Memo

Date:	Monday, June 22, 2020
Project:	Amity Road and Eagle Road Intersection
To:	Ryan Cutler, PM
From:	Cameron Waite, PE, PTOE Brett Kohring, PE
Subject:	Intersection Alternatives Comparison

Introduction

This memo summarizes a comparison of the operational analyses and conceptual layouts for two Amity Road and Eagle Road intersection improvement alternatives: a dual lane roundabout and a signalized intersection. These alternatives are being compared due to issues discovered through HDR's analysis and design of the roundabout expansion, including:

- The forecast operational analysis shows the improved roundabout operating at level of service (LOS) F with significant delays and queue lengths in the 2036 and 2041 analysis years
- Widening the legs to add a second lane to the outside and a second circulating lane to the inside contributes to entry speeds that are much higher than design standards and guidelines (43 mph versus 30 mph max) and are not safe

These comparisons will aid ACHD in determining the intersection control and lane configuration best suited to serve travel demand of all modes safely while reducing impacts to adjacent properties.

Operational Analysis Comparisons

Details of the traffic volumes, forecast travel demand methodology and volumes, and operational analyses are found in the *Draft Operational Analysis Memo* (June 13, 2020). Results from that memo and additional analysis HDR completed for a signalized intersection are summarized below. Roundabout analysis results presented are based on the SIDRA analysis method that treats the roundabout as a single interactive system of intersection approaches and circulating flows as described in the memo. Syncrho was used to analyze the traffic signal alternative at the intersection for the 2036 and 2041 years. The signal timing parameters in Table 3 in the ACHD Policy Manual Section 7106.4 and the values listed in 7106.6.2 were used and other assumptions included a flashing don't walk (FDW) time of 21 seconds and 2% for heavy vehicles on all movements.

2036 Results

The dual lane improved roundabout is expected to have movements operate with LOS A or B until sometime near 2036. At this point, the northbound commuters dominate the roundabout in

the morning and the southbound movements dominate in the evening. Operational analysis results for the 2036 roundabout with and without the southbound bypass lane 2036 are presented in **Tables 1 and 2**.

Table 1. 2036 Roundabout Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
Total	**1.09**	**C**	**30.0**	**-**	**1.04**	**C**	**23.0**	**-**
EBL/T	0.70	A	9.3	148.1	0.71	B	12.0	146.5
EBR/T	0.60	A	5.6	101.4	0.61	B	10.2	100.7
WBL/T	0.74	B	19.6	133.2	0.51	A	7.6	71.6
WBR/T	0.74	B	17.1	160.3	0.51	A	6.7	75.5
NBL/T	1.09	F	70.3	715.3	0.42	B	12.5	62.7
NBR/T	1.09	F	65.6	908.7	0.42	A	6.7	65.8
SBL/T	0.17	A	8.6	18.2	1.04	F	46.1	651.8
SBR/T	0.17	A	5.4	19.0	1.04	F	42.1	766.7

Table 2. 2036 Roundabout with SB Right-Turn Bypass Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
Total	**1.00**	**B**	**19.9**	**-**	**0.60**	**A**	**8.2**	**-**
EBL/T	0.64	A	9.9	117.4	0.60	B	11.7	95.8
EBR/T	0.64	A	5.5	116.6	0.60	A	8.5	106.0
WBL/T	0.78	C	23.5	151.9	0.50	A	7.6	69.4
WBR/T	0.78	C	20.9	186.6	0.50	A	6.7	73.1
NBL/T	1.00	F	39.4	429.7	0.40	B	11.9	52.8
NBR/T	1.00	F	34.2	525.0	0.40	A	6.1	55.1
SBL/T	0.11	A	9.6	11.7	0.60	B	11.0	104.5
SBR/T	0.11	A	5.0	12.8	0.60	A	7.8	121.5
SBR	0.05	A	3.9	0.0	0.29	A	3.9	0.0

With no bypass lane, a.m. peak hour delays are estimated to be about thirty seconds on average with significant 95th percentile queue lengths for northbound traffic extending from over 700 feet to over 900 feet. In the evening average delays are about 23 seconds, however queue lengths for southbound traffic are estimated to extend from 650 feet to 760 feet. The v/c ratio exceeds one for the a.m. northbound movements and the p.m. southbound movements.

