Northern Arizona University Transportation Capstones

- J3Z Engineering (Signal Design): Zach Crimmins, Joseph Davis, Jace Elkins & Jordan Weyrauch. Technical Advisor: Dr. Smaglik
- Transportation Engineering Services (Roundabout Design): Amal Abdelaziz, Kevin Farrel, TJ Sullivan, & Ralph Ubert. Technical Advisor: Dr. Russo

Project Overview

- Client: City of Flagstaff
- POC: Stephanie Sarty
- Location: N. Country Club Dr. and E. Old Walnut Canyon Rd.
- Project Budget: $1,115,000 FY2018
- Purpose: Redesign the intersection for both a traffic signal and roundabout

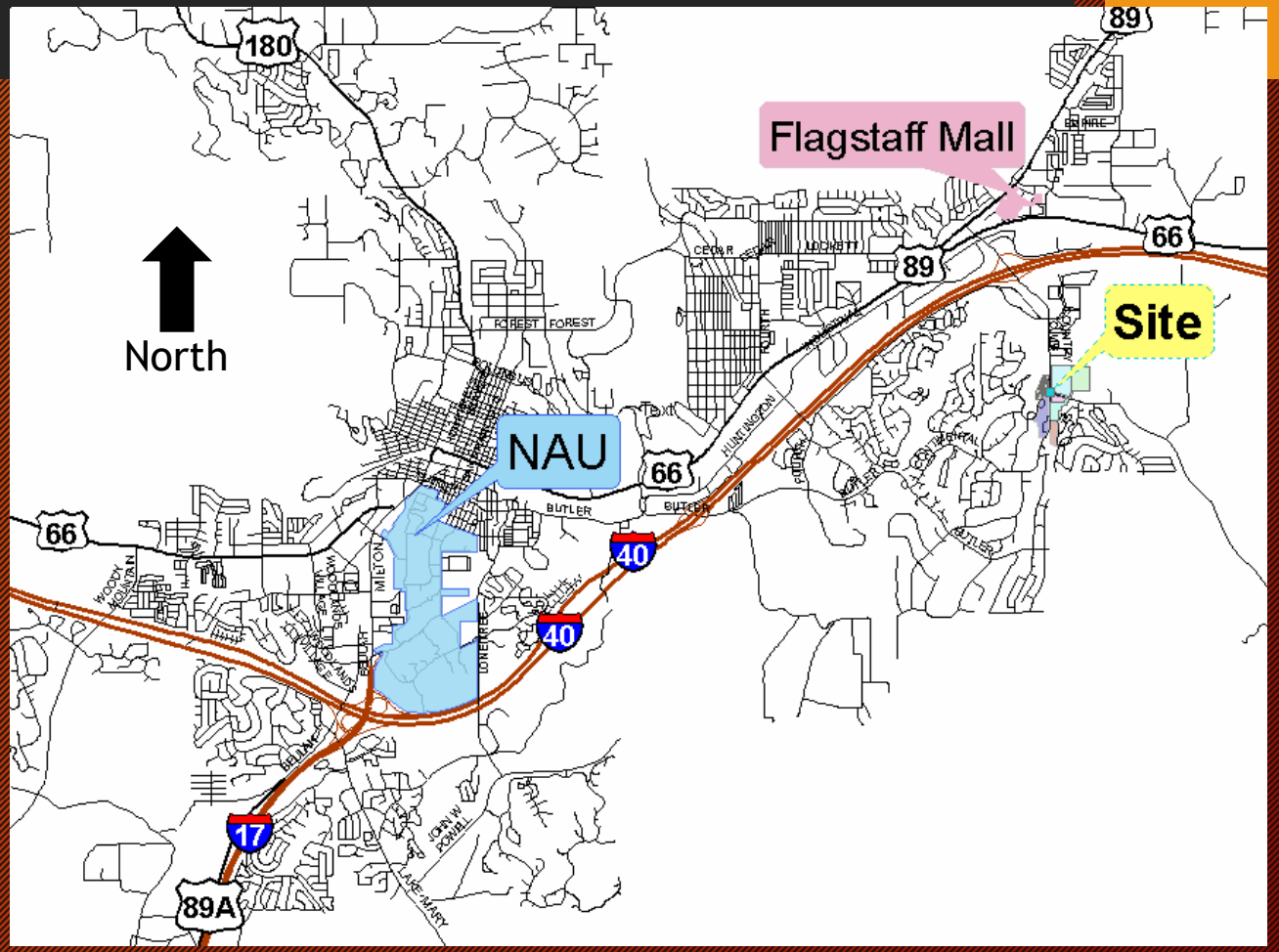


Figure 1: Intersection Location [1]

Agenda

- Current Conditions
- Traffic Studies
  - Speed & Volume Data
  - Vehicle Classification
  - Current/Projected LOS
  - Right of Way
  - Sight Distance
- Signal Alternative
- Roundabout Alternative
- Design Comparison

Figure 2: Intersection Location [1]

Current Speed/Volume Data

Figure 3: Speed and Volume Data

Peak Hour Volume				
Leg of Intersection	AM Peak Hour	AM Volume	PM Peak Hour	PM Volume
NB Country Club	8:00-9:00	228	4:30-5:30	263
SB Country Club	7:15-8:15	540	5:00-6:00	687
EB Oakmont	11:00-12:00	142	3:00-4:00	174
WB Old Walnut Canyon	8:00-9:00	284	5:00-6:00	399

Table 1: AM/PM Peak Hours and Volume

- Speeds indicate 85th percentile
- ADT=Average Daily Traffic

Vehicle Classification

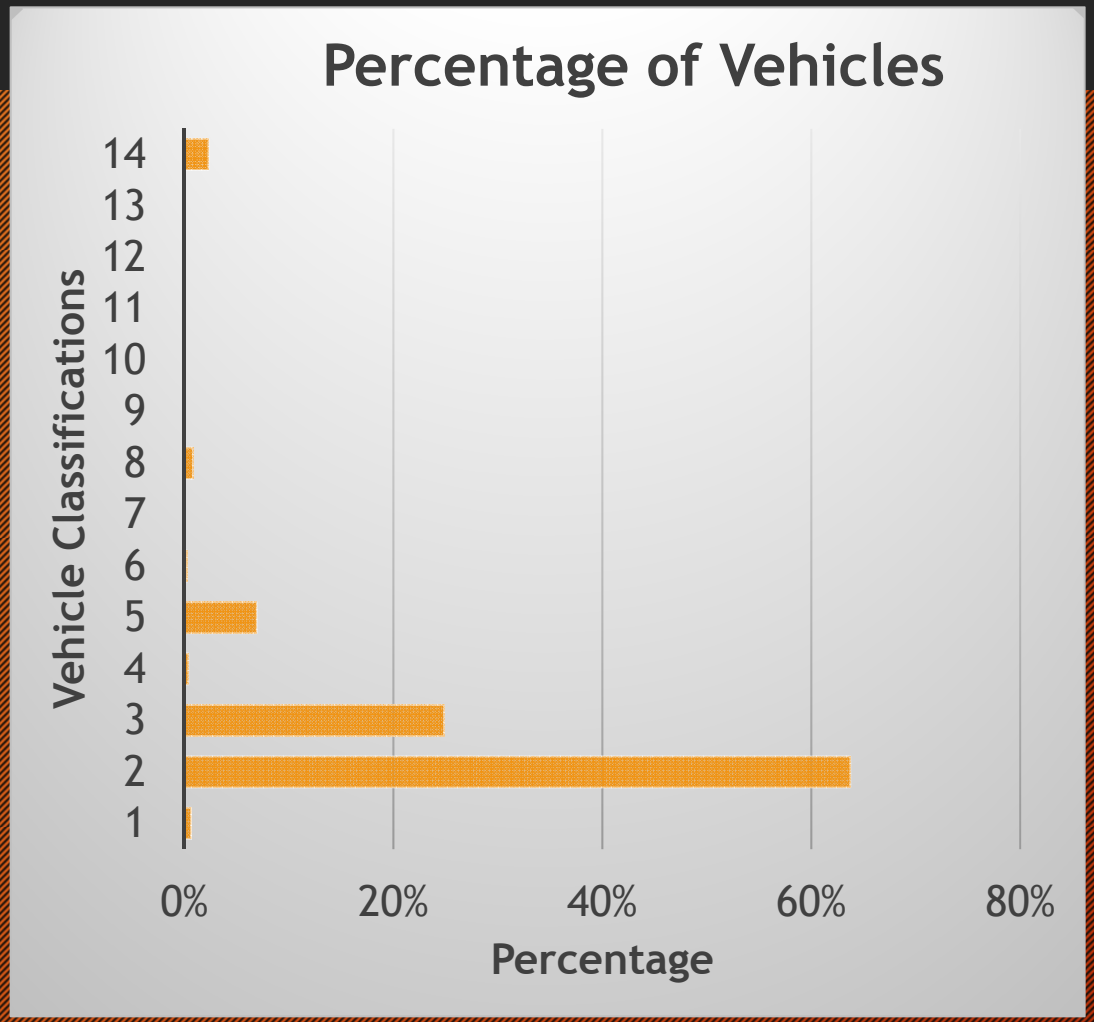
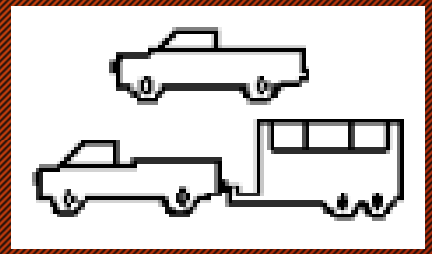


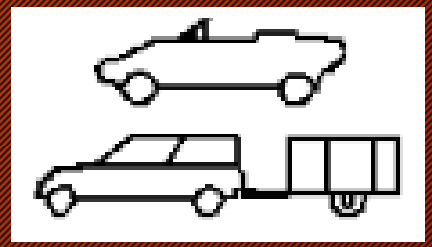
Figure 4: Vehicle Classification Statistics

Class 14: Unclassified vehicles

Class 5: Single Unit Trucks (2 Axle, 6 tire) including recreation vehicles



Class 3: Pickups & Vans (2 Axle, 4 tire) including those with light trailers



Class 2: Passenger vehicles including those pulling light trailers

VISSIM

Highway Capacity Software: Inputs

Highway Capacity Software (HCS) Inputs												
	Eastbound			Westbound			Northbound			Southbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Number of Lanes	0	1	0	0	1	1	1	1	0	1	1	1
Configuration		LTR		LT		R	L		TR	L	T	R
Volume (veh/hr)	65	14	4	19	16	167	6	122	36	274	157	87
Percent Heavy Vehicles	2	2	2	2	2	2	2			2		

