FEASIBILITY REPORT

PRESCOTT AREA ROUNDABOUT & TRAFFIC SIGNAL PROJECTS

(SIX PROPOSED LOCATIONS – SEVEN INTERSECTIONS)

Prepared For:

City of Prescott, Arizona

Prepared By:

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Roundabouts & Traffic Engineering

January 28, 2008

PRESCOTT AREA ROUNDABOUT & TRAFFIC SIGNAL PROJECT FEASIBILITY REPORT

FOR:

CITY OF PRESCOTT

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EXECUTIVE SUMMARY

Roundabouts & Traffic Engineering (RTE) has been retained by the City of Prescott to perform a feasibility study at six proposed locations (seven intersections) for new intersections or intersection improvement projects in Prescott, Arizona. The intersections will either need to be signalized or controlled by modern roundabouts. The purpose of this feasibility study is to provide a comparative analysis of the operational performance of a modern roundabout versus a traffic signal at the identified intersections with a final recommendation at each intersection. Comparisons between each alternative in terms of capacity, safety, and costs have been analyzed and documented for the future design years.

The changes in traffic control are proposed to address current and future level of service deficiencies as well as to provide access to new roadways being developed in many areas of the city. The City has concerns with the performance of signals and desires further consideration of roundabouts for their known safety and capacity benefits. The general conclusions of the feasibility study are provided below:

CONCLUSIONS

1. Modern roundabouts are **feasible and appropriate** traffic control devices at all of the studied intersections.
2. The modern roundabouts provide **superior capacity** over the signal alternatives with respect to the overall operations, level of service, delay, and queue lengths for all of the intersections.
3. The "before" and "after" safety statistics conducted in the United States and worldwide provide substantiating evidence of the **superior safety** performance of modern roundabouts versus traffic signals and other intersection types for both vehicles and pedestrians.
4. The **operational characteristics** of the roundabouts are superior to the traffic signals for all intersections studied. This includes adjacent access operations and emergency vehicle operations.
5. The roundabouts and proposed signals will require **additional right-of-way** in future conditions; however, no severe ROW issues were identified for either alternative at any location.
6. The roundabouts would reduce air pollutants / vehicle emissions.
7. The roundabouts would **enhance the character** of the City of Prescott at and near the intersections with added landscaping and potential ornamental features for public appeal.

8. The cost estimates of both alternatives (signal and roundabout) for all intersections identify an average cost savings of about 20 percent with the signal alternatives (not including maintenance costs, pre-emption devices, or cost-safety impacts of the signals).

It was determined by nearly all of the contributing factors within the study that the roundabouts are the identified recommended alternatives for all intersections. Please refer to Chapter VIII for additional conclusions and recommendations.

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I. INTRODUCTION

BACKGROUND

Roundabouts & Traffic Engineering (RTE) has been retained by the City of Prescott to perform a feasibility study at six proposed locations (seven intersections) for new intersections or intersection improvement projects in Prescott, Arizona. The intersections will either need to be signalized or controlled by modern roundabouts. The project sites are located at the following proposed or existing intersections:

1. SR 89 / Ruger Road (realigned)
2. SR 89 / Side Road Connector
3. Willow Creek Road / Park West Development (south of Pioneer Pkwy)
4. SR 89A / Side Road Interchange:
    - North Intersection – WB Ramps
    - South Intersection – EB Ramps
5. Prescott Lakes Parkway / Sundog Ranch Road
6. Prescott Lakes Parkway / Sundog Connector

The City of Prescott has concerns about the operational performance and safety of traffic signals at these locations and desires further investigation and consideration of modern roundabouts for their known safety and capacity benefits. Hence, the City has requested the analyses and consideration of modern roundabouts for these intersections.

The City has also requested general information on roundabouts and supporting evidence of the safety comparisons of traffic signals and modern roundabouts be provided. General cost comparisons for the two alternatives at the study intersection have also been developed by the City and are summarized herein. The proposed intersection locations are shown in **Figure 1** (vicinity map).

PURPOSE

The purpose of this feasibility study is to assess and provide a comparative analysis of the operational performance of a modern roundabout versus a traffic signal at all of the identified intersections with a final recommendation at each intersection location. A comparison between each alternative in terms of capacity, safety, and costs will be analyzed and documented for the future design year (or a percentage thereof) of 2030. In addition, this report will determine if the proposed intersections are viable locations for modern roundabouts, depending on the information provided by the City of Prescott and RTE. This report documents the existing and future traffic conditions and the recommended alternative for each intersection location.

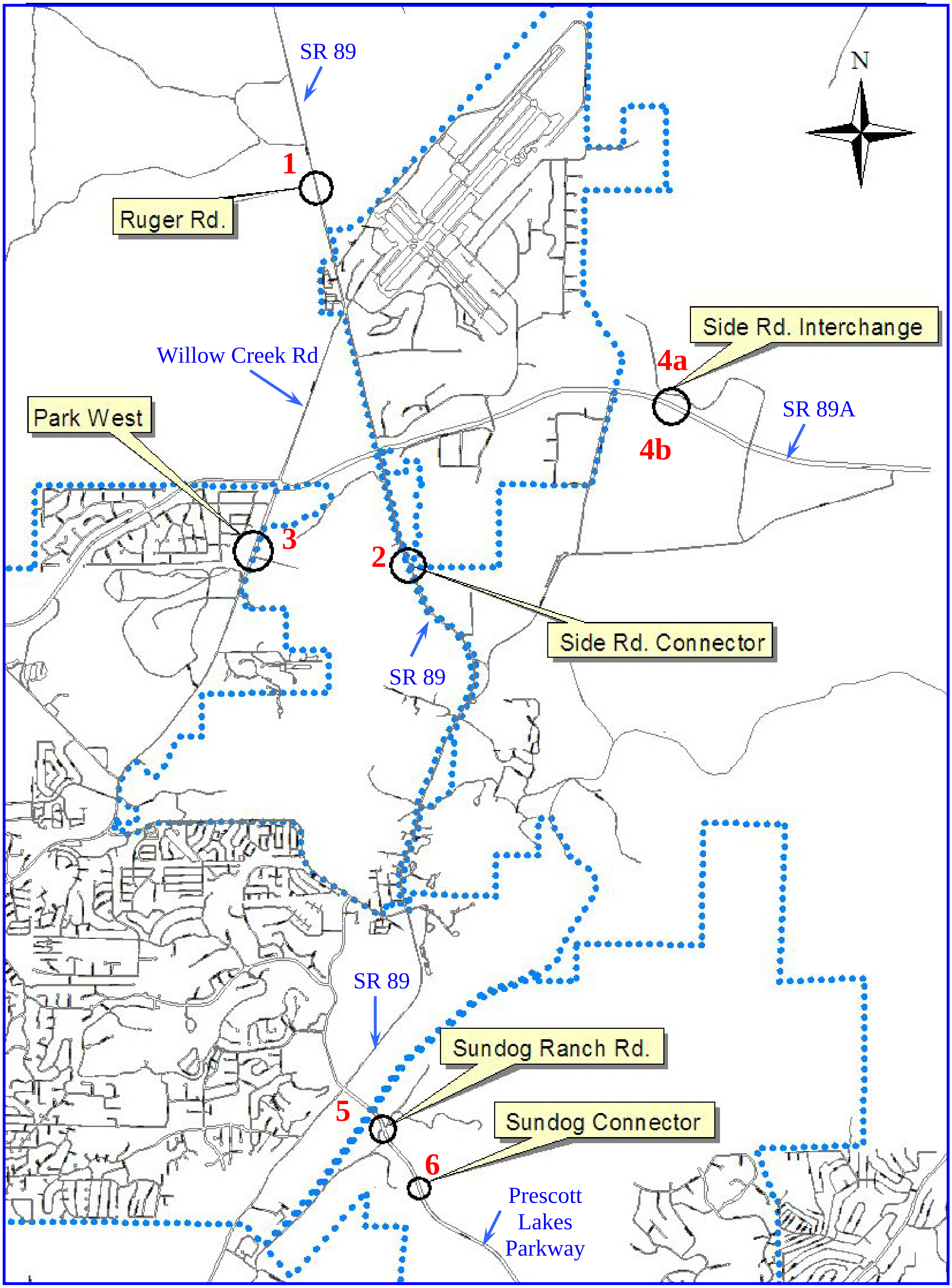
ORGANIZATION

This Roundabout Feasibility Report is organized into the following chapters:

I. Introduction
II. Existing Site Conditions
III. Traffic Volumes & Future Assumptions
IV. Capacity Analyses & Conceptual Design Alternatives
V. Capacity Comparisons
VI. Safety Comparisons
VII. Cost Comparisons
VIII. Conclusions & Recommendations
IX. Appendix

The report begins with the identification of the existing site conditions for the intersection. The next chapter of the report identifies the future conditions and assumptions used to determine the design volumes in the analyses of the report. Next, the report examines the future capacity and delay requirements for a modern roundabout or a traffic signal at each intersection location. The following chapter discusses the safety parameters and statistics of signals versus roundabouts. The next section briefly discusses the cost comparisons of each traffic control device at each intersection provided by the City of Prescott. The cost results are summarized and tabulated for comparison.

Finally, the feasibility study provides conclusions based on the results of the comparative analyses conducted for the intersections and recommendations for the selected alternatives.


SR 89
N
1
Ruger Rd.
Side Rd. Interchange
4a
Willow Creek Rd
Park West
SR 89A
4b
3
2
Side Rd. Connector
SR 89
SR 89
Sundog Ranch Rd.
5
Sundog Connector
6
Prescott
Lakes
Parkway

II. EXISTING SITE CONDITIONS

SURROUNDING AREA CONDITIONS

The City of Prescott has identified the need for roadway improvements and new roadway realignments for the street network due to future travel demands and mobility issues. Projected growth patterns with infill and development surrounding the study area and the unincorporated County lands will produce significantly high future travel demand and exceptionally high traffic volumes requiring increased capacity on existing roadways as well as new roadway systems. Hence, there is a need for higher level traffic control devices City-wide beginning at the identified six study locations (seven intersections) due to the limited existing roadways to carry future travel demand. The new intersections and traffic control devices are proposed to address future level of service deficiencies as well as alleviate roadway congestion on existing corridors.

The surrounding study areas consist of a mix of industrial, commercial, and residential zoning as well as public and private recreational spaces. Growth in the surrounding area City limits is relatively large or remarkably significant since the City and County has a vast amount of buildable land.

A review was performed of the most recent site plans and roadway alignment information as well as a review of the intersections' volumes as provided by the City. The proposed roadways' surrounding topography, centerlines, curb faces, edge of pavement, environmental, and right of way constraints were also reviewed from the available information provided. The following **Figures 2 through 22**, illustrate the existing roadway conditions near each of the six project site areas.

INTERSECTION LOCATIONS & ASSUMPTIONS

***SR 89 / Ruger Road (realigned)*:** The existing intersection of State Route 89 / Ruger Road (referred to as "Ruger" herein this document) is located about 450 yards north of Willow Creek Road / Airport Road and north of the Ernest Love Field Airport. The future intersection of State Route 89 / Ruger Road will be created by realigning Ruger Road about 400 yards north of the existing location. The new intersection along SR 89 will be a "T" or 3-way intersection functioning either as a traffic signal or a modern roundabout. The photos of the existing site area near the future intersection, as shown in **Figures 2 through 4**, illustrate the existing conditions, roadway alignment, lane configurations, shoulder widths, and surrounding land uses. Under existing conditions there are single travel lanes in each direction (northbound and southbound) along SR 89. Future conditions will have two lanes in each direction along SR 89. Further north of Ruger Road, northbound SR 89 has two lanes existing. The existing posted speed limit is 50 miles per hour near the site and 65 mph north of the intersection.

Figure 2: SR 89 / Future Ruger Rd (Looking South)

Figure 3: SR 89 / Future Ruger Rd (Looking North)

Figure 4: North of SR 89 / Future Ruger Rd (Looking South)

***SR 89 / Side Road Connector*:** The intersection of State Route 89 / Side Road Connector (herein referred to as "Side Road Connector") is located south of Pioneer Parkway / SR 89A at the access to the Phippen Museum. The future intersection of State Route 89 / Side Road Connector will be created with a new 4-lane roadway to the east of the existing location on Side Road Connector and a 4-lane roadway along SR 89. The new intersection along SR 89 will be a "T" or 3-way intersection functioning either as a traffic signal or a modern roundabout. The photos of the existing site area near the future intersection, as shown in **Figures 5 and 6**, illustrate the existing conditions, roadway alignment, lane configurations, shoulder widths, and surrounding land uses. Under existing conditions there are single travel lanes in each direction (northbound and southbound) along SR 89. Future conditions will have two lanes in each direction along SR 89. The existing posted speed limit near the study intersection is assumed to be 50 miles per hour.

Figure 5: SR 89 / Side Road Connector (Looking North)

Figure 6: SR 89 / Side Road Connector (Looking South)

***<u>Willow Creek Road / Park West Development</u>*:** The intersection of Willow Creek Road / Park West Development (herein referred to as "Park West") is located south of Pioneer Parkway and about 233 yards (700 feet) south of Pinon Oaks Drive. The future intersection of Willow Creek Road / Park West will be created with a new 2-lane roadway to the east with the existing 4-lane roadway along SR 89. The new intersection along SR 89 will be a "T" or 3-way intersection functioning either as a traffic signal or a modern roundabout. The photos of the existing site area near the future intersection, as shown in **Figures 7 through 10**, illustrate the existing conditions, roadway alignment, lane configurations, shoulder widths, and surrounding land uses. Under existing conditions there are two travel lanes in each direction (northbound and southbound) along SR 89 with a raised median. The existing posted speed limit near the study intersection is 45 miles per hour.

Figure 7: Willow Creek Rd / Park West (Looking South)

Figure 8: Willow Creek Rd / Park West (Looking North)

Figure 9: South of Willow Creek Rd / Park West (Looking South)

Figure 10: North of Willow Creek Rd / Park West (Looking South)

***SR 89A / Side Road Interchange*:** The existing SR 89A / Side Road intersection is a "T" or 3-way intersection along SR 89A currently controlled by a stop sign on Side Road located east of the existing Larry Caldwell Road Interchange. The SR 89A / Side Road Interchange (herein referred to as "Side Road TI") will be a grade-separated diamond interchange (with on-ramps and off-ramps and a multi-lane bridge over SR 89A) as Side Road is extended to the north of SR 89A.

As part of the new construction, both intersections of SR 89A WB / Side Road and SR 89A EB / Side Road will either have modern roundabouts or traffic signals installed. Depending on the alternative selected, this will effect the size of the bridge to be constructed, the alignments of the proposed on and off ramps, the right of way required, and the number of lanes for each approach/roadway section. For the purposes of this study's analyses, the bridge is anticipated to be six lanes wide (three lanes each direction) for 2030 conditions and two lanes wide (one lane in each direction) for interim conditions.

The photos of the existing site area near the future intersection, as shown in **Figures 11 through 14**, illustrate the existing conditions, roadway alignment, lane configurations, shoulder widths, and surrounding land uses. Under existing conditions there are two travel lanes in each direction (eastbound and westbound) along SR 89A with a raised median. The existing posted speed limit near the study intersection is 45 miles per hour.

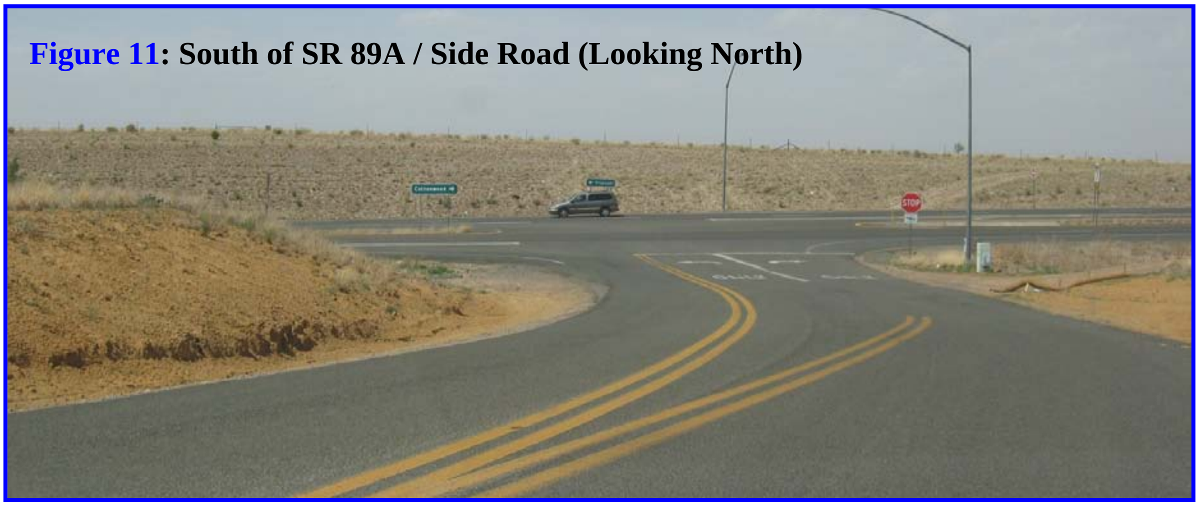


Figure 11: South of SR 89A / Side Road (Looking North)

Figure 12: West of SR 89A / Side Road (Looking East)

Figure 13: SR 89A / Side Road (Looking West)

Figure 14: East of SR 89A / Side Road (Looking West)

***Prescott Lakes Parkway / Sundog Ranch Road*:** The existing intersection of Prescott Lakes Parkway / Sundog Ranch Road (herein referred to as "Sundog Ranch") is a four-way intersection located 600 yards south (southeast) of the SR 89 / Prescott Lakes Parkway intersection. Prescott Lakes Parkway is currently a four lane divided roadway (two lanes in each direction with a median), whereas Sundog Ranch Road is a two lane roadway with stop control. Under future conditions, the intersection warrants a higher traffic control device and further roadway improvements along Sundog Ranch Road in order to operate properly. The photos of the existing site area near the future intersection, as shown in **Figures 15 through 19**, illustrate the existing conditions, roadway alignment, lane configurations, shoulder widths, and surrounding land uses. The existing posted speed limit on Prescott Lakes Parkway is 50 miles per hour and an assumed 25 miles per hour near the intersection on Sundog Ranch Road.

Figure 15: South of Prescott Lakes Pkwy / Sundog Ranch Rd (Looking South - SE)

Figure 16: East of Prescott Lakes Pkwy / Sundog Ranch Rd (Looking West - SW)

Figure 17: West of Prescott Lakes Pkwy / Sundog Ranch Rd (Looking East - NE)

Figure 18: Prescott Lakes Pkwy / Sundog Ranch Rd (Looking East)

Figure 19: South of Prescott Lakes Pkwy / Sundog Ranch Rd (Looking North)

***Prescott Lakes Parkway / Sundog Connector*:** The intersection of Prescott Lakes Parkway / Sundog Connector (herein referred to as "Sundog Connector") is a four-way intersection located approximately 600 yards south of the Prescott Lakes Parkway / Sundog Ranch Road intersection. Prescott Lakes Parkway is currently a four lane divided roadway (two lanes in each direction with a median), whereas Sundog Connector will be created as a two lane roadway on the west side of Prescott Lakes Parkway and a four lane roadway on the east side. The new intersection along SR 89 will be a 4-way intersection functioning either as a traffic signal or a modern roundabout. The photos of the existing site area near the future intersection, as shown in **Figures 20 through 22**, illustrate the existing conditions, roadway alignment, lane configurations, shoulder widths, and surrounding land uses. The existing posted speed limit on Prescott Lakes Parkway is 50 miles per hour. Sundog Connector is assumed to be 45 miles per hour with the west leg of the intersection assumed to be 25 miles per hour when built.

Figure 20: Prescott Lakes Pkwy / Sundog Connector (Looking East - NE)

Figure 21: North of Prescott Lakes Pkwy / Sundog Connector (Looking North)

Figure 22: Prescott Lakes Pkwy / Sundog Connector (Looking South)

III. TRAFFIC VOLUMES

FUTURE TRAFFIC ASSUMPTIONS & DESIGN VOLUMES

The City of Prescott worked with Al Williams to determine the proper future traffic volumes for this feasibility study's intersections in the future years for both the AM and PM peak hours. Ian Mattingly, City Traffic Engineer, produced the following information for each intersection for use in these analyses and report.

SR 89 / Ruger Road: Estimated peak hour AM and PM intersection turn movement projections were generated through the following process:

1. Using existing traffic count data on State Route 89, the City of Prescott determined the AM and PM peak hour factor (PHF) to be 7.6% and 8.8% respectively with a 24 hour traffic count of 25,800 (see **Appendix**).
2. This volume was then used as the base 2006 volume to project a growth rate of 3.75% for SR 89 north of Ruger Road using the future 2030 volume from the CYMPO study (see **Appendix**).
3. The new Ruger Road 2009 peak hour volumes and 24 hour volume was then calculated from the Prescott Airport Executive Park TIA trip generation charts. A peak hour factor of 12% was also assumed to all Ruger Road background traffic based on the high industrial use in the area.
4. Next, directional splits and trip distributions were assumed for new Ruger Road from the TIA data and from the recently collected traffic counts for SR 89. The south leg of SR89 was then calculated for each interim year to balance the intersection following the trip distribution assignment process.
5. Next, several interim years from 2009 to 2030 were created and the corresponding through volume projections generated. These volumes estimate growth of 3.75% for SR 89 and 3.7% for new Ruger Road. (see Appendix).
6. Using the numbers and splits previously calculated we can generate the total intersection peak hour turn movement projections for 2009, 2015, 2020, and 2030. The final 2030 traffic volumes used in this study for the intersection of SR 89 / Ruger Road are also shown in the signal and roundabout capacity figures herein.

SR 89 / Side Road Connector: Estimated peak hour AM and PM intersection turn movement projections were generated through the following process:

1. Using existing traffic count data on State Route 89, the City of Prescott determined the AM and PM peak hour factor (PHF) to be 7.6% and 8.8% respectively with a 24 hour traffic count of 17,600 (see **Appendix**).
2. This volume was then used as the base 2005 volume to project a growth rate for SR 89 north and south of the Side Road Connector intersection using the future 2030 volumes on each segment. This resulted in a growth rate of 2.5% north of SRC and 4.25% south of SRC.
3. The Side Road Connector 2009 24 hour volume was then calculated from the base peak hour volumes provided in the Centerpointe South TIA using a peak hour factor of 8.6%.
4. Next, trip distributions were assumed and turn movements were assigned for base year 2009. The peak hour factors on SR 89 were used on the north leg while a PHF of 8.6% was assumed for both the AM and PM peak hours on Side Road Connector. The peak hour factors for the south leg of SR 89 were then calculated for each interim year to balance the intersection following the trip distribution assignment process.
5. Next, several interim years from 2009 to 2030 were created and the corresponding through volume projections generated. These volumes estimate growth of 2.5% for the north leg of SR 89, 4.25% for the south leg of SR 89, and 4% for Side Road Connector (see Appendix).
6. Using these numbers and splits previously calculated we can generate the total intersection peak hour turn movement projections for 2009, 2015, 2020, and 2030. The final 2030 traffic volumes used in this study for the intersection of SR 89 / Side Road Connector are also shown in the signal and roundabout capacity figures herein.

Willow Creek Road / Park West Development: Estimated peak hour AM and PM intersection turn movement projections were generated through the following process:

1. Using the "Total Peak Hour Traffic at 2009 – Opening Year" diagram on page 19 of the Park West TIA conducted by Curtis Lueck & Associates we calculate the peak hour factors for both the AM and PM based on the 2005 through volume on Willow Creek Road of 22,800 grown to 2009 figures using a 5% growth rate. This results in a 2009 projected volume for WCR of 27,713 and peak hour factors of 8.57% in the AM and 8.84% in the PM (see **Appendix**).
2. Next a table which provides several interim years from 2009 to 2030 is created and the corresponding through volume projections are generated. This table estimates growth of 3.9% per year (see **Appendix**).
3. Using these numbers and the north/south splits calculated from the Park West TIA we can generate the total intersection peak hour turn movement (TM) projections for the 2009 development opening day.

4. Next we used the 2030 CYMPO numbers for WCR and the same peak hour factors and north/south slits from the Park West TIA to generate the TM projections for 2030. This diagram also includes increased numbers for the development which represent the full development traffic generation likely to occur in 2019 and shown on page 14 of the Park West TIA.
5. Finally we use the generated 2020 numbers projected on page 2 to provide the interim TM diagram. The final 2030 traffic volumes used in this study for the intersection of Willow Creek Road / Park West Development are also shown in the signal and roundabout capacity figures herein.

SR 89A / Side Road Interchange: Estimated peak hour AM and PM intersection turn movement projections were taken from the SR 89 A / Side Road Interchange Pre-Draft Traffic Report (June 2007) prepared by PARSONS for ADOT and the City of Prescott. In particular, Figure 3.9 on page 18 of the report were identified as the 2030 volumes to use in these analyses. The final 2030 traffic volumes used in this study for both intersections of the interchange are also shown in the signal and roundabout capacity figures herein.

Prescott Lakes Parkway / Sundog Ranch Road: Estimated peak hour AM and PM intersection turn movement projections were generated through the following process:

1. The traffic volumes collected in 2007 were grown at 4.6% to calculate the 2009 projected traffic volumes for Prescott Lakes Parkway (PLP) and Sundog Ranch Road.
2. These volumes were then placed on the network assuming a peak hour factor of 8.2% in the AM and 8.4% in the PM period for the south leg of PLP. Peak Hour factors for both legs of Sundog Ranch Road were assumed to be 15% based on the light industrial use in the area.
3. Next trip distributions were assumed (see **Appendix**) and turn movements were assigned. The peak hour factors for the north leg of PLP were then calculated to balance the intersection following the trip distribution assignment process.
4. Next several interim years from 2009 to 2030 were created and the corresponding through volume projections generated. These volumes estimate growth of 4.6% per year for both legs of PLP and the west leg of Sundog Ranch Road. The East leg of Sundog Ranch Road was grown at 4.6% from 2007 to 2009 then at 3.35% from 2009 to 2030 resulting in a volume that is double the 2009 numbers and which represents the projected 2030 population and its impacts on the transfer station trip generation (see **Appendix**).

