50
MATCHLINE C-3 STA 19+00
LEGEND
FULL DEPTH PAVEMENT
1" AC
LANDSCAPE AREA
CONSTRUCTION NOTES
1 TYPE "L" CURB AND GUTTER, PER STD. C-05.10
2 CONCRETE SIDEWALK, PER C-05.20
3 TYPE "A" ISLAND CURB, PER STD. C-05.10
4 CONCRETE MEDIAN ISLAND, PER STD. C-05.40
5 CONSTRUCT BUS SHELTER PAD
6 CONSTRUCT BUS BAY, PER STD. C-05.50
7 CONSTRUCT TYPE "B" SIDEWALK RAMP, PER C-05.30
8 CONSTRUCT BIKE RAMP, PER MAG STD. 222
CONSTRUCTION PLAN
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W
DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL
BETR engineering
REVISIONS
NO. DESCRIPTION DATE BY
DRAWING NO. C-2
SHT NO. 8 OF 19
0 7.5 15 30



CONSTRUCTION NOTES

1. TYPE "L" CURB AND GUTTER, PER STD. C-05.10
2. CONCRETE SIDEWALK, PER C-05.20
3. TYPE "A" ISLAND CURB, PER STD. C-05.10
4. CONCRETE MEDIAN ISLAND, PER STD. C-05.40
5. CONSTRUCT BUS SHELTER PAD
6. CONSTRUCT BUS BAY, PER STD. C-05.50
7. CONSTRUCT TYPE "B" SIDEWALK RAMP, PER C-05.30
8. CONSTRUCT BIKE RAMP, PER MAG STD. 222

LEGEND

- FULL DEPTH PAVEMENT
- 1" AC
- LANDSCAPE AREA

CONSTRUCTION PLAN

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W

DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL

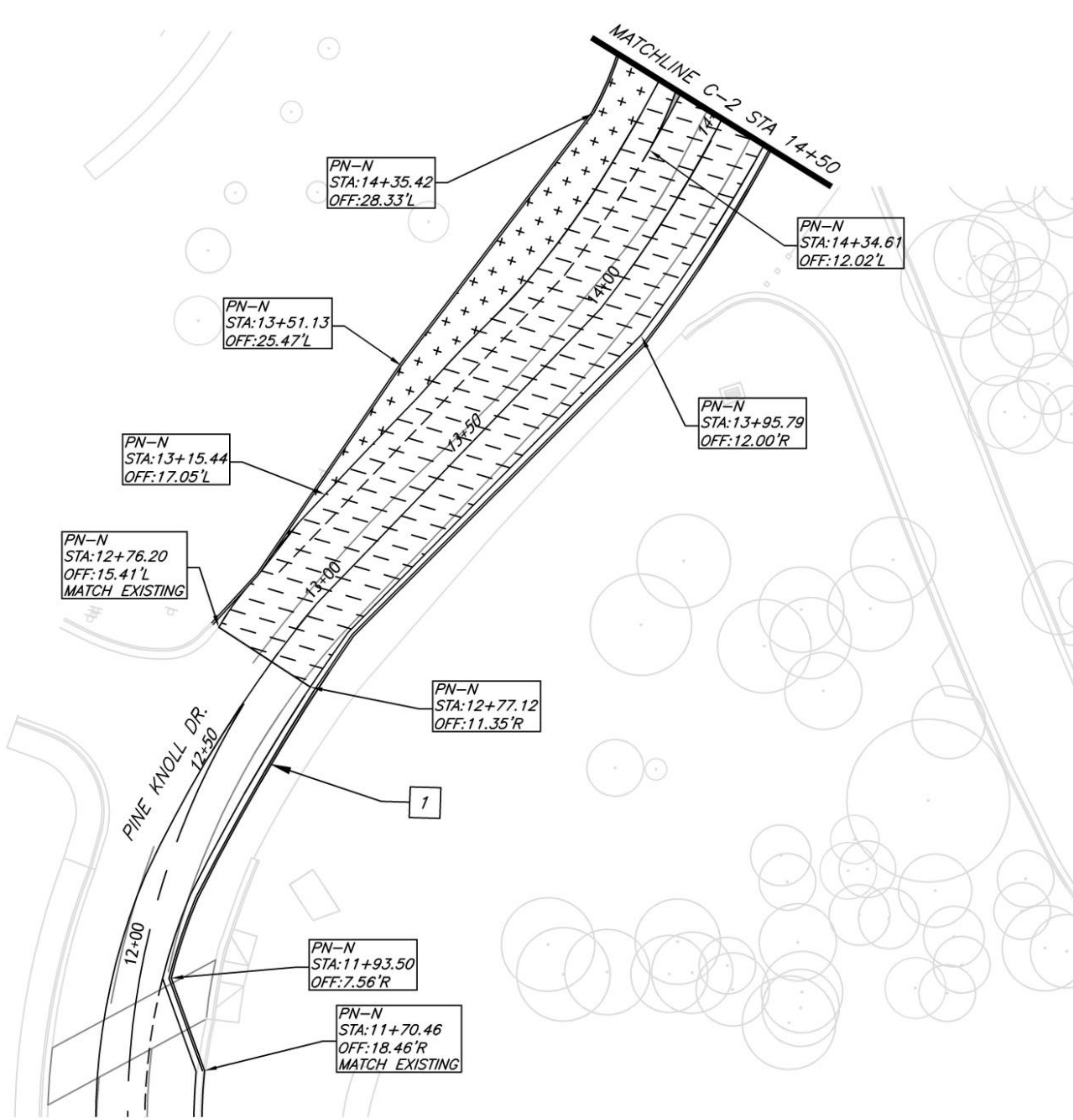
BETR engineering

REVISIONS			
NO.	DESCRIPTION	DATE	BY

0 7.5 15 30

DRAWING NO. C-3

SHT NO. 9 OF 19



CONSTRUCTION NOTES

1. TYPE "L" CURB AND GUTTER, PER STD. C-05.10
2. CONCRETE SIDEWALK, PER C-05.20
3. TYPE "A" ISLAND CURB, PER STD. C-05.10
4. CONCRETE MEDIAN ISLAND, PER STD. C-05.40
5. CONSTRUCT BUS SHELTER PAD
6. CONSTRUCT BUS BAY, PER STD. C-05.50
7. CONSTRUCT TYPE "B" SIDEWALK RAMP, PER C-05.30
8. CONSTRUCT BIKE RAMP, PER MAG STD. 222