Table 2: HCS Inputs

Highway Capacity Software: Outputs

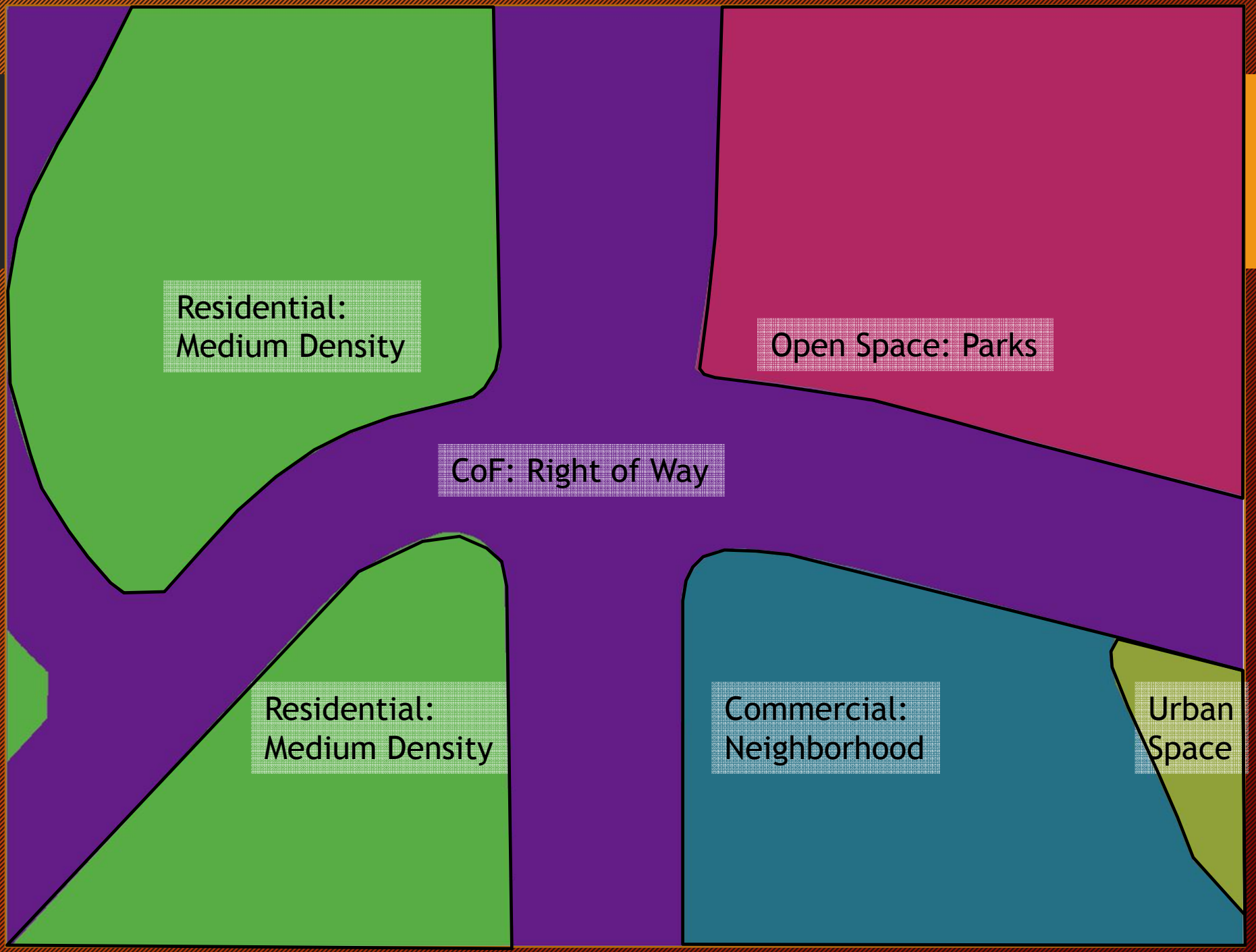
Current HCS Delay and LOS												
	Eastbound			Westbound			Northbound			Southbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Approach Delay (s/veh)	22.2			11.1			0.4			4.3		
Approach LOS	C			B			A			A		

Table 3: Current Delay & LOS

Future HCS Delay and LOS												
	Eastbound			Westbound			Northbound			Southbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Approach Delay (s/veh)	81			12.6			0.3			4.5		
Approach LOS	F			B			A			A		

Table 4: Future Delay & LOS

Right-of-Way



[2]

Figure 5: City of Flagstaff Zoning Boundaries

Warrant Analysis

- Warrant 1 (8 Hour Vehicular Volume)
  - Not Met Due to Lack of Volume
- Warrant 2 (4 Hour Vehicular Volume)
  - Not Met Due to Lack of Volume
- Warrant 7 (Crash History)
  - Meets Crash Criteria but not Volume

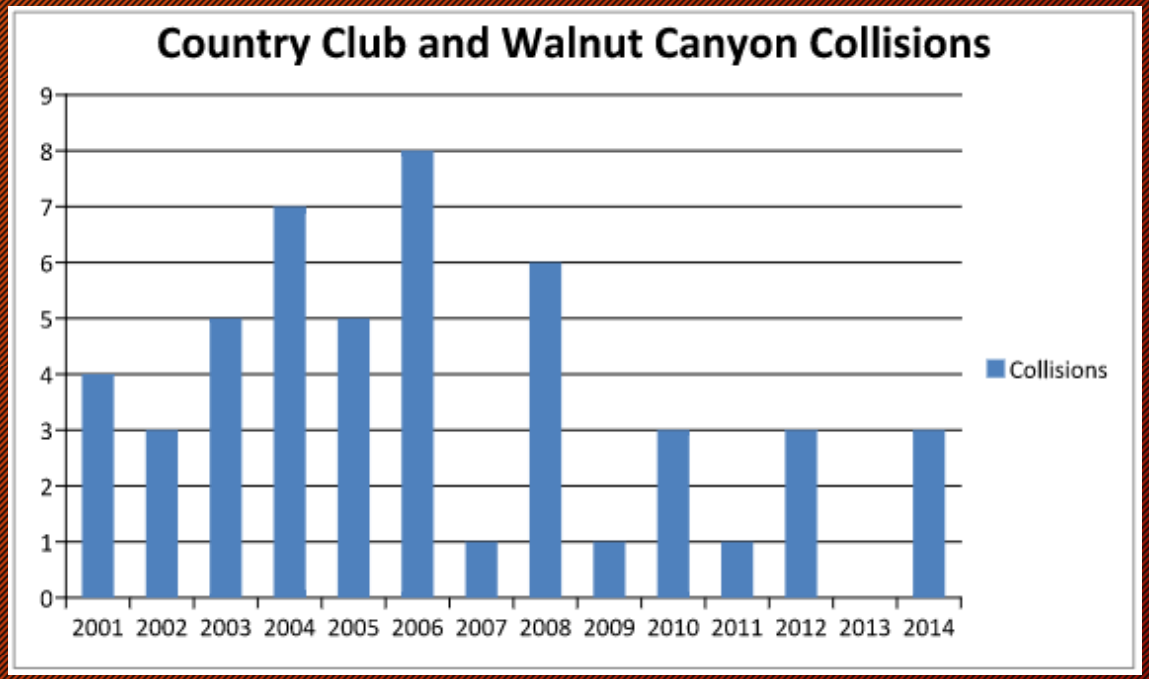


Figure 6: Crash Experience Statistics

Intersection Sight Distance

Per AASHTO Standards:

- 290’ (80’ Short)
- 290’ (30’ Short)
- 390’ (60’ Short)