Adding the southbound bypass lane improves operations in the 2036 a.m. and p.m. peak hours and significantly reduces the southbound p.m. peak queue lengths to just over 100 feet. The northbound movements are still estimated to fail in the a.m. peak hour with queue lengths between 400 feet and 525 feet.

The signalized intersection option assumed a 7 by 7 lane intersection, although the southbound and westbound movements only need a single left turn lane. The analyses results shown in **Table 3** estimate the intersection will operate at LOS D in both peak hours with higher average delays than the roundabout alternative but no failing movements. In the a.m. peak hour, the northbound through movement 95th percentile queue length is estimated to exceed 600 feet, the eastbound left turn moment queue length exceeds 400 feet, and the westbound right turn movement queue length is estimated to exceed 360 feet. In the p.m. peak hour the southbound through and westbound through movements are estimated to have queue lengths exceeding 500 feet.

Table 3. 2036 Signalized Intersection Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
Total	**-**	**D**	**45.3**	**-**	**-**	**D**	**43.9**	**-**
EBL	0.92	E	75.3	407.5	0.73	E	69.7	110.0
EBT	0.62	C	33.6	435.0	0.37	C	33.5	227.5
EBR	0.25	C	27.4	157.5	0.52	D	36.4	295.0
WBL	0.16	E	73.2	15.0	0.12	D	50.9	27.5
WBT	0.66	E	55.8	295.0	0.91	E	62.6	505.0
WBR	0.88	E	65.1	360.0	0.34	C	26.3	155.0
NBL	0.27	C	23.6	132.5	0.93	E	61.4	457.5
NBT	0.83	D	43.5	647.5	0.28	C	25.0	195.0
NBR	0.08	C	25.7	50.0	0.02	C	21.8	12.5
SBL	0.48	C	33.7	77.5	0.33	C	23.5	150.0
SBT	0.13	C	28.3	85.0	0.80	D	44.0	555.0
SBR	0.14	A	9.5	80.0	0.84	D	37.7	460.0

A comparison of overall delay for each option during the 2036 peak hours is shown in **Table 4**.

Table 4. 2036 Overall Delay Comparison

Option	AM Peak Hour			PM Peak Hour		
	Total Entering Vehicles	Average Delay (s/veh)	Total delay (hours)	Total Entering Vehicles	Average Delay (s/veh)	Total delay (hours)
Dual Lane Roundabout	3,576	30.0	29.8	3,741	23.0	23.9
Dual Lane Roundabout with SB Bypass		19.9	19.8		8.2	8.5
Signalized		45.3	45.0		43.9	45.6

The overall delay for all vehicles entering the intersection during the 2036 a.m. peak hour for the signalized option is 45 hours, more than twice the delay estimated for the dual lane roundabout with the southbound bypass lane. In the p.m. peak hour the difference is even greater at 45.6 hours compared to 8.5 hours.

2041 Results

Under 2041 conditions, the dual lane roundabout exceeds capacity in both the a.m. and p.m. peak hours as shown in **Table 5**. The delays for the a.m. northbound movements are estimated at over 400 seconds with queues extending beyond 300 feet. The vehicles attempting to enter the roundabout do not have enough gaps with the heavy eastbound movements dominating the roundabout.

Table 5. 2041 Roundabout Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
Total	**1.93**	**F**	**157.8**	**-**	**1.80**	**F**	**156.6**	**-**
EBL/T	0.87	D	12.2	312.3	0.71	B	10.2	149.8
EBR/T	0.75	A	7.1	182.0	0.61	A	8.4	103.8
WBL/T	0.74	B	18.5	143.7	0.76	B	11.8	145.3
WBR/T	0.74	B	16.1	169.8	0.76	B	10.1	160.6
NBL/T	1.93	F	433.4	3,019.0	0.59	B	15.2	114.)
NBR/T	1.93	F	429.9	4,087.0	0.56	A	8.3	110.1

Table 5. 2041 Roundabout Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
SBL/T	0.22	A	8.4	24.9	1.80	F	372.1	3,598.7
SBR/T	0.22	A	5.6	26.3	1.80	F	369.6	4,702.0

The eastbound left and northbound movements exceed ACHD's V/C ratio limit of 0.85 in the a.m. peak. The estimated delay is so extreme that the estimated 95th percentile queue lengths are significantly long, extending well over ½ mile from the roundabout. These estimated queue lengths may not be completely accurate due to the extreme delay calculated, but they indicate the significant delay vehicles traveling northbound will likely experience attempting to travel through the roundabout.