LEGEND

- FULL DEPTH PAVEMENT
- 1" AC
- LANDSCAPE AREA

CONSTRUCTION PLAN

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N 111°39'34"W

DATE: 10/26/2020
DRAWN: BRIAN CARPENTER
CHECKED: TESSA HUETTL

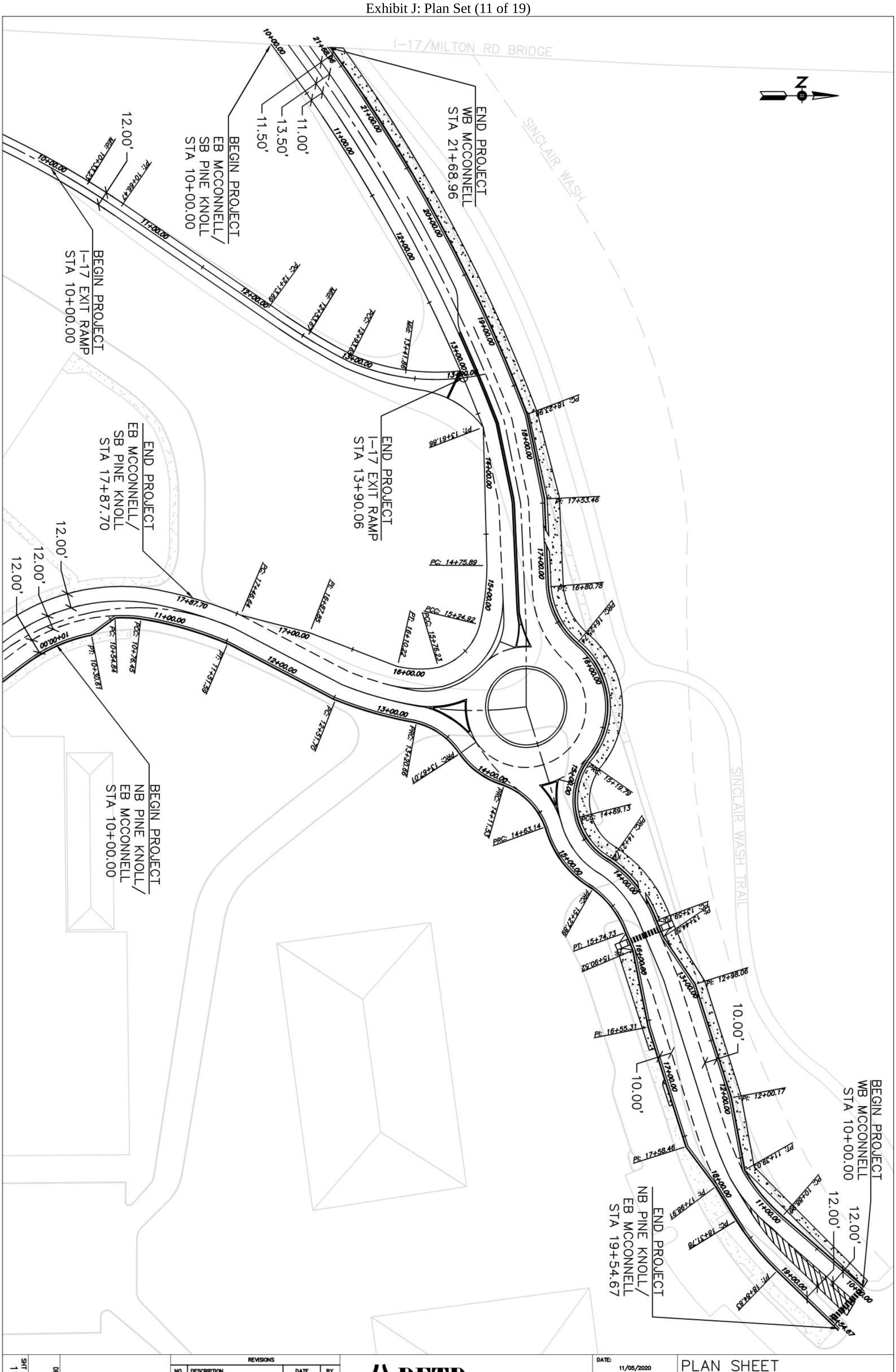
BETR engineering

REVISIONS			
NO.	DESCRIPTION	DATE	BY

0 7.5 15 30

DRAWING NO. C-4

SHT NO. 10 OF 19



DATE: 11/05/2020	PLAN SHEET
DRAWN: TESSA HUETTL	MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N, 111°39'34"W
CHECKED: BRIAN CARPENTER	