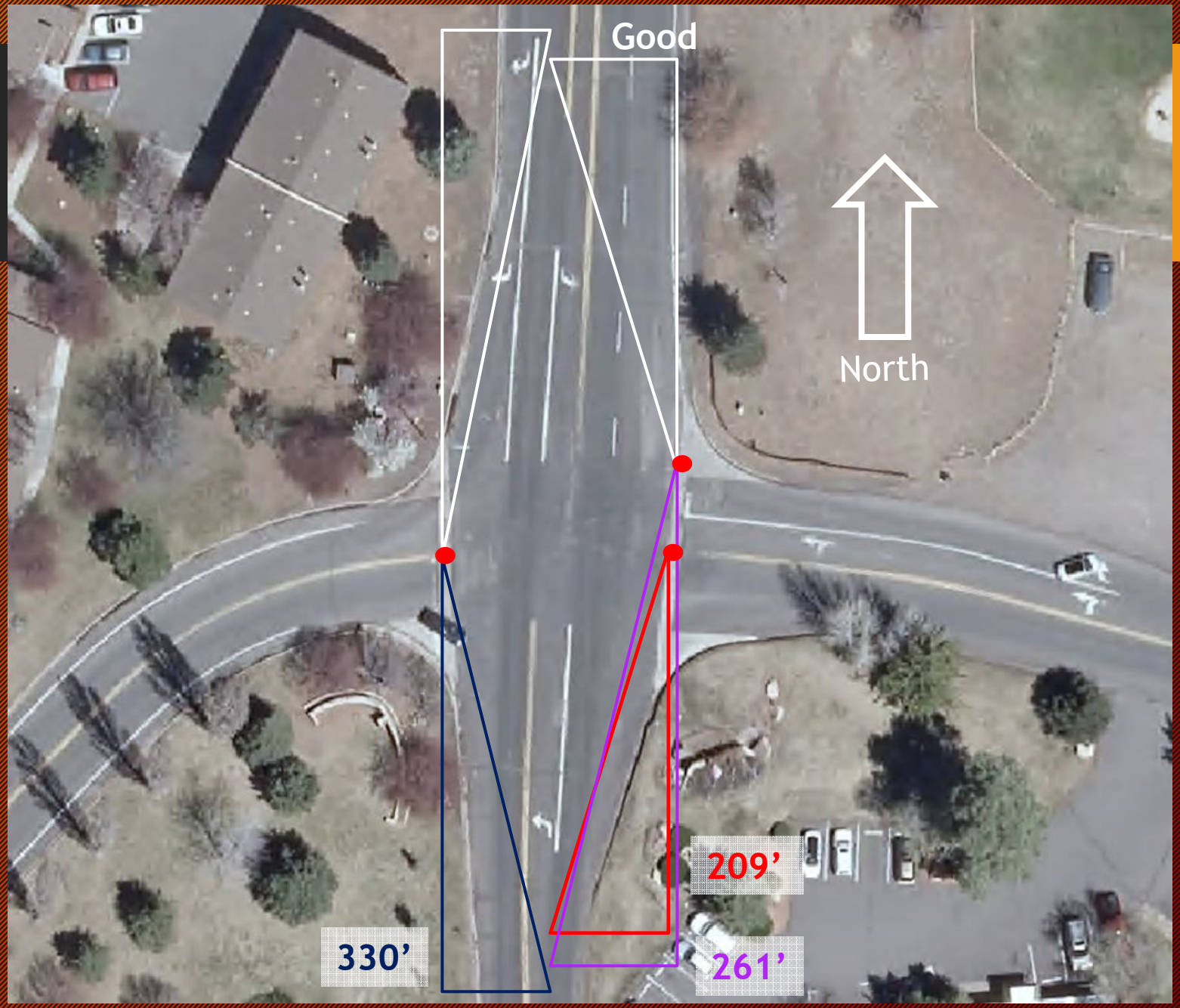


Figure 7: Intersection Sight Distance

Signal Design: Existing

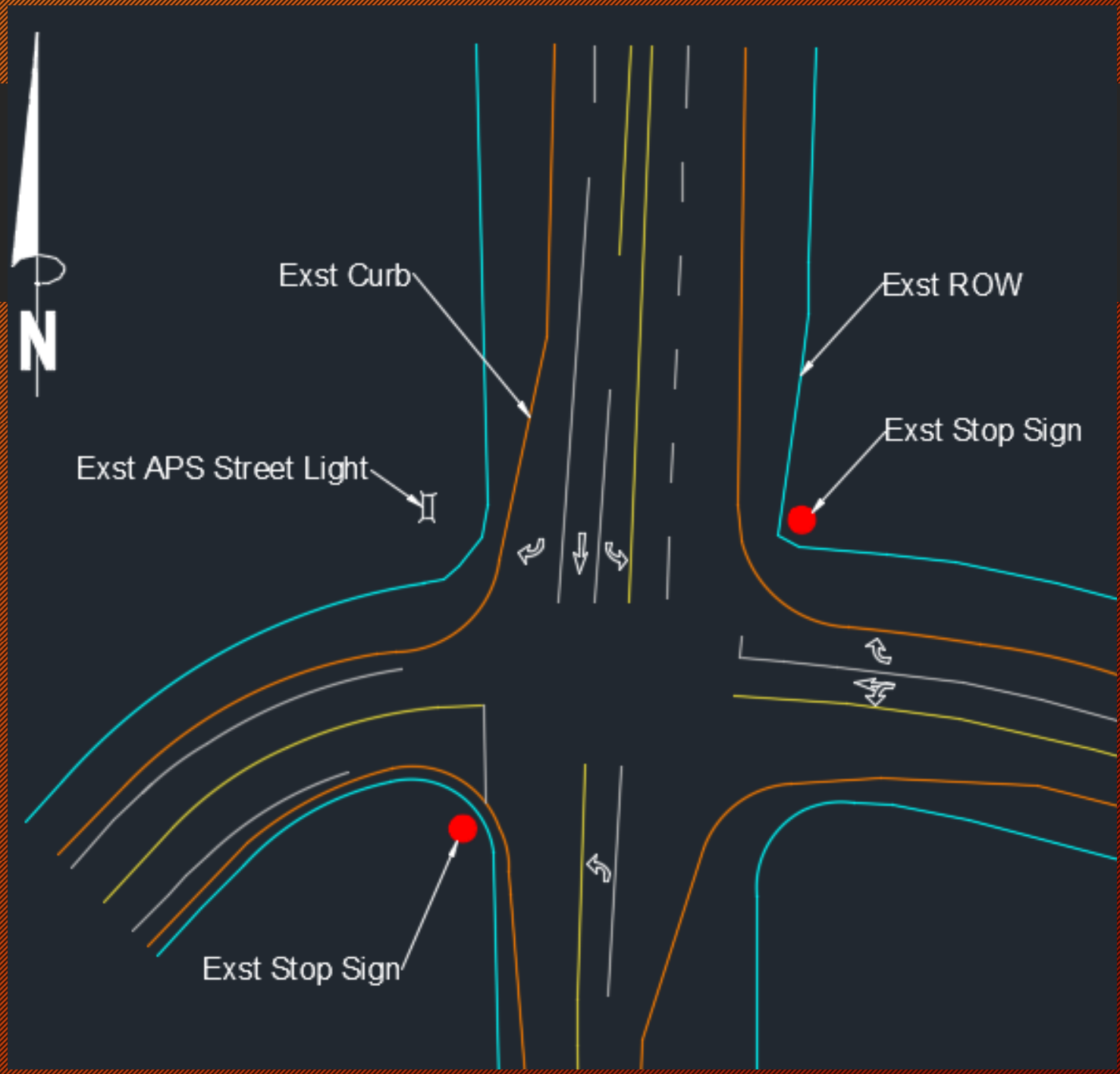


Figure 8: Existing Layout

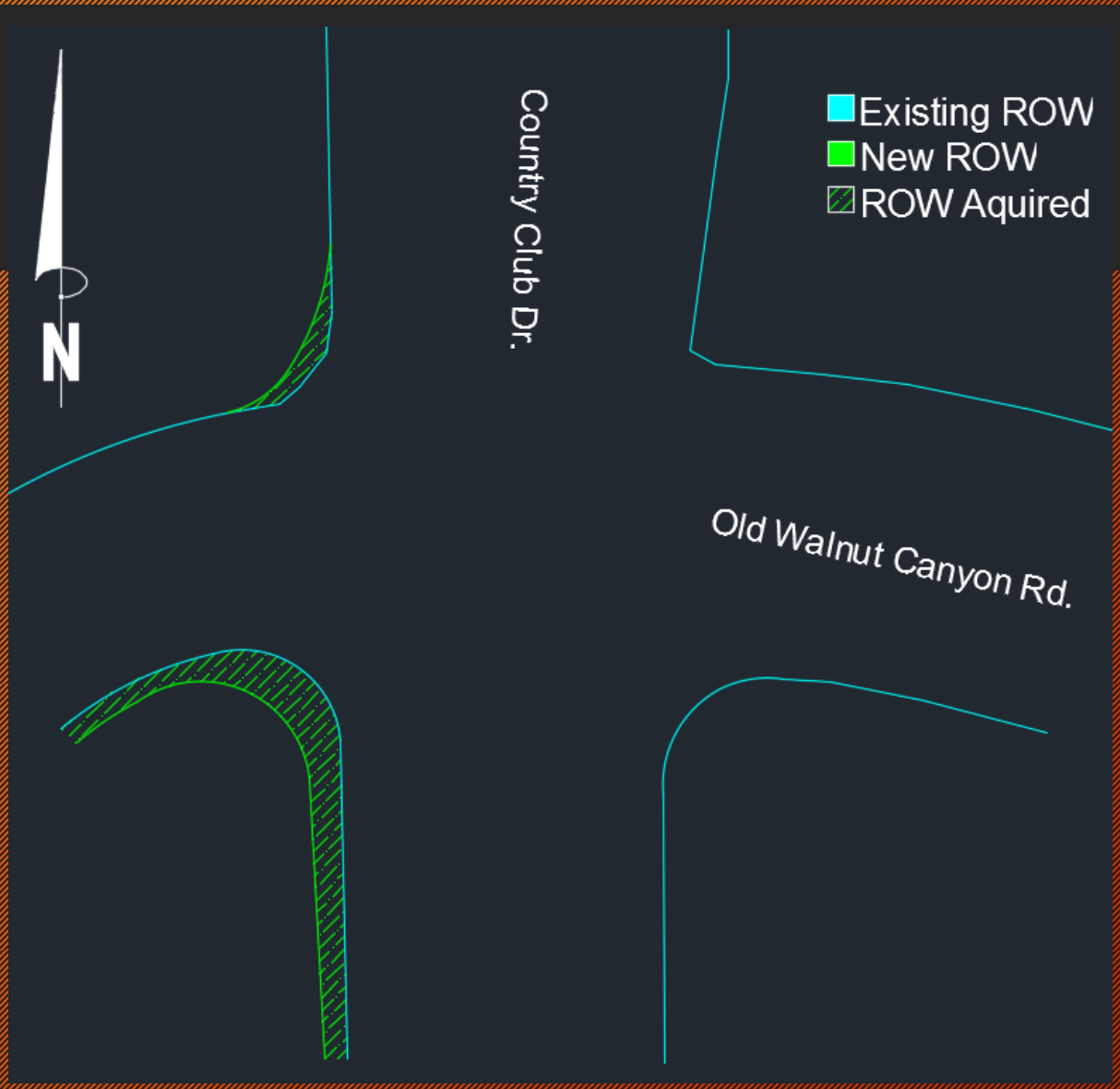


Figure 9: Right of Way Required

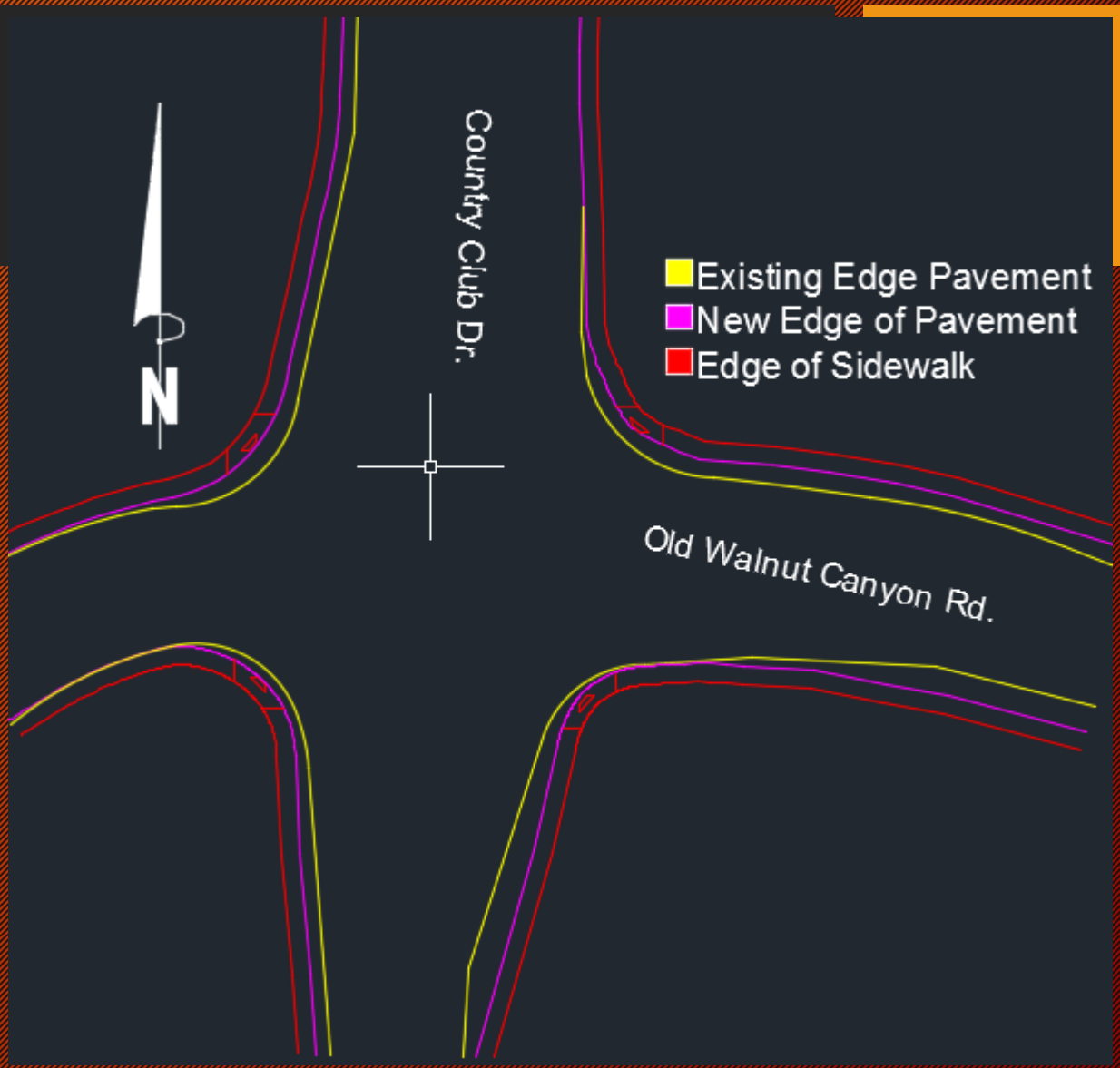
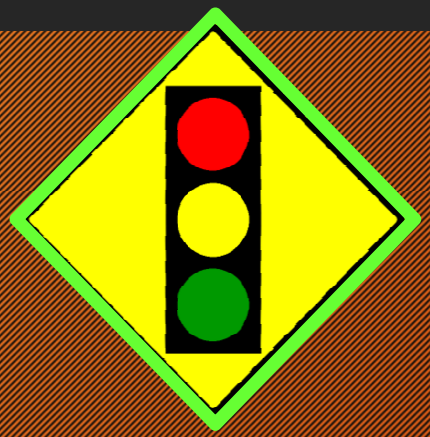


Figure 10: Edge of Pavement Detail

Striping and Signage



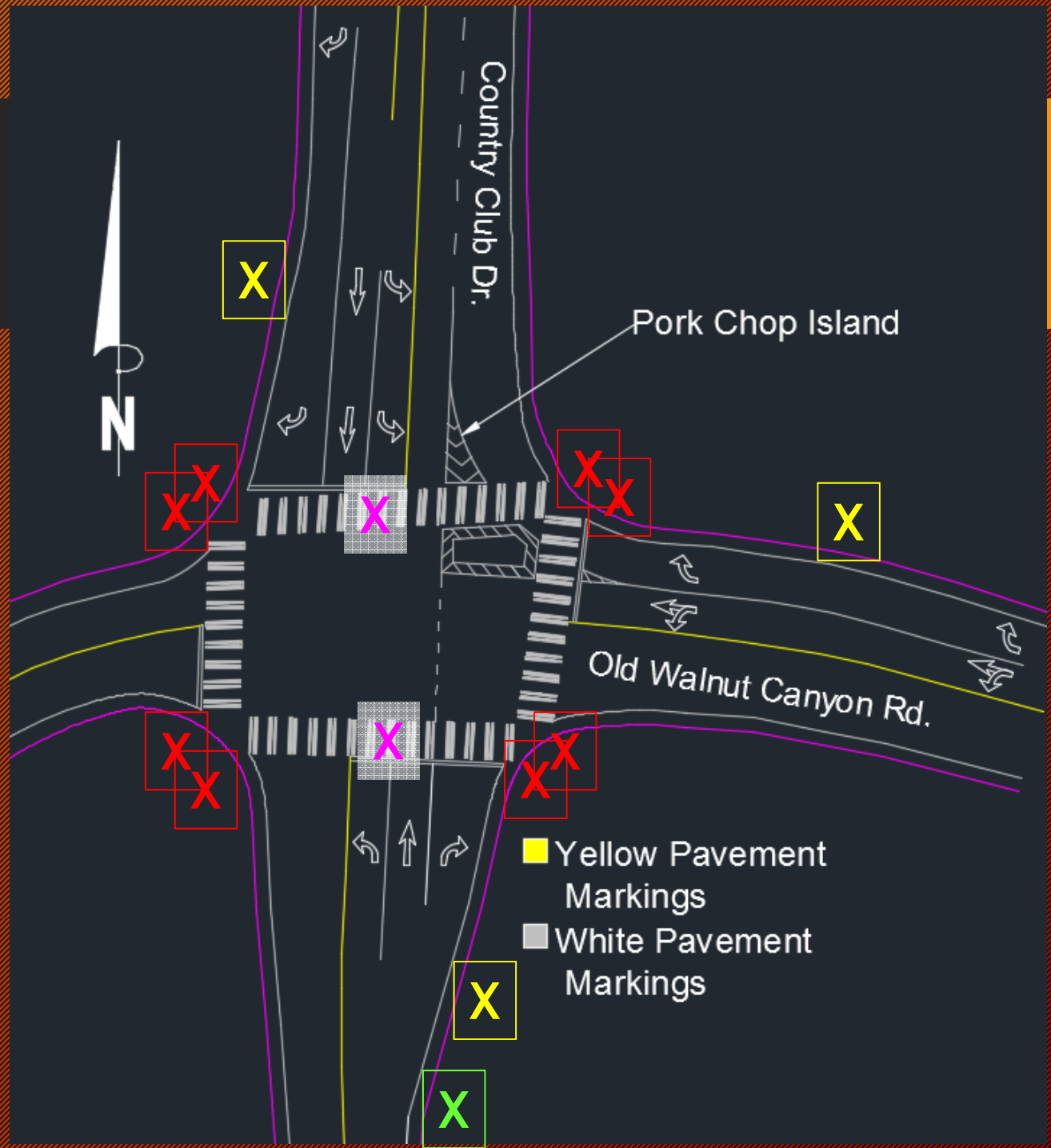


Figure 11: Signage Detail

Signal Heads

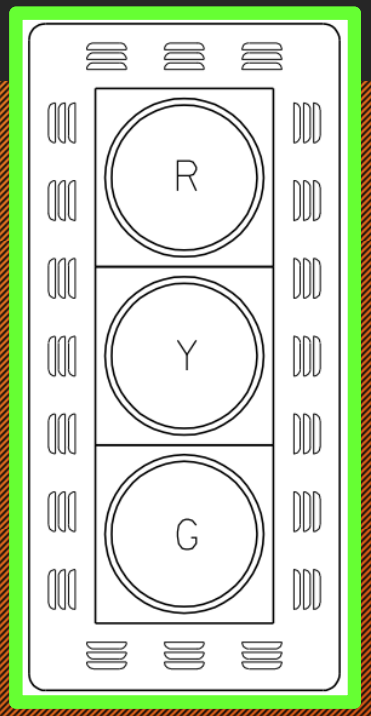


Figure 11: Type F Signal Head [5]