A similar result is found for the p.m. peak hour analysis results with the southbound movements experience significant delays of almost 400 seconds and even longer estimated queues. The V/C ratio for southbound movements well exceed ACHD's V/C ratio limit of 0.85.

Adding the southbound bypass lane improves operations in the 2041 a.m. and p.m. peak hours and significantly reduces the southbound p.m. peak queue lengths to between 400 feet and over 500 feet. The northbound movements in the morning are still estimated to fail with queue lengths over ½ mile in length. Also, the northbound movements exceed ACHD's V/C ratio limit of 0.85 in the a.m. peak hour. In the p.m. peak hour, the eastbound and southbound movements exceed ACHD's V/C ratio limit of 0.85 even as the overall intersection operates at LOS C. Results are shown in **Table 6**.

Table 6. 2041 Roundabout with SB Right-Turn Bypass Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
Total	**1.63**	**F**	**112.5**	**-**	**1.04**	**C**	**23.2**	**-**
EBL/T	0.80	B	12.1	219.4	1.04	F	50.5	440.5
EBR/T	0.80	A	7.0	219.6	1.04	F	45.0	543.5
WBL/T	0.82	C	25.4	180.4	0.75	B	11.6	142.9
WBR/T	0.82	C	22.3	219.9	0.75	A	10.0	157.8
NBL/T	1.63	F	301.1	2,440.5	0.60	B	14.5	106.5
NBR/T	1.63	F	297.4	3,314.0	0.57	A	7.6	101.3
SBL/T	0.13	A	9.3	14.6	0.97	E	34.2	396.5

Table 6. 2041 Roundabout with SB Right-Turn Bypass Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
SBR/T	0.13	A	5.2	16.3	0.97	E	32.1	537.1
SBR	0.08	A	3.9	0.0	0.45	A	3.9	0.0

The signalized intersection lane configuration for the 2041s analysis is still a 7 by 7. Volumes in 2041 require a shared southbound through/right turn lane in addition to the dedicated right turn lane and dual northbound left turn lanes. Additionally, the southbound right turns are given an overlap with the eastbound lefts to optimize signal timing.

The signalized option analyses results shown in **Table 7** estimate the intersection will operate at LOS E in both 2041 peak hours.

Table 7. 2041 Signalized Intersection Analysis Results

Movement	AM Peak Hour				PM Peak Hour			
	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)	V/C	LOS	Delay (s/veh)	95th-% Queue Length (ft)
Total	**-**	**E**	**66.0**	**-**	**-**	**E**	**76.4**	**-**
EBL	1.12	F	129.8	650.0	0.80	E	77.7	170.0
EBT	0.70	D	35.7	505.0	0.41	C	34.9	270.0
EBR	0.34	C	28.5	215.0	0.71	D	43.7	452.5
WBL	0.08	D	49.9	15.0	0.10	D	42.6	27.5
WBT	0.91	E	73.6	420.0	1.15	F	137.3	902.5
WBR	0.87	E	79.8	385.0	0.33	D	45.2	170.0
NBL	0.83	E	75.5	205.0	1.13	F	150.8	472.5
NBT	1.00	E	66.2	922.5	0.34	C	27.8	240.0
NBR	0.09	C	26.1	52.5	0.02	C	23.5	12.5
SBL	0.66	D	42.1	85.0	0.37	C	24.1	157.5
SBT	0.17	C	31.2	120.0	0.99	E	66.5	912.5
SBR	0.13	B	15.3	77.5	0.96	E	63.8	882.5

The northbound through movement 95th percentile queue length is estimated to exceed 900 feet in the a.m. peak hour with a V/C ratio of 1.00. The eastbound left movement also experiences long queue lengths of 650 feet and a v/c ratio of 1.12. In the p.m. peak hour the southbound

through and right turn lanes are estimated to be around 900 feet long. The westbound through movements are also estimated to have queue lengths exceeding 900 feet with a v/c ratio of 1.15.