REVISIONS

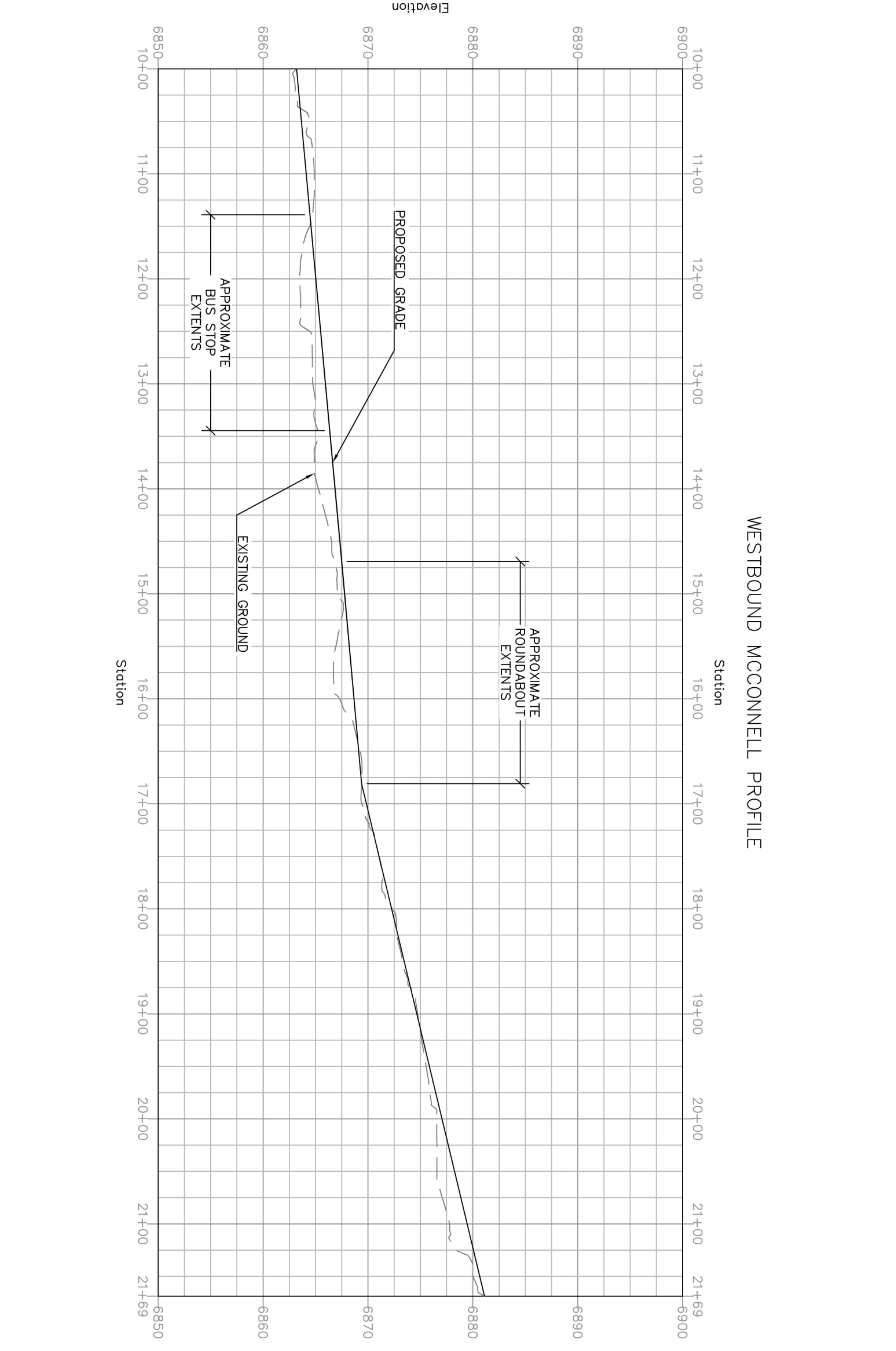
NO.	DESCRIPTION	DATE	BY

BETR engineering

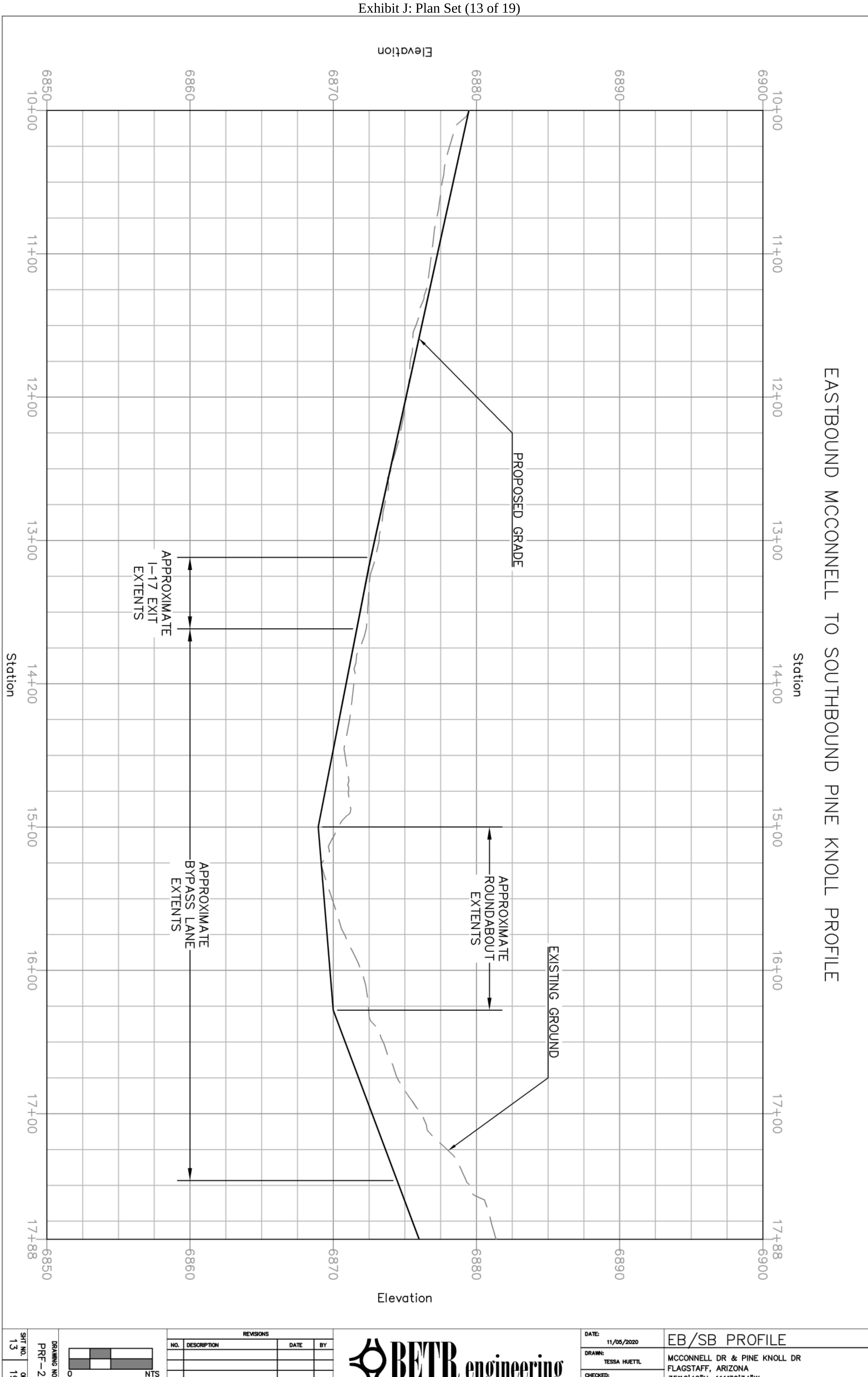
0 17.5 35 70

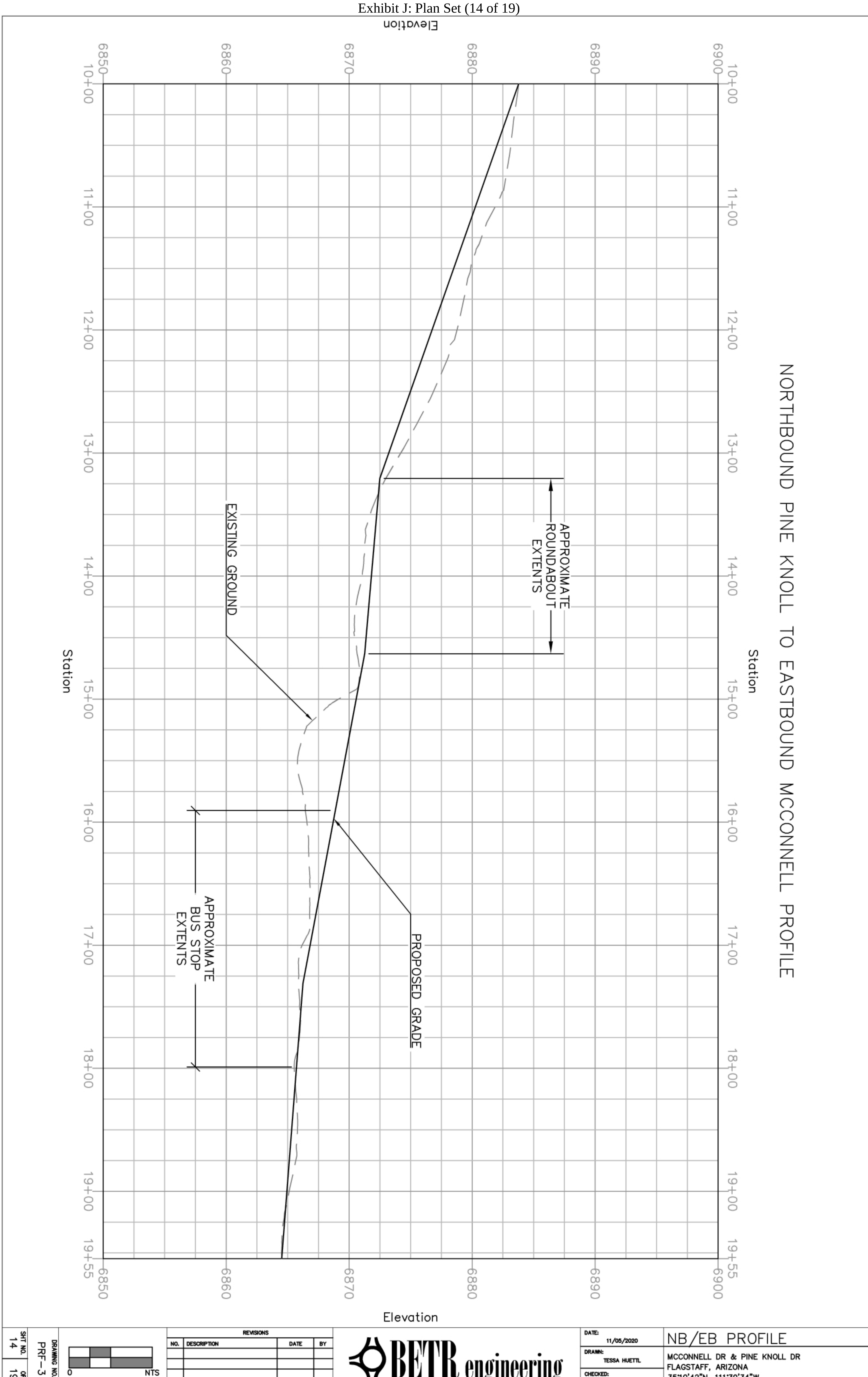
DRAWING NO. PLN

SHT NO. 11 OF 19

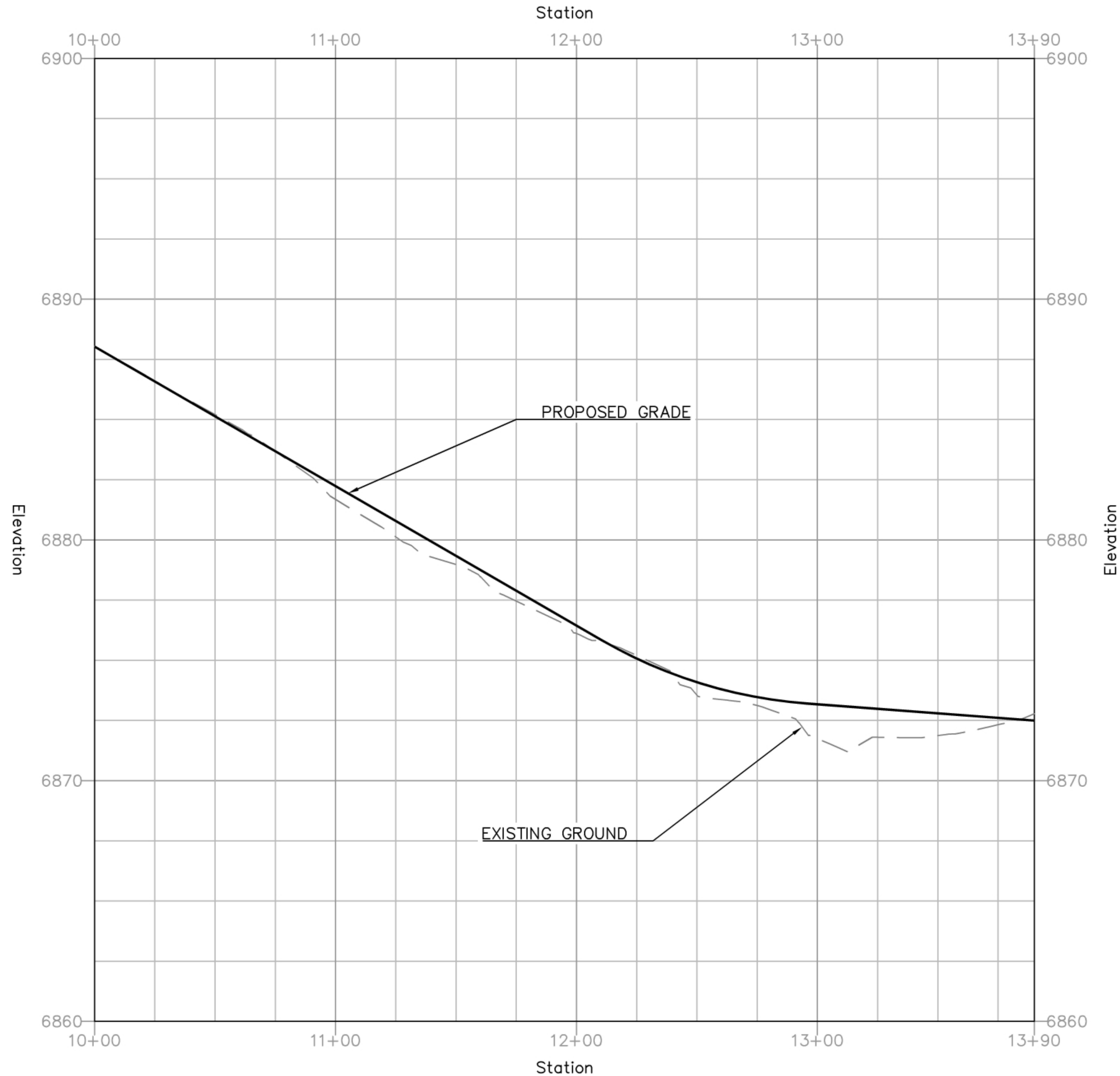


SHT NO. 12 OF 19	DRAWING NO. PRF-1	0 NTS	REVISIONS	BETR engineering	DATE: 11/05/2020	WB PROFILE
			NO. / DESCRIPTION / DATE / BY		DRAWN: TESSA HUETTL	MCCONNELL DR & PINE KNOLL DR FLAGSTAFF, ARIZONA 35°10'42"N, 111°39'34"W
					CHECKED: BRIAN CARPENTER	


EASTBOUND MCCONNELL TO SOUTHBOUND PINE KNOLL PROFILE
Elevation
6850
6860
6870
6880
6890
6900
Station
10+00
11+00
12+00
13+00
14+00
15+00
16+00
17+00
17+88
PROPOSED GRADE
EXISTING GROUND
APPROXIMATE I-17 EXIT EXTENTS
APPROXIMATE BYPASS LANE EXTENTS
APPROXIMATE ROUNDABOUT EXTENTS
SHT NO. 13 OF 19
DRAWING NO. PRF-2
0
NTS
REVISIONS
NO.
DESCRIPTION
DATE
BY
BETR engineering
DATE: 11/05/2020
DRAWN: TESSA HUETTL
CHECKED: BRIAN CARPENTER
EB/SB PROFILE
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W