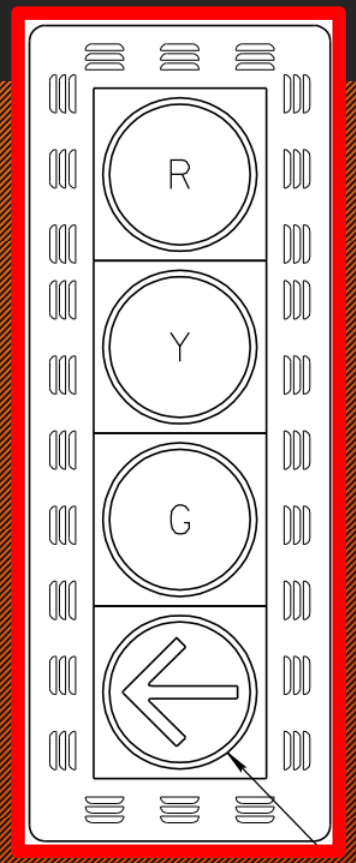


Figure 10: Type G Signal Head [5]

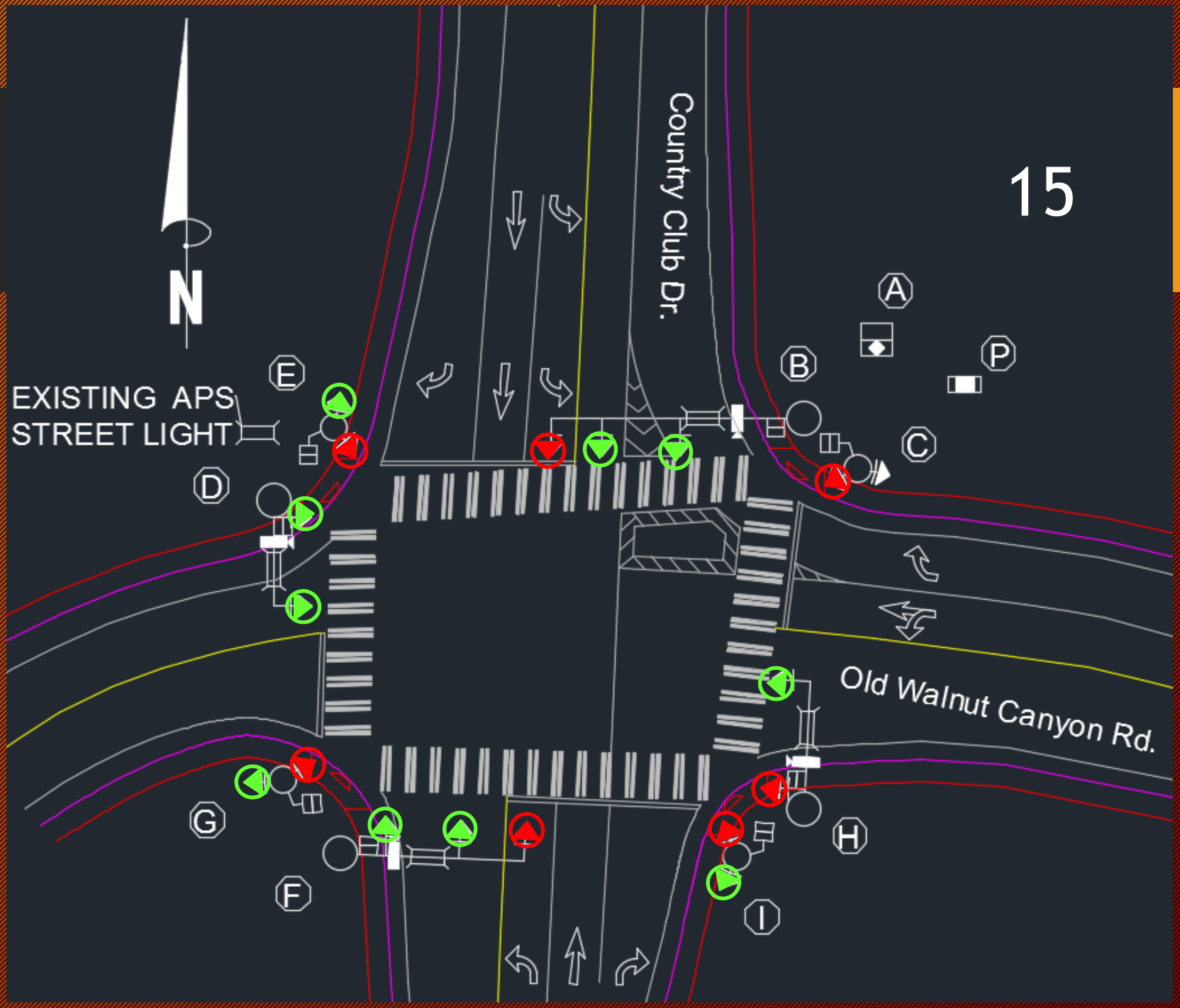


Figure 12: Signal Head Layout

Synchro

**Speed Simulated 8X

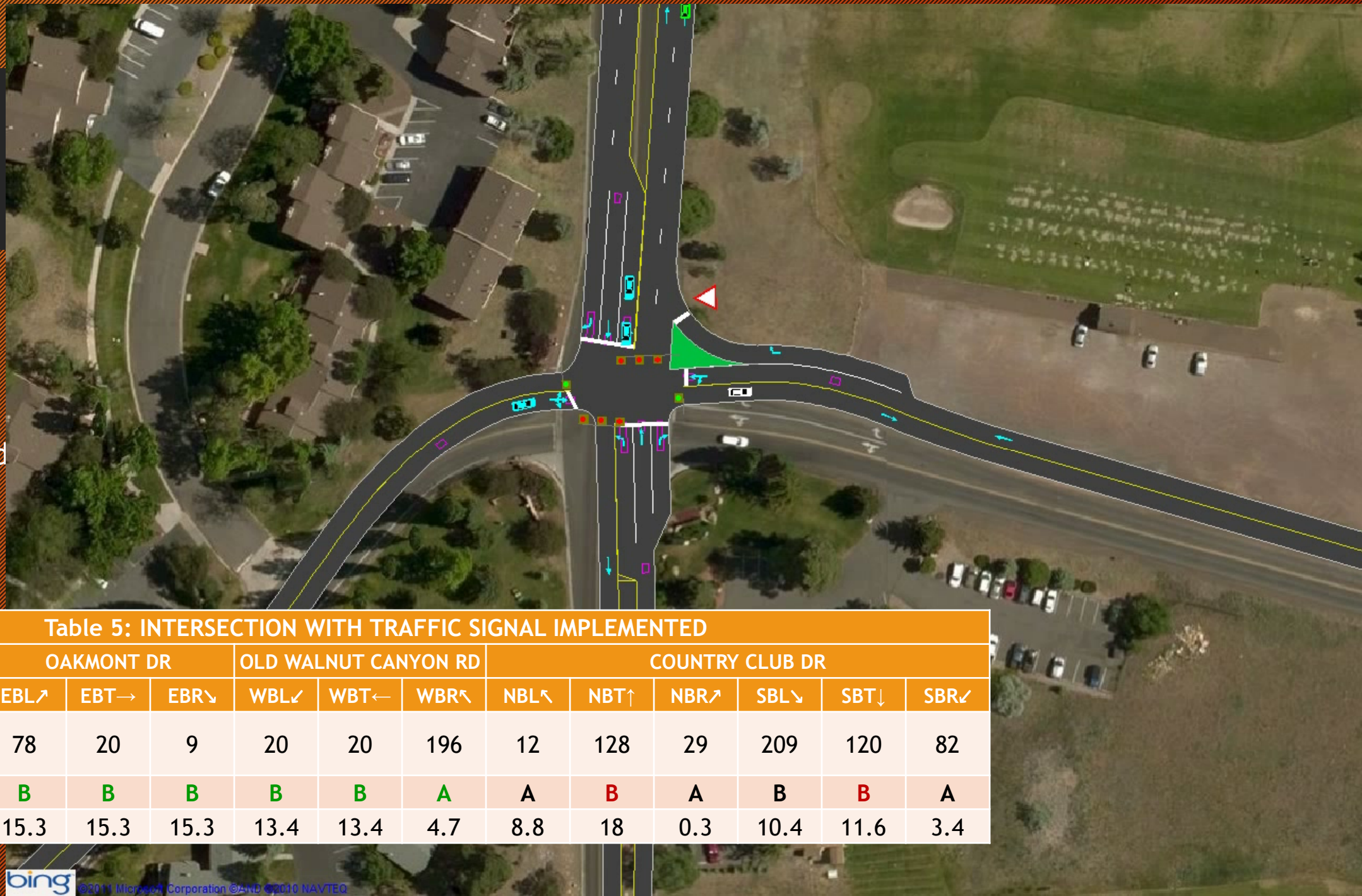


Table 5: INTERSECTION WITH TRAFFIC SIGNAL IMPLEMENTED												
STREET	OAKMONT DR			OLD WALNUT CANYON RD			COUNTRY CLUB DR					
DIRECTION	EBL↗	EBT→	EBR↘	WBL↙	WBT←	WBR↖	NBL↖	NBT↑	NBR↗	SBL↘	SBT↓	SBR↙
TRAFFIC VOLUME (VPH)	78	20	9	20	20	196	12	128	29	209	120	82
LEVEL OF SERVICE	B	B	B	B	B	A	A	B	A	B	B	A
TOTAL DELAY (S)	15.3	15.3	15.3	13.4	13.4	4.7	8.8	18	0.3	10.4	11.6	3.4

Signal-Construction Cost

Description	Unit	QTY	Unit Price ($)	Amount ($)
Traffic control				
Remove Curb & Gu				
Obliterate Paveme (4" Equivalent Widt				
Asphalt Rubber Ma				
Aggregate Base, Cl				
Sidewalk				
Sidewalk Ramp (10				
Pavement Marking				
Pavement Marking				
Pavement Symbols				

Table 6: Signal

Description	Unit	QTY	Unit Price ($)	Amount ($)
SIGN POST U-CHAN STEEL)				
W3-3 SIGN (30" X 3(				
STREET NAME SIGN				
4-10 Pole				
4-19 Pole				
POLE FOUNDATION				
MAST ARM (20 FT.)				
CONTRACTOR TRAN				
MAST ARM (30 FT.)				
CONTRACTOR TRAN				
MAST ARM (35 FT.)				
CONTRACTOR TRAN				
MAST ARM (60 FT.)				
CONTRACTOR TRAN				
ELECTRICAL CONDU				
ELECTRICAL CONDU				
ELECTRICAL CONDU				

Description	Unit	QTY	Unit Price ($)	Amount ($)
ELECTRICAL CONDUIT (2-3") (PVC) (DIRECTIONAL DRILLED)	LF	400	50	20000
PULL BOX (NO.7)	EA	3	750	2250
PULL BOX (NO.7) (W/EXTENSION)	EA	1	1200	1200
CONDUCTORS	LS	1	18000	18000
TRAFFIC SIGNAL FACE (TYPE F)	EA	5	900	4500
TRAFFIC SIGNAL FACE (TYPE G)	EA	6	1100	6600
TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE VII)	EA	8	450	3600
CONTROL CABINET(ECONOLITE ASC/3-2100)(CITY FURNISHED, CONTRACTOR TRANSP & INSTALL)	EA	1	4000	4000
VIDEO DETECTION SYSTEM (4-CAMERA SYSTEM)	LS	4	22000	88000
LUMINAIRE (LED) Cooper Model No. OVHA04LEDEUOO04	EA	4	700	2800
MISCELLANEOUS ELECTRICAL (AS-BUILT DRAWINGS)	LS	1	500	500
FORCE ACCOUNT WORK (PROVIDE ELECTRICAL SERVICE)	LS	1	250	250
CONTRACT ALLOWANCE	LS	1	18800	18800
ALTERNATE NO. 1	LS	1	10000	10000
Total Cost of Traffic Signal Construction				$233,960.00