5. Using these numbers and the north/south splits previously calculated we can generate the total intersection peak hour turn movement (TM) projections for 2020.
6. Next we used the 2030 CYMPO numbers for the roadways and the same peak hour factors and north/south slits to generate the TM projections for 2030. The final AM and PM 2030 traffic volumes used in this study for the intersection of Prescott Lakes Parkway / Sundog Ranch Road are also shown in the signal and roundabout capacity figures herein.

Prescott Lakes Parkway / Sundog Connector: Estimated peak hour AM and PM intersection turn movement projections were generated through the following process:

1. Using the Base 2007 traffic counts grown at 4.6% we calculate the 2009 projected traffic volumes for Prescott Lakes Parkway (PLP). The traffic projections from the Storm Ranch TIA were then used to provide the Sundog Connector traffic volumes (Sundog Connector at this time will only be built to serve the development) and the ITE trip generation land use 733 was used to provide an estimated trip generation of 609 vehicles in 24 hours for the west leg (County complex).
2. These volumes were then placed on the network assuming a peak hour factor of 8% in both the AM and PM period for the north leg of PLP. Peak Hour factors for the Sundog Connector were calculated according to the Storm Ranch TIA for opening year 2009, but were assumed to be 8% for both AM and PM for the 2020 and 2030 horizon years.
3. Next trip distributions were assumed (see **Appendix**) and turn movements were assigned. The peak hour factors for the south leg of PLP were then calculated to balance the intersection following the trip distribution assignment process (see **Appendix**).
4. Next several interim years fro 2009 to 2030 were created and the corresponding through volume projections generated. These volumes estimated growth of 2.5% per year for the south leg of PLP and 4.6% per year for the north leg of PLP and Sundog Connector.
5. Using these numbers and the north/south splits previously calculated we can generate the total intersection peak hour turn movement (TM) projections for 2020.
6. Next we used the 2030 CYMPO numbers for the roadways and the same peak hour factors and north/south slits to generate the TM projections for 2030. The final 2030 traffic volumes used in this study for the intersection of Prescott Lakes Parkway / Sundog Connector are also shown in the signal and roundabout capacity figures herein.

Although a considerable amount of effort was undertaken by the City of Prescott to develop the 2030 traffic volumes, it should be understood that these volumes are estimates only. In RTE's opinion, the 2030 volumes are very conservative (high) estimations of potential traffic volumes in both the AM and PM peak hours. Hence, the traffic volumes used in the analyses of this feasibility study produce very conservative results. For specific details regarding the development of the projected traffic volumes, please refer to **Appendix A**. No pedestrian, bicycle, or transit volumes were collected, provided, or used in these analyses since these volumes would be relatively insignificant to the capacity calculations.

Heavy Vehicle Movements: Other heavy vehicles will travel through the intersections to make deliveries to commercial establishments in the vicinity as well as travel through the area. The largest of the vehicles is typically a WB-67 truck with semi-trailer. Other heavy vehicles (including transit buses) are shorter and would traverse the intersection adequately. The percentage of heavy vehicles at the intersection is typically less than one percent of all traffic volumes. Because of the presence of WB-50s, WB-60s, WB-62s, and on State Routes WB-67s, the geometry of a roundabout or traffic signal would need to be able to accommodate the larger vehicles.

According to the City of Prescott, the design vehicle was identified as a WB-50 for all residential side road turning movements, similar to the illustration provided in **Figure 23**, and a WB-62 for all other movements, similar to the illustration provided in **Figure 24**.

Figure 23: Design Vehicle

Figure 24: Design Vehicle

The heavy truck percentages for the City intersections were assumed to be a conservative percentage of 5% for all legs of the intersection. RTE also reviewed other local data on SR 89 and confirmed that existing truck percentages are approximately 2% on mainlines within the area. Hence, a future conservative value of 5% for heavy trucks is appropriate and was used in the analyses of this report for all intersections.

IV. CAPACITY ANALYSES & CONCEPTUAL DESIGN ALTERNATIVES

Following RTE's review of the available site plan files and traffic volumes of the proposed project locations and roadways, capacity analyses were commenced for both the traffic signal and modern roundabout design alternatives. The information in this chapter set the initial parameters for the capacity calculations and lane configurations of the proposed signal or roundabout location, geometry, and how they will function as a system with the proposed roadway network. No nearby access locations at any intersection were identified to incorporate into the designs at this feasibility stage of each intersection.

GENERAL CAPACITY METHODOLOGY

Both the traffic signal and the modern roundabout capacity analyses are based on the general principles and performance measuring criteria identified in the Highway Capacity Manual. The Highway Capacity Manual[1] evaluates intersections based on vehicular delay as well as their Level of Service.

Traffic operations are assessed in terms of Level of Service (LOS) and delay. The level of service for an intersection is determined by the amount of delay experienced at the intersection. Delay is measured as the average time from when a vehicle stops at the end of the queue until the vehicle departs from the stop or yield line. The numerical value of delay per vehicle (typically in seconds or minutes) of a turning movement, approach, or total intersection is quantified with an assigned letter value or "grade" of measurement called LOS. The LOS is determined from the length of the average delay experienced at the intersection during the peak hour.

LOS is a concept that was developed by transportation engineers to quantify the level of operation of intersections and roadway segments. The LOS for most jurisdictions at intersections is classified in grades "A" through "F." These grades of LOS are the quantified terms that relate to the average delay per vehicle. A LOS "A" reflects full freedom of operation for a driver, while a LOS "F" represents very long delays of operation for a driver, forcing the driver to wait for adequate gaps in conflicting traffic. Under the HCM methodology, an intersection operating at LOS "F" is considered to have failed. Generally, LOS "D" and LOS "E" are considered the thresholds of acceptable operation for

[1] Highway Capacity Manual, Transportation Research Board, 2000

signalized and unsignalized intersections, respectively. The City of Prescott's identified to maintain a traffic threshold of LOS D or better.

SIGNAL CAPACITY ANALYSES

After obtaining and reviewing all of the currently available and pertinent information regarding each intersection's roadways, site, and traffic volumes, an analysis of the proposed signal at each intersection using the software program *Traffix For Windows* was conducted to analyze the capacity requirements of each signalized intersection alternative for the design year of 2030. *Traffix* is based upon the HCM 2000 methodologies described above. Both the AM and PM peak hours were analyzed to ensure adequate signal operations during both future peak conditions.

Signal Capacity Methodology: For signalized intersections under the Highway Capacity methodology, LOS is primarily measured in terms of average delay. The Volume to Capacity ratio (V/C) is used as an additional measure for quantifying the capacity utilization/design adequacy of the intersection. Typically, an intersection with a v/c ratio over 0.85 indicates the *potential* need for additional capacity on the approach. However, recent research has indicated that an intersection can operate at an acceptable level of service even though the V/C ratio exceeds 1. Therefore, a signalized intersection can operate at an acceptable LOS even if entering traffic volumes at that intersection exceed its theoretical capacity. Such situations occur primarily when unbalanced heavy demands occur on one or two approaches.

As directed by the City of Prescott, the capacity analysis figures below provide the following results for maintaining a LOS D. An **iterative** analysis of the 2030 design year traffic volumes was performed to arrive upon the requested results, which depict the following:

- The Percentage of the 2030 Traffic Volumes Used in the Analyses while Maintaining a LOS D
- The Design Year while Maintaining LOS D (assuming linear growth rates)
- Required Lane Configurations (see assumptions in paragraph above)
- Anticipated Queue Lengths of Each Lane while Maintaining a LOS D
- Peak Hour Signal Timing in the LOS D Maximum Design Year
- Peak Hour Cycle Lengths in the LOS D Maximum Design Year
- LOS Results for AM and PM Peak Hours (for 100% of the 2030 traffic volumes, otherwise LOS D was maintained as the threshold)

Based on the established design criteria for the signalized intersection analyses, the *Traffix* software program and engineering analyses produced the following results, as shown in **Figures 30 through 43**. Each intersection's planned lane configurations were attempted to match existing conditions, the planned future road conditions as identified by the City, and the comparative lane configurations of the roundabouts. Furthermore, some of the signalized intersections required additional lanes to be added above and beyond the roundabout's required lanes, the existing conditions, or the planned future road conditions since traffic signals typically have mutually exclusive left turn lanes. The intersection's lane configuration assumptions are shown within each intersection's capacity analysis figure. The signal phasing was analyzed by RTE to determine the most accurate field conditions for each intersection location. Please note that only fully protected or split phasing were considered for each signal since permitted or protected-permitted phasing is not reasonably advised due to significantly decreased safety with the existing or future roadway speed limits and presence of medians.

Table 1 below summarizes the results shown in the signal capacity figures. As shown, none of the intersections could reach 100% of the 2030 traffic volume conditions and still maintain a LOS D or better in both the AM and PM peak hours. Hence, either additional turn lanes or through lanes must be added to the planned roadway cross sections to accommodate the 2030 volumes if traffic signals are the selected alternatives for all intersections analyzed.

Table 1: Signalized Intersection Capacity Summary

AM and PM Peak Hour Results - % of 2030

Intersection - Peak Period	Intx LOS	Intx Delay (sec)	Mainline Through Movement Queue	% of 2030 Volumes	Max Design Year
SR 89 / Ruger Road - AM	C	32.0	2350'	100%	2030
SR 89 / Ruger Road - PM	D	53.8	2575'	85%	2027
SR 89 / Side Rd Connector - AM	D	54.6	675'	86%	2027
SR 89 / Side Rd Connector - PM	D	53.6	725'	96%	2029
Willow Creek Rd / Park West - AM	D	54.9	2,225'	78%	2025
Willow Creek Rd / Park West - PM	D	52.3	1,700'	58%	2020
SR 89A / Side Rd TI North - AM	D	52.7	2075'	71%	2023
SR 89A / Side Rd TI North - PM	D	52.6	2275'	71%	2023
SR 89A / Side Rd TI South - AM	D	52.2	925'	74%	2024
SR 89A / Side Rd TI South - PM	D	53.0	750'	53%	2019
Prescott Lakes Pkwy/Sundog Ranch Rd - AM	D	36.7	775'	100%	2030
Prescott Lakes Pkwy/Sundog Ranch Rd - PM	D	52.7	1175'	95%	2029
Prescott Lakes Pkwy/Sundog Connector - AM	D	54.7	450'	77%	2025
Prescott Lakes Pkwy/Sundog Connector - PM	D	52.8	475'	58%	2020