A comparison of overall delay for each option during the 2041 peak hours is shown in **Table 8**. The overall delay for all vehicles entering the intersection during the a.m. peak hour for the signalized option is 79 hours with the dual lane roundabout delay estimated at 190 hours. The delay estimated for the dual lane roundabout with the southbound bypass lane is 135 hours. In the p.m. peak hour the difference is reversed with an estimated 101.9 hours of delay for the signalized intersection compared to 30.9 hours dual lane roundabout with the southbound bypass lane.

Table 8. 2041 Overall Delay Comparison

Option	AM Peak Hour			PM Peak Hour		
	Total Entering Vehicles	Average Delay (s/veh)	Total delay (hours)	Total Entering Vehicles	Average Delay (s/veh)	Total delay (hours)
Dual Lane Roundabout	4,332	157.8	190.0	4,802	156.6	208.9
Dual Lane Roundabout with SB Bypass		112.5	135.4		23.2	30.9
Signalized		66.0	79.4		76.4	101.9

Conceptual Layout Comparisons

Roundabout Layout

To develop the dual lane roundabout, the originally proposed improvements added a second approach lane on the legs by widening to the outside, while the second circulating lane was added to the inside of the roundabout. This contributed to entry speeds that are much higher than design standards and guidelines (43 mph versus 30 mph max). At ACHD's direction, HDR updated the layout to provide the needed deflection and entry speeds, as shown in **Figure 1**. This layout uses the right-of-way (ROW) from the parcel ACHD purchased in the northeast quadrant of the intersection to expand the roundabout to meet design and safety needs while reducing ROW impacts on the other three quadrants. Estimated needed ROW areas are shown in yellow in **Figure 1** and tabulated in **Table 9**. The addition of the southbound bypass lane is shown in **Figure 2** along with the additional ROW needed, which is also tabulated in **Table 9.** Both roundabout alternatives require ROW to taper each leg back into the existing two lane rural section on the east, west and south legs.