NORTHBOUND PINE KNOLL TO EASTBOUND MCCONNELL PROFILE
Elevation
Station
6850
6860
6870
6880
6890
6900
10+00
11+00
12+00
13+00
14+00
15+00
16+00
17+00
18+00
19+00
19+55
APPROXIMATE ROUNDABOUT EXTENTS
EXISTING GROUND
APPROXIMATE BUS STOP EXTENTS
PROPOSED GRADE
SHT NO. 14 OF 19
DRAWING NO. PRF-3
0
NTS
REVISIONS
NO.
DESCRIPTION
DATE
BY
BETR engineering
DATE: 11/05/2020
DRAWN: TESSA HUETTL
CHECKED: BRIAN CARPENTER
NB/EB PROFILE
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

I-17 EXIT RAMP PROFILE



I-17 PROFILE

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

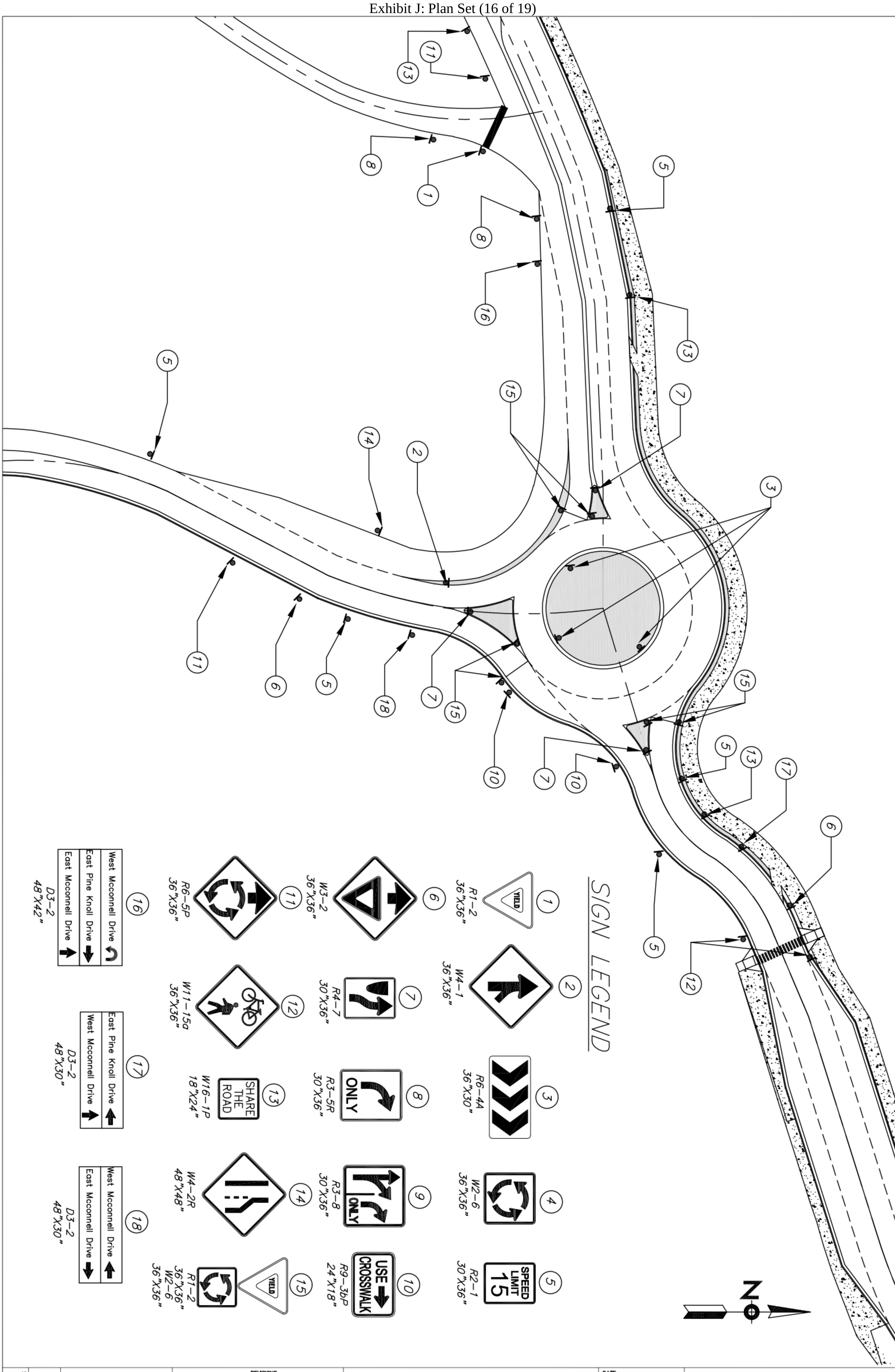
DATE: 11/05/2020
DRAWN: TESSA HUETTL
CHECKED: BRIAN CARPENTER

BETR engineering

REVISIONS			
NO.	DESCRIPTION	DATE	BY

0 NTS

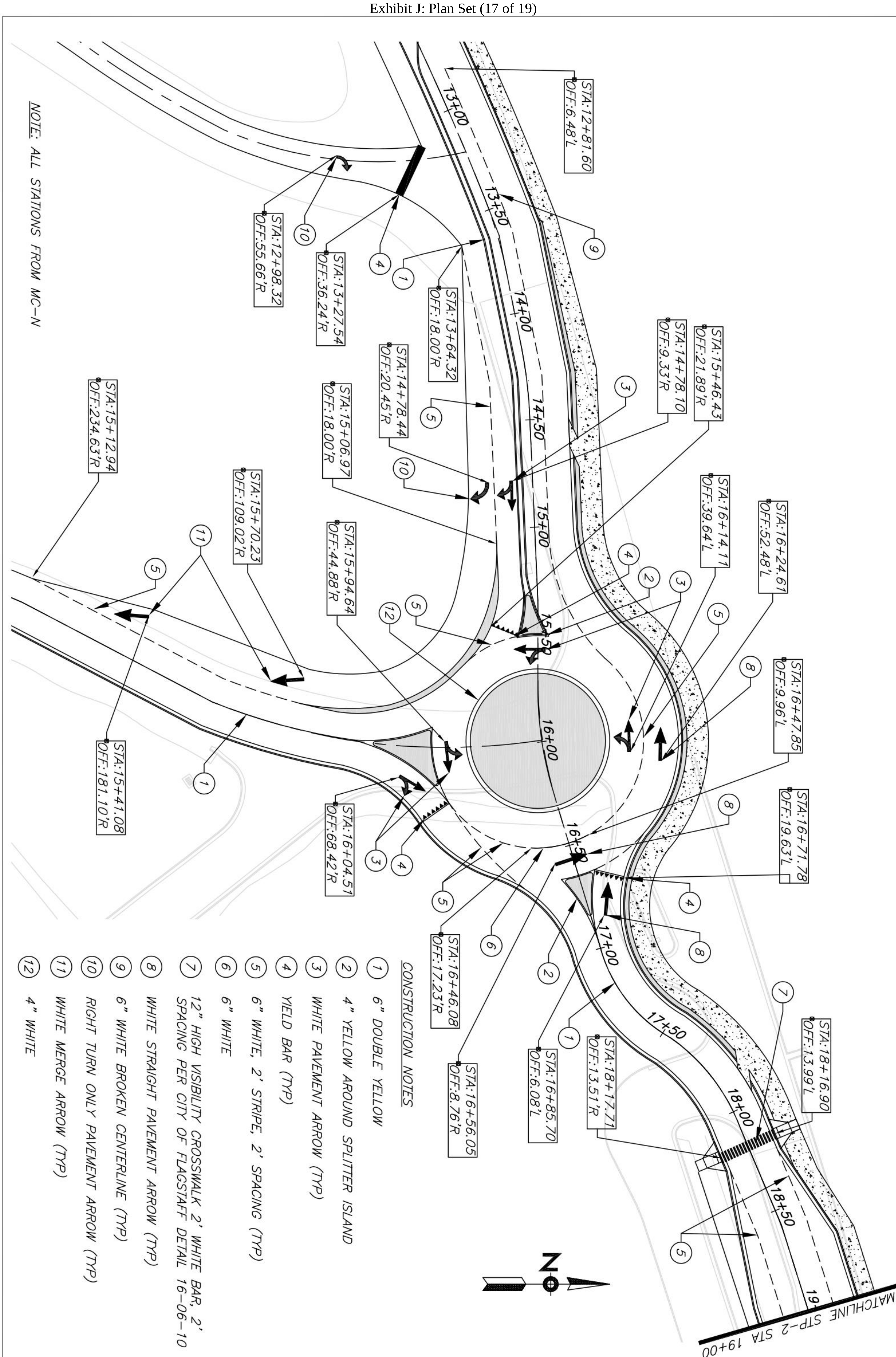
DRAWING NO.	
PRF-4	
SHT NO.	OF
15	19



SHT NO.	DRAWING NO.		REVISIONS					
16 OF 19	SGN	0 NTS	NO.	DESCRIPTION	DATE	BY	BETR engineering	DATE: 10/30/2020 DRAWN: EMERY ELLSWORTH CHECKED: BRIAN CARPENTER