Signal-Team Schedule

Task ID	Task	Expected Completion Date	Actual Completion Date
1.0	Preliminary Assessment	Sept. 19, 2015	Sept. 19, 2015
2.0	Data Collection		
2.1	Volume/Speed Counts	Sept. 28, 2015	Sept. 28, 2015
2.2	Turning Movement Counts	Oct. 14, 2015	Oct. 14, 2015
2.3	Stop Sign Delay Study	Feb. 2, 2016	Feb. 10, 2016
2.4	Sight Distance Study	Feb. 20, 2016	Feb. 20, 2016
3.0	Analysis		
3.1	Peak Hour Analysis	Oct. 14, 2015	Oct. 16, 2015
3.2	Determine LOS	Oct. 27, 2015	Feb. 5, 2016
3.2.1	Acquire As-Builts	Nov. 11, 2015	Feb. 2, 2016
3.2.2	Determine ROW	Dec. 10, 2015	Feb. 5, 2016
3.2.3	VISSIM/Synchro Existing	Feb. 26, 2016	Feb. 24, 2016
3.3	Crash Analysis	Jan. 26, 2016	Jan. 26, 2016
3.4	Vehicle Classification	Feb. 2, 2016	Feb. 2, 2016
3.5	Warrant Analysis	Feb. 25, 2016	Feb. 28, 2016
4.0	Design		
4.1	Signal Design		
4.1.1	Determine Signal Type	Mar. 9, 2016	Mar. 23, 2016
4.1.2	Determine Detection Method	Mar. 11, 2016	Apr. 6, 2016
4.1.3	Determine Signal Head	Mar. 11, 2016	Mar. 11, 2016
4.2	Geometry	Mar. 25, 2016	Apr. 13, 2016
4.3	Determine Grade	Apr. 4, 2016	April. 18, 2016
4.4	Determine LOS of Redesign	Apr. 8, 2016	Apr. 18, 2016
5.0	Cost Analysis		
5.1	Analysis of Bid History	Feb. 26, 2016	Feb. 15, 2016
5.2	Cost Estimate	Apr. 28, 2016	Apr. 18, 2016
6.0	Project Management		
6.1	50% Report	Mar. 10, 2016	Mar. 10, 2016
6.2	Final Report	May 12, 2016	Upcoming
6.2.1	100% Plan Set	Apr. 28, 2016	Upcoming
6.3	UGrads Presentation	Apr. 29, 2016	Apr. 29, 2016
6.3.1	Practice Presentation	Apr. 19, 2016	Apr. 19, 2016
6.4	Website	May 12, 2016	Upcoming

Table 7: Signal Team Schedule

Signal-Hours

Task ID	Task	Predicted	Actual
1.0	Preliminary Assessment	9	12
2.0	Data Collection		
2.1	Volume/Speed Counts	6	9
2.2	Turning Movement Counts	12	21.5
2.3	Stop Sign Delay Study	6	9
2.4	Sight Distance Study	0	2.25
3.0	Analysis		
3.1	Peak Hour Analysis	4	5
3.2	Determine LOS	4	5
3.2.1	Meeting with the COF	60	20
3.2.2	Acquire As-Builts	4	3
3.2.3	Determine ROW	4	10
3.2.4	VISSIM/Synchro Existing	10	7.5
3.3	Crash Analysis	10	6
3.4	Vehicle Classification	4	2
3.5	Warrant Analysis	6	10
4.0	Design		
4.1	Signal Design		
4.1.1	Determine Signal Type	6	8
4.1.2	Determine Detection Method	6	2
4.1.3	Determine Signal Head	2	4
4.1.4	Determine Signal Timing	10	2
4.2	Geometry	0	17
4.3	Determine Grade	40	0
4.4	Determine LOS of Redesign	4	0
4.4.1	VISSIM/Synchro Redesign	10	12
5.0	Cost Analysis		
5.1	Analysis of Bid History	8	11
5.2	Cost Analysis	40	8
6.0	Project Management		
6.1	50% Report	30	24.5
6.1.1	50% Plan Set	90	31
6.2	Final Report	40	0
6.2.1	100% Plan Set	105	5
6.3	Meetings	0	28
6.4	Final Presentation	35	14
6.4.1	Practice Presentation	12	13
6.5	Website	24	8
6.6	Project Scheduling	0	14.5
	Subtotal	601	323

Table 8: Signal Team Hours

Benefits of the Signal Design

- Improve the safety of the intersection.
  - Maximum degree of control.
  - Improved safety for bicyclists and pedestrians.
- Reduce the delay time.
  - Ability to assign right of way to various traffic movements.
  - Orderly movement of conflicting flows.
  - Interrupts heavy flows on the major street to permit crossing of minor movements.
- Little ROW needed.

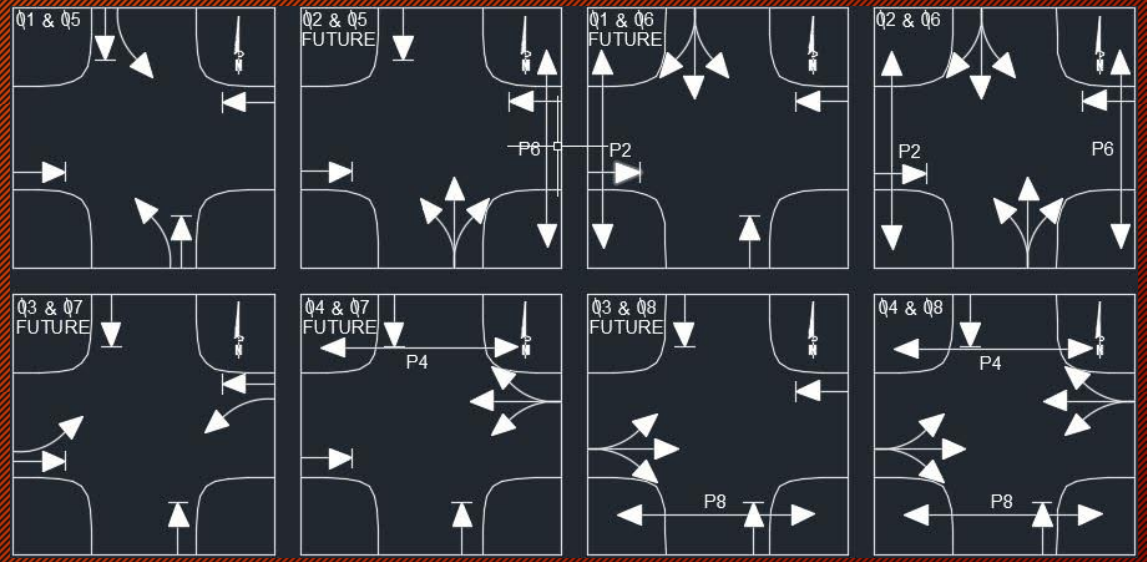


Figure 13: Proposed Phasing Diagram

Signal-Impacts

Economic Impacts	Societal Impacts	Safety Impacts
• Lower upfront cost • Improved delay	• Improved pedestrian travel • Allows for future area growth	• Reduce high-impact collisions • Improved travel for bicyclists

Roundabout: Existing Site

North Bound:2 Lanes
- Width - 60 ft
- mph - 40 mph

West Bound: 2 Lanes
- Width - 45 ft
- mph - 25 mph

South Bound: 3 Lanes
- Width - 42 ft
- mph - 30 mph

East Bound: 1 Lanes
- Width - 35 ft
- mph - 25 mph

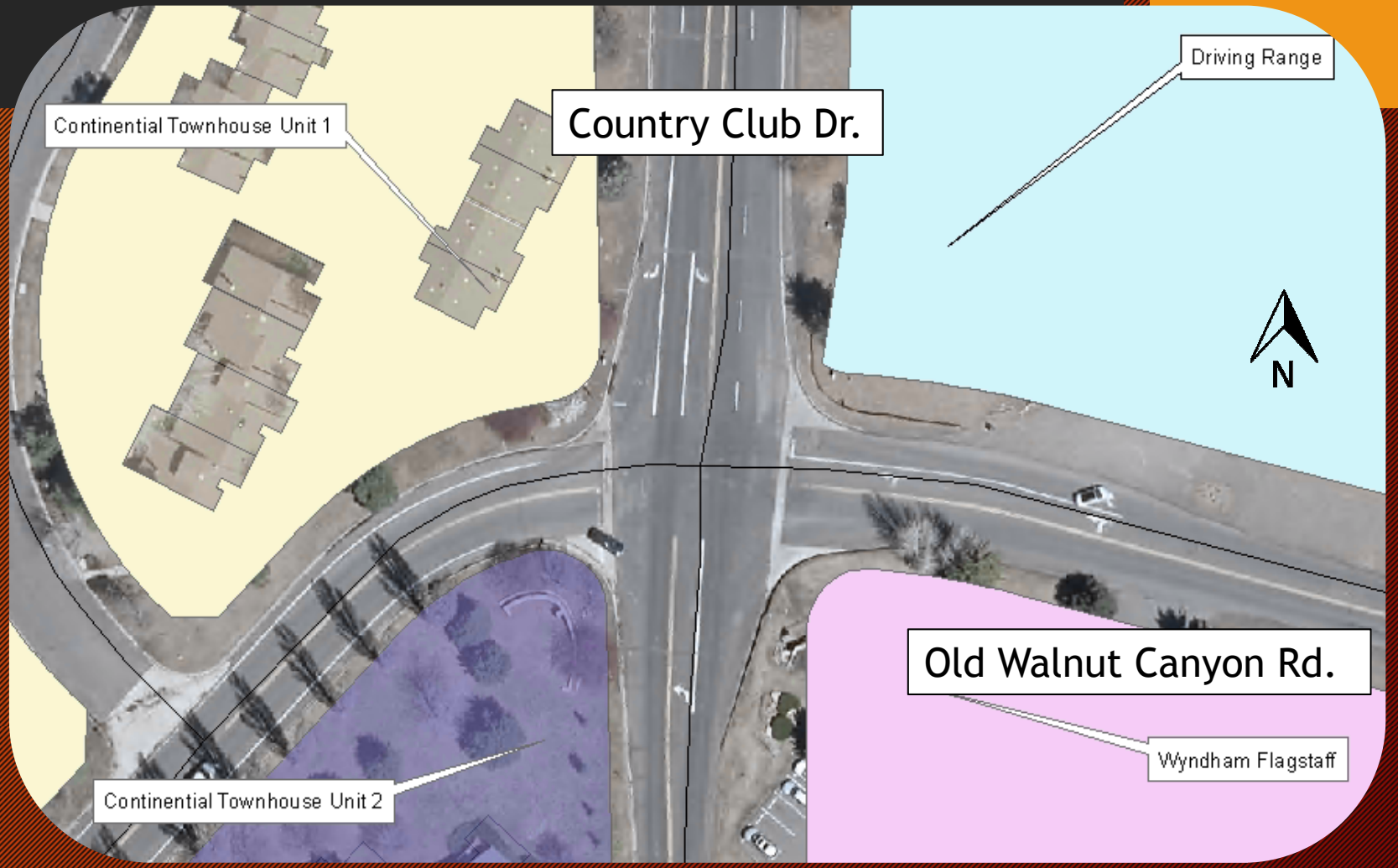


Figure 14: Existing Conditions

Roundabout Design Alternative

	Mini Roundabout	Singe Lane Roundabout
Entry Speed	15-20 MPH	20-25 MPH
Number of Approach Lanes	1	1
Inscribed Diameter	45 – 90 ft	90 – 180 ft

Table 9: Alternative Comparisons

Roundabout Design Alternative

Single Lane Roundabout

1st Provide slow entry speeds and consistent speeds through the roundabout by using deflection