Source: RTE　　Prescott Feasibility Tables.xls

Figure 30: Ruger Rd AM Signal Capacity 100% of 2030

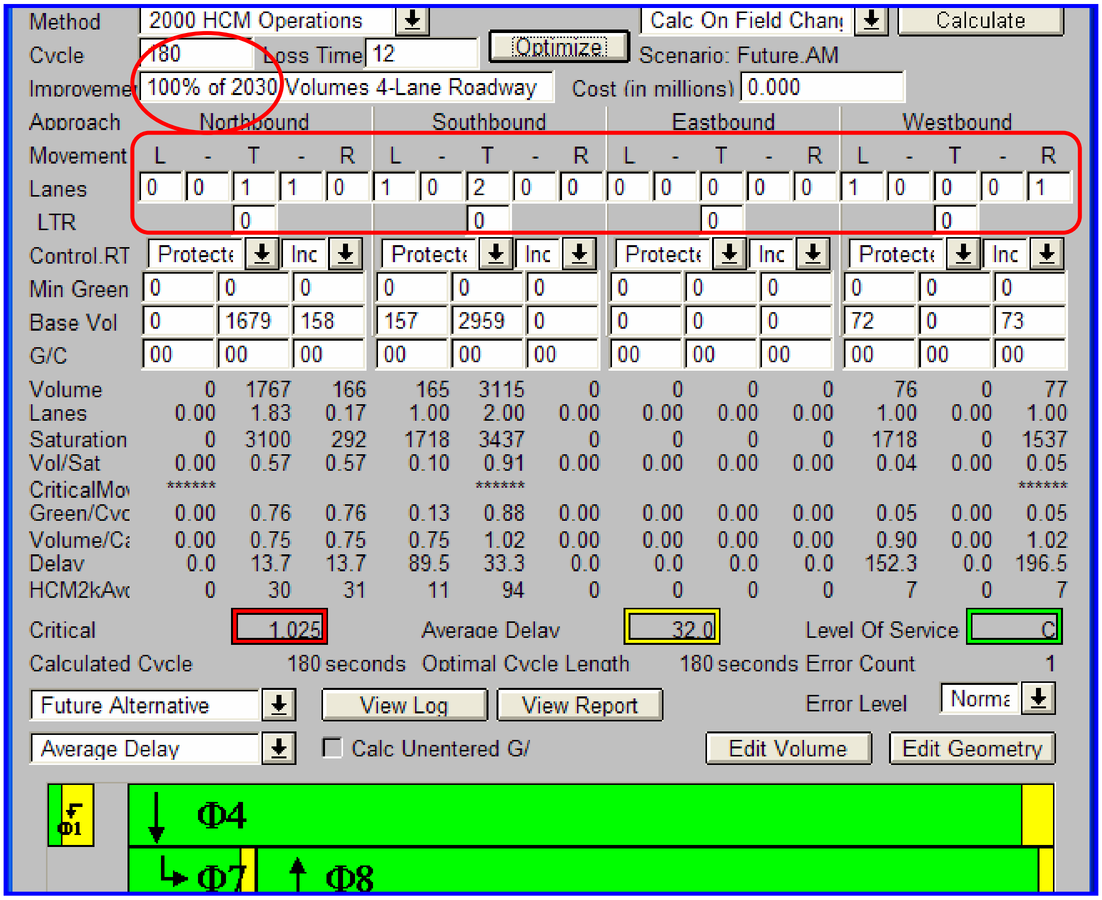


Figure 31: Ruger Rd PM Signal Capacity 85% of 2030 ~ 2027

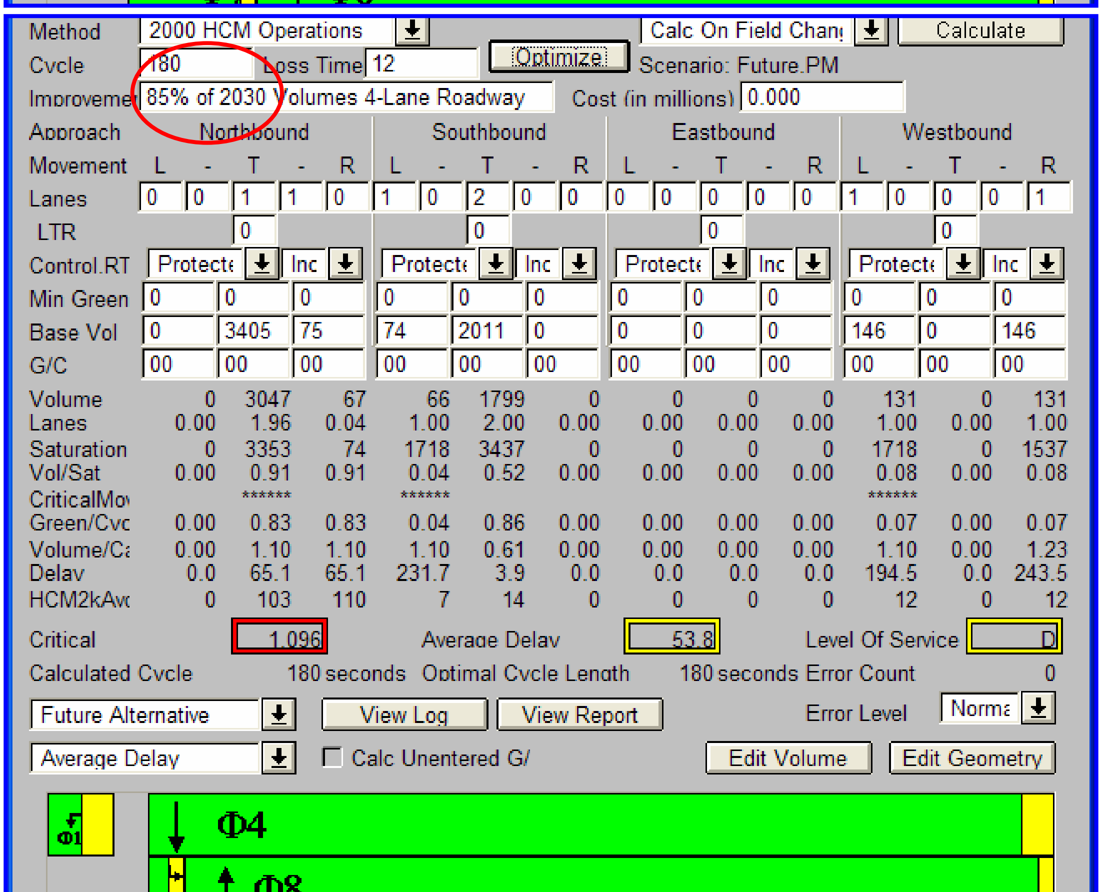


Figure 32: Side Rd Connector AM Signal Capacity 86% of 2030 ~ 2027

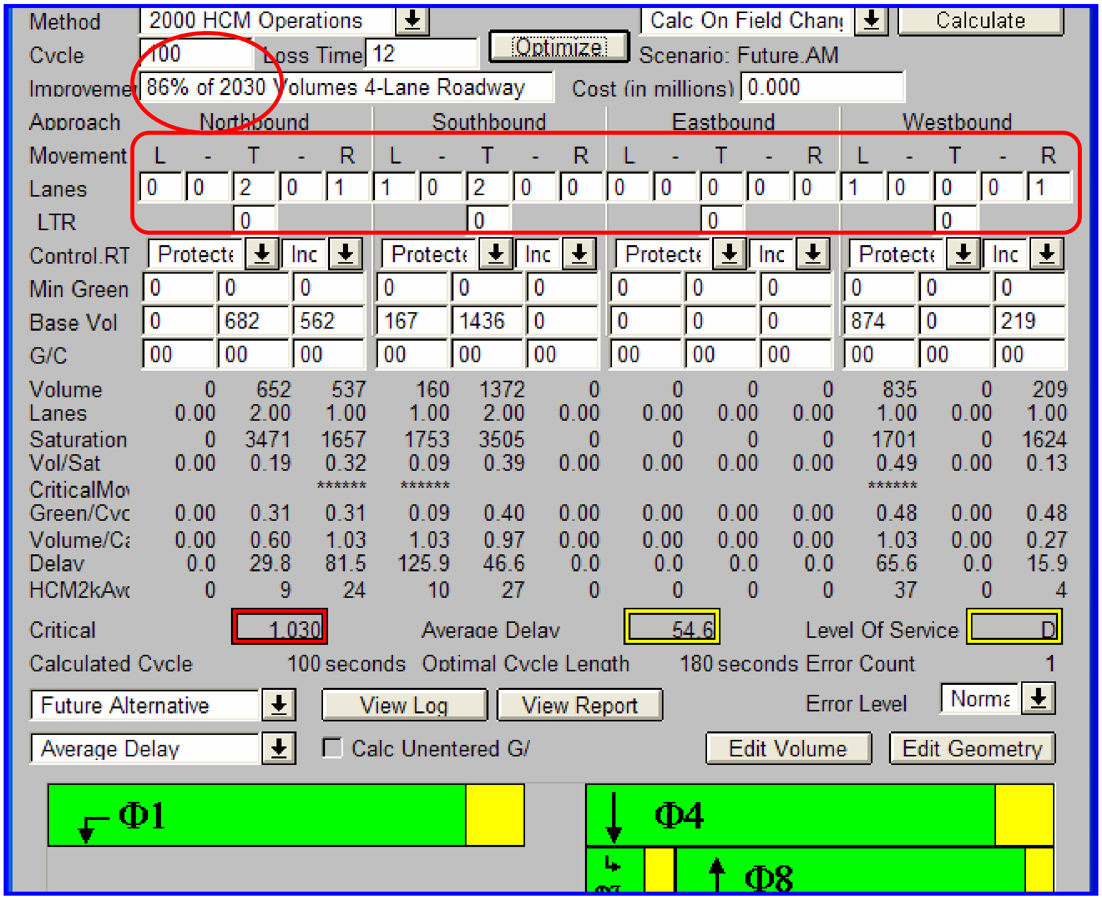


Figure 33: Side Rd Connector PM Signal Capacity 96% of 2030 ~ 2029

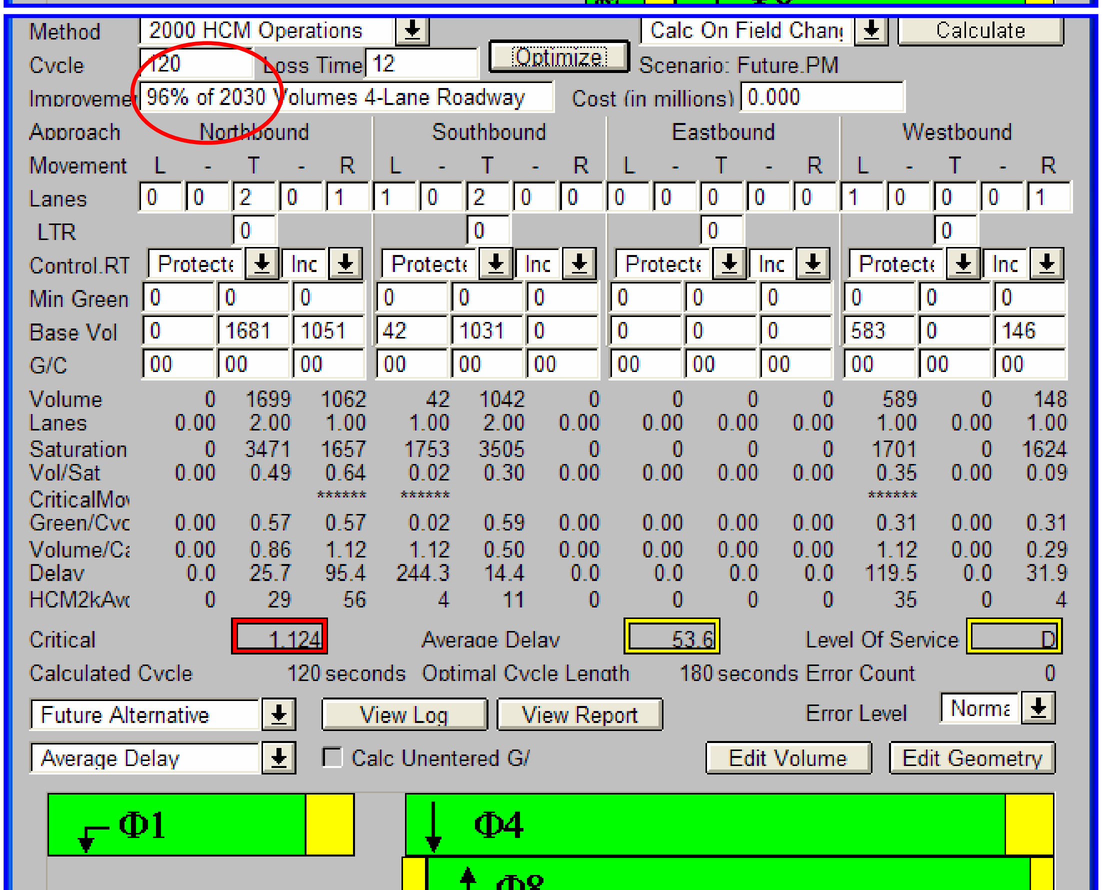


Figure 34: Park West AM Signal Capacity 78% of 2030 ~ 2025

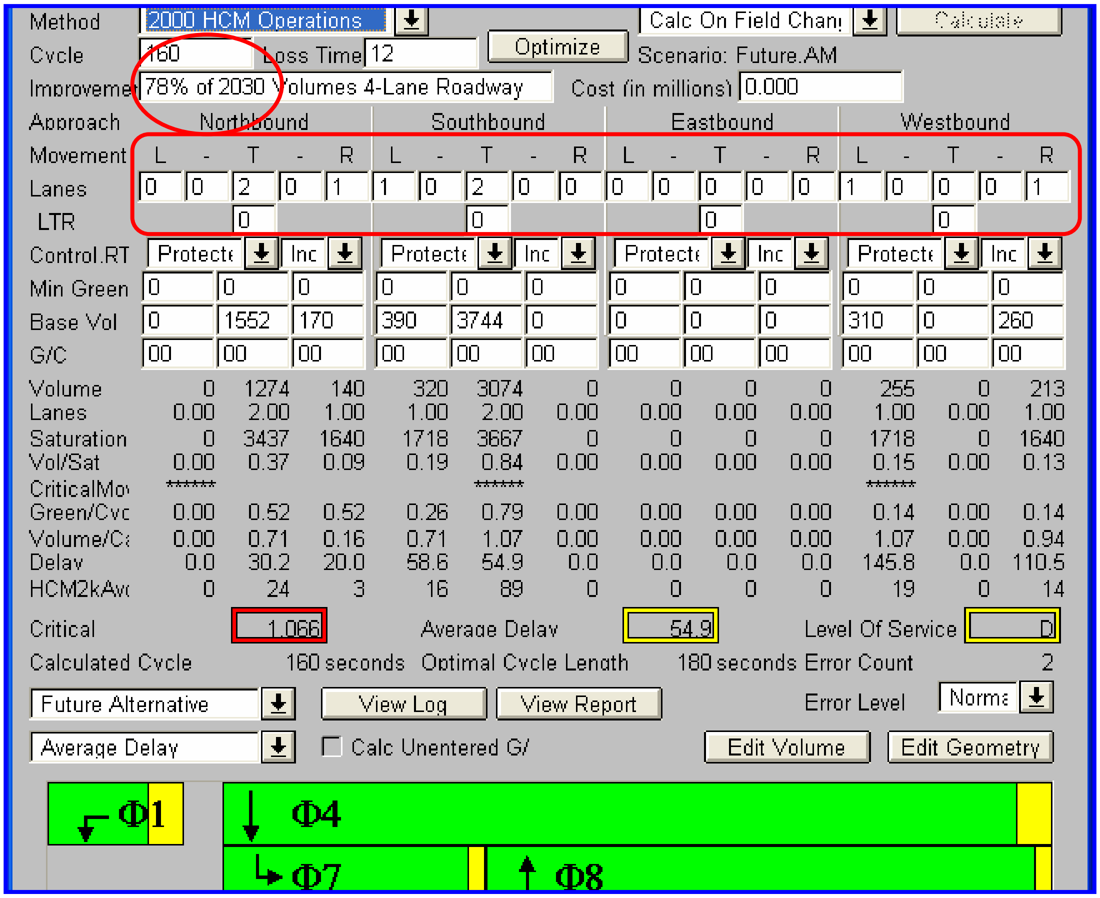
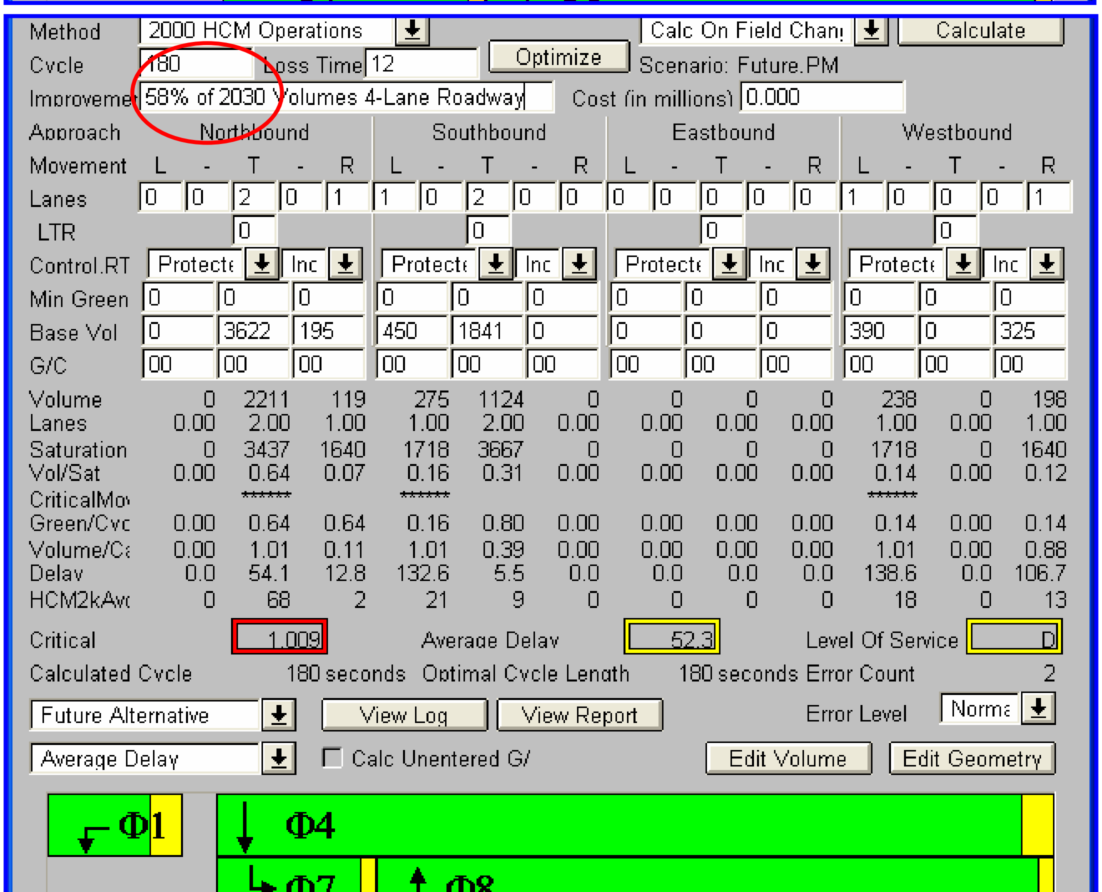


Figure 35: Park West PM Signal Capacity 58% of 2030 ~ 2020



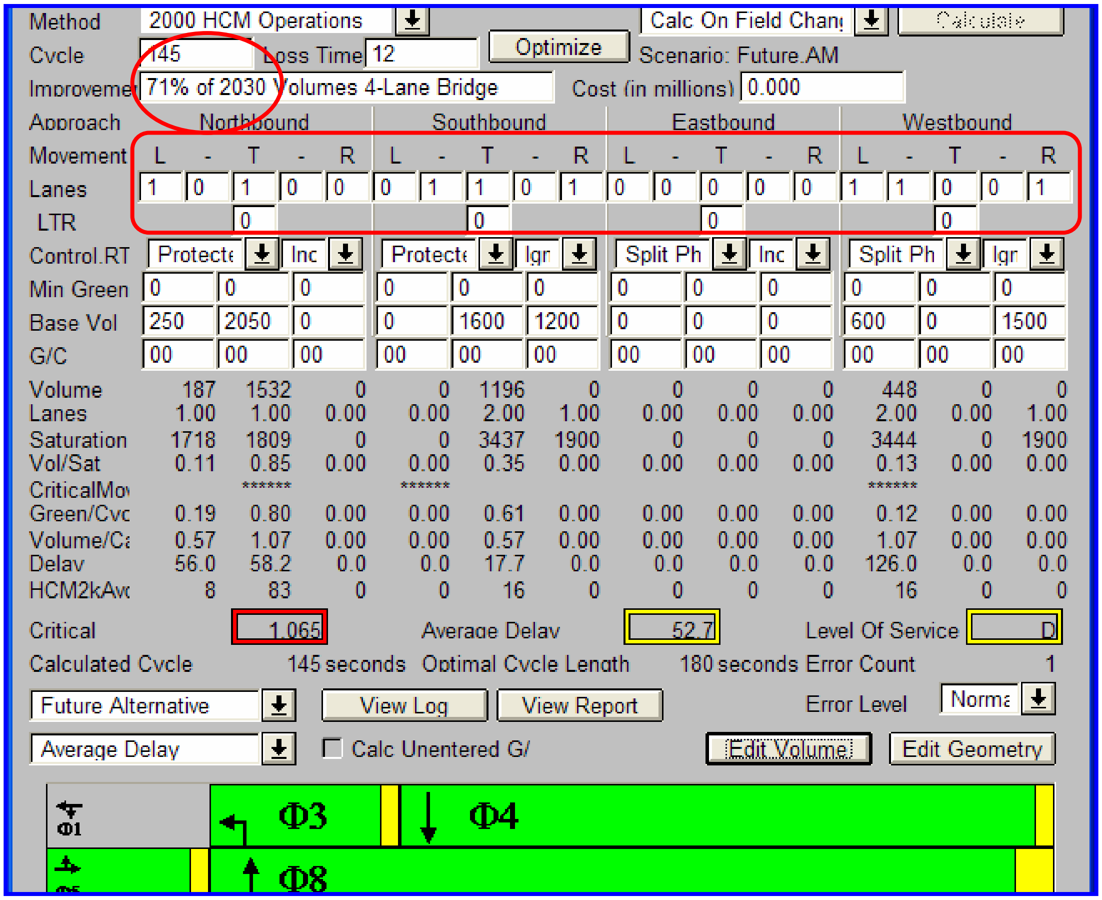


Figure 36:
Side Road TI
North
AM
Signal
Capacity
71% of 2030
~ 2023

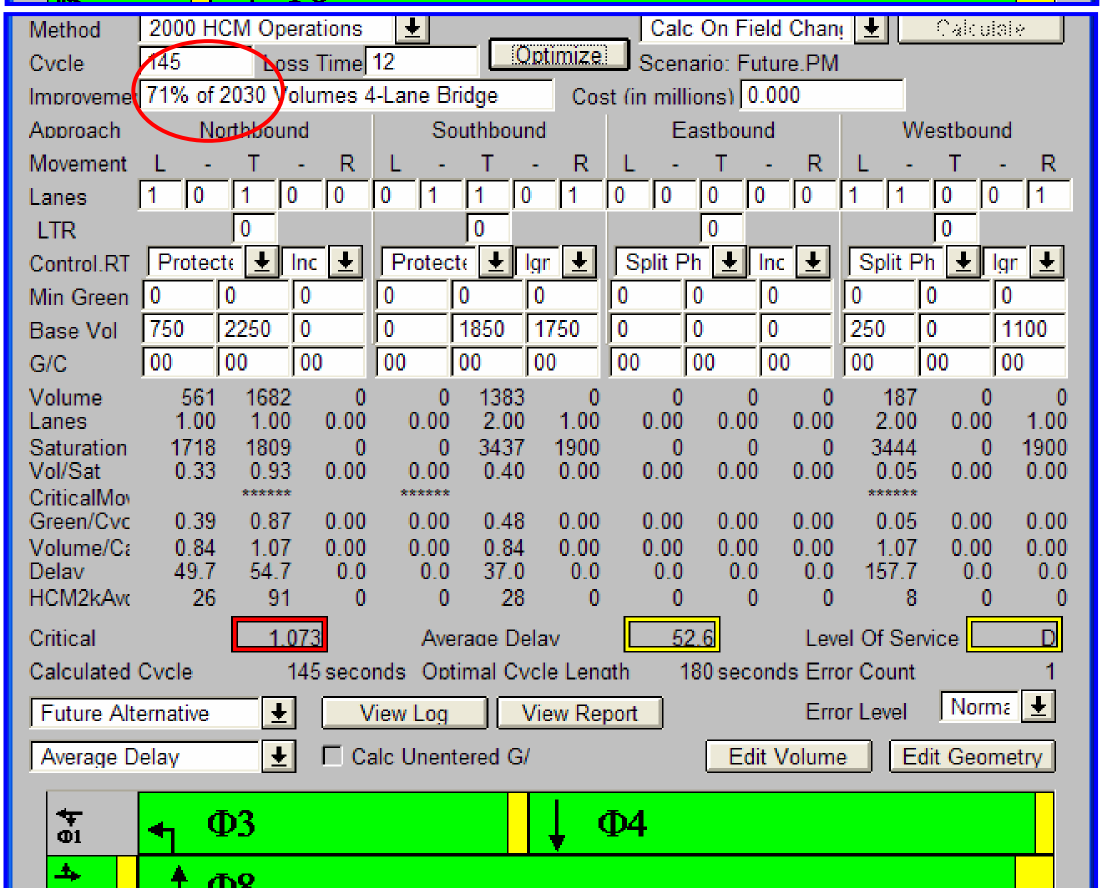
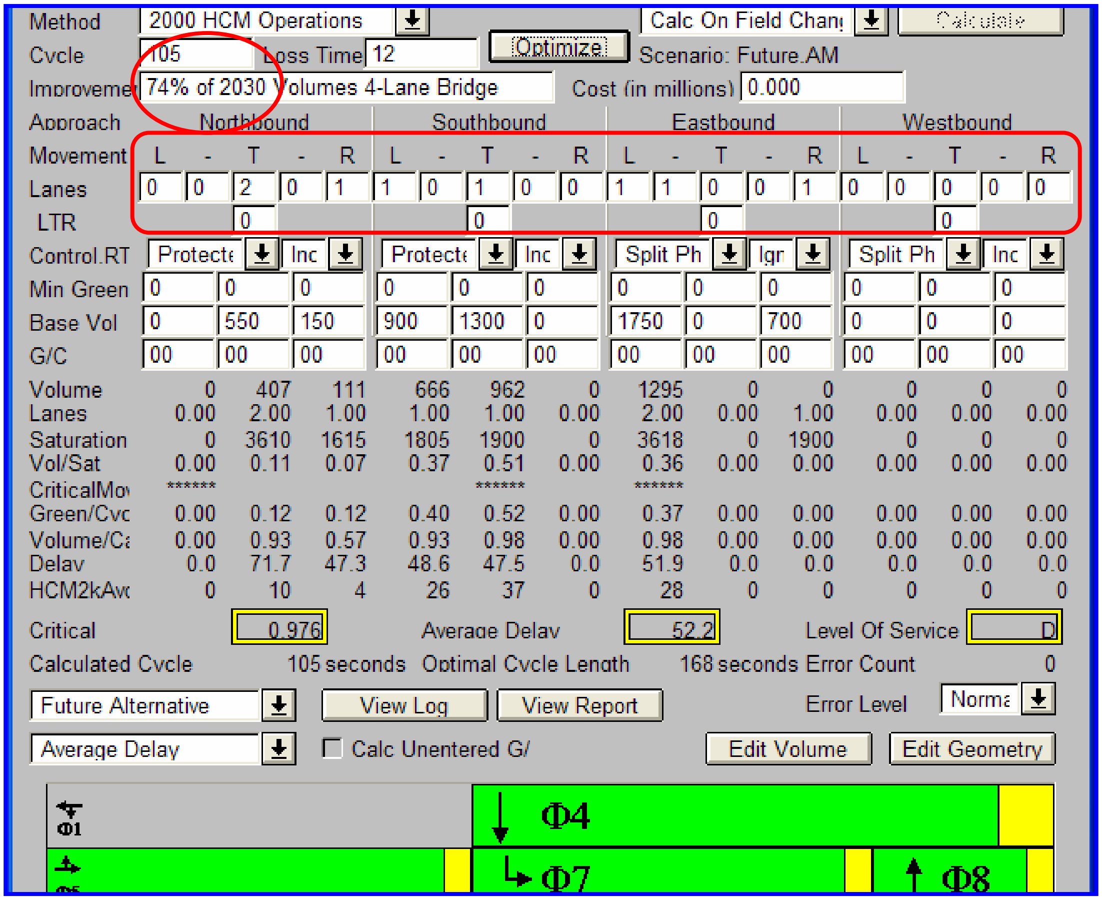


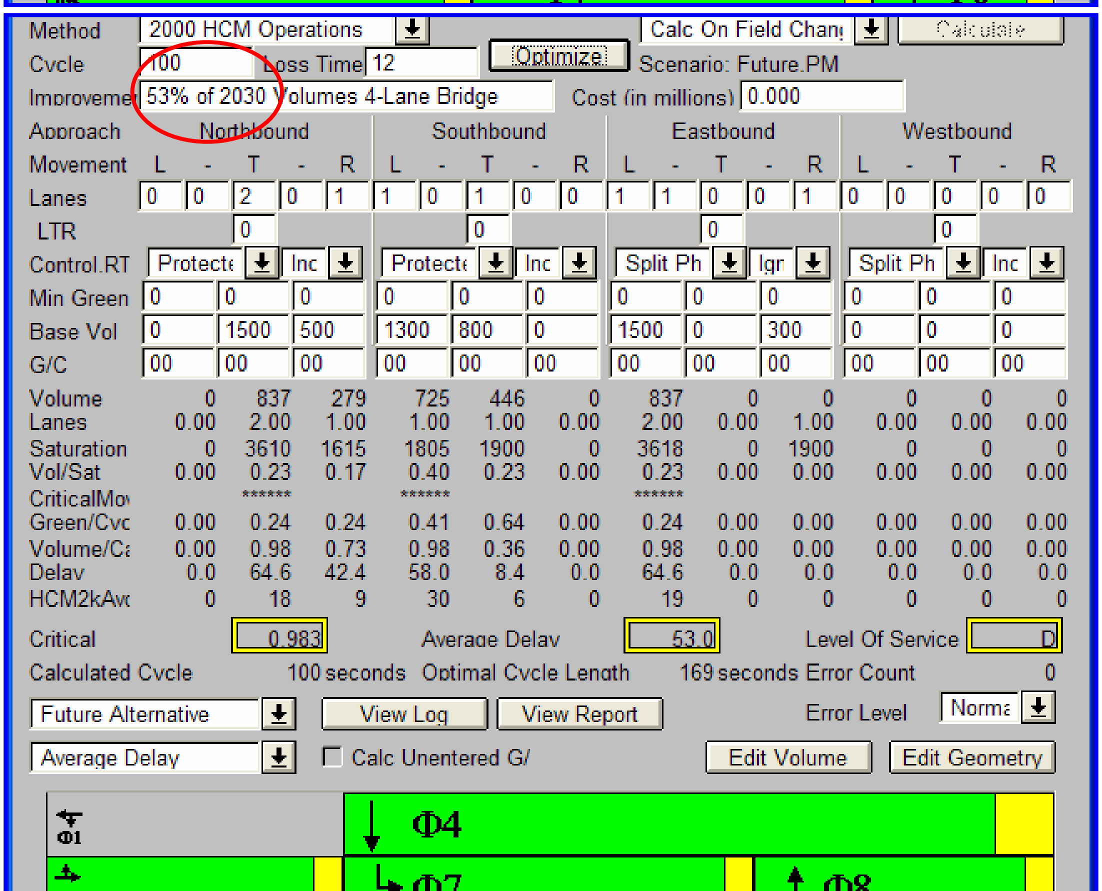
Figure 37:
Side Road TI
North
PM
Signal
Capacity
71% of 2030
~ 2023

Figure 38: Side Road TI South AM Signal Capacity 74% of 2030 ~ 2024



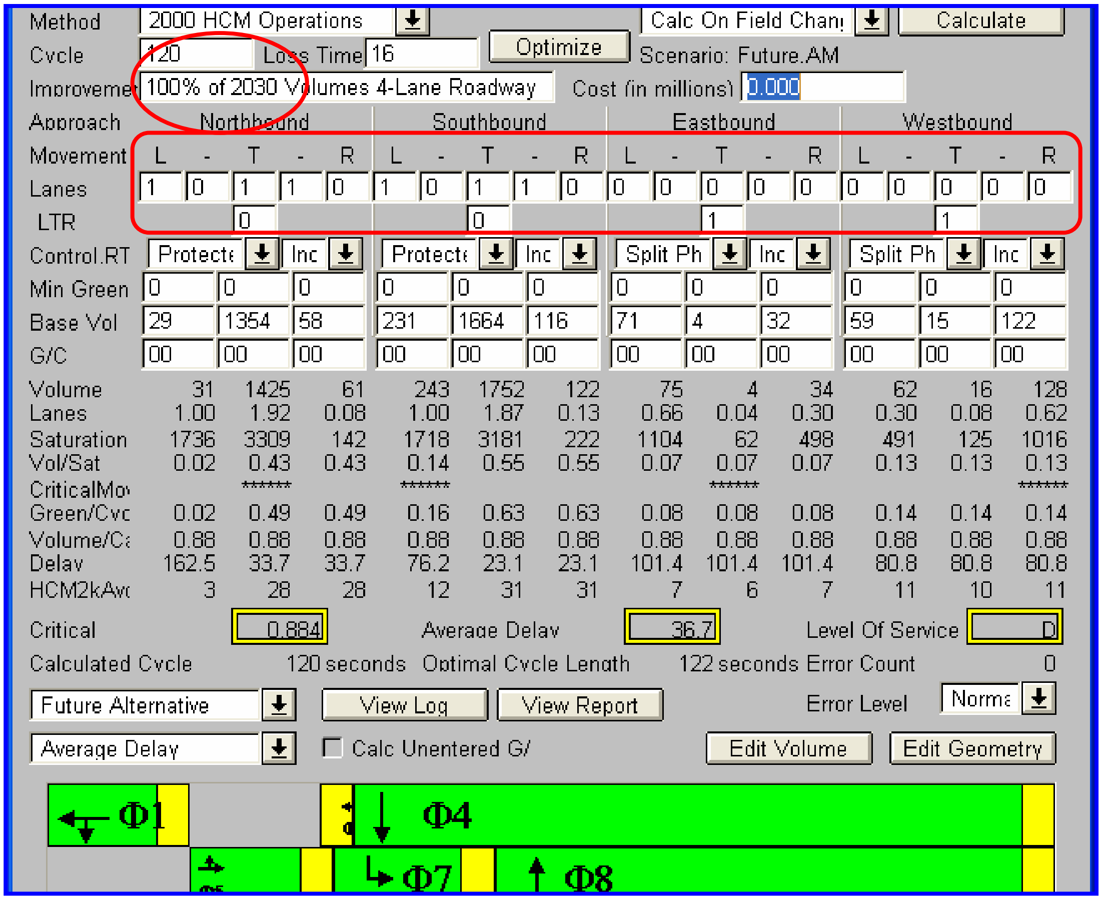
	NB L	NB T	NB R	SB L	SB T	SB R	EB L	EB T	EB R	WB L	WB T	WB R
Volume	0	407	111	666	962	0	1295	0	0	0	0	0
Lanes	0.00	2.00	1.00	1.00	1.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00
Saturation	0	3610	1615	1805	1900	0	3618	0	1900	0	0	0
Vol/Sat	0.00	0.11	0.07	0.37	0.51	0.00	0.36	0.00	0.00	0.00	0.00	0.00
CriticalMov	******				******		******					
Green/Cyc	0.00	0.12	0.12	0.40	0.52	0.00	0.37	0.00	0.00	0.00	0.00	0.00
Volume/Ca	0.00	0.93	0.57	0.93	0.98	0.00	0.98	0.00	0.00	0.00	0.00	0.00
Delay	0.0	71.7	47.3	48.6	47.5	0.0	51.9	0.0	0.0	0.0	0.0	0.0
HCM2kAvg	0	10	4	26	37	0	28	0	0	0	0	0

Figure 39: Side Road TI South PM Signal Capacity 53% of 2030 ~ 2019



	NB L	NB T	NB R	SB L	SB T	SB R	EB L	EB T	EB R	WB L	WB T	WB R
Volume	0	837	279	725	446	0	837	0	0	0	0	0
Lanes	0.00	2.00	1.00	1.00	1.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00
Saturation	0	3610	1615	1805	1900	0	3618	0	1900	0	0	0
Vol/Sat	0.00	0.23	0.17	0.40	0.23	0.00	0.23	0.00	0.00	0.00	0.00	0.00
CriticalMov		******		******			******					
Green/Cyc	0.00	0.24	0.24	0.41	0.64	0.00	0.24	0.00	0.00	0.00	0.00	0.00
Volume/Ca	0.00	0.98	0.73	0.98	0.36	0.00	0.98	0.00	0.00	0.00	0.00	0.00
Delay	0.0	64.6	42.4	58.0	8.4	0.0	64.6	0.0	0.0	0.0	0.0	0.0
HCM2kAvg	0	18	9	30	6	0	19	0	0	0	0	0

Figure 40: Sundog Ranch AM Signal Capacity 100% of 2030



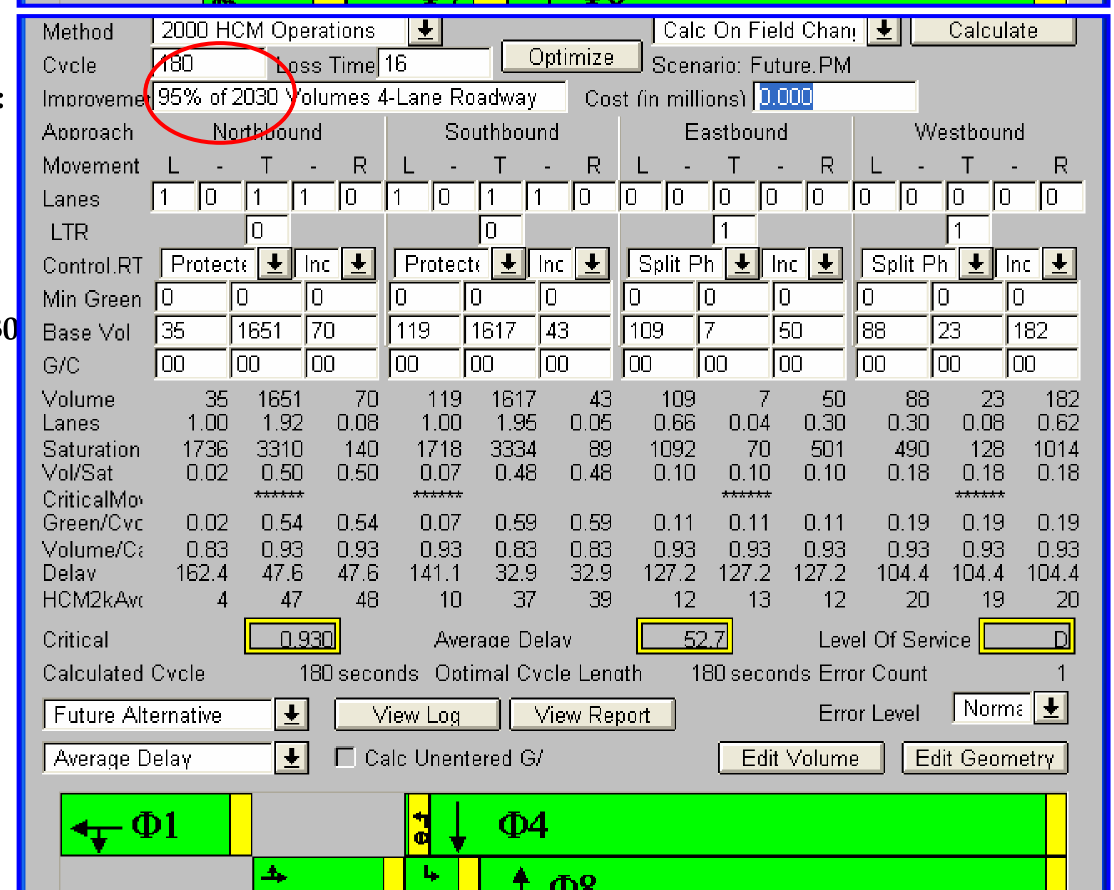
Method: 2000 HCM Operations | Calc On Field Chang | Calculate
Cycle: 120 | Loss Time: 16 | Optimize | Scenario: Future.AM
Improvement: 100% of 2030 Volumes 4-Lane Roadway | Cost (in millions): 0.000