Figure 1. Roundabout Layout

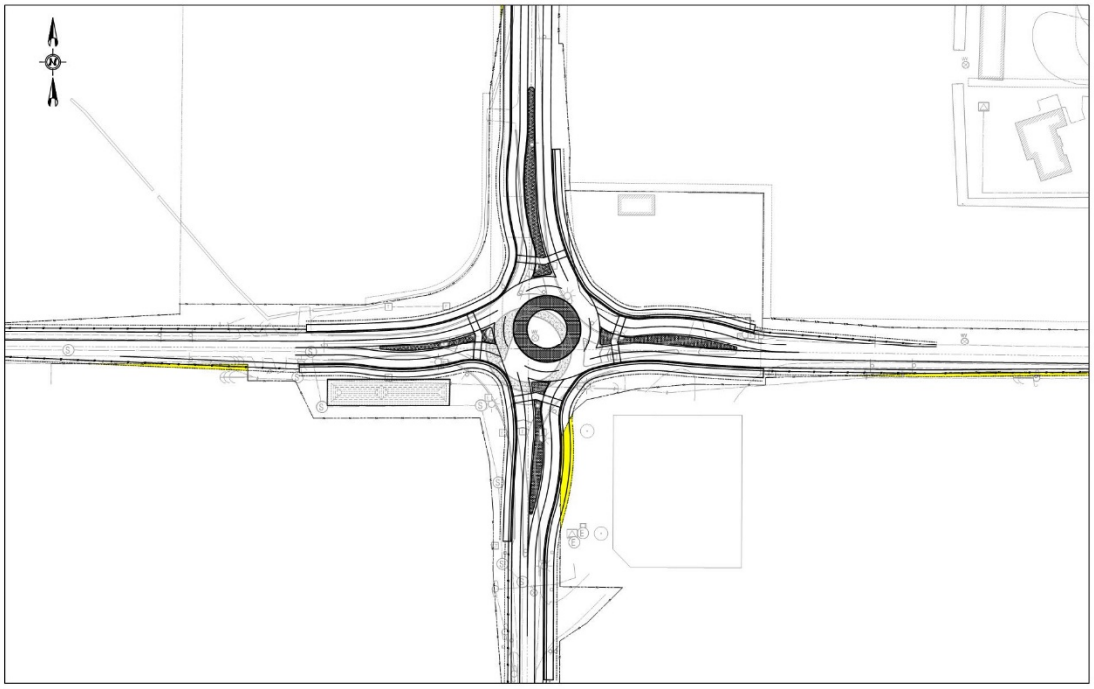


Figure 2. Roundabout with Bypass Layout

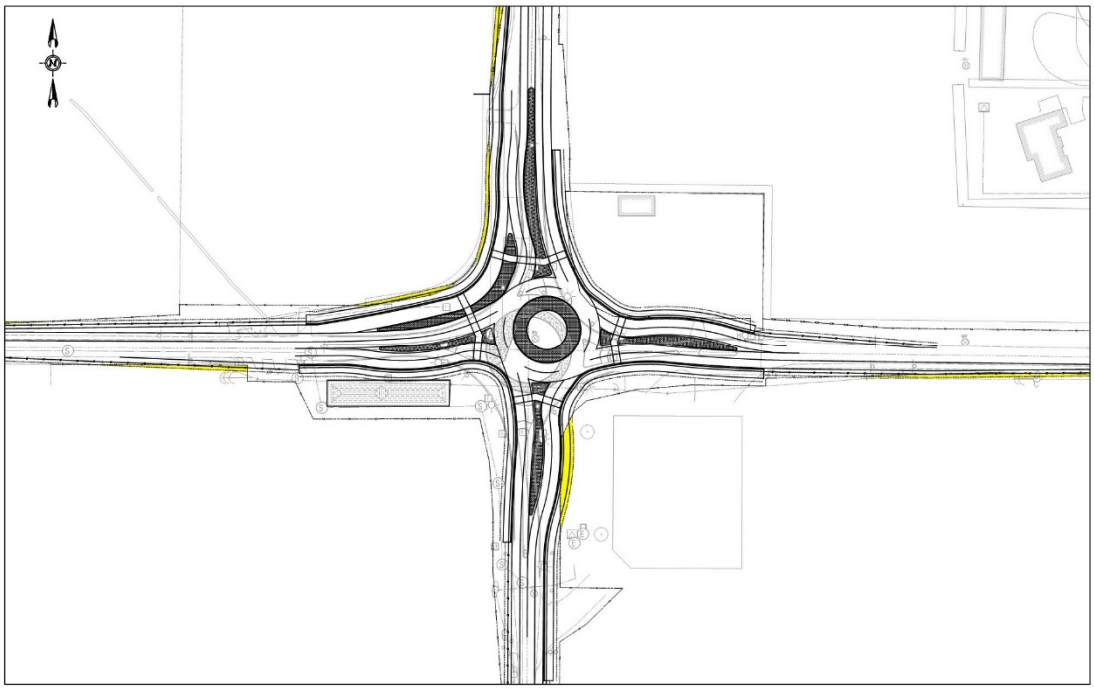
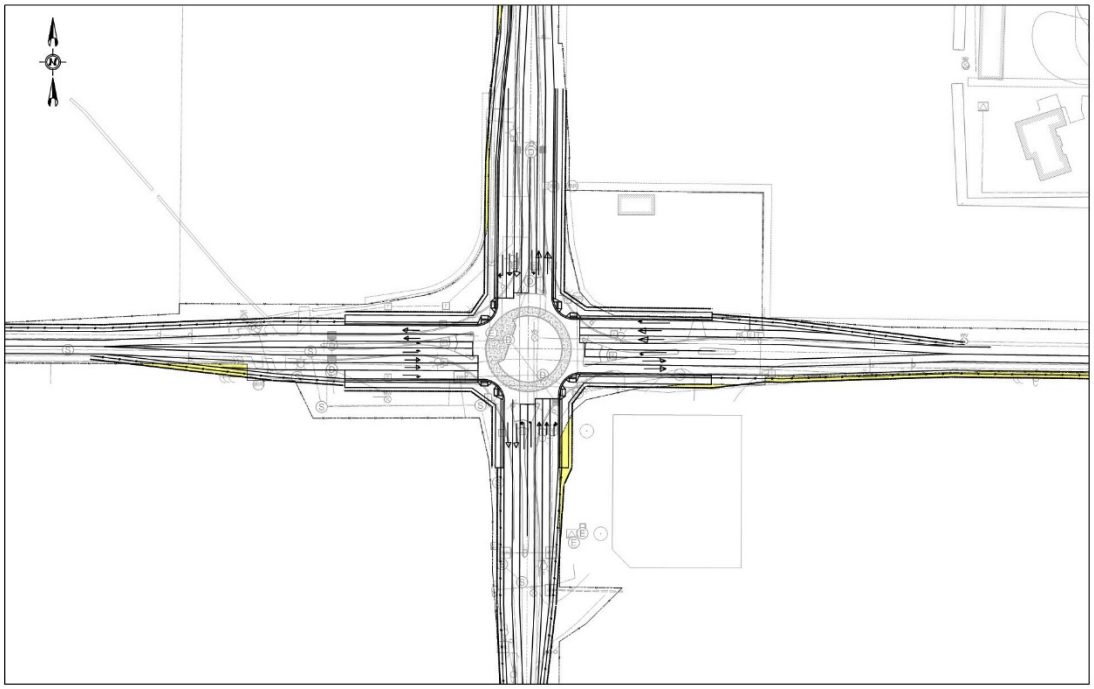