Roundabout

Diameter	110 ft
Inner Island	
Speed	20 mph

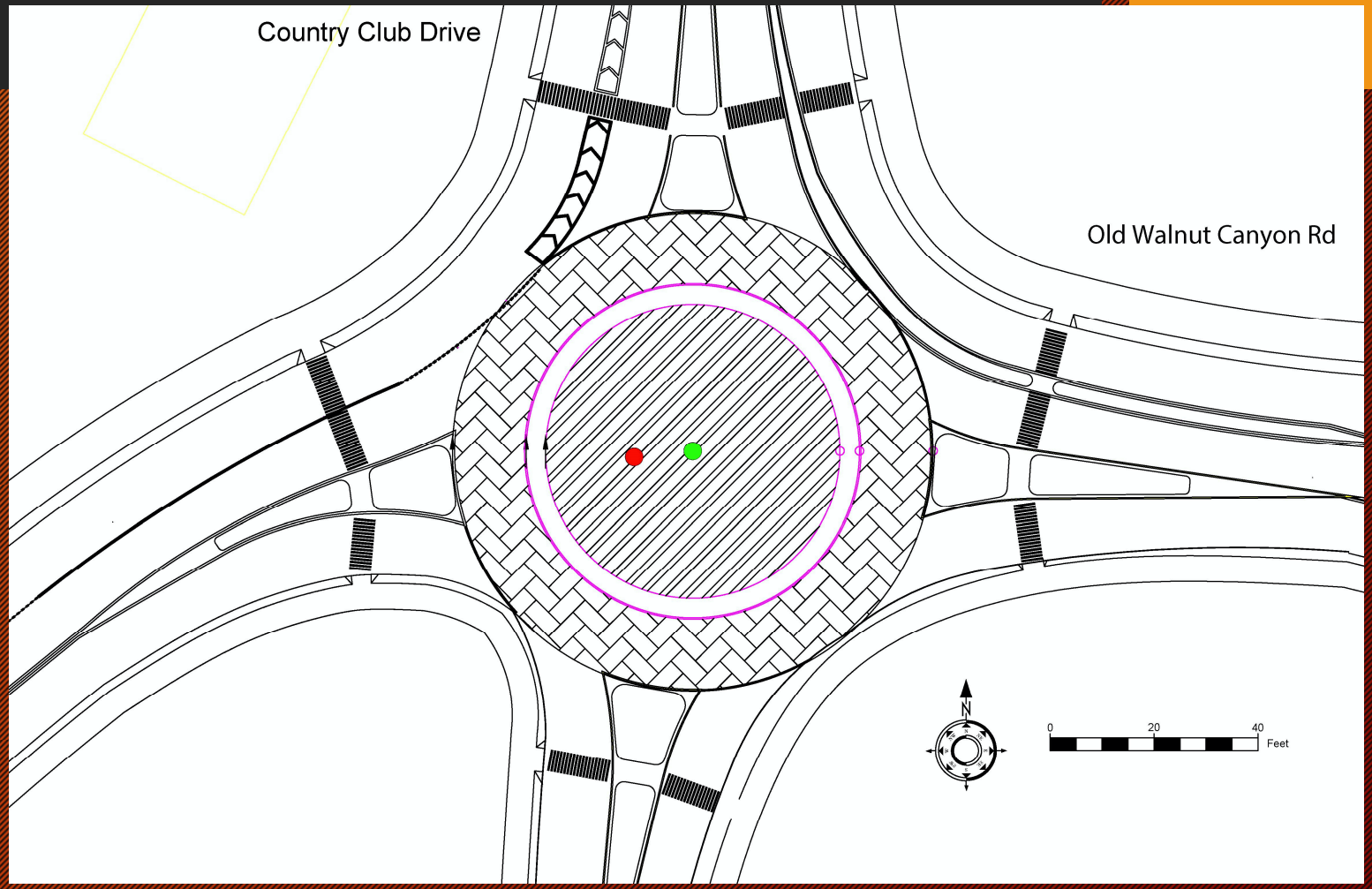


Figure 15: Roundabout-Inscribed Diameter

Roundabout Design Alternative

Single Lane Roundabout

2nd Provide the appropriate number of lanes and lane assignment to achieve adequate capacity, lane volume balance, and lane continuity

Roundabout

Right-turn only (WB)

Right-turn by pass (NB)

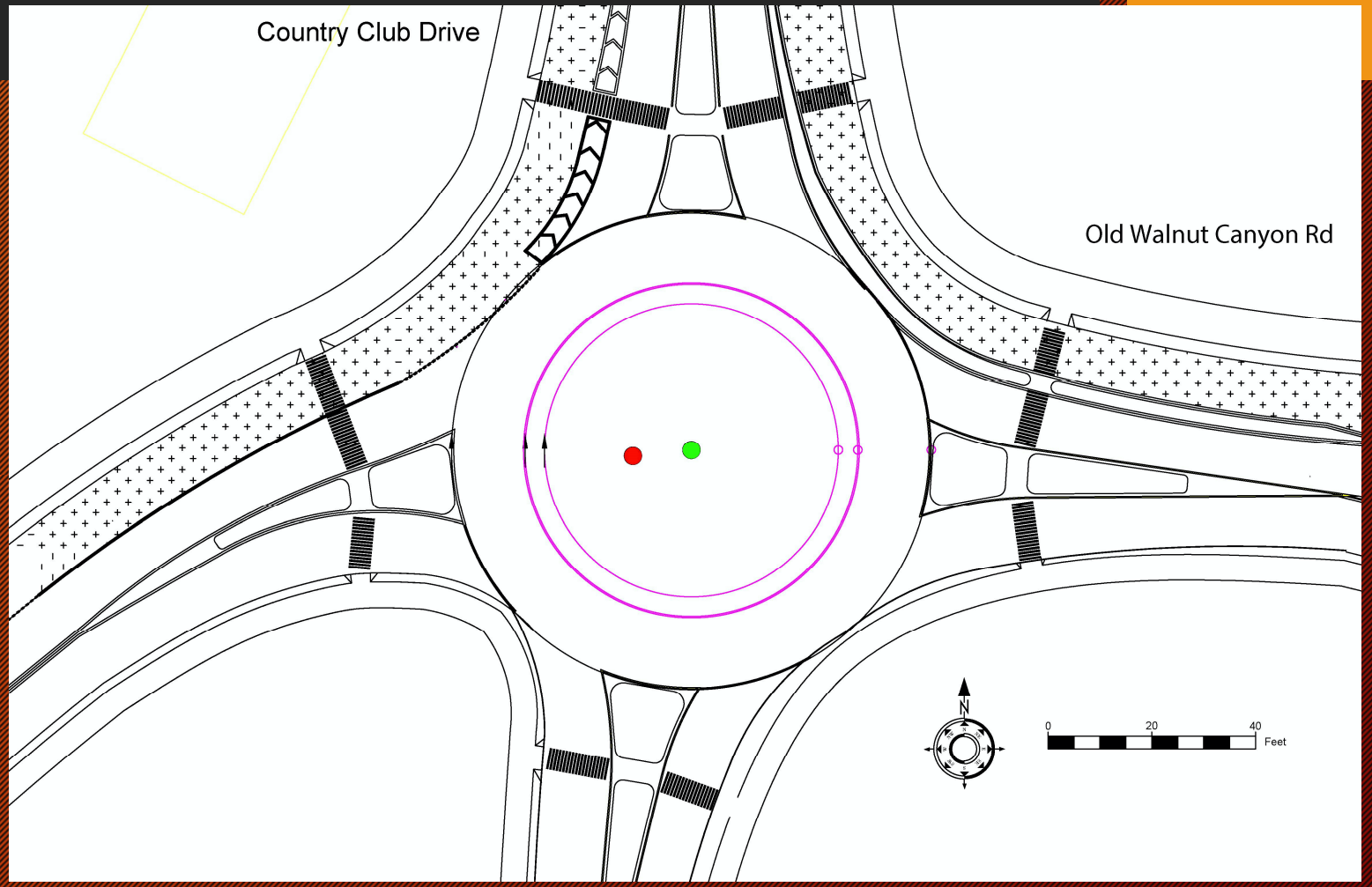


Figure 16: Roundabout-Right Turn Bypass

Roundabout Design Alternative

<u>Single Lane Roundabout</u>

3rd Provide smooth channelization that is intuitive to drivers and results in vehicles naturally using the intended lanes.

Roundabout
- 16 foot lanes
- Splitter Islands

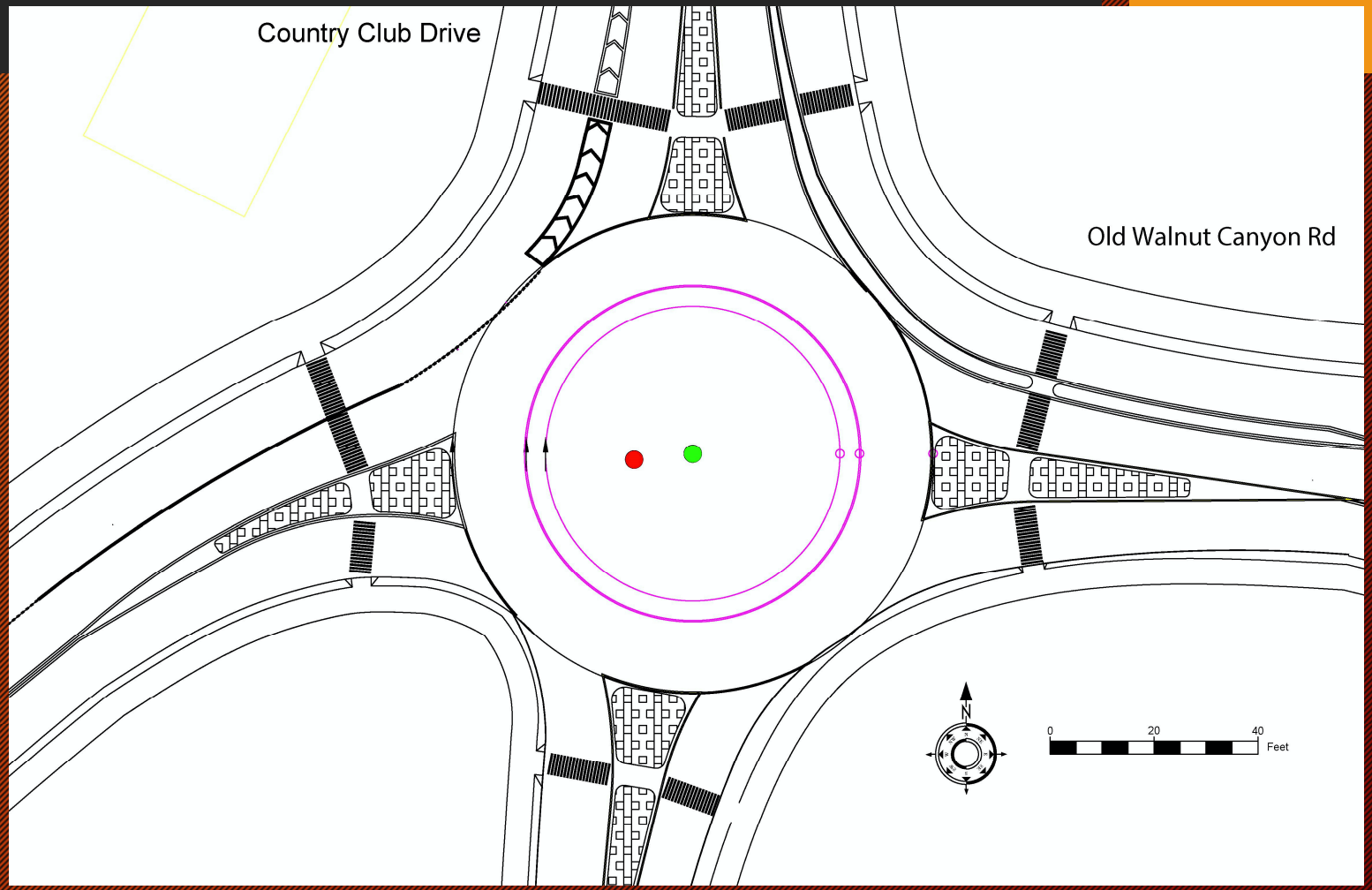


Figure 17: Roundabout- Island Splitters

Roundabout Design Alternative

Single Lane Roundabout

4th Provide adequate accommodation for the design vehicles.
5th Design to meet the needs of pedestrians and cyclists.