Approach	Northbound					Southbound					Eastbound					Westbound				
Movement	L	-	T	-	R	L	-	T	-	R	L	-	T	-	R	L	-	T	-	R
Lanes	1	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
LTR			0					0					1					1		

	Northbound			Southbound			Eastbound			Westbound		
Control.RT	Protecte		Inc	Protecte		Inc	Split Ph		Inc	Split Ph		Inc
Min Green	0	0	0	0	0	0	0	0	0	0	0	0
Base Vol	29	1354	58	231	1664	116	71	4	32	59	15	122
G/C	00	00	00	00	00	00	00	00	00	00	00	00
Volume	31	1425	61	243	1752	122	75	4	34	62	16	128
Lanes	1.00	1.92	0.08	1.00	1.87	0.13	0.66	0.04	0.30	0.30	0.08	0.62
Saturation	1736	3309	142	1718	3181	222	1104	62	498	491	125	1016
Vol/Sat	0.02	0.43	0.43	0.14	0.55	0.55	0.07	0.07	0.07	0.13	0.13	0.13
CriticalMov		******		******				******				******
Green/Cyc	0.02	0.49	0.49	0.16	0.63	0.63	0.08	0.08	0.08	0.14	0.14	0.14
Volume/Ca	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Delay	162.5	33.7	33.7	76.2	23.1	23.1	101.4	101.4	101.4	80.8	80.8	80.8
HCM2kAvg	3	28	28	12	31	31	7	6	7	11	10	11

Critical: 0.884 | Average Delay: 36.7 | Level Of Service: D
Calculated Cycle: 120 seconds | Optimal Cycle Length: 122 seconds | Error Count: 0
Future Alternative | View Log | View Report | Error Level: Norma
Average Delay | Calc Unentered G/ | Edit Volume | Edit Geometry

Figure 41: Sundog Ranch PM Signal Capacity 95% of 2030 ~ 2029



Method: 2000 HCM Operations | Calc On Field Chang | Calculate
Cycle: 180 | Loss Time: 16 | Optimize | Scenario: Future.PM
Improvement: 95% of 2030 Volumes 4-Lane Roadway | Cost (in millions): 0.000

Approach	Northbound					Southbound					Eastbound					Westbound				
Movement	L	-	T	-	R	L	-	T	-	R	L	-	T	-	R	L	-	T	-	R
Lanes	1	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
LTR			0					0					1					1		

	Northbound			Southbound			Eastbound			Westbound		
Control.RT	Protecte		Inc	Protecte		Inc	Split Ph		Inc	Split Ph		Inc
Min Green	0	0	0	0	0	0	0	0	0	0	0	0
Base Vol	35	1651	70	119	1617	43	109	7	50	88	23	182
G/C	00	00	00	00	00	00	00	00	00	00	00	00
Volume	35	1651	70	119	1617	43	109	7	50	88	23	182
Lanes	1.00	1.92	0.08	1.00	1.95	0.05	0.66	0.04	0.30	0.30	0.08	0.62
Saturation	1736	3310	140	1718	3334	89	1092	70	501	490	128	1014
Vol/Sat	0.02	0.50	0.50	0.07	0.48	0.48	0.10	0.10	0.10	0.18	0.18	0.18
CriticalMov		******		******				******			******	
Green/Cyc	0.02	0.54	0.54	0.07	0.59	0.59	0.11	0.11	0.11	0.19	0.19	0.19
Volume/Ca	0.83	0.93	0.93	0.93	0.83	0.83	0.93	0.93	0.93	0.93	0.93	0.93
Delay	162.4	47.6	47.6	141.1	32.9	32.9	127.2	127.2	127.2	104.4	104.4	104.4
HCM2kAvg	4	47	48	10	37	39	12	13	12	20	19	20

Critical: 0.930 | Average Delay: 52.7 | Level Of Service: D
Calculated Cycle: 180 seconds | Optimal Cycle Length: 180 seconds | Error Count: 1
Future Alternative | View Log | View Report | Error Level: Norma
Average Delay | Calc Unentered G/ | Edit Volume | Edit Geometry

Figure 42: Sundog Connector AM Signal Capacity 77% of 2030 ~ 2025

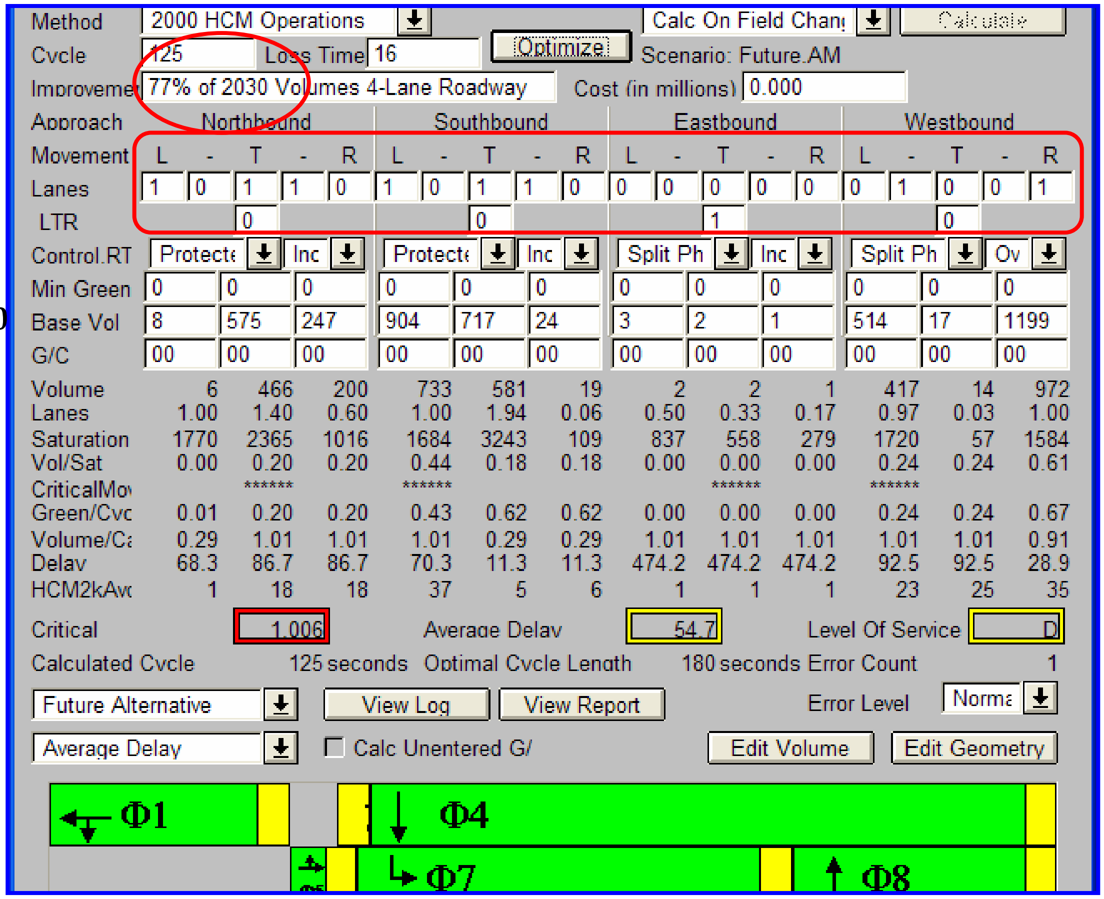
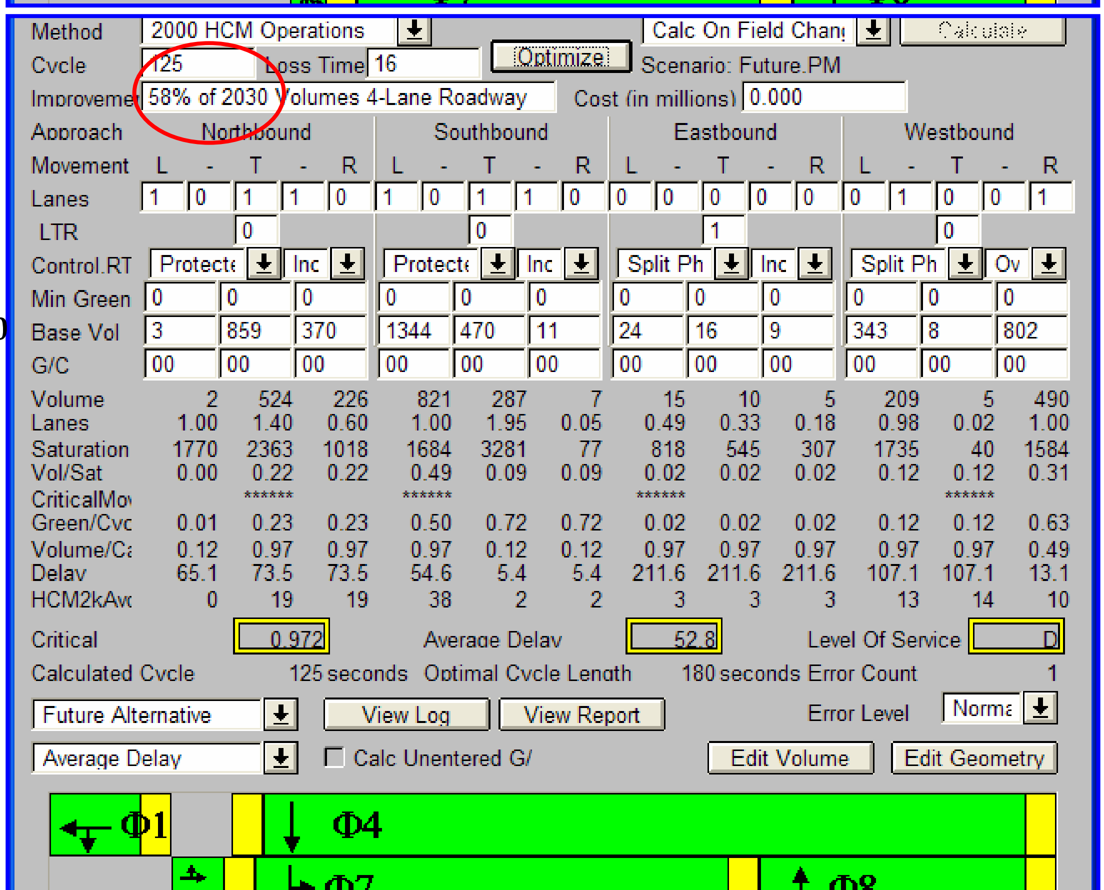


Figure 43: Sundog Connector PM Signal Capacity 58% of 2030 ~ 2020



As stated above, it must be noted that each intersection's lane configurations were attempted to match planned future road conditions and the comparative lane configurations of the roundabouts in an attempt to compare similar project alternatives. In addition, some of the signalized intersections required additional lanes to be added above and beyond the roundabout's required lanes or the planned future road conditions since traffic signals typically have mutually exclusive left turn lanes. The intersection's lane configuration assumptions are shown within each intersection's capacity analysis figure (circled in red) and are discussed in Chapter V (Capacity Comparisons) as well.

As shown in the capacity analysis figures, none of the intersections could reach 100% of the 2030 traffic volume conditions and still maintain a LOS D or better in both the AM and PM peak hours. Hence, either additional turn lanes or through lanes must be added to the planned roadway cross sections to accommodate the 2030 volumes if traffic signals are the selected alternatives for all intersections analyzed.

In addition, significant queue lengths form on mainlines of the roadways with nearly all of the intersections. Significant turn lane storage lengths are also required for the left and right turn lanes at the signalized intersections. This is documented in **Table 1** as well as in the comparison analyses between the signals and roundabouts at the end of the next chapter following the roundabout capacity analyses.

ROUNDABOUT CAPACITY ANALYSES

After obtaining and reviewing all of the pertinent information regarding the roadways, site, and traffic volumes, geometric analyses of the proposed roundabout at each intersection using the roundabout design software tool called RODEL was conducted. With the exception of the ultimate buildout conditions of the Side Road / SR 89 Side Road Interchange, the City of Prescott requested two-lane roundabouts and a LOS D as the threshold for the capacity analyses by using a percentage of the 2030 traffic volumes. Hence, RTE iteratively calculated the capacity of each intersection as a two-lane roundabout beginning with 100% of the 2030 traffic volumes and, if LOS D or better could not be obtained, taking a percentage of the 2030 volumes until at least a LOS D could be reached.

The RODEL calculations provided the initial lane geometry and capacity requirements for the roundabout design alternative based on the design year traffic volumes. RODEL is based on empirical equations (observed and checked from field data) developed by the United Kingdom and utilizes specific geometric relationships to determine the capacity requirements of a roundabout.

A further discussion on RODEL software and the geometric factors affecting roundabout capacity is provided in the next section of this report (RODEL Software and Roundabout Geometric Parameters). In general, RODEL (roundabout delay) calculates the required geometry for the roundabout to function within the desired capacity or, alternatively, to determine if the existing/planned geometry will be adequate with respect to capacity and delay.

Since multiple sets of both AM and PM peak hour volumes were required as part of each intersection's design, separate RODEL calculations were completed for each intersection location to arrive upon the desired two-lane configuration of the roundabout to ensure it will operate appropriately under both peak hour traffic conditions and determine the final two-lane roundabout design year via a percentage of the 2030 volumes. Prior to beginning final design of any of the study area intersection, the capacity calculations should be reanalyzed with refined data. In addition, separate RODEL calculations should also be performed prior to final design under the peak minutes of the peak hour at an 85^{th} percentile confidence level to ensure the proposed design would be adequate under the recommended geometric parameters provided herein. Nearly all software programs that analyze traffic volumes with respect to operations and level of service are reported at a 50^{th} percentile confidence level. RODEL offers a "design check" at an 85^{th} percentile confidence level to determine if the roundabout has been designed adequately. This ensures adequate capacity of the roundabout during both peak hours of the selected design year.

***Roundabout Capacity Methodology*:** The predominant consideration in roundabout capacity analyses is the volume of the circulating traffic and the volume of the entering traffic on each approach. Traffic entering a roundabout will look for gaps in the circulating traffic in order to enter the roundabout. This behavior is called gap seeking. In addition to gap seeking, the geometric design of the roundabout affects the speeds and comfort level at which drivers will negotiate the roundabout. This also affects the capacity and safety of roundabouts.

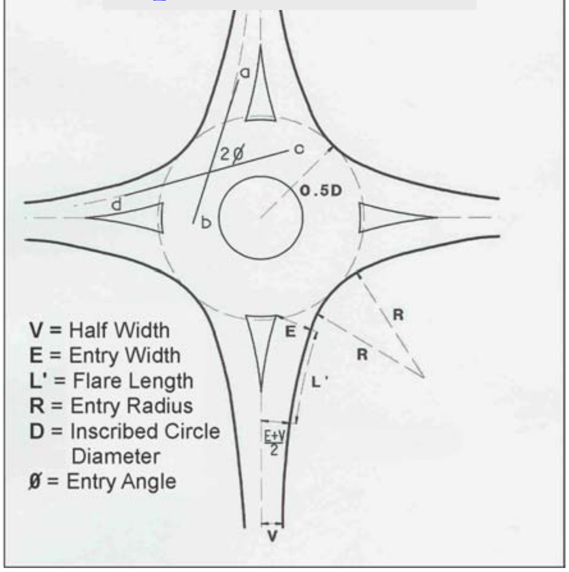
The Highway Capacity Manual[2] evaluates roundabouts based on their volume to capacity ratios as well as their level of service. The volume to capacity (v/c) ratio describes the volume of traffic entering the circulating roadway from one approach as compared to the capacity of that approach. The capacity of an approach is dependent on the traffic volume within the circulating roadway at each specific approach. As the traffic within the circulating roadway goes up, the capacity of an approach would be reduced.

[2] Highway Capacity Manual, Transportation Research Board, 2000

Because of this, traffic engineers prefer to leave a "reserve capacity" for an approach. Typically, an intersection with a v/c ratio over 0.85 indicates the *potential* need for additional capacity on the approach. However, too much reserve capacity results in an unsafe (too fast or "too loose") roundabout design. Hence, careful and specific ***balance*** is needed in the design of roundabouts for safety and operational capacity purposes.

<u>Roundabout Geometry Parameters / RODEL Software:</u> Empirical studies in England have shown that the following six (6) dimensions collectively control traffic speed, capacity, and safety at a roundabout (see **Figure 44** below):

Figure 44: Geometrics



1. Inscribed Circle Diameter (ICD): the diameter of the outside curb of the circulating roadway. The ICD is established based on the tracking characteristics of the vehicle the roundabout is to accommodate, and the number of circulating lanes required to accommodate the projected traffic volumes. Increasing or decreasing this parameter (and thus increasing or decreasing the central island diameter) has minor effects on the safety of the roundabout (theoretically). However, it can be demonstrated that changing the size (ICD) of the roundabout can substantially change the safety of a roundabout design.

2. Half Width (V): the width of the approach roadway. This dimension is typically known before the roundabout design process has begun, as it is an element of the upstream roadway cross section. The half width has a significant impact on the capacity of the roundabout and some impact on travel speeds and safety of the roundabout.

3. Entry Width (E): the width of the entering roadway at the point of its intersection with the outside curb of the circulating roadway. Increasing or decreasing the entry width can have large impacts on the safety and capacity of the roundabout.

4. Flare Length (L'): the average *effective* length of flare from the transition between the point where the half width ends and the yield line. Flare

length is accident neutral. As the flare gets longer the capacity of the roundabout increases. However, the entry speed increases and the roundabout's deflection decreases. Hence, flare length and entry width are related. If the approaches to the roundabout were parallel, the half width is equal to the entry width, and the flare length is zero (not recommended in modern roundabout designs and proven to increase accidents).

5. Entry Angle (∅) – the mean angle tangential between the direction of entry into the roundabout and tangential to the direction of the adjacent exit (or circulating traffic, depending on the size of the roundabout). The figure above shows the entry angle as half the angle formed by the junction of the tangent line (a-b) projected from the entry and the tangent line (c-d) projected from the adjacent exit. If all other dimensions remain constant, reducing the entry angle will increase the speed at which the roundabout can be entered which, in turn, tends to reduce the safety of the roundabout.

6. Entry Radius (R) – The radius of the outside curb of the entering roadway at its point of intersection with the outside curb of the circulating roadway. The entry radius is a critical component in roundabout design that determines many factors such as entry speed and entry deflection.

After inputting the future traffic turning movement volumes into RODEL for the peak hours, each roundabout was analyzed with a **two-lane entry maximum** (per the City's direction) as well as the need for bypass lanes at each entry or approach of the roundabout. Specifically, the recommended geometric requirements for each roundabout were initially set at a **maximum of two-lanes** and the traffic volumes were iteratively reduced from 2030 to obtain a LOS D or better. Each roundabout was also analyzed to verify that the entering approach widths, average effective flare lengths, entry angles, entry radii, and roundabout diameter are adequate for the software program for the percentage of traffic volumes used. The results of the RODEL analyses are shown in the following RODEL output in **Figures 45 through 58**.