SIGNING PLAN

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W



SHT NO.	DRAWING NO.		REVISIONS					
17 OF 19	STP-1	0 NTS	NO.	DESCRIPTION	DATE	BY	BETR engineering	DATE: 10/30/2020 DRAWN: EMERY ELLSWORTH CHECKED: BRIAN CARPENTER

STRIPING PLAN

MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

CONSTRUCTION NOTES

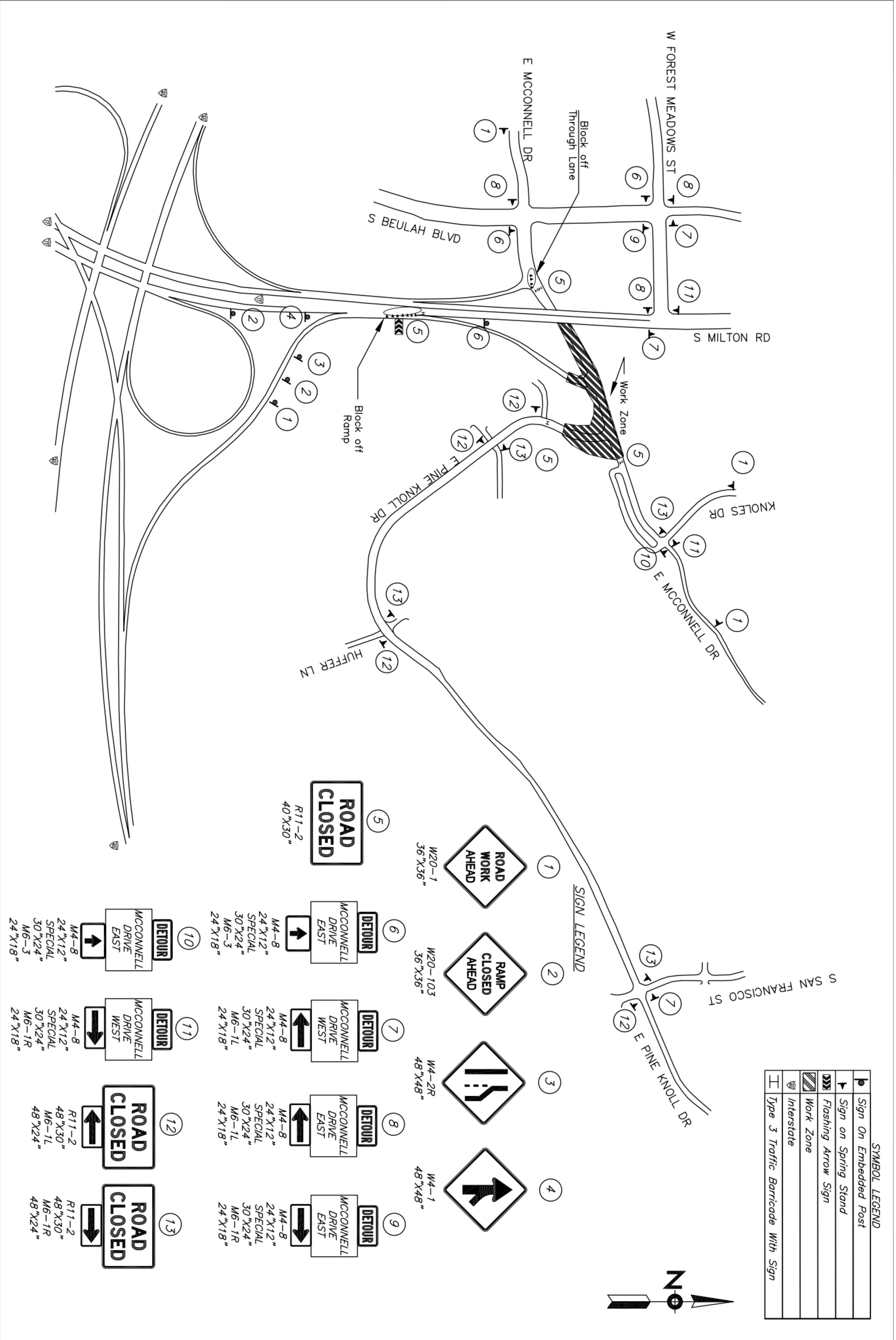
1. 6" DOUBLE YELLOW
2. 4" YELLOW AROUND SPLITTER ISLAND
3. WHITE PAVEMENT ARROW (TYP)
4. YIELD BAR (TYP)
5. 6" WHITE, 2' STRIPE, 2' SPACING (TYP)
6. 6" WHITE
7. 12" HIGH VISIBILITY CROSSWALK 2' WHITE BAR, 2' SPACING PER CITY OF FLAGSTAFF DETAIL 16-06-10
8. WHITE STRAIGHT PAVEMENT ARROW (TYP)
9. 6" WHITE BROKEN CENTERLINE (TYP)
10. RIGHT TURN ONLY PAVEMENT ARROW (TYP)
11. WHITE MERGE ARROW (TYP)
12. 4" WHITE
13. 12" YELLOW AT 60°