Roundabout
- 50 foot single truck trailer (Class 5)
- 9 foot sidewalks
- 2 foot Landscape Strip
- Raised Splitter Islands

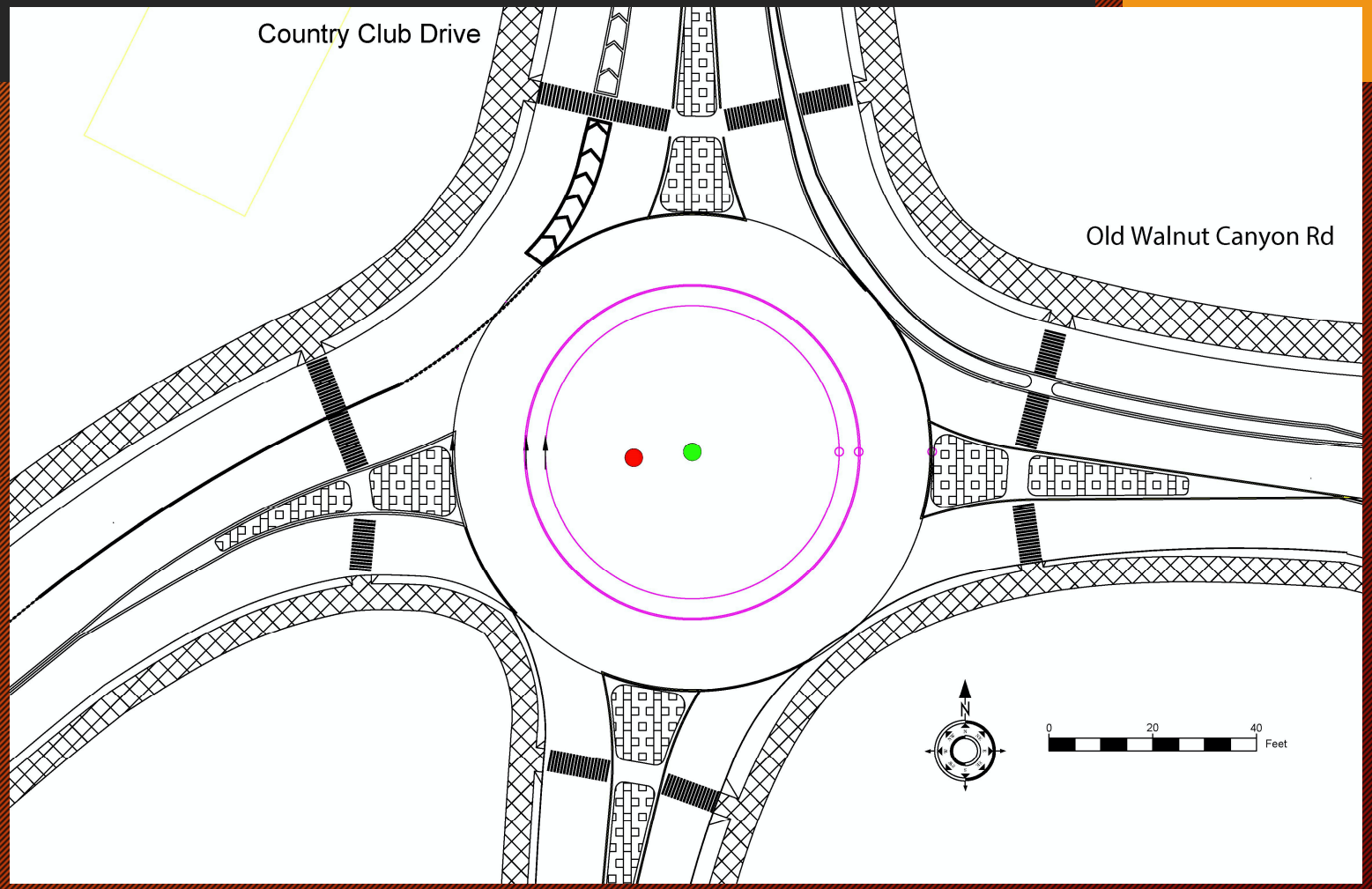


Figure 18: Roundabout- Pedestrian Considerations

Roundabout Design Alternative Cont. Signage

- **Circulation plaque:** South and west bounds.
- **Keep right plaque:** Installed at the splitter island.
- **One way sign:** Middle of the roundabout.
- **Yield plaque:** Installed at each approach leg.
- **Roundabout ahead:** Placed on every approaching leg.
- **Reduce Speed:** Installed on the Southbound and Northbound lanes

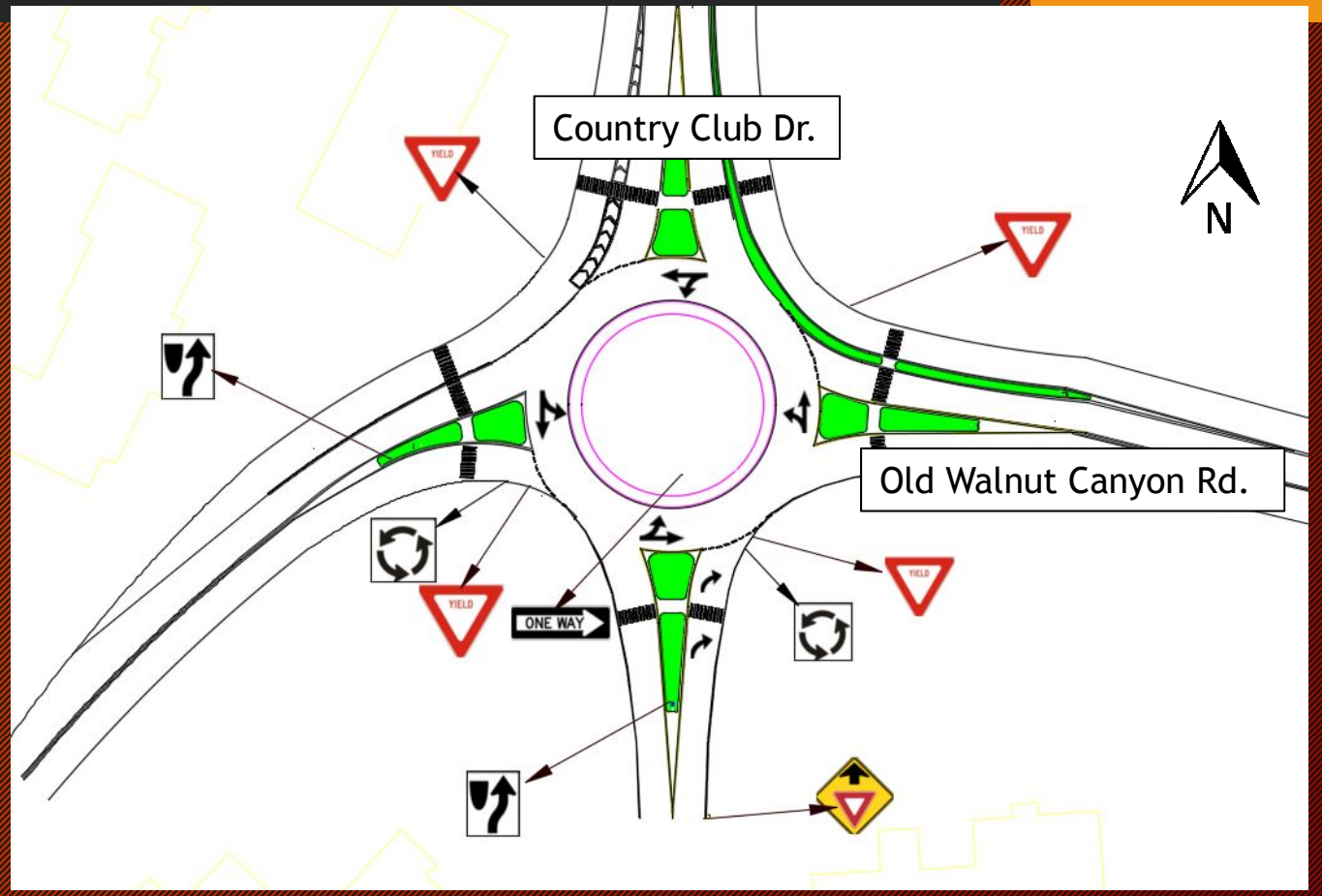


Figure 19: Roundabout- Signage Plan

Roundabout Design Alternative Cont. Striping

- **Dotted lines:** Installed at entrances of roundabout.
- **Ground lane arrows:** Normal arrows based on MUTCD.
- **Yellow Lines:** A double yellow line will surround the splitter islands and divide approach lanes.
- **Pedestrian Crosswalk:** Installed to go through every leg of the roundabout.
- **Bike Considerations:** Accordance with MUTCD Manual bikes are not designed for in the roundabout.

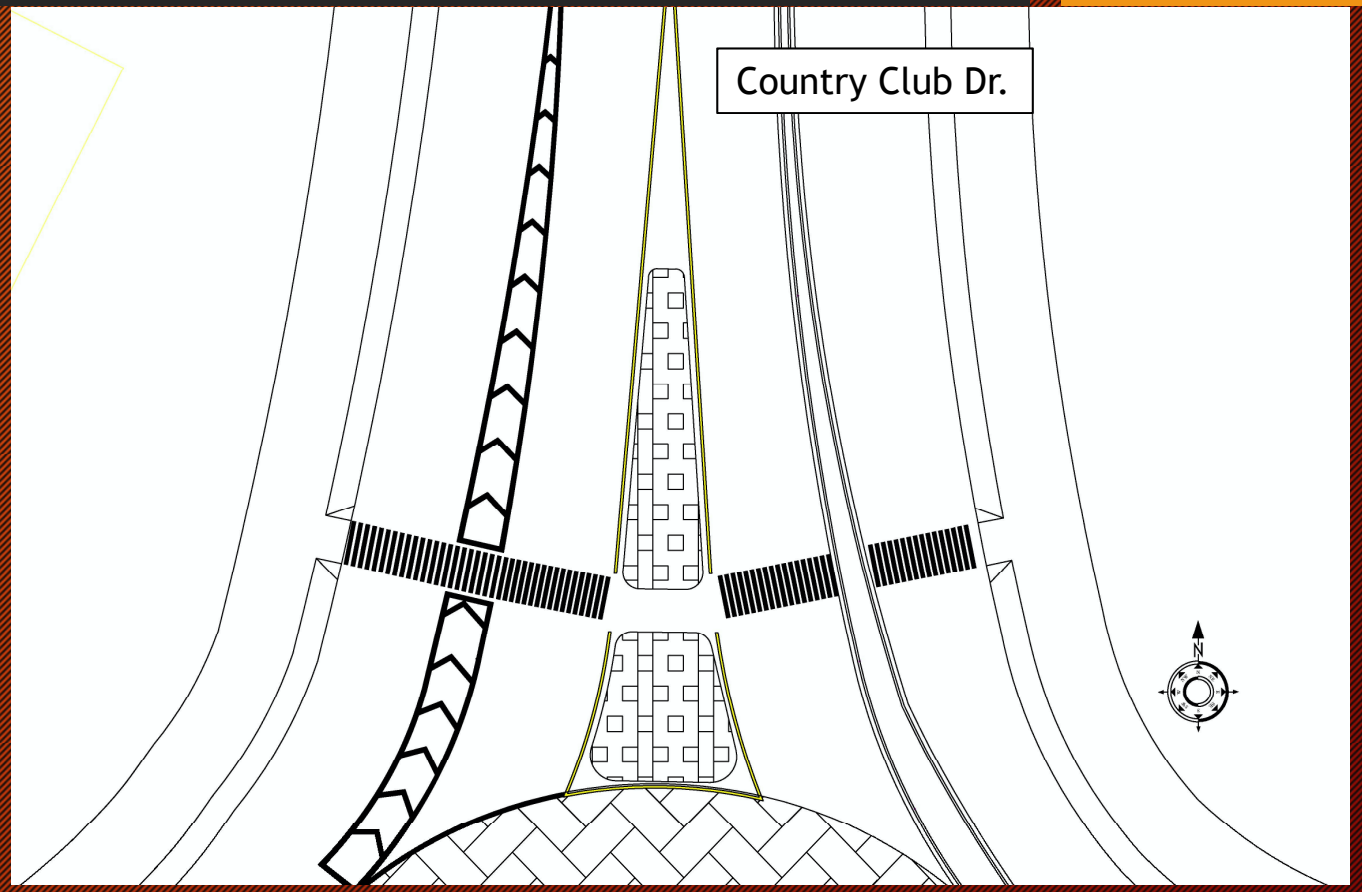


Figure 20: Roundabout- Striping Plan

Roundabout Design Alternative

Single Lane Roundabout

- Diameter -110 ft
- Speeds - 20 mph
- Splitter Island
- Pedestrian cross walks
- Entry Width and Circulatory Roadway Width of 16 ft
- Design Vehicle - large semi-trailer (WB-50)
- Center offset of 1.5 ft N / 13.5 ft E
- Total right-away need from surrounding parcels ~5,475 sqft