Figure 45: Ruger Road AM RODEL Analyses: 2-Lane Rbt Only

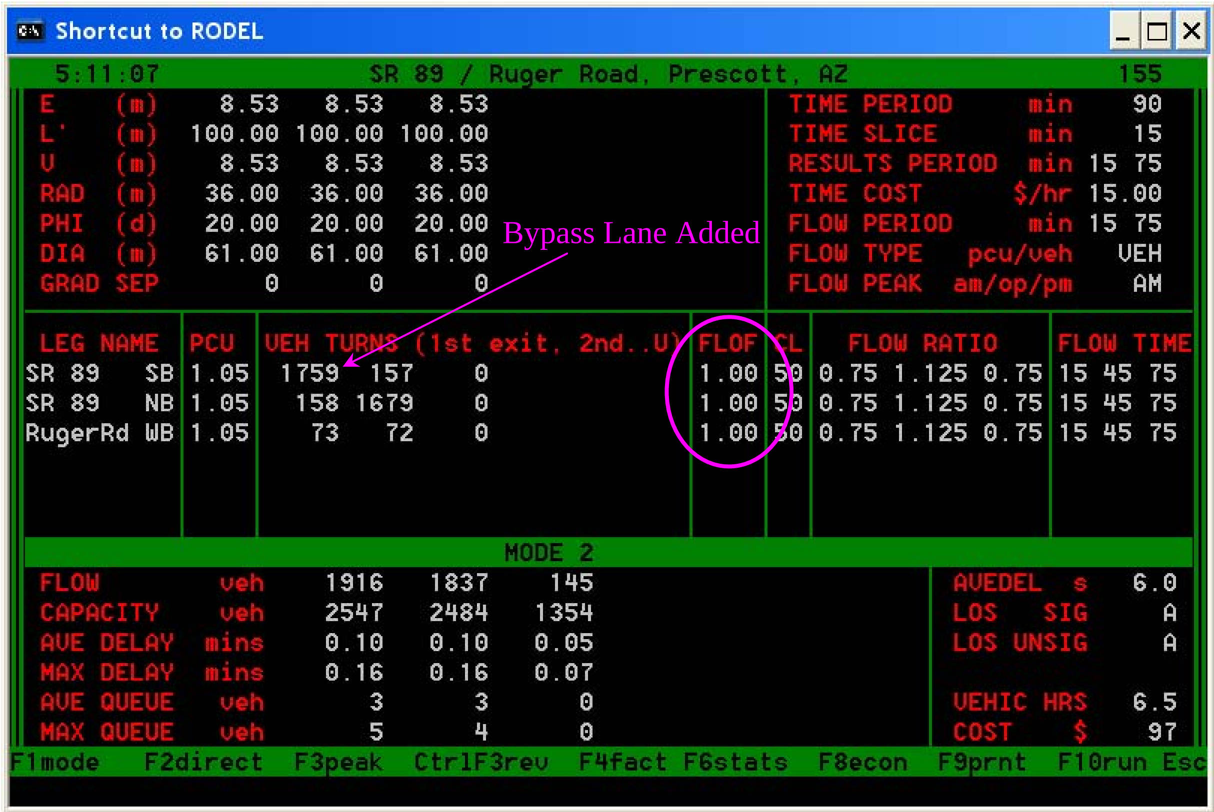


Figure 46: Ruger Road PM RODEL Analyses: 2-Lane Rbt Only

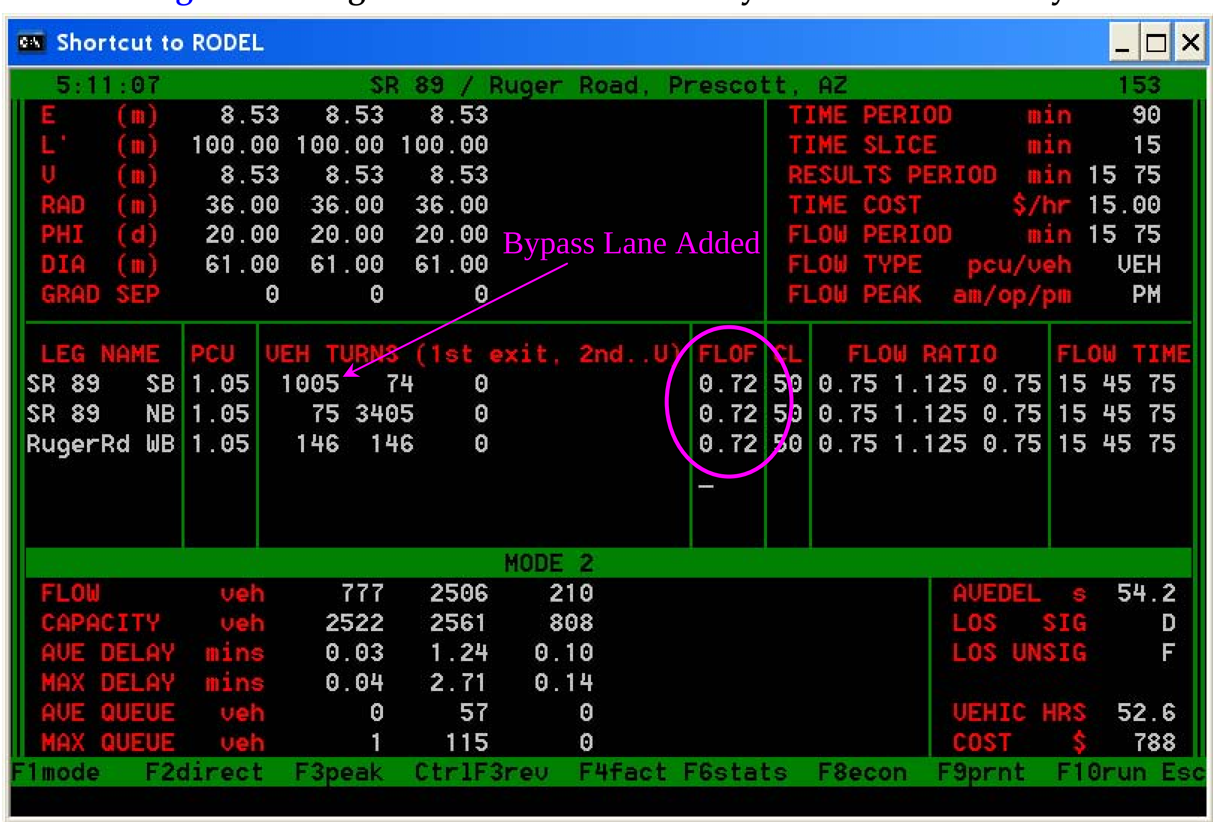


Figure 47: Side Rd Connector AM RODEL Analyses: 2-Lane Rbt Only

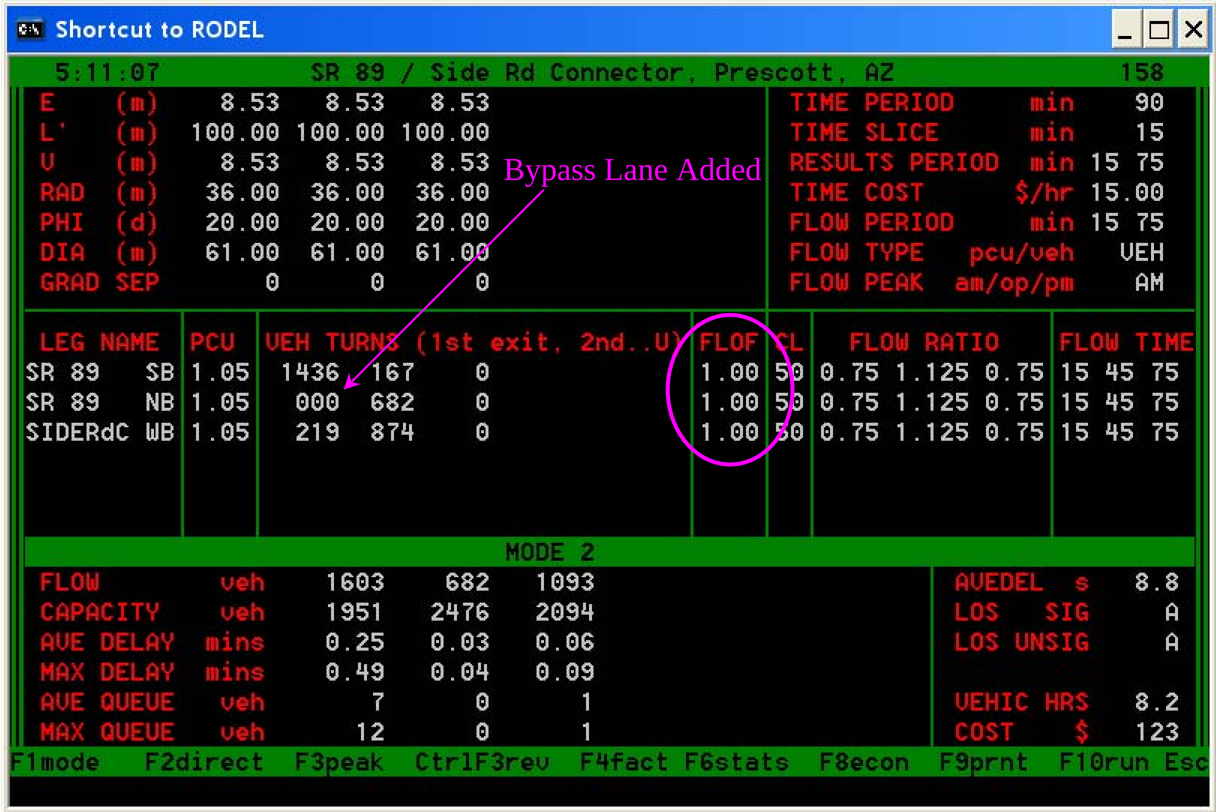


Figure 48: Side Rd Connector PM RODEL Analyses: 2-Lane Rbt Only

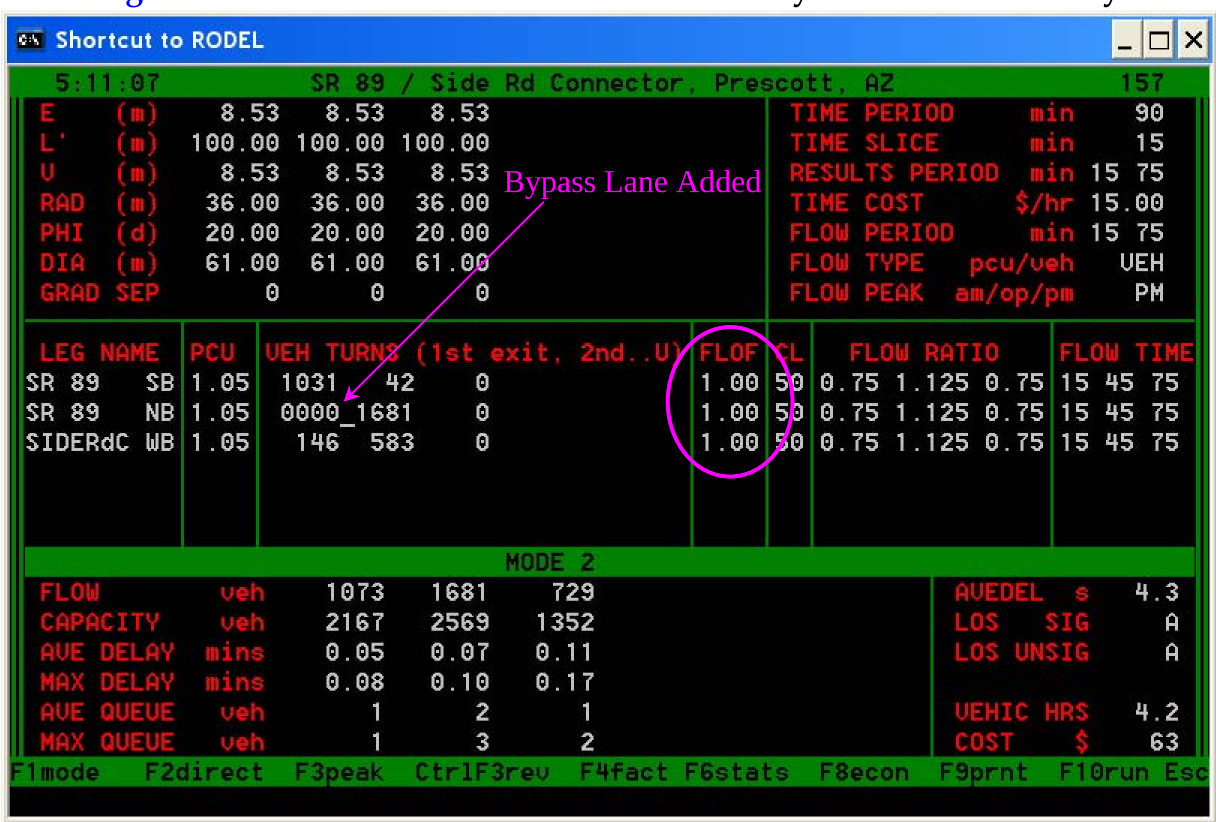


Figure 49: Park West AM RODEL Analyses: 2-Lane Rbt Only

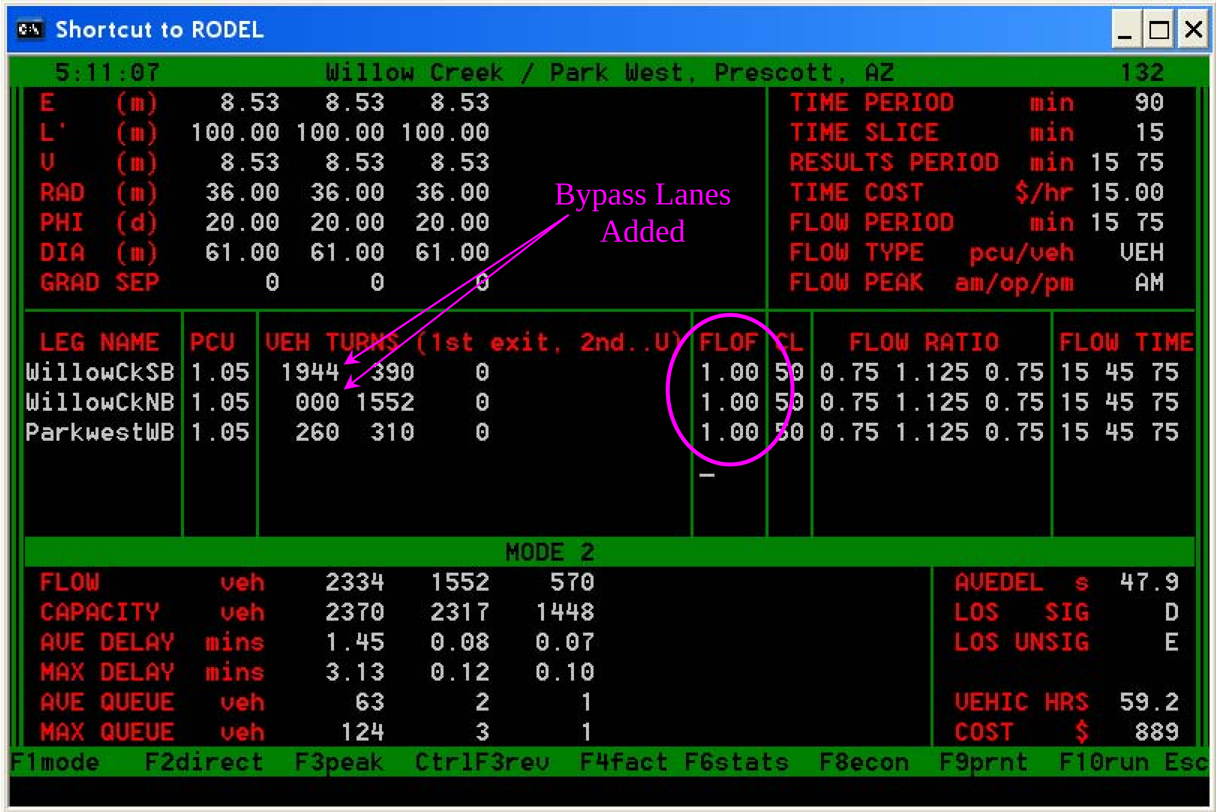


Figure 50: Park West PM RODEL Analyses: 2-Lane Rbt Only

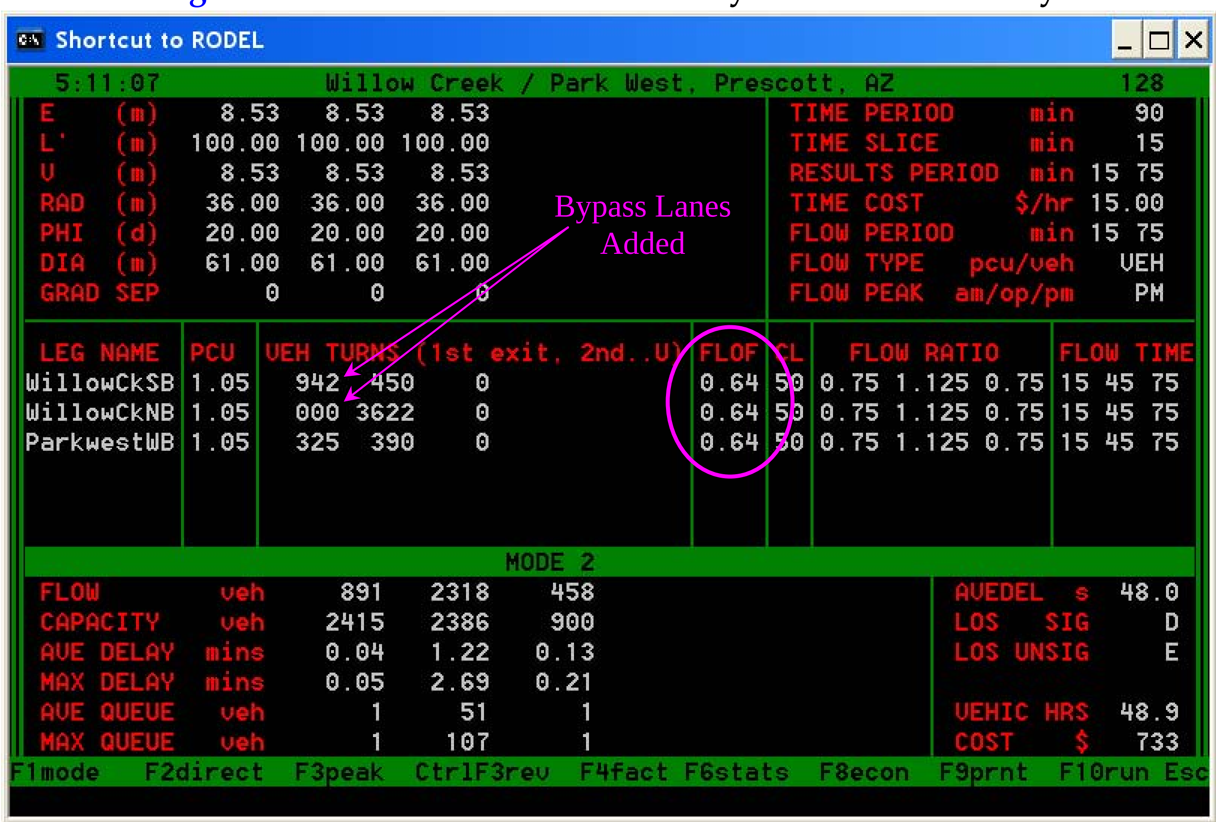


Figure 51: Side Rd TI North AM RODEL Analyses: 2-Lane Rbt Only

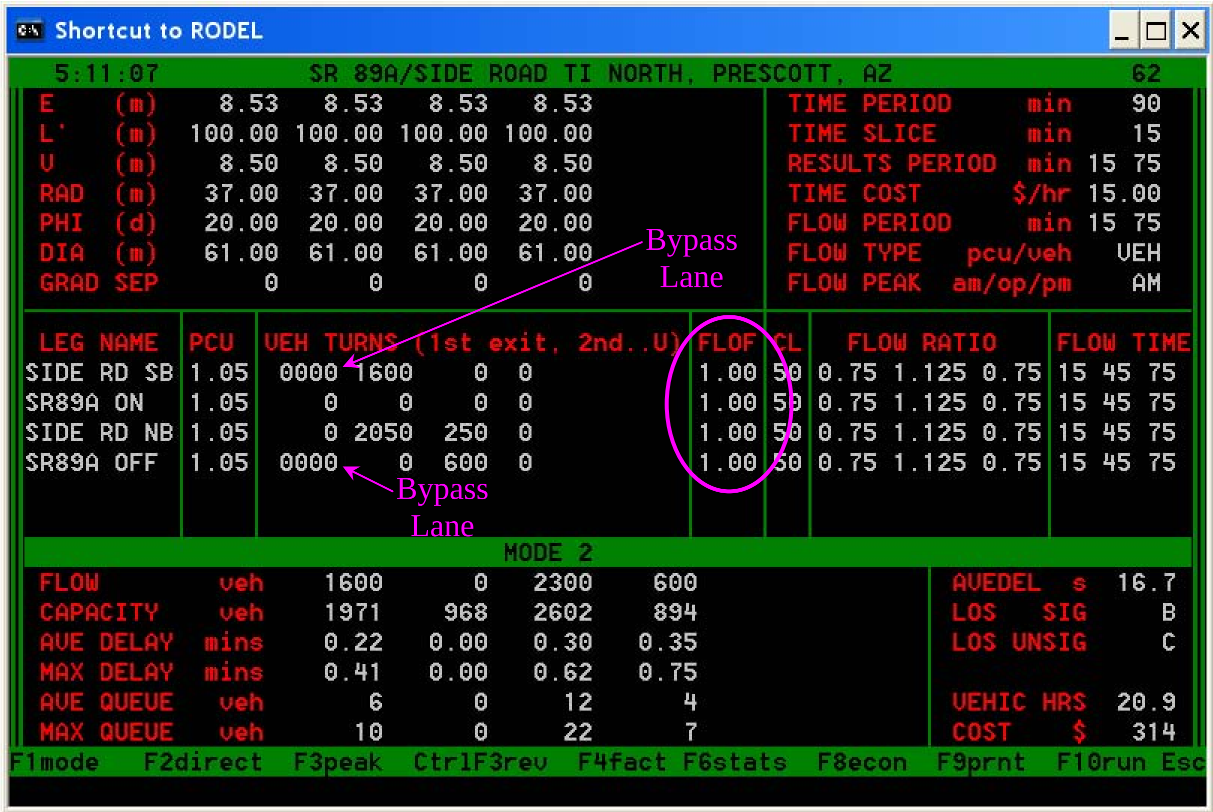


Figure 52: Side Rd TI North PM RODEL Analyses: 2-Lane Rbt Only

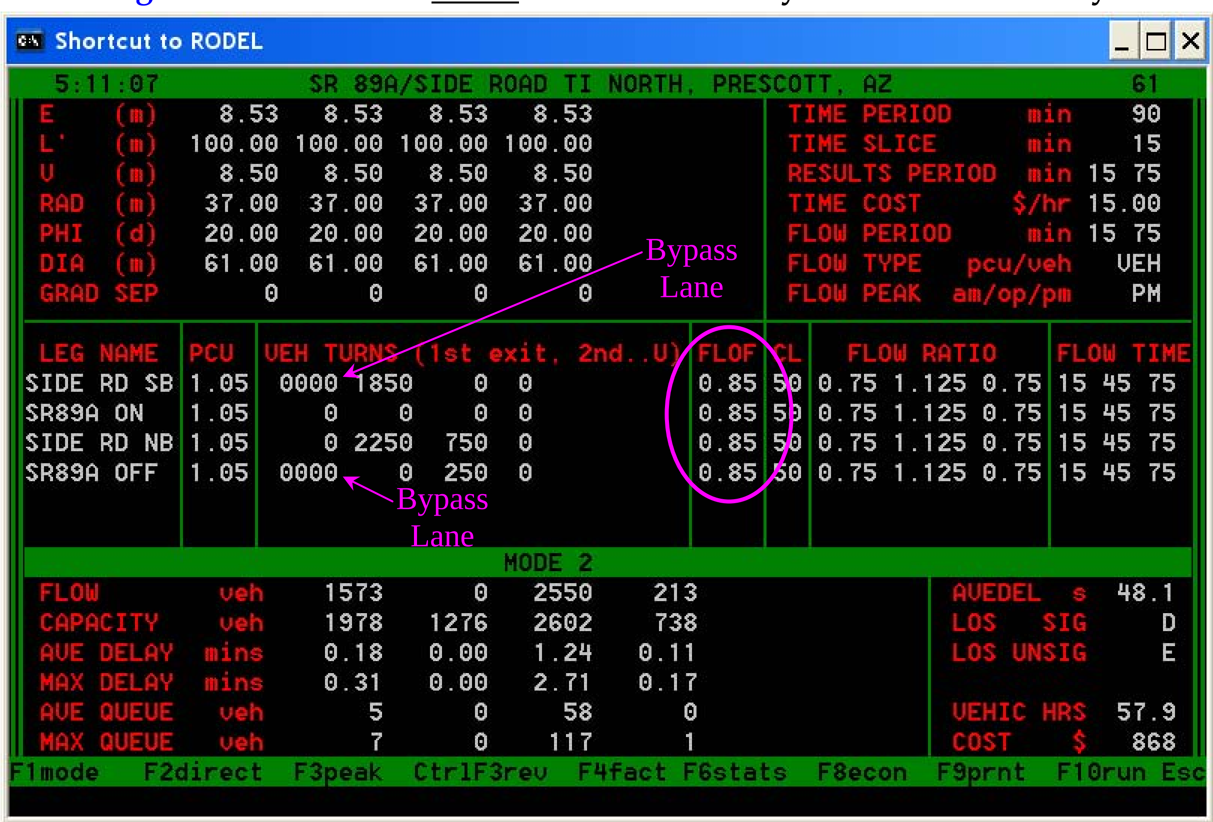


Figure 53: Side Rd TI South AM RODEL Analyses: 2-Lane Rbt Only

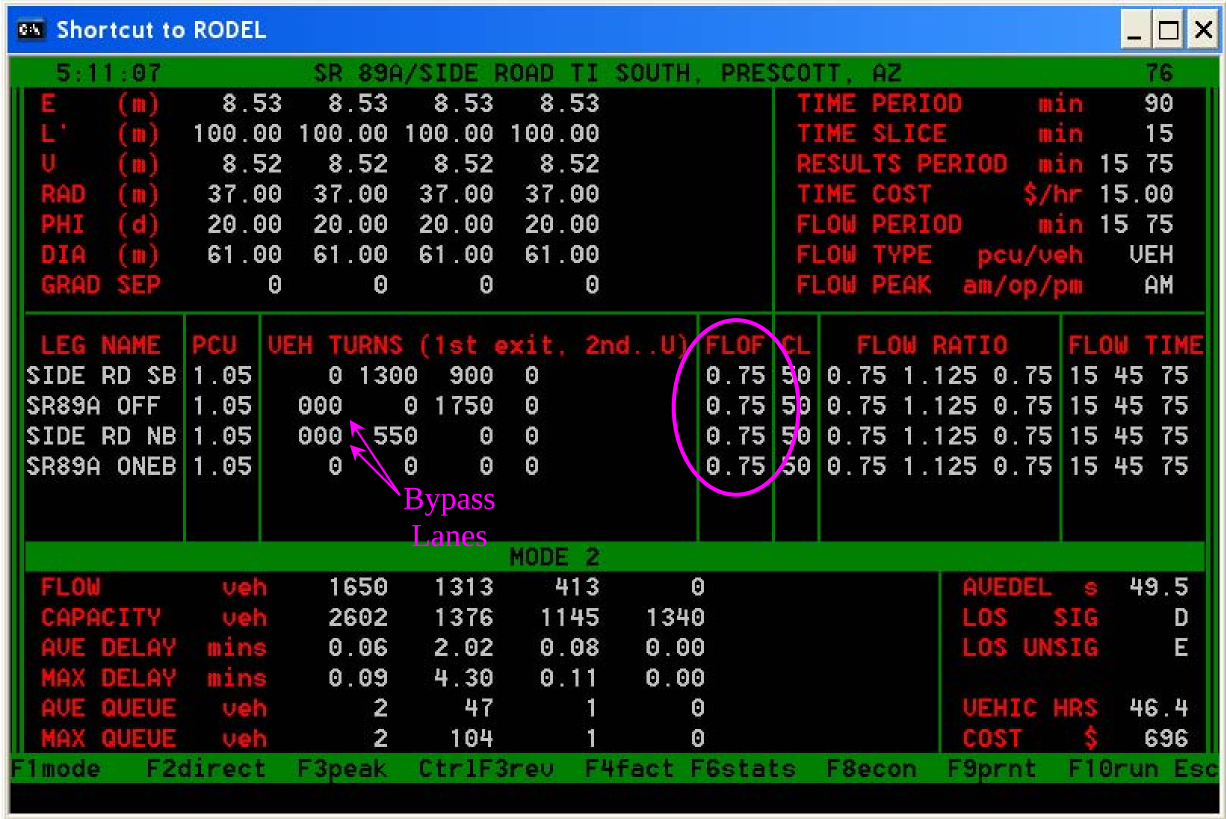


Figure 54: Side Rd TI South PM RODEL Analyses: 2-Lane Rbt Only

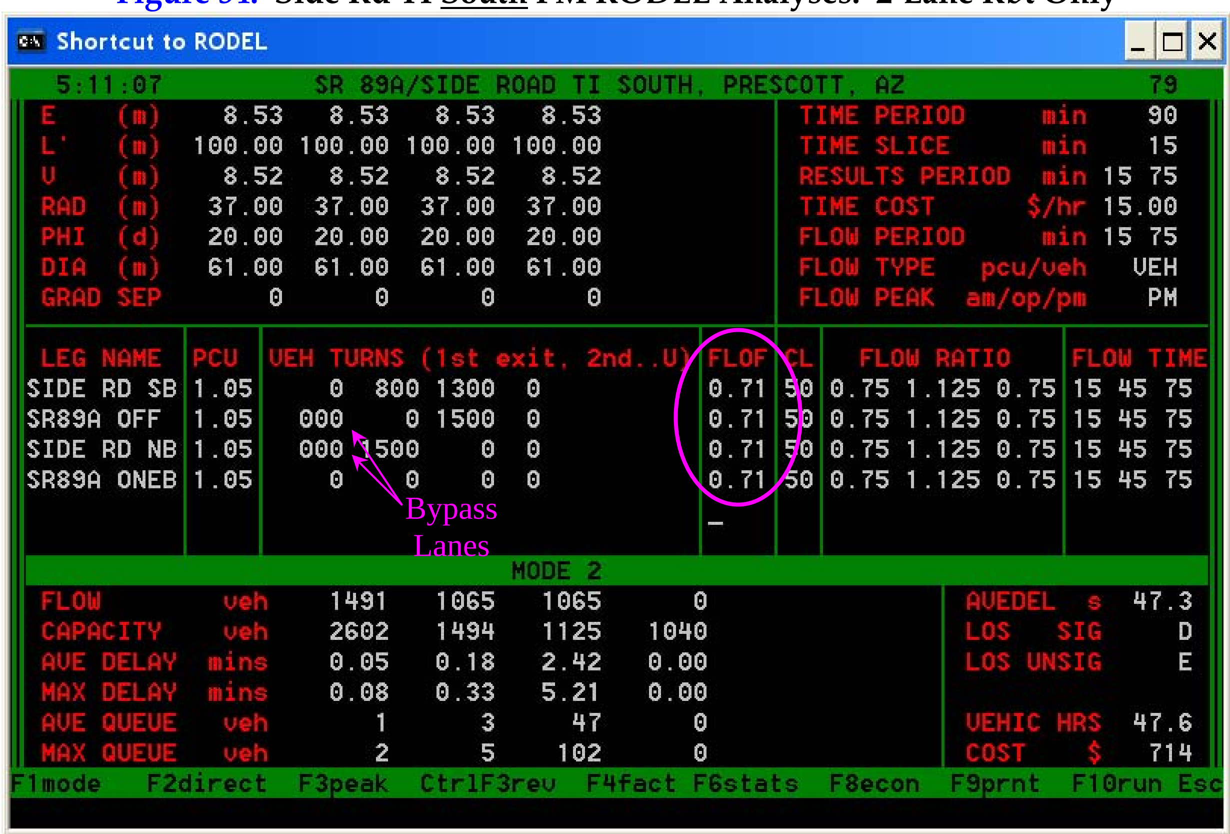


Figure 55: Sundog Ranch AM RODEL Analyses: 2-Lane Rbt Only

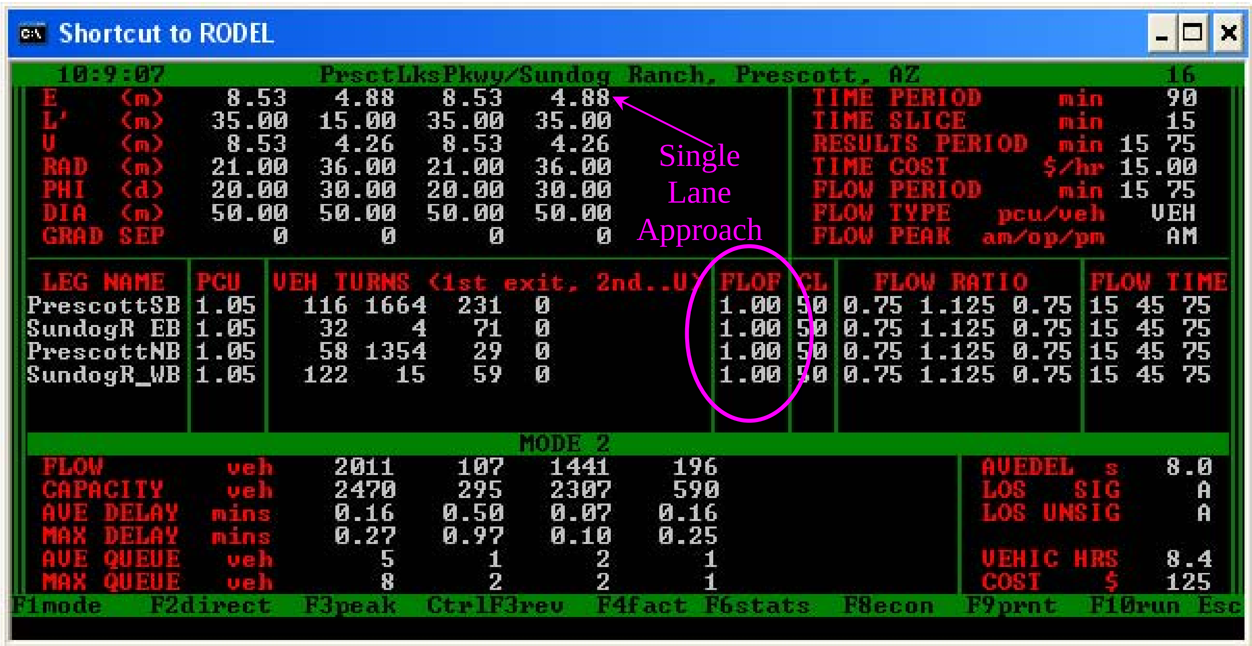


Figure 56: Sundog Ranch PM RODEL Analyses: 2-Lane Rbt Only

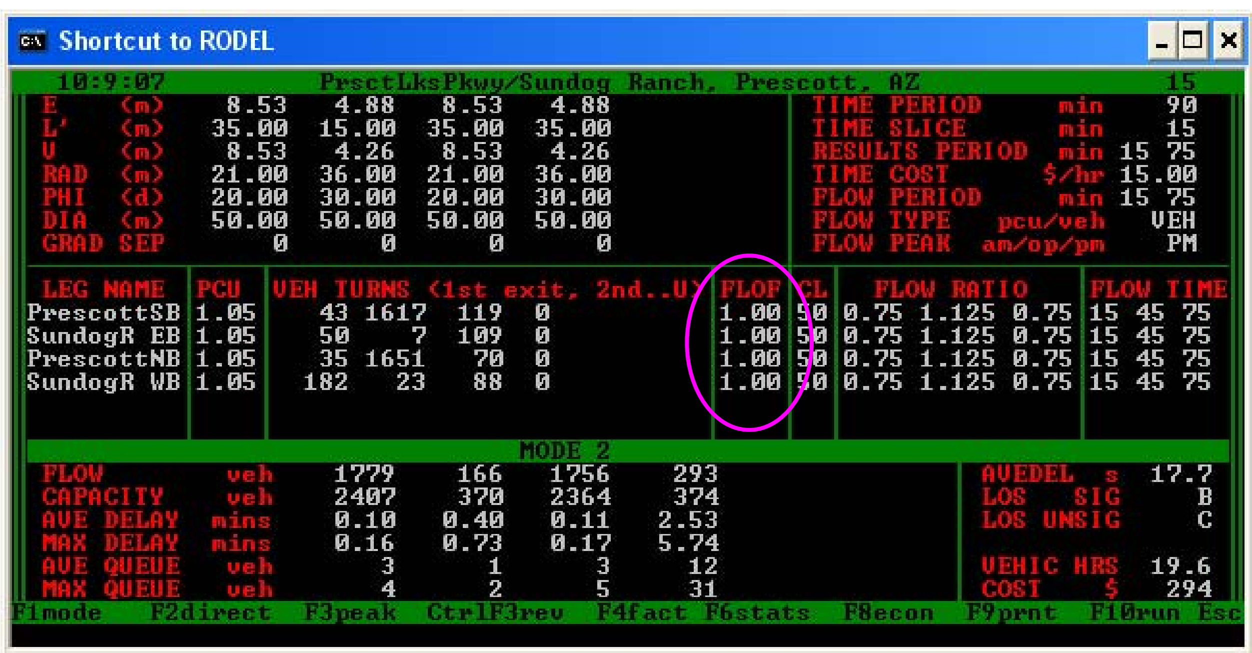


Figure 57: Sundog Connector AM RODEL Analyses: 2-Lane Rbt Only

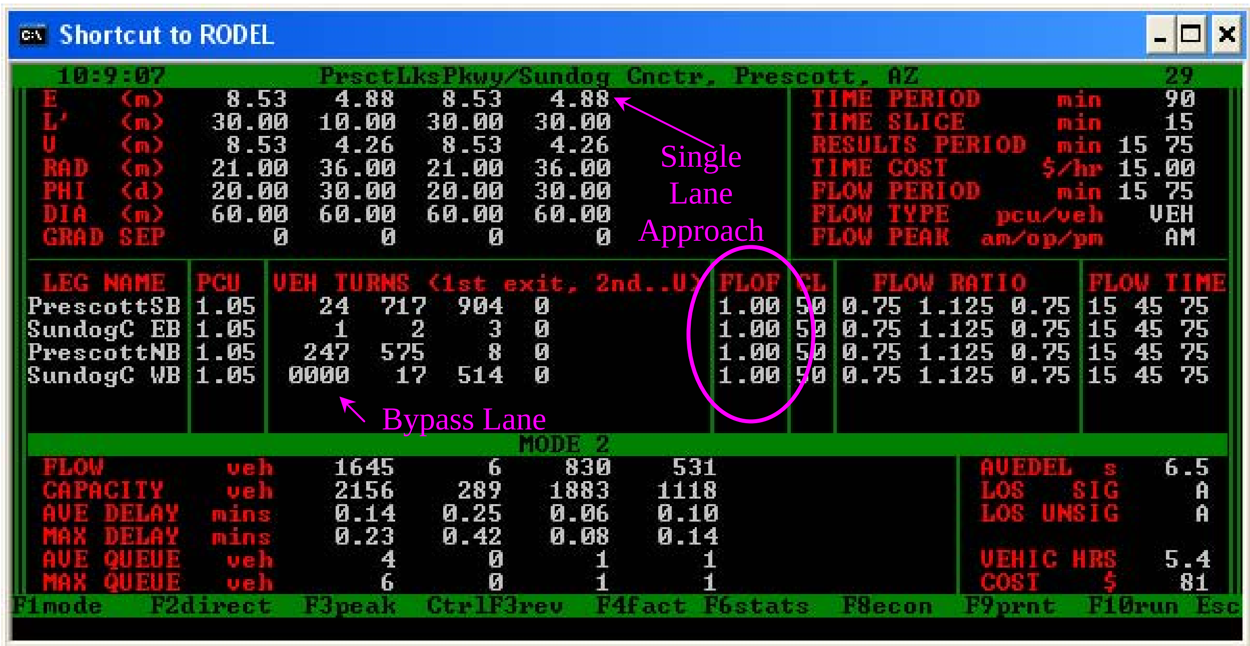
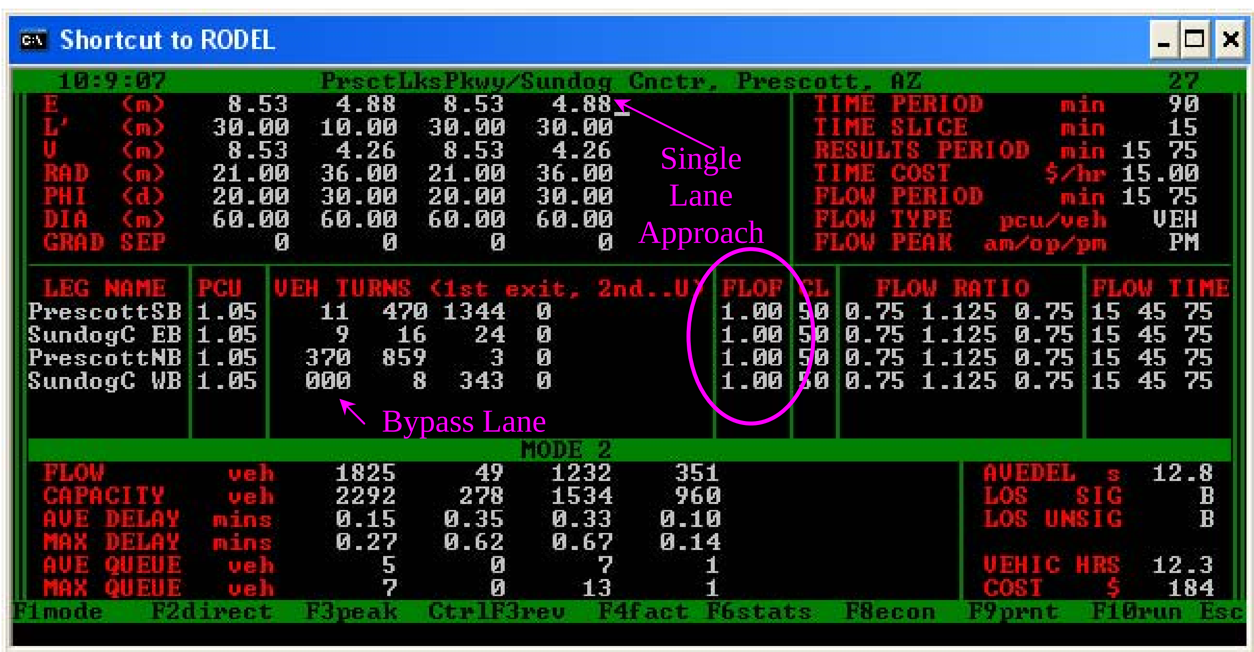


Figure 58: Sundog Connector PM RODEL Analyses: 2-Lane Rbt Only



Based on the established design criteria for the roundabout intersection analyses, the RODEL software program and engineering analyses produced the results above. Each intersection's planned lane configurations were attempted to match existing conditions, the planned future road conditions as identified by the City, and the comparative lane configurations of the traffic signals **while maintaining a maximum of two-lane approaches**. The analyses provide the following results:

- Required Entry Lane Configurations
- Anticipated Queue Lengths of Each Approach
- Estimated Roundabout Geometry (E, L', R, Phi, D)
- LOS Results for AM and PM Peak Hours

Table 2 below summarizes the results shown in the roundabout capacity analysis figures above. As shown, nearly all of the roundabouts were able to handle 100% of the 2030 traffic volume conditions during either the AM or PM peak hours and still maintain a LOS D or better. Analyzing both the AM and PM peak hours reveals three of the six locations as reaching the 2030 design year volumes. However, for the remaining four intersections that could not reach the 2030 traffic volumes in both the AM and PM peak hours, either additional turn lanes or through lanes must be added to the roundabout intersections (not roadways) to accommodate the 2030 volumes if roundabouts are the selected alternatives.

Table 2: Roundabout Capacity Summary

AM and PM Peak Hour Results - % of 2030

Intersection - Peak Period	Intx LOS	Intx Delay (sec)	Mainline Through Movement Queue	% of 2030 Volumes	Max Design Year