SHT NO.	OF	DRAWING NO.	SCALE	REVISIONS: NO.	DESCRIPTION	DATE	BY
18	19	STP-2	0 NTS				

BETR engineering

DATE: 10/30/2020
DRAWN: EMERY ELLSWORTH
CHECKED: BRIAN CARPENTER

STRIPING PLAN
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W



SHT NO. 19 OF 19	DRAWING NO. TTC	0 NTS	REVISIONS: NO. / DESCRIPTION / DATE / BY

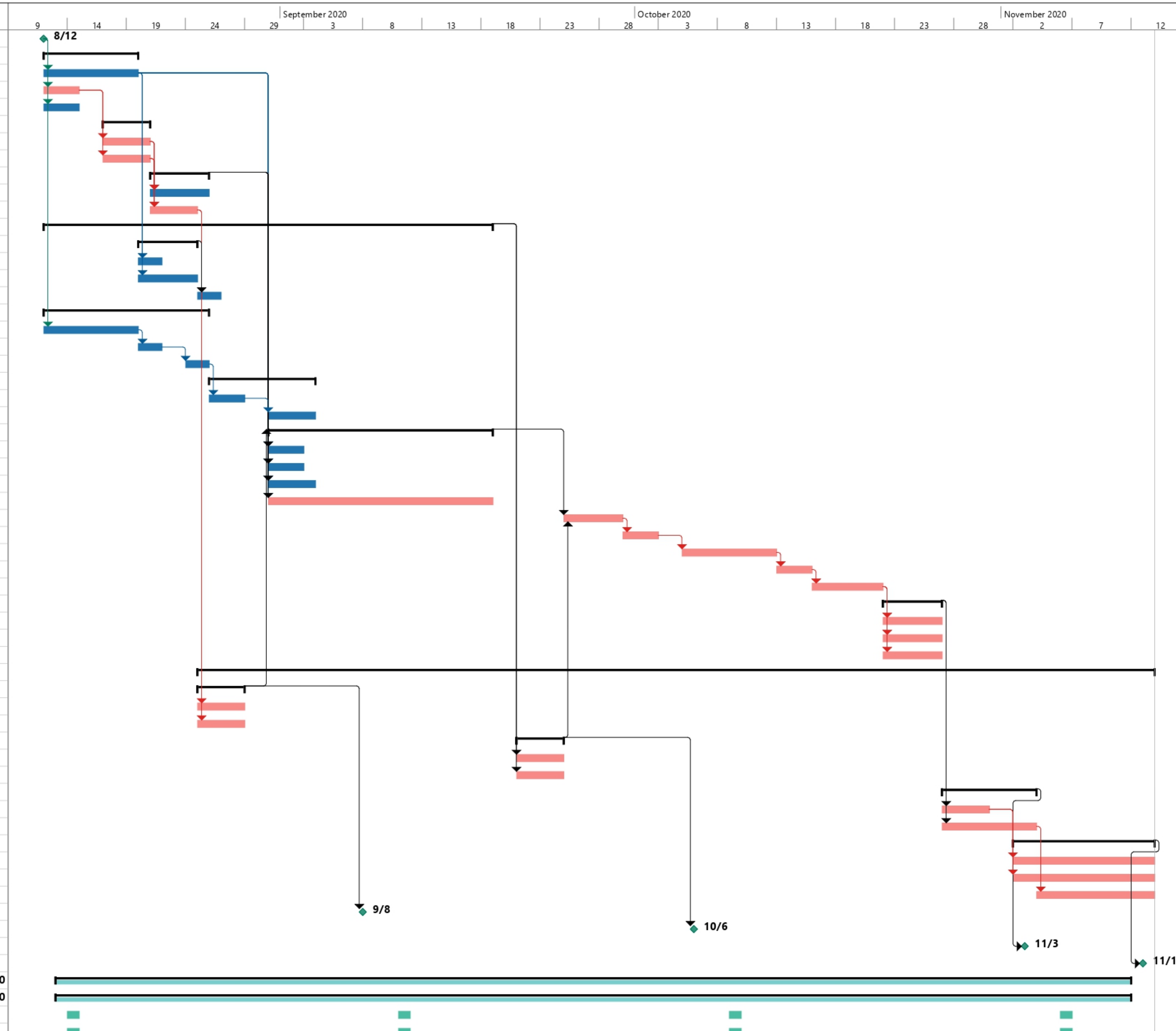
BETR engineering

DATE: 10/30/2020
DRAWN: EMERY ELLSWORTH
CHECKED: BRIAN CARPENTER

TRAFFIC CONTROL PLAN
MCCONNELL DR & PINE KNOLL DR
FLAGSTAFF, ARIZONA
35°10'42"N, 111°39'34"W

Exhibit K: Predicted Schedule

ID	Task Name	Duration	Start	Finish
1	Project Start	0 days	Wed 8/12/20	Wed 8/12/20
2	**TASK 1: Review Existing Data**	**6 days**	**Wed 8/12/20**	**Wed 8/19/20**
3	1.1 Traffic Data	6 days	Wed 8/12/20	Wed 8/19/20
4	1.2 Survey Data	3 days	Wed 8/12/20	Fri 8/14/20
5	1.3 Right-of-Ways	3 days	Wed 8/12/20	Fri 8/14/20
6	**TASK 2: Site Investigation**	**4 days**	**Mon 8/17/20**	**Thu 8/20/20**
7	2.1 Surveying	4 days	Mon 8/17/20	Thu 8/20/20
8	2.2 Field Notes	4 days	Mon 8/17/20	Thu 8/20/20
9	**TASK 3: Existing Site Conditions**	**3 days**	**Fri 8/21/20**	**Tue 8/25/20**
10	3.1 Existing Topographic Map, Structures, and Environmental Features	3 days	Fri 8/21/20	Tue 8/25/20
11	3.2 Existing Roadway Alignments	2 days	Fri 8/21/20	Mon 8/24/20
12	**TASK 4: Roundabout Design and Check**	**28 days**	**Wed 8/12/20**	**Fri 9/18/20**
13	**4.1 Preliminary Roundabout Design**	**3 days**	**Thu 8/20/20**	**Mon 8/24/20**
14	4.1.1 Radius of the Inscribed Circle	2 days	Thu 8/20/20	Fri 8/21/20
15	4.1.2 Assessment of Lanes	3 days	Thu 8/20/20	Mon 8/24/20
16	**4.2 Grading to Roundabout Requirements**	**2 days**	**Tue 8/25/20**	**Wed 8/26/20**
17	**4.3 Hydrology Assessment**	**10 days**	**Wed 8/12/20**	**Tue 8/25/20**
18	4.3.1 Contributing Area and Weighted Runoff Coefficient	6 days	Wed 8/12/20	Wed 8/19/20
19	4.3.2 Duration and Intensity	2 days	Thu 8/20/20	Fri 8/21/20
20	4.3.3 Design and Check Storm Volumes	2 days	Mon 8/24/20	Tue 8/25/20
21	**4.4 Hydraulic Assessment**	**7 days**	**Wed 8/26/20**	**Thu 9/3/20**
22	4.4.1 Assess Flow Criteria	3 days	Wed 8/26/20	Fri 8/28/20
23	4.4.2 Hydraulic Structures	4 days	Mon 8/31/20	Thu 9/3/20
24	**4.5 Finalize Roundabout Geometry**	**15 days**	**Mon 8/31/20**	**Fri 9/18/20**
25	4.5.1 Roadway Alignments	3 days	Mon 8/31/20	Wed 9/2/20
26	4.5.2 Splitter Islands and Crosswalk Locations	3 days	Mon 8/31/20	Wed 9/2/20
27	4.5.3 Safety and Code Checks	4 days	Mon 8/31/20	Thu 9/3/20
28	4.5.4 Redesign As Needed	15 days	Mon 8/31/20	Fri 9/18/20
29	**TASK 5: Signage and Striping**	**3 days**	**Fri 9/25/20**	**Tue 9/29/20**
30	**TASK 6: Temporary Traffic Control**	**3 days**	**Wed 9/30/20**	**Fri 10/2/20**
31	**TASK 7: Plan Set Production**	**6 days**	**Mon 10/5/20**	**Mon 10/12/20**
32	**TASK 8: Drainage Analysis**	**3 days**	**Tue 10/13/20**	**Thu 10/15/20**
33	**TASK 9: Traffic Analysis**	**4 days**	**Fri 10/16/20**	**Wed 10/21/20**
34	**TASK 10: Evaluate Project Impacts**	**3 days**	**Thu 10/22/20**	**Mon 10/26/20**
35	10.1 Social Impacts	3 days	Thu 10/22/20	Mon 10/26/20
36	10.2 Economic Impacts	3 days	Thu 10/22/20	Mon 10/26/20
37	10.3 Environmental Impacts	3 days	Thu 10/22/20	Mon 10/26/20
38	**TASK 11: Project Deliverables**	**59 days**	**Tue 8/25/20**	**Fri 11/13/20**
39	**11.1 30% Submittal**	**4 days**	**Tue 8/25/20**	**Fri 8/28/20**
40	11.1.1 30% Report	4 days	Tue 8/25/20	Fri 8/28/20
41	11.1.2 30% Presentation	4 days	Tue 8/25/20	Fri 8/28/20
42	**11.2 60% Submittal**	**4 days**	**Mon 9/21/20**	**Thu 9/24/20**
43	11.2.1 60% Report	4 days	Mon 9/21/20	Thu 9/24/20
44	11.2.2 60% Presentation	4 days	Mon 9/21/20	Thu 9/24/20
45	**11.3 90% Submittal**	**6 days**	**Tue 10/27/20**	**Tue 11/3/20**
46	11.3.1 90% Report	4 days	Tue 10/27/20	Fri 10/30/20
47	11.3.2 90% Website	6 days	Tue 10/27/20	Tue 11/3/20
48	**11.4 Final Submittal**	**10 days**	**Mon 11/2/20**	**Fri 11/13/20**
49	11.4.1 Final Report	10 days	Mon 11/2/20	Fri 11/13/20
50	11.4.2 Final Presentation	10 days	Mon 11/2/20	Fri 11/13/20
51	11.4.3 Final Website	8 days	Wed 11/4/20	Fri 11/13/20
52	30% Completion	0 days	Tue 9/8/20	Tue 9/8/20
53	60% Completion	0 days	Tue 10/6/20	Tue 10/6/20
54	90% Completion	0 days	Tue 11/3/20	Tue 11/3/20
55	Full Completion	0 days	Fri 11/13/20	Fri 11/13/20
56	**TASK 12: Project Management**	**65 days**	**Thu 8/13/20**	**Wed 11/11/20**
57	**12.1 Meetings**	**65 days**	**Thu 8/13/20**	**Wed 11/11/20**
90	**12.2 Schedule Managment**	**61 days**	**Fri 8/14/20**	**Fri 11/6/20**
95	**12.3 Budget Management**	**61 days**	**Fri 8/14/20**	**Fri 11/6/20**



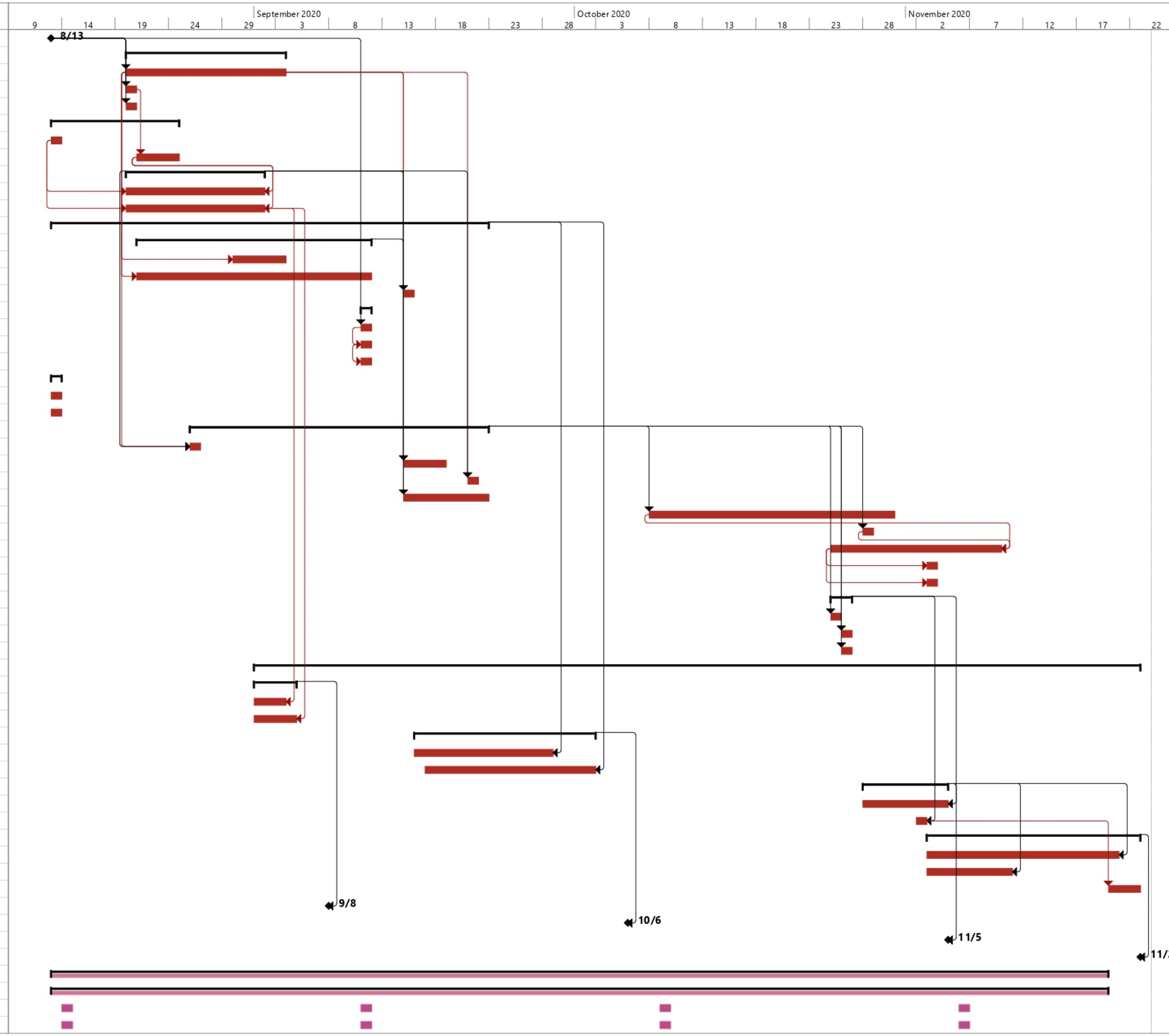
Project: Roundabout Schedule
Date: Sun 8/23/20

Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Critical

Critical Split
Progress
Manual Progress

Exhibit L: Actual Schedule

ID	Task Name	Duration	Start	Finish
1	Project Start	0 days	Thu 8/13/20	Thu 8/13/20
2	**TASK 1: Review Existing Data**	**15 days**	**Thu 8/20/20**	**Thu 9/3/20**
3	1.1 Traffic Data	15 days	Thu 8/20/20	Thu 9/3/20
4	1.2 Survey Data	1 day	Thu 8/20/20	Thu 8/20/20
5	1.3 Right-of-Ways	1 day	Thu 8/20/20	Thu 8/20/20
6	**TASK 2: Site Investigation**	**12 days**	**Thu 8/13/20**	**Mon 8/24/20**
7	2.1 Surveying	1 day	Thu 8/13/20	Thu 8/13/20
8	2.2 Field Notes	4 days	Fri 8/21/20	Mon 8/24/20
9	**TASK 3: Existing Site Conditions**	**13 days**	**Thu 8/20/20**	**Tue 9/1/20**
10	3.1 Existing Topographic Map, Structures, and Environmental Features	13 days	Thu 8/20/20	Tue 9/1/20
11	3.2 Existing Roadway Alignments	13 days	Thu 8/20/20	Tue 9/1/20
12	**TASK 4: Roundabout Design and Check**	**41 days**	**Thu 8/13/20**	**Tue 9/22/20**
13	**4.1 Preliminary Roundabout Design**	**22 days**	**Fri 8/21/20**	**Fri 9/11/20**
14	4.1.1 Radius of the Inscribed Circle	5 days	Sun 8/30/20	Thu 9/3/20
15	4.1.2 Assessment of Lanes	22 days	Fri 8/21/20	Fri 9/11/20
16	**4.2 Grading to Roundabout Requirements**	**1 day**	**Tue 9/15/20**	**Tue 9/15/20**
17	**4.3 Hydrology Assessment**	**1 day**	**Fri 9/11/20**	**Fri 9/11/20**
18	4.3.1 Contributing Area and Weighted Runoff Coefficient	1 day	Fri 9/11/20	Fri 9/11/20
19	4.3.2 Duration and Intensity	1 day	Fri 9/11/20	Fri 9/11/20
20	4.3.3 Design and Check Storm Volumes	1 day	Fri 9/11/20	Fri 9/11/20
21	**4.4 Hydraulic Assessment**	**1 day**	**Thu 8/13/20**	**Thu 8/13/20**
22	4.4.1 Assess Flow Criteria	1 day	Thu 8/13/20	Thu 8/13/20
23	4.4.2 Hydraulic Structures	1 day	Thu 8/13/20	Thu 8/13/20
24	**4.5 Finalize Roundabout Geometry**	**28 days**	**Wed 8/26/20**	**Tue 9/22/20**
25	4.5.1 Roadway Alignments	1 day	Wed 8/26/20	Wed 8/26/20
26	4.5.2 Splitter Islands and Crosswalk Locations	4 days	Tue 9/15/20	Fri 9/18/20
27	4.5.3 Safety and Code Checks	1 day	Mon 9/21/20	Mon 9/21/20
28	4.5.4 Redesign As Needed	8 days	Tue 9/15/20	Tue 9/22/20
29	**TASK 5: Signage and Striping**	**23 days**	**Thu 10/8/20**	**Fri 10/30/20**
30	**TASK 6: Temporary Traffic Control**	**1 day**	**Wed 10/28/20**	**Wed 10/28/20**
31	**TASK 7: Plan Set Production**	**16 days**	**Sun 10/25/20**	**Mon 11/9/20**
32	**TASK 8: Drainage Analysis**	**1 day**	**Tue 11/3/20**	**Tue 11/3/20**
33	**TASK 9: Traffic Analysis**	**1 day**	**Tue 11/3/20**	**Tue 11/3/20**
34	**TASK 10: Evaluate Project Impacts**	**2 days**	**Sun 10/25/20**	**Mon 10/26/20**
35	10.1 Social Impacts	1 day	Sun 10/25/20	Sun 10/25/20
36	10.2 Economic Impacts	1 day	Mon 10/26/20	Mon 10/26/20
37	10.3 Environmental Impacts	1 day	Mon 10/26/20	Mon 10/26/20
38	**TASK 11: Project Deliverables**	**83 days**	**Tue 9/1/20**	**Sun 11/22/20**
39	**11.1 30% Submittal**	**4 days**	**Tue 9/1/20**	**Fri 9/4/20**
40	11.1.1 30% Report	3 days	Tue 9/1/20	Thu 9/3/20
41	11.1.2 30% Presentation	4 days	Tue 9/1/20	Fri 9/4/20
42	**11.2 60% Submittal**	**17 days**	**Wed 9/16/20**	**Fri 10/2/20**
43	11.2.1 60% Report	13 days	Wed 9/16/20	Mon 9/28/20
44	11.2.2 60% Presentation	16 days	Thu 9/17/20	Fri 10/2/20
45	**11.3 90% Submittal**	**8 days**	**Wed 10/28/20**	**Wed 11/4/20**
46	11.3.1 90% Report	8 days	Wed 10/28/20	Wed 11/4/20
47	11.3.2 90% Website	1 day	Mon 11/2/20	Mon 11/2/20
48	**11.4 Final Submittal**	**20 days**	**Tue 11/3/20**	**Sun 11/22/20**
49	11.4.1 Final Report	18 days	Tue 11/3/20	Fri 11/20/20
50	11.4.2 Final Presentation	8 days	Tue 11/3/20	Tue 11/10/20
51	11.4.3 Final Website	3 days	Fri 11/20/20	Sun 11/22/20
52	30% Completion	0 days	Tue 9/8/20	Tue 9/8/20
53	60% Completion	0 days	Tue 10/6/20	Tue 10/6/20
54	90% Completion	0 days	Thu 11/5/20	Thu 11/5/20
55	Full Completion	0 days	Mon 11/23/20	Mon 11/23/20
56	**TASK 12: Project Management**	**99 days**	**Thu 8/13/20**	**Thu 11/19/20**
57	**12.1 Meetings**	**99 days**	**Thu 8/13/20**	**Thu 11/19/20**
92	**12.2 Schedule Managment**	**85 days**	**Fri 8/14/20**	**Fri 11/6/20**
97	**12.3 Budget Management**	**85 days**	**Fri 8/14/20**	**Fri 11/6/20**