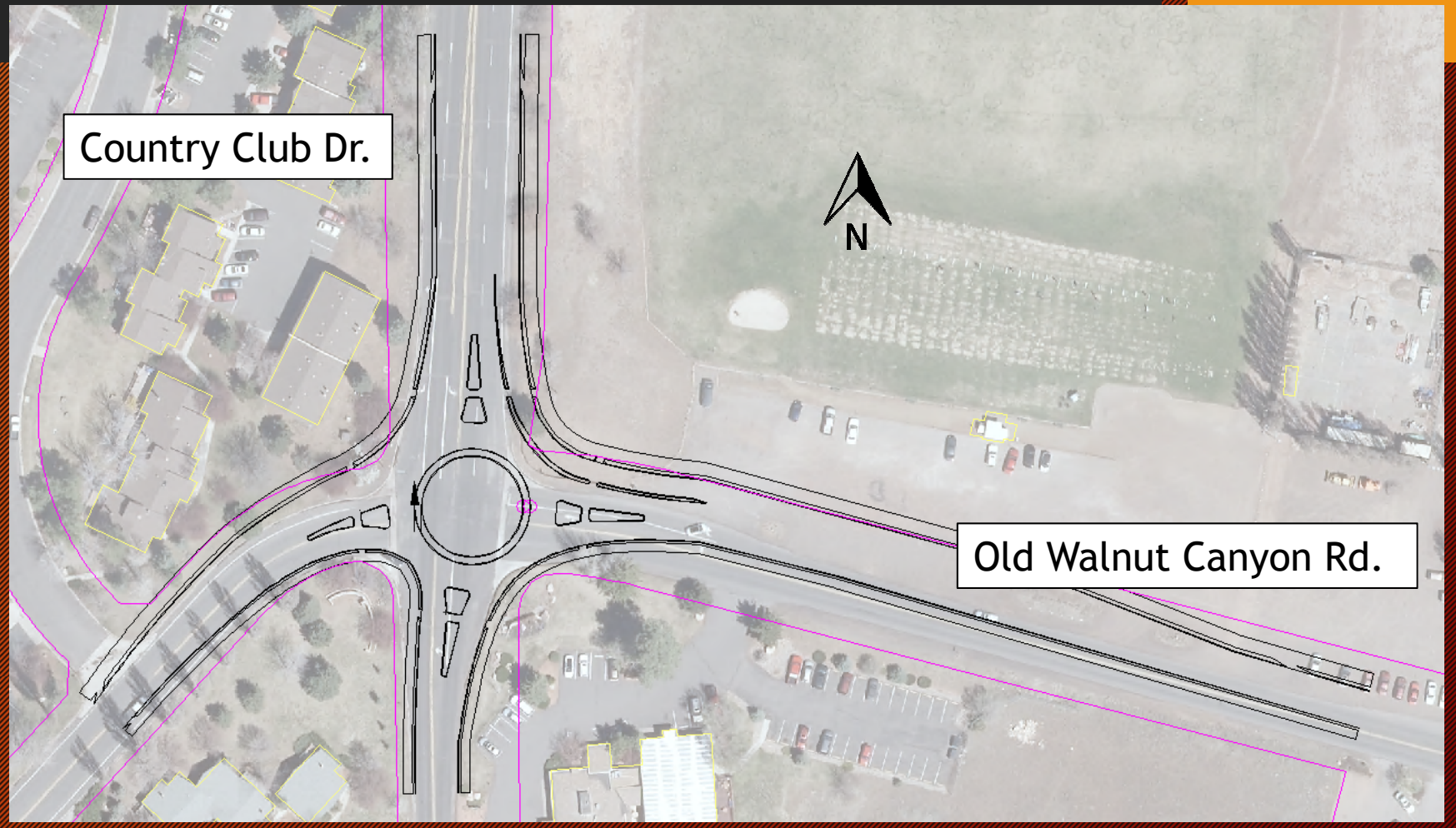


Figure 21: Roundabout- Over Existing Conditions

Roundabout-Construction Cost

Item Description	Unit	Quantity	Unit Price	Total
Landscape Removal	ACRE	0.5	$2,500.00	$1,250.00
Removal of Concrete Curb and Gutter	FT.	336	$15.00	$5,040.00
Removal (Sign)	EACH	6	$200.00	$1,200.00
Roadway Excavation	CU. YD.	1203	$20.00	$24,060.00
Aggregate Base, Class 2	CU. YD.	800	$105.00	$84,000.00
Asphalt Concrete (Asphalt-Rubber)	Ton	110	$40.00	$4,400.00
Asphalt Rubber Material	Ton	10	$650.00	$6,500.00
Mineral Admixture	Ton	1	$90.00	$90.00
Slip Base (Perforated Post)	EACH	16	$250.00	$4,000.00
Sign Post (Perforated)	FT.	96	$17.00	$1,632.00
Warning, Marker, or Regulatory Sign Panel	SQ. FT.	96	$35.00	$3,360.00
Pavement Markings (White Thermoplastic)	FT.	3480	$2.00	$6,960.00
Pavement Markings (Yellow Thermoplastic)	FT.	1464	$2.00	$2,928.00
Pavement Symbol (Extruded Thermoplastic)	EACH	6	$300.00	$1,800.00
Paint Bull Nose	EACH	4	$175.00	$700.00
Seeing (Class II)	ACRE	1	$4,500.00	$4,500.00
Concrete Curb (C-05.10)(Type G)	FT.	960	$23.00	$22,080.00
Concrete Curb and Gutter (C-05.10)(Type G)	FT.	2280	$27.00	$61,560.00
Concrete Sidewalk (C-05.20)	SQ. FT.	7000	$12.00	$84,000.00
Concrete Sidewalk Ramp (C-05.30 Type B)	EACH	8	$2,200.00	$17,600.00
			Total	$337,660.00

Table 10: Roundabout Construction Costs

*Overall total does not include labor

Roundabout Team-Schedule

Task ID	Task	Projected Completion Date	Actual Completion Date
1.0	Data Collection		
1.1	Site Evaluation	Thu 9/10/15	Thu 9/10/15
1.2	Topographic Survey	Mon 9/14/15	Tue 11/17/15
1.3	Client Meeting	Tue 11/3/15	Tue 11/3/15
2.0	Roadway Design Guidelines		
2.1	Research guidelines	Fri 4/29/16	Wed 4/27/16
3.0	Data Analysis		
3.1	Survey Data	Tue 11/3/15	Fri 1/29/16
3.2	Traffic Statistics	Tue 11/10/15	Mon 2/1/16
3.3	Level of Service: TWSC	Wed 11/18/15	Fri 3/11/16
3.4	LOS: Roundabout	Fri 3/4/16	Sat 4/2/16
4.0	Site Design		
4.1	Roundabout		
4.1.1	Geometry	Sun 2/21/16	Fri 4/15/16
4.1.2	Grading	Sun 2/21/16	Thur 4/14/16
4.1.3	Striping	Thu 3/11/16	Fri 3/11/16
4.1.4	Signage	Mon 3/11/16	Fri 3/11/16
4.2	Site Development		
4.2.1	Drainage	Fri 3/25/16	Fri 4/1/16
4.2.2	Landscaping	Wed 3/25/16	Fri 3/11/16
4.2.3	Pedestrian Consideration	Thu 3/25/16	Fri 3/11/16
5.0	Economics		
5.1	Construction Costs	Wed 4/1/16	Sun 4/17/16
5.2	Benefits	Fri 4/1/16	Sun 4/17/16
5.3	Impacts	Fri 4/1/16	Sun 4/17/16
6.0	Project Management		
6.1	Project Schedule	Thu 5/12/16	Thu 5/12/16
6.2	50% Design Report	Fri 3/11/16	Fri 3/11/16
6.3	Final Design Report	Thu 5/12/16	Thu 5/12/16
6.4	Final Presentation	Fri 4/29/16	Fri 4/29/16
6.5	Website	Thu 5/12/16	Thu 5/12/16

Table 11: Roundabout Schedule

Roundabout Team-Hours

	Tasks	Total Predicted	Total Actual
1	Data Collection		
1.1	Site Evaluation	4	8
1.2	Topographic Survey	16	14
2	Roadway Design Guidelines		
2.1	Research Guidelines	28	16
3	Data Analysis		
3.1	Survey Data	3	12
3.2	Traffic Statistics	24	6
3.3	LOS: TWSC	24	10
3.4	LOS: Roundabout	0	8
4	Site Design		
4.1	Roundabout		
4.1.1	Geometry	96	44
4.1.2	Grading	56	12
4.1.3	Striping	16	21
4.1.4	Signage	16	9

	Task	Total Predicted	Total Actual
4.2	Site Development		
4.2.1	Drainage	96	4
4.2.2	Landscaping	32	6
4.2.3	Pedestrian Considerations	48	9
5	Economics		
5.1	Construction Pricing	40	17
5.2	Benefits	16	12
5.3	Impacts	16	12
6	Project Management		
6.1	Project Schedule	40	16
6.2	50% Design Report	16	19
6.3	Final Report and Presentation	16	20
6.4	Website	80	22
6.5	Team Meetings	40	24
6.6	TA Meetings	20	4
	Total Hours	743	325

Table 12: Roundabout Hours

Benefits of the Roundabout Design

- **Improve the safety of the intersection.**
- 78.2% reduction in total number of crashes.
- 77.6% reduction in injury and fatal crushes.
- **Safer for pedestrians compared to TWSC intersection.**
- **Reduce the delay time.**

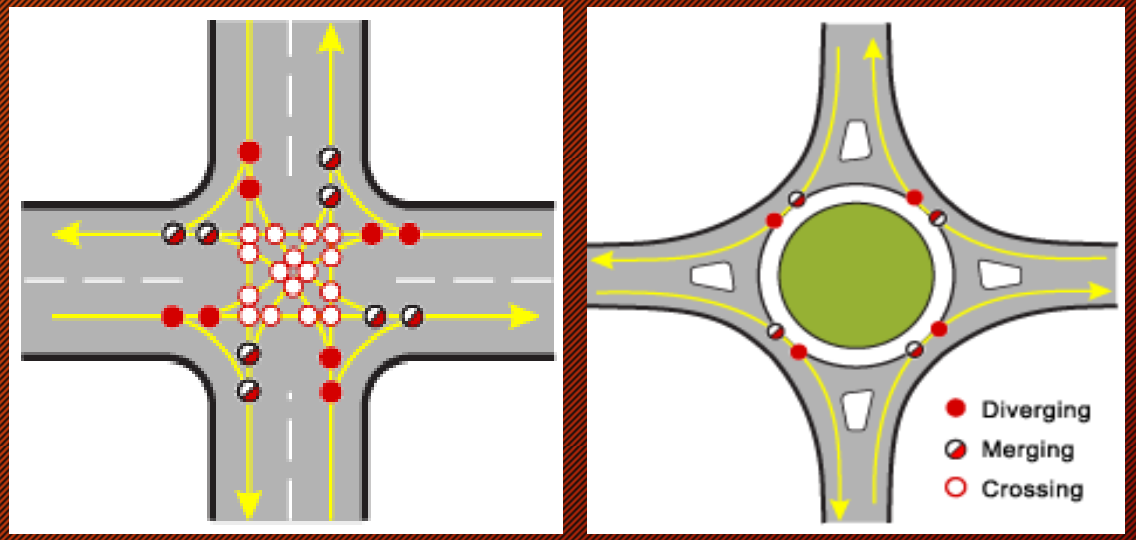


Figure 22: Conflict Point Comparison

	Current	Year 2035
Percent reduction in delay time	58%	81%

Table 13: Roundabout Delay Reduction

Impacts of the Roundabout Design

Environmental Impacts

- Less fuel consumption
- Improve air quality
- Noise reduction

Societal Impacts

- Change in traffic patterns confuses drivers
- Public education
- Construction time
- Signage during and after construction

Cost Impacts

- Ongoing operations and Maintenance

Design Comparison

Category:	Roundabout	Traffic Signal
Estimated Installation Cost:	$338,000* *Does not include construction	$234,000
Additional Right of Way Required:	5,475 Sq. Feet	1,443 Sq. Feet
Projected Level of Service for 2035:	LOS A	LOS B
Life Cycle Benefit-cost Ratio:	☑	☒
Reduced Collisions:	☑	☒
Bicyclist Safety:	☒	☑
Pedestrian Safety:	☒	☑

Table 14: Roundabout & Signal Comparison

Questions

VS

References

[1] “Google Maps.” *Google Maps*. Web. Oct. 2016.

[2] “City of Flagstaff” *City of Flagstaff*. Web. 2016

[3] “Nonneseter-Simulation in VISSIM” *Ramboll*. Web. 2013

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[6] "Arizona Department of Transportation," Federal Highway Administration. [Online]. [Accessed March 2016].

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