SR 89 / Ruger Road - AM	A	6.0	75'	100%	2030
SR 89 / Ruger Road - PM	D	54.2	1425'	72%	2024
SR 89 / Side Rd Connector - AM	A	8.8	175'	100%	2030
SR 89 / Side Rd Connector - PM	A	4.3	50'	100%	2030
Willow Creek Rd / Park West - AM	D	47.9	1575'	100%	2030
Willow Creek Rd / Park West - PM	D	48.0	1275'	64%	2022
SR 89A / Side Rd TI North - AM	B	16.7	300'	100%	2030
SR 89A / Side Rd TI North - PM	D	48.1	1450'	85%	2027
SR 89A / Side Rd TI South - AM	D	49.5	1175'	75%	2024
SR 89A / Side Rd TI South - PM	D	47.3	1175'	71%	2023
Prescott Lakes Pkwy/Sundog Ranch Rd - AM	A	8.0	125'	100%	2030
Prescott Lakes Pkwy/Sundog Ranch Rd - PM	B	17.7	75'	100%	2030
Prescott Lakes Pkwy/Sundog Connector - AM	B	12.8	100'	100%	2030
Prescott Lakes Pkwy/Sundog Connector - PM	A	6.5	175'	100%	2030

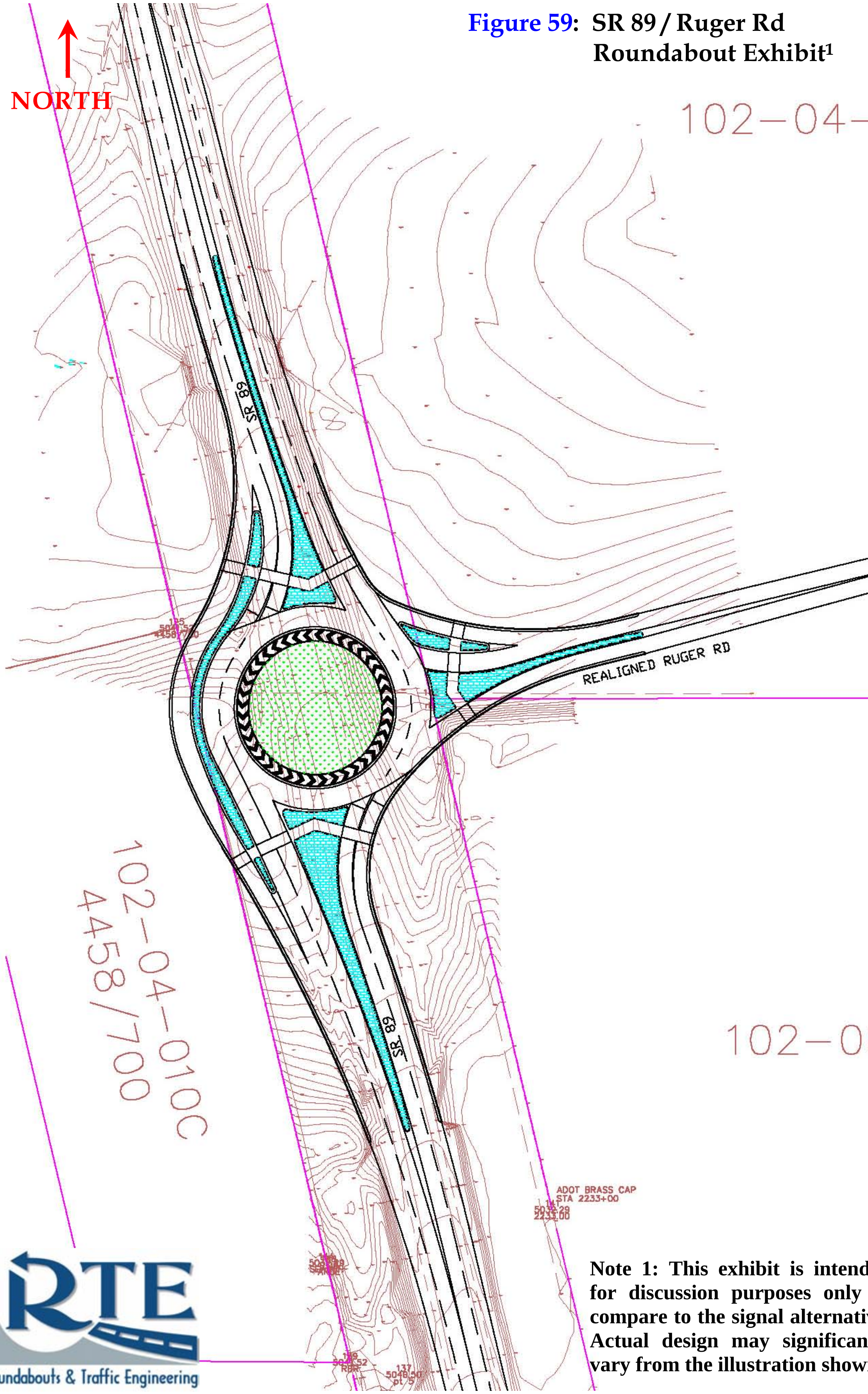
Source: RTE Prescott Feasibility Tables.xls

In addition, significant queue lengths form on mainlines of the roadways for the roundabout intersections that could not reach the 2030 design year. This is documented in **Table 2** as well as in the comparison analyses between the signals and roundabouts at the end of the next chapter following these capacity analyses.

As a result of all of the above capacity analyses the initial roundabout concepts were developed. **Figures 59 through 65** graphically represent the ***conceptual*** layouts of the roundabouts at each intersection.

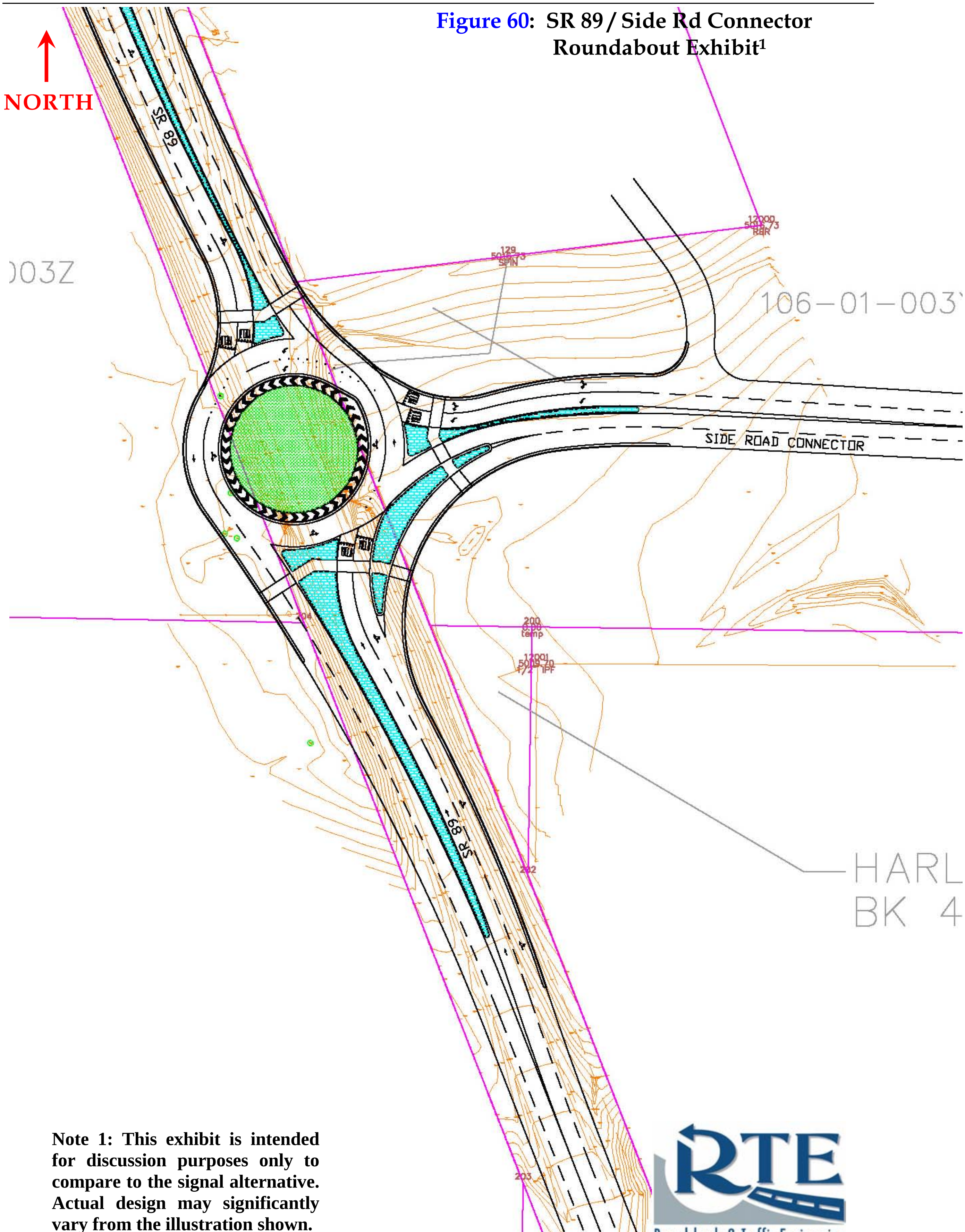
It should be noted that **Figures 59 through 65** are illustrations or conceptual exhibits developed for the intersections for preliminary discussion purposes only. These sketches simply demonstrate the recommended design lane configurations and initial geometry recommendations with special consideration of the 2030 traffic flows or portion thereof as well as the similar signal lane configurations to create relatively equal alternatives. **The actual design plans (PS&E) for either the signal or roundabout alternative will be designed differently than what is shown in the exhibits based on more detailed design criteria, funding, and the appropriate lane configurations requested by the City. Following this report, full intersection designs with proper geometrics, signing, striping, lighting, grading, and landscaping design plans will need to be developed for either alternative. The provided conceptual roundabout sketches will require further modifications for final PS&E plans.**

Figure 59: SR 89 / Ruger Rd Roundabout Exhibit[1]



Note 1: This exhibit is intended for discussion purposes only to compare to the signal alternative. Actual design may significantly vary from the illustration shown.

Figure 60: SR 89 / Side Rd Connector Roundabout Exhibit[1]



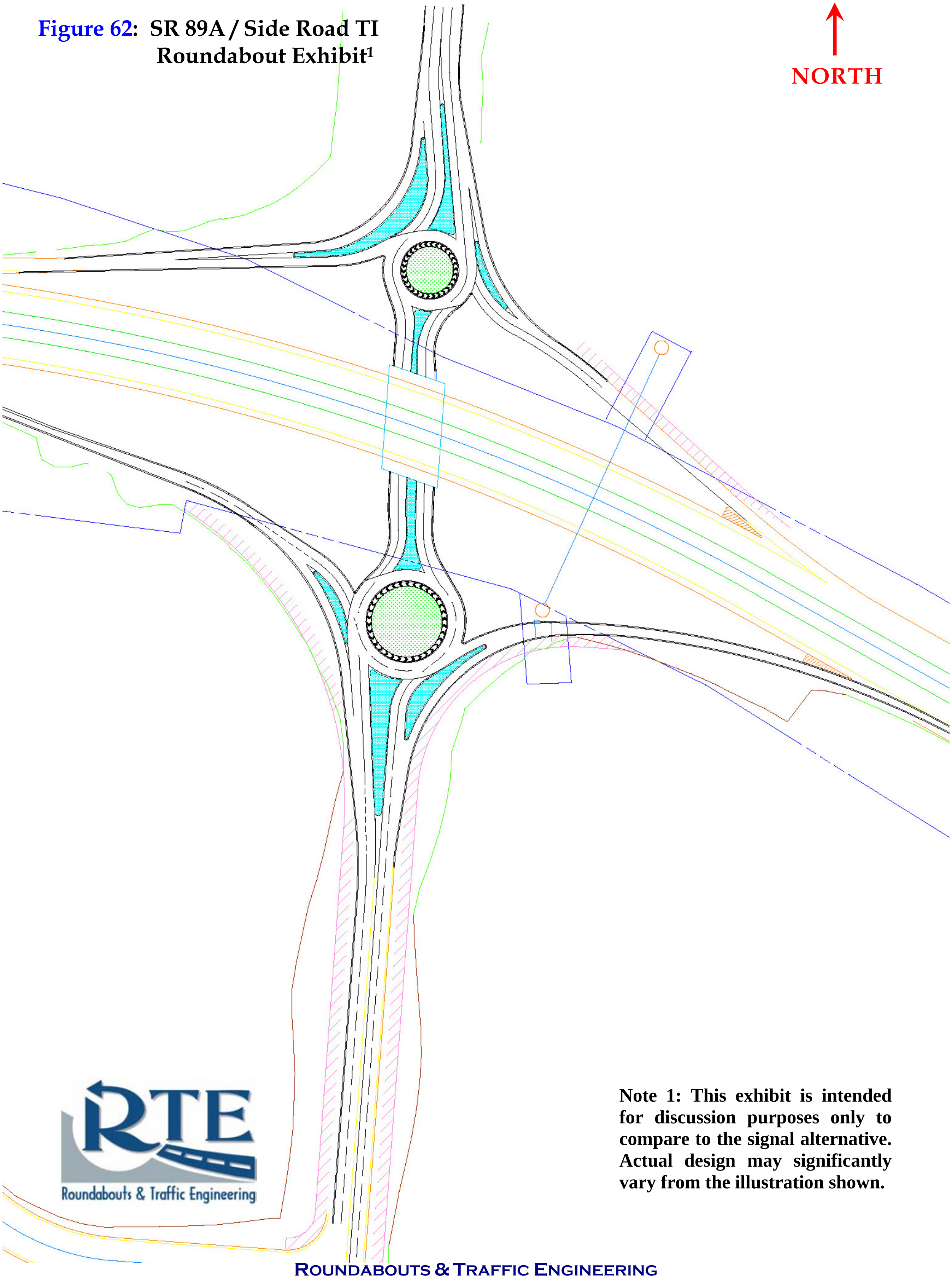
Note 1: This exhibit is intended for discussion purposes only to compare to the signal alternative. Actual design may significantly vary from the illustration shown.