Project: Roundabout Schedule
Date: Wed 11/18/20

Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	

Exhibit M: Superimposed Schedule

ID	Task Name	Duration	Start	Finish
1	Project Start	0 days	Thu 8/13/20	Thu 8/13/20
2	**TASK 1: Review Existing Data**	**15 days**	**Thu 8/20/20**	**Thu 9/3/20**
3	1.1 Traffic Data	15 days	Thu 8/20/20	Thu 9/3/20
4	1.2 Survey Data	1 day	Thu 8/20/20	Thu 8/20/20
5	1.3 Right-of-Ways	1 day	Thu 8/20/20	Thu 8/20/20
6	**TASK 2: Site Investigation**	**12 days**	**Thu 8/13/20**	**Mon 8/24/20**
7	2.1 Surveying	1 day	Thu 8/13/20	Thu 8/13/20
8	2.2 Field Notes	4 days	Fri 8/21/20	Mon 8/24/20
9	**TASK 3: Existing Site Conditions**	**13 days**	**Thu 8/20/20**	**Tue 9/1/20**
10	3.1 Existing Topographic Map, Structures, and Environmental Features	13 days	Thu 8/20/20	Tue 9/1/20
11	3.2 Existing Roadway Alignments	13 days	Thu 8/20/20	Tue 9/1/20
12	**TASK 4: Roundabout Design and Check**	**41 days**	**Thu 8/13/20**	**Tue 9/22/20**
13	**4.1 Preliminary Roundabout Design**	**22 days**	**Fri 8/21/20**	**Fri 9/11/20**
14	4.1.1 Radius of the Inscribed Circle	5 days	Sun 8/30/20	Thu 9/3/20
15	4.1.2 Assessment of Lanes	22 days	Fri 8/21/20	Fri 9/11/20
16	**4.2 Grading to Roundabout Requirements**	**1 day**	**Tue 9/15/20**	**Tue 9/15/20**
17	**4.3 Hydrology Assessment**	**1 day**	**Fri 9/11/20**	**Fri 9/11/20**
18	4.3.1 Contributing Area and Weighted Runoff Coefficient	1 day	Fri 9/11/20	Fri 9/11/20
19	4.3.2 Duration and Intensity	1 day	Fri 9/11/20	Fri 9/11/20
20	4.3.3 Design and Check Storm Volumes	1 day	Fri 9/11/20	Fri 9/11/20
21	**4.4 Hydraulic Assessment**	**1 day**	**Thu 8/13/20**	**Thu 8/13/20**
22	4.4.1 Assess Flow Criteria	1 day	Thu 8/13/20	Thu 8/13/20
23	4.4.2 Hydraulic Structures	1 day	Thu 8/13/20	Thu 8/13/20
24	**4.5 Finalize Roundabout Geometry**	**28 days**	**Wed 8/26/20**	**Tue 9/22/20**
25	4.5.1 Roadway Alignments	1 day	Wed 8/26/20	Wed 8/26/20
26	4.5.2 Splitter Islands and Crosswalk Locations	4 days	Tue 9/15/20	Fri 9/18/20
27	4.5.3 Safety and Code Checks	1 day	Mon 9/21/20	Mon 9/21/20
28	4.5.4 Redesign As Needed	8 days	Tue 9/15/20	Tue 9/22/20
29	**TASK 5: Signage and Striping**	**23 days**	**Thu 10/8/20**	**Fri 10/30/20**
30	**TASK 6: Temporary Traffic Control**	**1 day**	**Wed 10/28/20**	**Wed 10/28/20**
31	**TASK 7: Plan Set Production**	**16 days**	**Sun 10/25/20**	**Mon 11/9/20**
32	**TASK 8: Drainage Analysis**	**1 day**	**Tue 11/3/20**	**Tue 11/3/20**
33	**TASK 9: Traffic Analysis**	**1 day**	**Tue 11/3/20**	**Tue 11/3/20**
34	**TASK 10: Evaluate Project Impacts**	**2 days**	**Sun 10/25/20**	**Mon 10/26/20**
35	10.1 Social Impacts	1 day	Sun 10/25/20	Sun 10/25/20
36	10.2 Economic Impacts	1 day	Mon 10/26/20	Mon 10/26/20
37	10.3 Environmental Impacts	1 day	Mon 10/26/20	Mon 10/26/20
38	**TASK 11: Project Deliverables**	**83 days**	**Tue 9/1/20**	**Sun 11/22/20**
39	**11.1 30% Submittal**	**4 days**	**Tue 9/1/20**	**Fri 9/4/20**
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42	**11.2 60% Submittal**	**17 days**	**Wed 9/16/20**	**Fri 10/2/20**
43	11.2.1 60% Report	13 days	Wed 9/16/20	Mon 9/28/20
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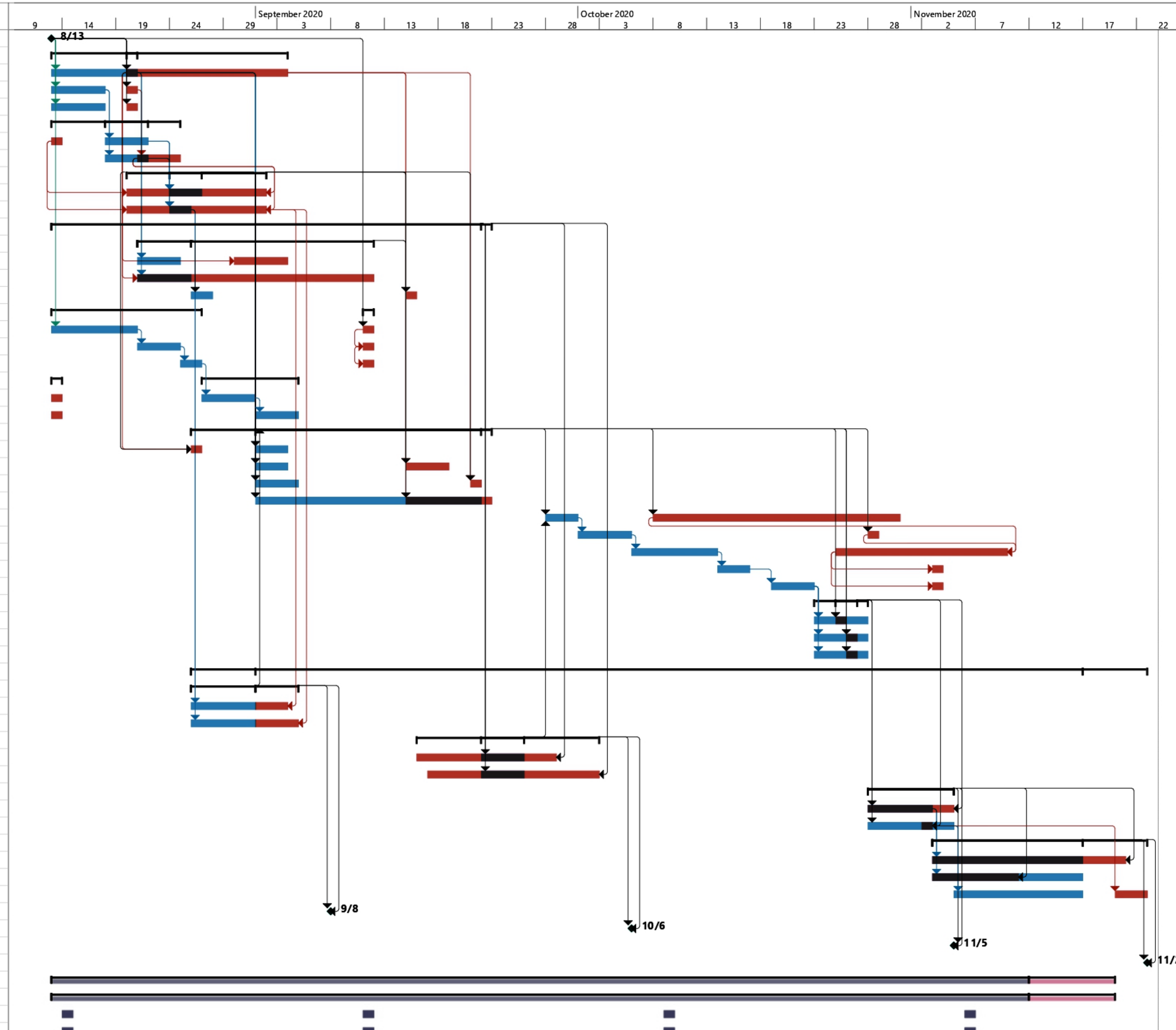
48	**11.4 Final Submittal**	**20 days**	**Tue 11/3/20**	**Sun 11/22/20**
49	11.4.1 Final Report	18 days	Tue 11/3/20	Fri 11/20/20
50	11.4.2 Final Presentation	8 days	Tue 11/3/20	Tue 11/10/20
51	11.4.3 Final Website	3 days	Fri 11/20/20	Sun 11/22/20
52	30% Completion	0 days	Tue 9/8/20	Tue 9/8/20
53	60% Completion	0 days	Tue 10/6/20	Tue 10/6/20
54	90% Completion	0 days	Thu 11/5/20	Thu 11/5/20
55	Full Completion	0 days	Mon 11/23/20	Mon 11/23/20
56	**TASK 12: Project Management**	**99 days**	**Thu 8/13/20**	**Thu 11/19/20**
57	**12.1 Meetings**	**99 days**	**Thu 8/13/20**	**Thu 11/19/20**
92	**12.2 Schedule Managment**	**85 days**	**Fri 8/14/20**	**Fri 11/6/20**
97	**12.3 Budget Management**	**85 days**	**Fri 8/14/20**	**Fri 11/6/20**



Project: Roundabout Schedule
Date: Wed 11/18/20

Task		Summary		Inactive Milestone		Duration-only		Start-only		External Milestone	
Split		Project Summary		Inactive Summary		Manual Summary Rollup		Finish-only		Deadline	
Milestone		Inactive Task		Manual Task		Manual Summary		External Tasks		Progress	
										Manual Progress	