Figure 2. Signal Layout



Signalized Intersection Layout

The signalized intersection layout is a traditional urban intersection set within the existing roundabout ROW, as shown in **Figure 3**. Additional ROW is needed on each leg to taper the roadway from the full 7 by 7 intersection configuration to the existing two lane rural section on the east, west, and south legs. Estimated needed ROW is shown in **Figure 3** and tabulated in **Table 9**.

Table 9. Conceptual ROW Needs Comparison

	Roundabout w/o Bypass	Roundabout w/ Bypass	Signal
ROW Needed (sf)	9,975	14,230	18,680

Qualitative Safety Comparison

Roundabouts have been proven to reduce crash severity, inducing reducing fatal and serious injury crashes, at intersections where they implemented because they reduce speeds and have low angles of impact. While they make pedestrian travel more out of the way, they have simple crossings that allow the pedestrian to cross one direction of traffic between refuge areas with slower vehicle speeds than a signal. The southbound bypass will operate as a free right turn which can be a safety concern for pedestrians. Bicyclists can travel through the roundabout as vehicles or use the adjacent pathways and travel through the crosswalks with pedestrians.

Traffic signals provide more direct access for pedestrians and bicyclists to cross the intersection from the pathways. Additionally, pedestrian signal heads provide positive indications that a pedestrian has the right-of-way to cross.

Conclusions

Based on the operational analysis completed, demand at the dual lane roundabout will begin to exceed capacity sometime near 2036. The addition of a southbound-right turn bypass lane will provide enough additional capacity to function at acceptable levels in 2036, but only in the p.m. peak. The north-south through movements are expected to dominate the roundabout in 2041 and will cause excessive delays and queuing while also decreasing operations to LOS F.

The signalized intersections operates acceptably under 2036 conditions with some significant estimated 95th percentile queue lengths for the heavy northbound and southbound movements. Under 2041 conditions the intersection is estimated to operate at LOS E overall with some significant delays and estimated queue lengths for the major northbound and southbound movements along with some of the eastbound and westbound movements. Overall delay is estimated to be lower for roundabout alternatives than the signalized option in the 2036 peak hours. Under 2041 conditions the signalized option has lower overall delay in the a.m. peak hour and the roundabout with bypass lane has lower overall delay in the p.m. peak hour.

In terms of ROW needed, all three alternatives will require right-of-way to taper the improvements back to the existing roadway sections on the east, west and south legs. However, the roundabout alternatives require less ROW than the signal. The signalized intersection also impacts the drainage pond located in the southeast corner, while the roundabouts do not.