Figure 61: Willow Creek Rd / Park West Roundabout Exhibit[1]

NORTH

Note 1: This exhibit is intended for discussion purposes only to compare to the signal alternative. Actual design may significantly vary from the illustration shown.

Figure 62: SR 89A / Side Road TI Roundabout Exhibit[1]



Note 1: This exhibit is intended for discussion purposes only to compare to the signal alternative. Actual design may significantly vary from the illustration shown.

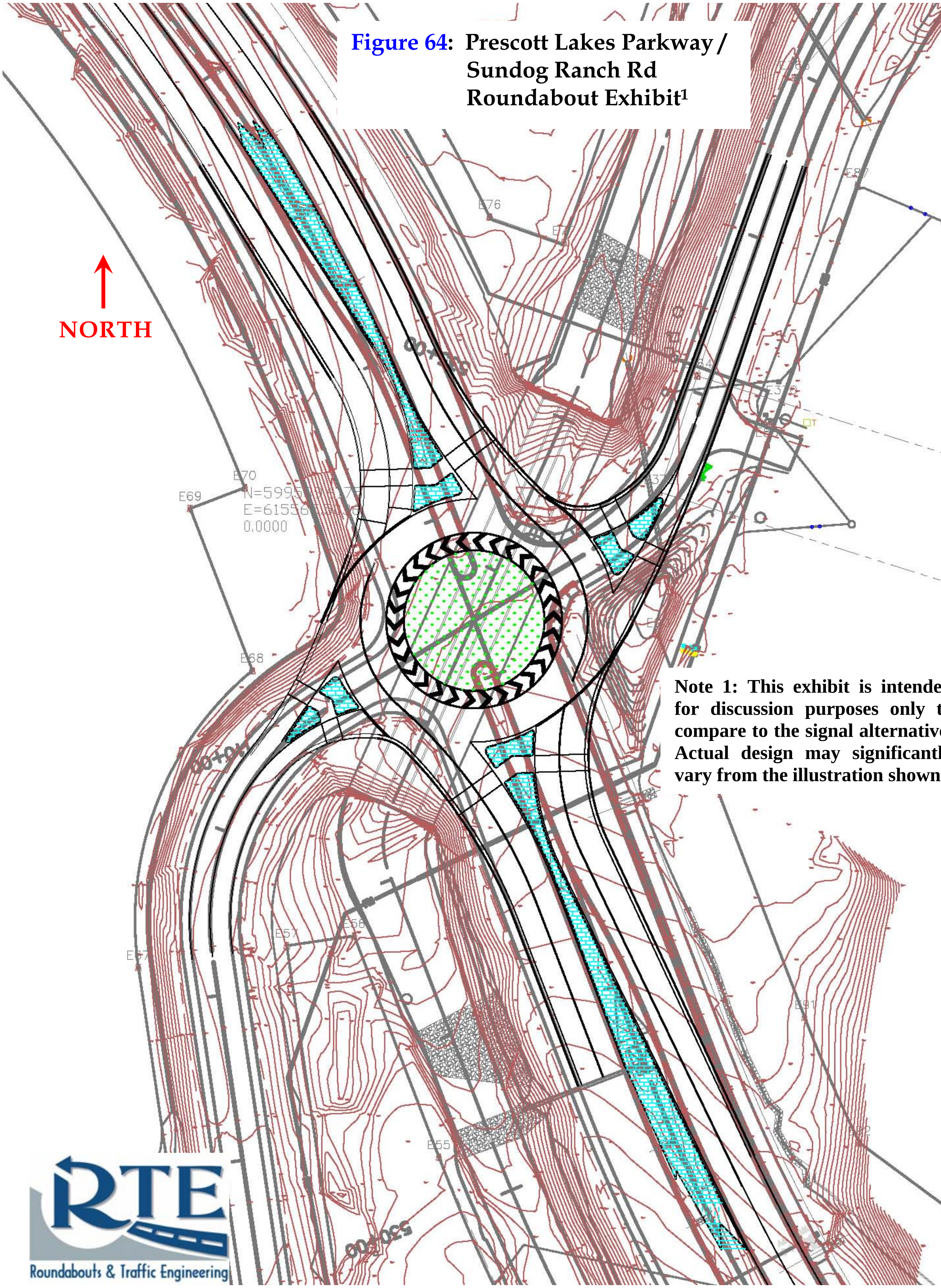
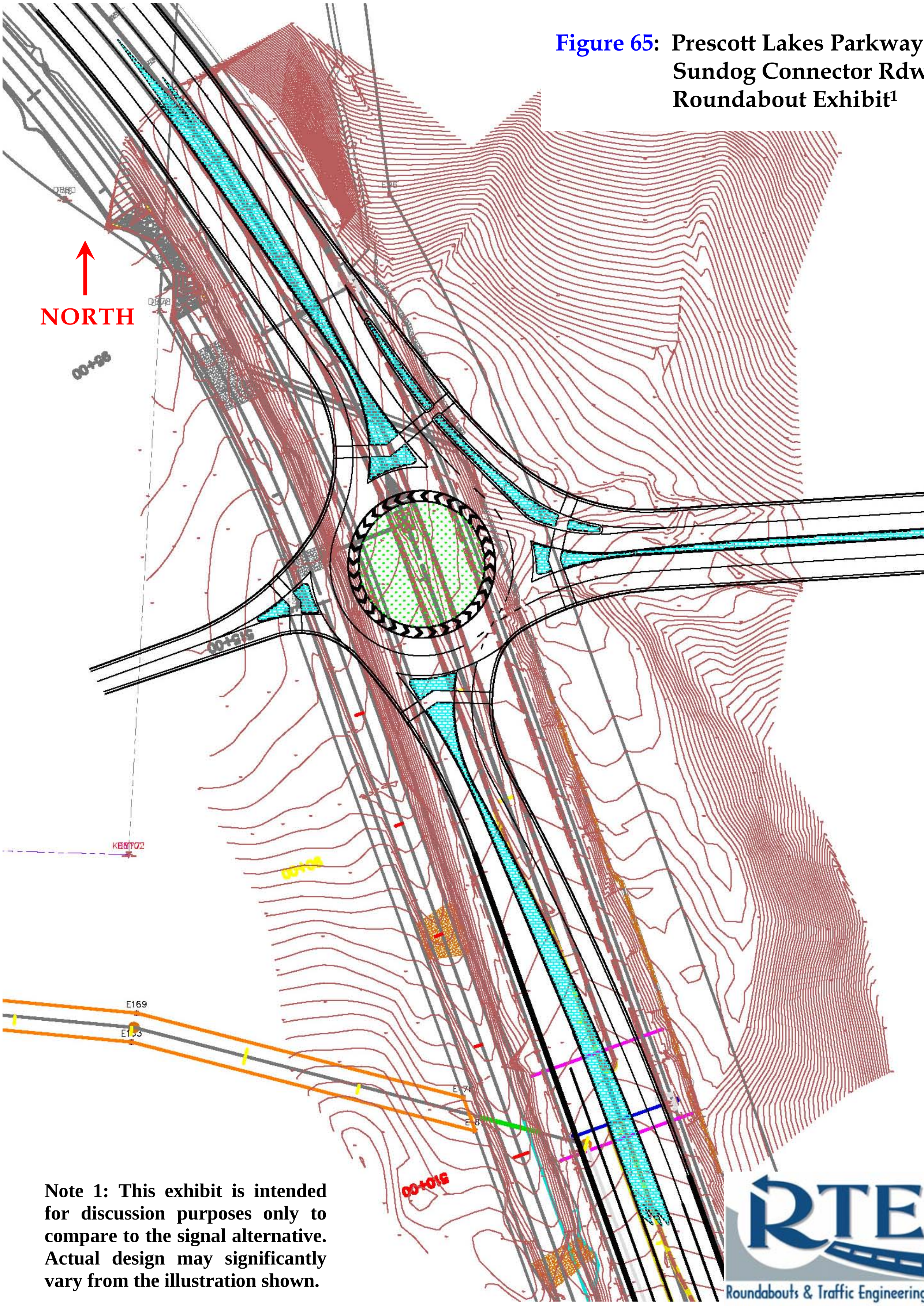


Figure 64: Prescott Lakes Parkway / Sundog Ranch Rd Roundabout Exhibit[1]

Note 1: This exhibit is intended for discussion purposes only to compare to the signal alternative. Actual design may significantly vary from the illustration shown.

Figure 65: Prescott Lakes Parkway / Sundog Connector Rdwy Roundabout Exhibit[1]



Note 1: This exhibit is intended for discussion purposes only to compare to the signal alternative. Actual design may significantly vary from the illustration shown.

V. CAPACITY COMPARISONS

This chapter compares the proposed roundabout alternatives to the proposed signal alternatives. The primary focus for these intersection's capacity analyses has been the ability to reach the anticipated 2030 design year traffic volumes while maintaining a LOS D. In addition, there are other various capacity related issues other than the design year such as the average queuing for the intersection's LOS D design year, the LOS results if the 2030 design year was reached, and average delay per vehicle for the intersection as a whole if the 2030 design year was achieved.

SIGNALS VS. ROUNDABOUTS

Capacity Design Year: **Table 3** illustrates the design year achieved while maintaining a LOS D or better for both the signal and roundabout alternatives for each intersection during the AM and PM peak hours. The actual signal and roundabout capacity analyses were shown in the previous chapter of this report.

As shown in the table below, the modern roundabouts operate significantly superior to the signalized intersections with respect to capacity with a higher achieved design year for all intersections except SR 89 / Ruger Road.

Table 3: Capacity Comparison - Design Year Achieved[1,2]

Underlined Values Denote Wost Case for AM and PM Peak Hour Results

Highlighted Values Identifies Capacity 'Winner'

	Signal		Roundabout[2]	
	AM	PM	AM	PM
SR 89 / Ruger Road	2030	**2027**	2030	**2024**
SR 89 / Side Rd Connector[1]	**2027**	2029	2030	**2030**
Willow Creek Rd / Park West	2025	**2020**	2030	**2022**
SR 89A / Side Rd TI North	2023	**2023**	2030	**2027**
SR 89A / Side Rd TI South	2024	**2019**	2024	**2023**
Prescott Lakes Pkwy / Sundog Ranch Rd[1]	2030	**2029**	2030	**2030**
Prescott Lakes Pkwy / Sundog Connector[1]	2025	**2020**	2030	**2030**

Note 1: Signal Required Additional Turn Lanes Than Roundabout (Not An Equal Comparison)

Note 2: Roundabouts Were Limited to Two-Lane Approaches Only

Source: RTE Prescott Feasibility Tables.xls

The intersection of SR 89 / Ruger Road has an extremely high amount of through movement traffic both northbound and southbound with a relatively low amount of traffic anticipated for Ruger Road in 2030. According to data from the City and ADOT, State Route 89 is functioning with approximately 26,000 Average Daily Traffic (ADT). This volume is anticipated to grow to over 64,000 ADT in 2030. In particular, 3,480 peak hour vehicles would travel northbound, 2,086 southbound, and 292 westbound during the PM peak hour. According to the Highway Capacity Manual's maximum thresholds of saturated vehicle flow rates per lane, a six lane roadway would be required opposed to the analyzed four lane roadway. Hence, if the anticipated 2030 traffic volumes are reached, additional through lanes on mainline would be required for either alternative.

Hence, the results above have exceeded the capacity allowances for a four lane roadway on SR 89 and can be considered optimistic for the SR 89 / Ruger Road intersection. Regardless, the signal theoretically performs better (by three years) than the roundabout during the PM peak hour with respect to capacity.

Capacity (Delay & LOS): For this report, it is unbefitting to compare the LOS and delay since **none** of the signalized intersections could achieve the 2030 traffic volumes during both the AM and PM peak hours. Hence, all of the signalized intersections would function at the City of Prescott's LOS D threshold. In addition, comparing the LOS and delay results between the traffic signals and roundabouts would be inappropriate since each alternative reached different design years. Therefore, a comparison table documenting the delay and LOS results between alternatives will not be tabulated herein. However, the delay and LOS results **based on the design year achieved** are shown in **Tables 1 and 2** in the previous chapter.

Lane Configurations: As stated above, each intersection's planned lane configurations were attempted to match existing conditions, the planned future road conditions as identified by the City, and the comparative lane configurations of the other alternative. However, as mentioned in the previous chapter, some of the signalized intersections required additional lanes to be added above and beyond the roundabout's required lanes or the planned future road conditions since traffic signals typically have mutually exclusive left turn lanes. Likewise, some of the roundabout intersections required additional lanes than typically needed (not required) in an attempt to match the associated signal alternative. **It must be noted that the actual lane configurations to be constructed for the signal or roundabout may differ from the illustrations herein based on more detailed design criteria, funding, and the appropriate lane configurations requested by the City at the time of design.**

The lane configurations between the signal and roundabout alternatives for each intersection can be summarized as follow:

- The ***SR 89 / Ruger Road*** intersection had the same number of approaches for both the signal and roundabout alternatives.

- The ***SR 89 / Side Road Connector*** intersection had **three** southbound lanes (2 through, 1 left) for the signal alternative, whereas the roundabout had **only two** southbound lanes in order to maintain the two lane approach requirement from the City. This is not an equal comparison between the signal and roundabout with the advantage to the signal. Regardless, the roundabout alternative still performed superior over the signal alternative.

- The ***Willow Creek Road / Park West*** intersection had the same number of approaches for both the signal and roundabout. Although the roundabout's northbound right turn lane may not be required in final design, the lane was added to compare the roundabout equally to the signal.

- The ***SR 89A / Side Road Interchange North*** intersection had the same number of approaches for both the signal and roundabout alternatives.

- The ***SR 89A / Side Road Interchange South*** intersection had the same number of approaches for both the signal and roundabout alternatives.

- The ***Prescott Lakes Parkway / Sundog Ranch Road*** intersection had **three** northbound lanes (2 through, 1 left) and **three** southbound lanes (2 through, 1 left) for the signal alternative, whereas the roundabout had only **two** northbound and **two** southbound lanes in order to maintain the two lane approach requirement from the City. This is not an equal comparison between the signal and roundabout with the advantage to the signal. Regardless, the roundabout alternative still performed superior over the signal alternative.

- The ***Prescott Lakes Parkway / Sundog Connector*** intersection had **three** northbound lanes (2 through, 1 left) and **three** southbound lanes (2 through, 1 left) for the signal alternative, whereas the roundabout had only **two** northbound and **two** southbound lanes in order to maintain the two lane approach requirement from the City. This is not an equal comparison between the signal and roundabout with the advantage to the signal. Regardless, the roundabout alternative still performed superior over the signal alternative.

Right-of-Way & Topographical Constraints: Digital base mapping and aerial photography were reviewed by RTE to identify any major existing constraints for either the roundabouts or traffic signal. Based on RTE's preliminary reviews of each location as well as the roundabout sketches in **Figures 59 through 65**, it appears additional right-of-way is generally available for either traffic control alternative. However, some of the study area intersections have topographical constraints that will require further attention in the design phase of the project. The primary issues with each intersection are as follows:

- ***SR 89 / Ruger Road:*** No significant ROW issues were identified for either alternative if the roundabout's southbound bypass lane is not constructed or if the roundabout is moved east. The roundabout's southbound bypass lane could slightly exceed the existing ROW on the west side of SR 89 if it is not moved; however, no impedances are present in the field to prevent the ROW takes. The roundabout alternative will require more "space" at the intersection itself, but not on the approaching roadways; whereas the signal alternative will require more "space" on the approaching roadways, but not at the intersection itself. However, either alternative does not have significant ROW issues.

  No significant topographical issues were identified. Sight distance should be excellent for either the signal or roundabout alternative. With respect to ROW and topographical constraints, both alternatives would function well.

- ***SR 89 / Side Road Connector:*** No severe ROW issues were identified for either alternative. The roundabout's circular roadway will exceed the existing ROW on the west side of SR 89 by approximately 50 feet at it's widest point for a short section of about 250 feet in length for an approximate total of 0.20 acres (8700 square feet); however, no impedances are present in the field to prevent the ROW take. The ROW impacts could be less if the roundabout is moved east.

  The roundabout alternative will require more "space" at the intersection itself, but not on the approaching roadways; whereas the signal alternative will require more "space" on the approaching roadways, but not at the intersection itself. However, the roundabout alternative could have more ROW impacts than the signal.

  The intersection would fall in a sag vertical curve, which is ideal for a modern roundabout due to the visibility of the intersection's geometry. Sight distance appears to be adequate as long as the approaches to either alternative can be created with approximately a 4% grade or flatter within approximately 200 feet of the intersection. A more detailed design could identify a solution. With respect to ROW and topographical constraints, both alternatives would function well.

- ***Willow Creek Road / Park West:*** No severe ROW issues were identified for either alternative. The roundabout's circular roadway could exceed the existing ROW on the west side of Willow Creek Road if the roundabout is not moved east.

  This location may be one location where moving the roundabout east is probable due to the existing retaining wall on the west side of Willow Creek Road (depending on the exact location). The ROW impacts could be less if the roundabout is moved east. As stated above, the roundabout alternative will require more "space" at the intersection itself, but not on the approaching roadways; whereas the signal alternative will require more "space" on the approaching roadways, but not at the intersection itself. The roundabout alternative could have more ROW impacts than the signal.

  Depending on the exact location of the proposed intersection, RTE believes a relatively minor soil "cut" would be needed on the east side of Willow Creek Road. The west side of Willow Creek Road near the intersection has an existing retaining wall that should be avoided. Based on the preliminary sketches of the roundabout intersection, the retaining wall would be impacted unless the roundabout and roadway alignments are shifted east, which is possible.

  In addition, the location of the proposed intersection (roundabout or signal) should be closely evaluated with respect to sight distances since there is a potential concern due to the vertical alignment of Willow Creek Road for either alternative. The City may consider slightly relocating the intersection if the preliminary design phase cannot remedy or identifies any sight distance issues. With respect to ROW and topographical constraints, both alternatives could function well.

- ***SR 89A / Side Road Interchange North:*** This intersection's exact location is still pending and will be determined after the completion of the SR89A/ Side Road Interchange Traffic Report conducted by PARSONS. However, at this preliminary stage, no ROW or topographical issues are known to RTE.

- ***SR 89A / Side Road Interchange South:*** This intersection's exact location is still pending and will be determined after the completion of the SR89A/ Side Road Interchange Traffic Report conducted by PARSONS. At this preliminary stage, no ROW or topographical issues are known to RTE.

- ***Prescott Lakes Parkway / Sundog Ranch Road:*** Although, this existing intersection has significant topographical and existing structure constraints in all four quadrants with the presence of large drainage culverts, guardrail, a bridge deck to the south, and detention basins, no additional ROW would be required for either the roundabout or signal alternative.

  The signal alternative would not require any significant changes to the existing roadway infrastructure on Prescott Lakes Parkway, but significant issues could arise on Sundog Ranch Road. This intersection is ideal for the roundabout alternative due to the existing skewed intersection and topographical constraints.

  RTE's preliminary roundabout sketch identifies the project limits exceeding a very small portion of the existing buildable area in the southeast quadrant (small detention basin present) and the northwest quadrant (vertical / topographical impact of approximately 200 square feet). Similar impacts, if not greater, would also occur with a signal alternative assuming the need of left turn lanes on Sundog Ranch Road.

  Neither alternative should impact the existing drainage culverts under Prescott Lakes Parkway. Small amounts of civil engineering will be required for either alternative in the northwest quadrant with either earthwork or structural needs. The roundabout alternative would impact approximately 200-300 square feet depending on tie-in points to existing grade.

  Concerns arise for the signal alternative on Sundog Ranch Road due to the skewed intersection, guardrail, and peak hour average queues that would form along the sharply curved roadways on both sides of Prescott Lakes Parkway. Sight distances are better suited for the roundabout alternative along Sundog Ranch Road.

- ***Prescott Lakes Parkway / Sundog Connector:*** This future intersection has significant topographical constraints on the east and west sides of Prescott Lakes Parkway. However, either alternative requires construction of the roadways on both sides of Prescott Lakes Parkway. A considerable amount of civil engineering will be required regardless of the alternative for the side streets. It is recommended to try obtain all approaches with approximately a 4% grade or flatter approximately 300 feet east and 100 feet west of Prescott Lakes Parkway. No ROW issues were identified for either alternative.

Sight distances and grades of stopped vehicles may become a significant issue or deterrent for the signal alternative with a 500 foot average peak hour queue northbound and should be a consideration if the signal alternative is elected.

No parking issues were identified at any of the proposed intersections. It does not appear that any proposed intersection, regardless of the alternative, will significantly impact business owners.

The most effective method to compare the right-of-way impacts is to compare the conceptual design exhibits for each alternative. However, the signal design layouts are not included in the scope of work for this feasibility study. If the City of Prescott questions any intersection's ROW constraints or the differences in ROW impacts to the signal alternative, this can be completed as an addendum or supplement to this report by others. No signal alternative appears to exceed ROW limits. Please refer to **Figures 59 through 65** for the preliminary roundabout layouts.

Overall, the signals may have less of an impact on the adjacent right-of-way at the intersections than the roundabouts. However, the traffic volumes that would queue up at the intersections would block existing and future business accesses, which would ultimately have a greater impact on the roadways. The signals are able to utilize the existing lane geometry and can be implemented more easily, with the exception of Sundog Ranch Road. The roundabouts could require minor additional right-of-way acquisitions from some intersections.

Queue Lengths: Queue length comparisons between signals and roundabouts are typically performed in roundabout feasibility studies. However, since this project's feasibility study focuses on the design year achieved, accurate comparisons are difficult to arrive upon conclusions with contrasting years. Hence, both the design year and the queue lengths for the primary road's through movement for each alternative and intersection are shown in **Table 4** below as well as in **Tables 1 and 2** in the previous chapter of this report. Please note these queue lengths are peak hour averages and **not turn lane queue lengths**. Turn lane queue length for the traffic signals are shown in the capacity analysis figures.

Table 4: Queue Comparison[1]

Highlighted Values Identifies Shortest Queue 'Winner'

Intersection - Peak Period	Signal[1] Mainline Through Movement Queue	Signal[1] Max Design Year	Roundabout[1] Mainline Through Movement Queue	Roundabout[1] Max Design Year
SR 89 / Ruger Road - AM	2350'	2030	75'	2030
SR 89 / Ruger Road - PM	2575'	2027	1425'	2024
SR 89 / Side Rd Connector - AM	675'	2027	175'	2030
SR 89 / Side Rd Connector - PM	725'	2029	50'	2030
Willow Creek Rd / Park West - AM	2,225'	2025	1575'	2030
Willow Creek Rd / Park West - PM	1,700'	2020	1275'	2022
SR 89A / Side Rd TI North - AM	2075'	2023	300'	2030
SR 89A / Side Rd TI North - PM	2275'	2023	1450'	2027
SR 89A / Side Rd TI South - AM	925'	2024	1175'	2024
SR 89A / Side Rd TI South - PM	750'	2019	1175'	2023
Prescott Lakes Pkwy/Sundog Ranch Rd - AM	775'	2030	125'	2030
Prescott Lakes Pkwy/Sundog Ranch Rd - PM	1175'	2029	75'	2030
Prescott Lakes Pkwy/Sundog Connector - AM	450'	2025	100'	2030
Prescott Lakes Pkwy/Sundog Connector - PM	475'	2020	175'	2030

Note 1: Signal & Roundabout Years May Not Be The Same Year (Not An Equal Comparison - Favor Towards Signal)

Source: RTE   Prescott Feasibility Tables.xls

Typically, roundabouts have significantly less queue buildup than traffic signals since roundabouts provide a continuous traffic flow pattern. The roundabout and traffic signal capacity analyses output figures (**Figures 30 through 43** and **Figures 45 through 58**) show the average peak hour queue lengths (in vehicles). This data was converted into feet assuming 25 feet per vehicle and transferred to **Tables 1 and 2**. Therefore, based on the capacity calculations in the previous chapter, the following average queue length summary information can be provided for the roundabout and signal analyses.

As shown above, despite the fact that the roundabout and signal years do not match for most of the intersections (with the advantage or lower year favoring the signal), the roundabout queue lengths are significantly shorter for all intersections with the exception of the SR 89A / Side Road TI South intersection.

Depending on the design alternative selected by the City for each intersection, the design queue lengths should be reevaluated to determine if any access issues and queues between intersections would occur for either alternative based on the design phase's traffic volumes. The design traffic volumes may be different than those reported herein since this feasibility report analyzes the worst case scenario at each intersection and the worst case design year.

Capacity Comparison Summary: In summary, there are demonstrated capacity benefits for the modern roundabout operations versus the signalized alternative at all intersections. Even though the SR 89 / Ruger Road intersection theoretically could function to a higher year as a signal opposed to a roundabout, the queue lengths that would form at the signal would backup into the SR 89 / Willow Creek Road intersection and all those intersections in between; whereas, the roundabout would not.

This can mostly be explained by the basic operational characteristics of a signal versus a roundabout. A signal requires traffic flows to stop and wait for the permission of the traffic signal to move forward, whereas the roundabout has continuously flowing traffic with yield conditions to approaching vehicles. The approaching traffic flow is only required to search for an available gap in the traffic stream of the roundabout's circulating roadway, which will occur quite frequently with the yielding approaches and since the traffic flows have separate turning movements.

Since the decision making for the driver to enter the roundabout is based on driver judgment, similar to a four-way stop controlled intersection, for only a right turn movement, the natural driver behavioral instinct occurs at the yield line, which is different for every type of driver (aggressive, passive, etcetera). Hence, adequate gaps for conflicting traffic movements automatically form in the roundabout and all traffic continues to flow with minimal delay, relatively slow vehicular speeds, and a high amount of safety. In most studied cases, slowing all traffic at an intersection with continuous flow has been proven to provide faster travel times for a corridor than stopping selected phases or approaches.

RTE encourages discussions on each topic above in more detail with the City. However, with respect to this report's capacity analyses, all of the six locations (seven intersections) would function better with roundabout control than signalized control based on the data provided and the analyses conducted herein.

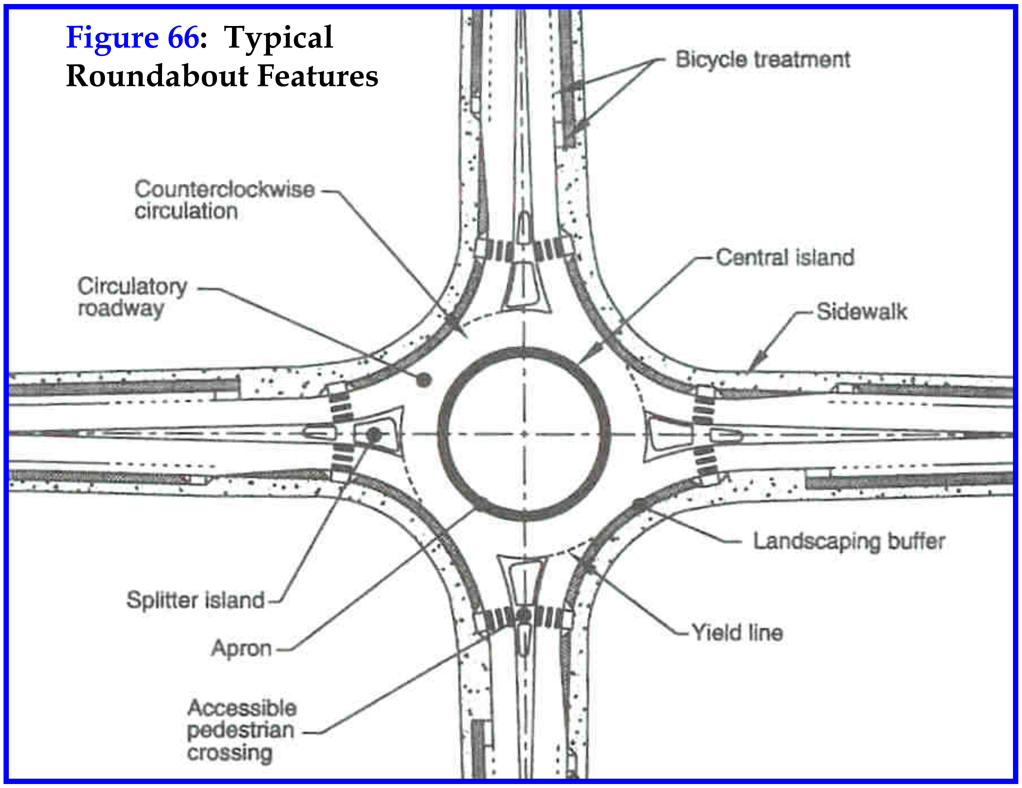
SAFETY COMPARISONS

The previous chapters analyzed the capacity requirements of both a traffic signal and a modern roundabout at each intersection and provided conceptual design illustrations. The previous section demonstrated the capacity comparisons between the two alternatives. This chapter discusses the safety considerations and comparisons between roundabouts and signalized intersections as well as the function of the high amount of pedestrians at the intersections.

GENERAL ROUNDABOUT INFORMATION

Modern roundabouts are a type of circular intersection with specific design and traffic control features to control driver behavior. **Figure 66** identifies key modern roundabout features[3] required in roundabout design. Some of these features include yield control for entering traffic, channelized approaches, and a geometric design that ensures travel speeds are relatively low and safe. Modern roundabouts are unique from other circular intersections in that they use *splitter islands* (or curved medians) and physical geometry (raised concrete curb) to control and slow the speeds of vehicles entering the roundabout and traveling

Figure 66: Typical Roundabout Features



[3] U.S. Department of Transportation, Federal Highway Administration, *Roundabouts: An Information Guide,* 2000

through the roundabout. The splitter islands help control speeds, guides drivers into the roundabout, physically separate entering and exiting traffic streams, significantly increases intersection safety, deters wrong-way movements, and provides safe pedestrian crossings. Modern roundabouts are designed and sized to accommodate specific design speeds, traffic flows, and large design vehicles.

Roundabouts improve the safety of an intersection through the introduction of a raised island in the center of the intersection and the conversion of all movements through the intersection to right turns thus eliminating vehicle-to-vehicle crossing conflicts.

The horizontal and vertical geometry of a roundabout is crucial to the operation and safety of the roundabout. Since the capacity of a roundabout is dependent on the turning movement volumes at each approach, the capacity or RODEL analyses completed above identified the required lane geometry and the number of entries required for the design. As depicted in the RODEL analyses, the geometric design is identified only with respect to the capacity of the entry lanes. The safety factors of each design's geometry now become the primary concerns for the operational adequacy of the roundabout. The "body language" of the roundabout directly relates how comfortable and safe drivers will use the roundabout. The body language of the roundabout must adequately communicate to the driver in order to avoid accident problems.

The geometric analysis of a roundabout evaluates the geometric parameters that affect roundabout **capacity and safety**. However, for the purposes of this feasibility study, the capacity and safety of the roundabout have been divided into separate sections for ease of reader comprehension. The geometric safety design includes the design of fast path speeds and speed consistency within the roundabout design. The roundabout designs also consider other safety parameters such as vehicle deflection into the roundabout, splitter island design, crosswalk locations and the ability of the design vehicle to negotiate the roundabout.

In addition, a large part of roundabout design involves specific non-geometric details such as the roundabout's signing, striping, and lighting of the roundabout. These intersection locations have not progressed to this level of detail yet. However, many other proposed roundabout features were analyzed during the roundabout designs.

The design of roundabout entries and exits is an intricate and complicated procedure that involves numerous variables that need to be addressed to ensure a safe design and adequate capacity. Some of these variables include the following:

- Entry Width
- Entry Flare
- Entry Angle
- Entry Radius
- Entry Deflection
- Entry Path Curvature
- Entry Path Overlap
- Entry Speeds
- Fast Path Speeds
- Speed Consistency
- Sight Distance
- Exit Path Overlap
- Entry and Circulating Visibility
- Splitter Island Design
- Exit Lanes and Geometry
- Pedestrian Crossings/Crosswalks
- Maneuverability of Large Trucks
- Vertical Design Parameters

SAFETY COMPARISONS (RESEARCH FACTS & STATISTICS)

The best method of comparing traffic signals to roundabouts is through "before" and "after" case study results with respect to roundabouts compared to other types of stop controlled and signalized intersections. The Insurance Institute for Highway Safety (IIHS) performed a study[4] titled *Crash Reductions Following Installation of Roundabouts in the United States* in 2000 on 24 U.S. intersections that had converted both signalized intersections and stop-controlled intersections to modern roundabouts. Similarly, the Institute of Transportation Engineers (ITE) also completed a related study[5] in 2002. The US Department of Transportation, Federal Highway Administration (FHWA) also produced *Roundabouts: An Information Guide* in 2000 with safety statistics contained. All of these studies revealed very consistent "before" and "after" results with respect to the safety of modern roundabouts compared to other types of stop controlled and signalized intersections. The following is a brief summary of these results with regard to the extent to which modern roundabout conversions improved the accident safety of the intersections:

- 38 - 40% average reduction in all crash types
- 74 - 78% average decrease in injury accidents
- 90% average decrease in fatalities or incapacitating injuries
- 30 - 40% average decrease in pedestrian accidents (depending on the roundabout location and existing pedestrian volumes)
- As much as a 75% reduction in delay where roundabouts replaced traffic signals

[4] IIHS, Status Report, 5/13/2000

[5] ITE Journal, September 2002

The FHWA information guide on roundabouts states that accident frequency and severity is less for a roundabout than a traffic signal. These study results replicate the results of numerous other studies conducted on roundabouts in Europe and Australia and provide quantitative evidence that the selection of a roundabout over the more conventional intersection geometrics and traffic control can have significantly positive traffic safety implications. Studies completed in England have revealed that the total number of pedestrian accidents with vehicles at roundabouts is lower than that of other intersection types by 33 to 54 percent. Norway has also indicated in several studies over the years that roundabouts have provided a 73 percent reduction in pedestrian crashes at intersections converted to roundabouts.

The unaware person typically asks why roundabouts are safer than traffic signals. The following bulleted list of items provides these answers as well as further discussions and illustrations below:

- Roundabouts have fewer conflict points for vehicles, pedestrians, and cyclists. The potential for many hazardous conflicts, such as right-angle accidents and conflicting left turn head-on crashes, are eliminated with modern roundabouts.
- Speeds at roundabouts are significantly lower (average of 22 mph) than other types of crossings, which allows drivers more time to react to potential conflicts.
- There is a lower speed ***differential*** between the users of roundabouts (e.g. vehicles to pedestrians to cyclists) since the road users travel at similar speeds through the roundabout.
- Lower speeds and speed differentials between users of roundabouts significantly reduces the accident severity if an accident occurs.
- Pedestrian crossings at roundabouts are much shorter in distance and entails interruption in only one direction of the traffic stream at a time. Since conflicting vehicles arrive in one direction only to the pedestrians, the pedestrians need only to check to their left for conflicting vehicles. In addition, the speed of the vehicles in the roundabout at entry and exit are reduced with a proper roundabout design.

The following are some facts on traffic signals, red light running, and roundabouts:

1. In 2002, more than 1.8 million intersection crashes occurred throughout the nation. Of those crashes, about 219,000 are due to red light running; resulting in about 1,000 deaths and 181,000 injuries. (*Insurance Institute for Highway Safety, IIHS, and Federal Highway Administration, FHWA, 2003*)

2. A study conducted by the Insurance Institute for Highway Safety (IIHS) in 2003 found that at a busy intersection in Virginia, a motorist ran a red light every 20 minutes. During peak commuting times red light running was more frequent.

3. Researchers at the IIHS studied police reports of crashes on public roads in four urban areas. Of thirteen crash types identified, violating traffic control devices accounted for 22 percent of all crashes. Of those, 24 percent were attributed to red-light-running.

4. According to a survey conducted by the U.S. Department of Transportation and the American Trauma Society, two out of three Americans see someone running a red light at least a few times a week and, at most, once a day. (1998)

5. One in three Americans knows someone who has been injured or killed in a red light running crash. (FHWA, 2002)

6. Research from the IIHS illustrates far fewer crashes occur at intersections with roundabouts than at intersections with signals or stop signs. Modern roundabouts are substantially safer than intersections controlled by stop signs, traffic signals or traffic circles.

7. Compared to the former traffic circle or rotary, the majority of modern roundabouts have excellent safety performance mostly due to their small diameter, slower circulating speeds, flared approach, deflection, and yield control entrances. Studies from around the world have shown modern roundabouts typically reduce crashes by 40 to 60 percent compared to stop signs and traffic signals. They also typically reduce injury crashes by 35 to 80 percent and almost completely eliminate fatal and incapacitating crashes.

Roundabouts are self-regulating traffic control devices that automatically control driver speeds. Lower speeds at roundabouts, compared to traffic signals, directly relates to intersection safety. To elaborate on this concept, lower speeds on a roadway or at an intersection equate to shorter braking distances. The following bar chart (**Figure 67**) demonstrates a comparison of traffic signals to roundabouts based on braking distance and driver perception/reaction distances for braking.

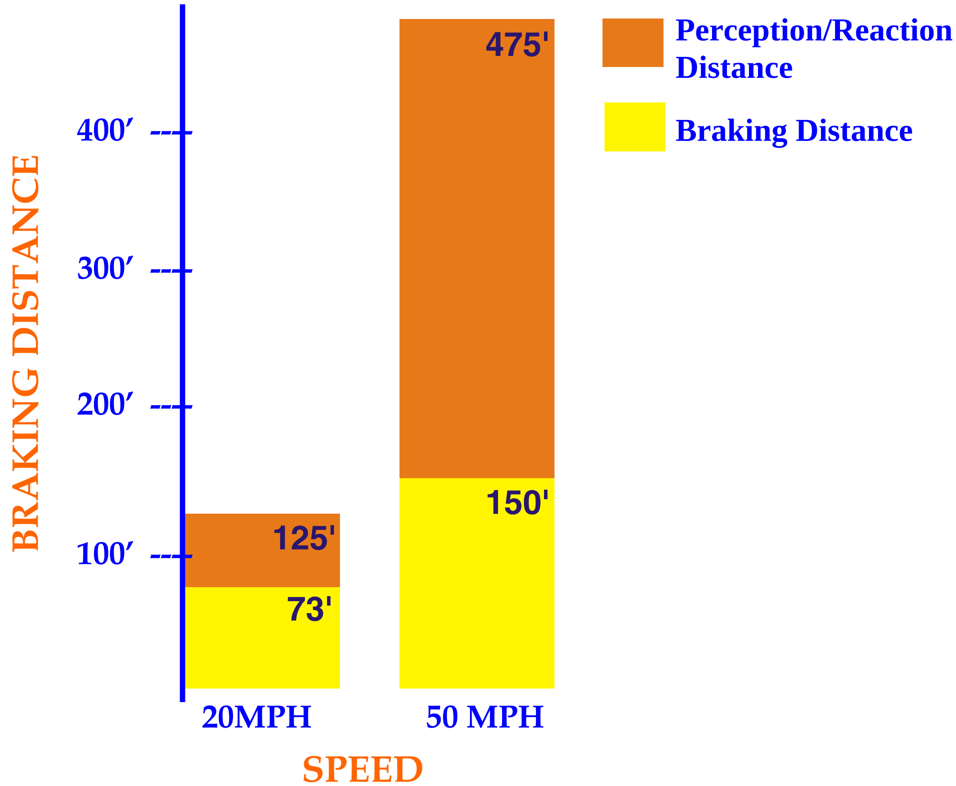


Figure 67: **Braking Distances & Speeds**

As mentioned above, since the speeds at roundabouts are significantly lower with a lower speed differential between the users of roundabouts, this significantly reduces the accident severity of collisions at roundabouts. Figure 68 illustrates the accident severity of collisions at roundabouts versus traffic signals based upon vehicle speeds. As shown in the chart below, roundabouts will have a lower accident severity rate than that of traffic signals. Hence, there will be less injuries and fatalities at roundabouts than signals as well as other types of intersections. The statistics discussed above or the "before" and "after" field studies verify this reality.

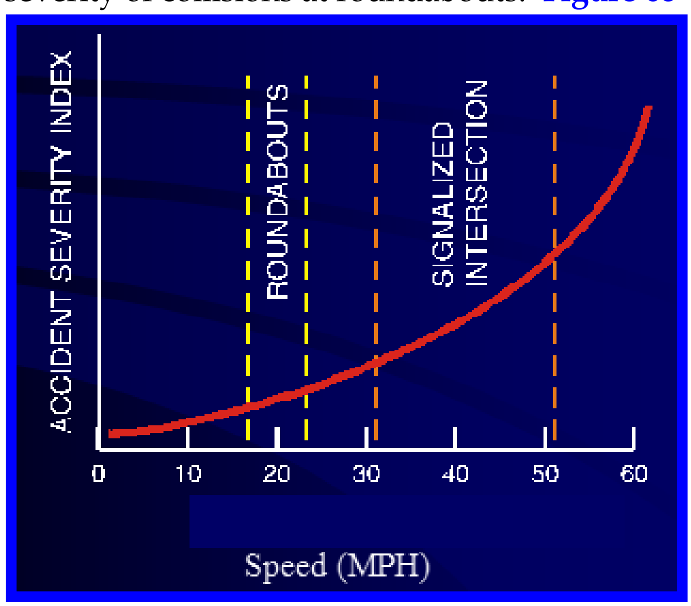


Figure 68: **Accident Severity & Speeds**

Another reason why roundabouts are safer types of intersections are the reduced number of conflict points at a roundabout versus a signal. The following illustrations (Figures 69 and 70) show the number of vehicle-to-vehicle (black dots) and vehicle-to-pedestrian (white dots) conflicts at a roundabout and signal.

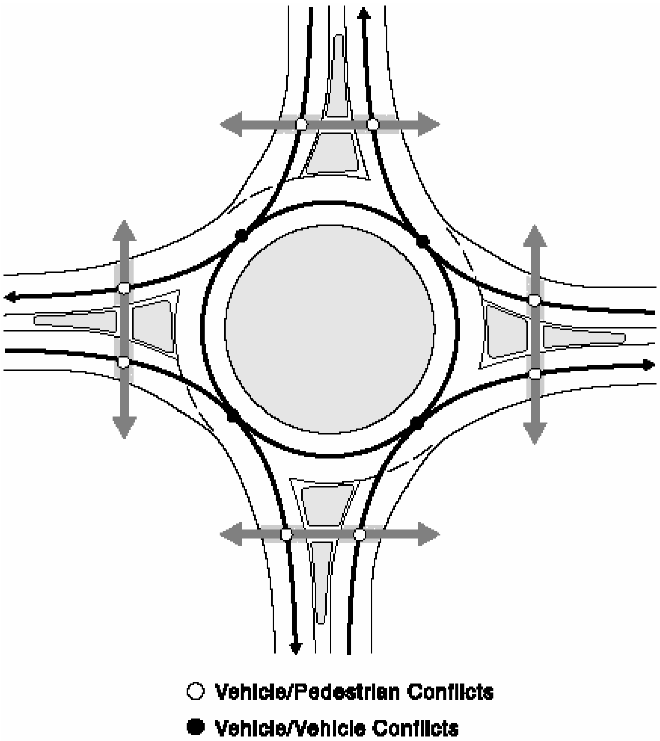


Figure 69: Roundabout Points of Conflict

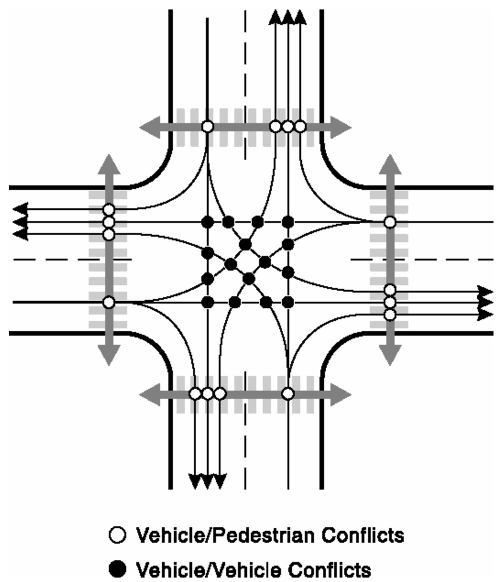


Figure 70: Signal Points of Conflict

As shown above, there are more vehicular and pedestrian points of conflicts at a signalized intersection than a roundabout. This solves the question in a very basic way of why roundabouts are safer than a signalized intersection.

In addition to a significant reduction in traffic accidents, roundabout installation can generate reductions in delays and associated air emissions, improve intersection capacity and pedestrian travel, reduce intersection improvement costs and associated operation and maintenance costs, and can be a key element in improving the visual quality of roadway corridors and town centers.

In general, if roundabouts are designed by a qualified roundabout specialist, the modern roundabout will function as a self-regulating traffic control device that offers numerous capacity, safety, aesthetic, and often cost benefits to a community and/or public jurisdiction.

EMERGENCY VEHICLES

With respect to operational safety, the traffic signal should have pre-emption for emergency vehicles to pass through the intersection. Once the intersection clears of traffic (usually taking a few moments to turn from green to yellow to red followed by vehicles needing to exit the intersection) and assuming no traffic run the red light or stop in the middle of the intersection, the emergency vehicle could pass through the intersection with a relatively high degree of safety with respect to traffic signals. The emergency vehicle could then make any turn necessary to proceed to an incident.

A notable concern is when an emergency vehicle decides to create the new green phase (stopping other traffic). It is common, with the sudden phase change tripped seconds after a green light has been shown to a stopped phase of traffic waiting at the signal, that confusion to pedestrians and drivers occurs with their sudden termination of phase or drivers being unaware that their phase has turned red in such a short time. However, the sirens, lights, and horn of the emergency vehicle usually are sufficient warning regardless of the sudden change from green to red at the signal to stop drivers from running a red light with the short time of a green light. It is also required by law to stop at all red lights (despite the statistics showing 24% of all accidents at signals are red light runners).

There are operational concerns if traffic stops in the intersection as emergency vehicles enter. Stopped traffic in the intersection may hinder the emergency vehicle's ability to maneuver through the intersection since the traffic may not be aware of which direction the emergency vehicle needs to travel.

However, the roundabout would not require any special phasing, pedestrian or design modifications, or special traffic control features at the intersection. All traffic and drivers are already anticipating to yield to circulating traffic in the roundabout and thus are anticipating a reduced speed if not a brief stop condition at the intersection. Similar to the signal, the emergency vehicle would sound its sirens, horn, and lights while approaching the roundabout. By law, all approaching traffic at the roundabout must yield to vehicles in the roundabout (circulating). However, unlike the signal, the geometry of the roundabout (right curb faces, splitter islands, and the central island) enforces and forces the speed for all traffic to slow down at the intersection to a near maximum of 25 miles per hour at entry and 15 miles per hour circulating the roundabout. This significantly decreases the likelihood of accidents with vehicles and the entering emergency vehicle. The emergency vehicle would traverse the roundabout or truck apron in the same direction as traffic (counterclockwise).

The only conflicting movements with the emergency vehicle after entering the roundabout are any remaining traffic in the circulating roadway, with a driver choice to either exit the roundabout or pull over. All approaching traffic to the roundabout would be required to yield to the emergency vehicle now in the circulating roadway. The emergency vehicle would enter the roundabout with the same movements as normal traffic using the intersection and proceed around the roundabout (counterclockwise) to whichever exit or direction the emergency requires.

The roundabout would operate safer than the signal with respect to the emergency vehicle making the same anticipated movements as a vehicle using the intersection. This reduces driver and pedestrian confusion and allows traffic to proceed around the roundabout as normal. The addition of sirens and lights increases traffic safety with a stopped/yielded condition of other traffic at the yield line and nearly guarantees emptying of the roundabout.

In the event of traffic stopping within the circulating roadway of the roundabout (uncommon), the emergency vehicle may also use the truck apron of the roundabout to bypass any stopped traffic or incidents. This can be shown in video clips taken by RTE. Vehicular traffic is relatively undisturbed with little driver frustration once the emergency vehicle passes and can continue to operate normally. The emergency vehicle has access anywhere to any direction, including u-turn options within the roundabout.

<u>Other Site Comparison</u>: Since emergency vehicle operations are a common question for communities with a new roundabout, additional field data is provided below. For data comparison, RTE has provided an example of a fire station in a similar setting located approximately 180 feet from a modern roundabout. Initially, the City and fire personnel were concerned of installing a traffic signal at the intersection of Hamilton Drive / Wilson Street due to the same issues identified above (the short distance between the fire station driveway and the signalized intersection causing potential problems with stopped vehicles and long queues blocking the driveway access to the fire station). However, the City of Hamilton (Village of Ancaster) decided to install a modern roundabout to eliminate and reduce the potential safety and access issues with the fire station. The images below (**Figures 71** and **72**) show illustrations of the intersection before and after construction. The after construction photo was taken from the roof of the fire station.

Figure 71: Before Roundabout

Figure 72: After Roundabout

The roundabout opened in 2002 with extremely positive comments from the city and fire department on the operations of the intersection as a roundabout. The fire department has commended the easy emergency vehicle operations, lack of delay at the intersection, and fast emergency response times. In addition, the fire station has installed a web-cam on the Internet of live operations of the roundabout on the radio tower pole on top of the fire station. An aerial photo of the site is shown in **Figure 73**.

Figure 73: Fire Station Near Roundabout

The roundabout allows the emergency vehicles to proceed in any direction, as needed. Please contact Scott Ritchie with RTE to obtain more information on emergency vehicles at roundabouts.

There are also other locations where emergency response personnel and stations have embraced the modern roundabout as a preferred solution to public safety and response times. The illustration below in **Figure 74** shows a fire station being implemented on a modern roundabout itself in Chico, California.

Figure 74: Fire Station on Roundabout in Chico, CA

Regarding the original case study in Ancaster, speed studies[6] were also performed along the Wilson Street Corridor as well in the roundabout itself to test the operational performance of the effects of the roundabout before and after installation as well as to test the predicted design speeds of the roundabout before construction to the actual speeds of traffic after construction.

As a result of these studies it was shown that the 85th percentile speeds as well as the highest speeds through the roundabout and along the Wilson Street corridor (see **Figures 75** and **76** for the locations of the speed survey points) were all reduced substantially and lower than the fastest path design speeds predicted. Please refer to Scott Ritchie's *High Speed Approaches At Roundabouts* published by the Transportation Research Board in 2005 for more detailed results and data.

[6] High Speed Approaches At Roundabouts, Scott Ritchie, P.E., Roundabouts & Traffic Engineering, 2005, Published By the Transportation Research Board and Presented At The International Roundabout Conference in Vail, 2005.

Figure 75: Speed Study Locations at Roundabout

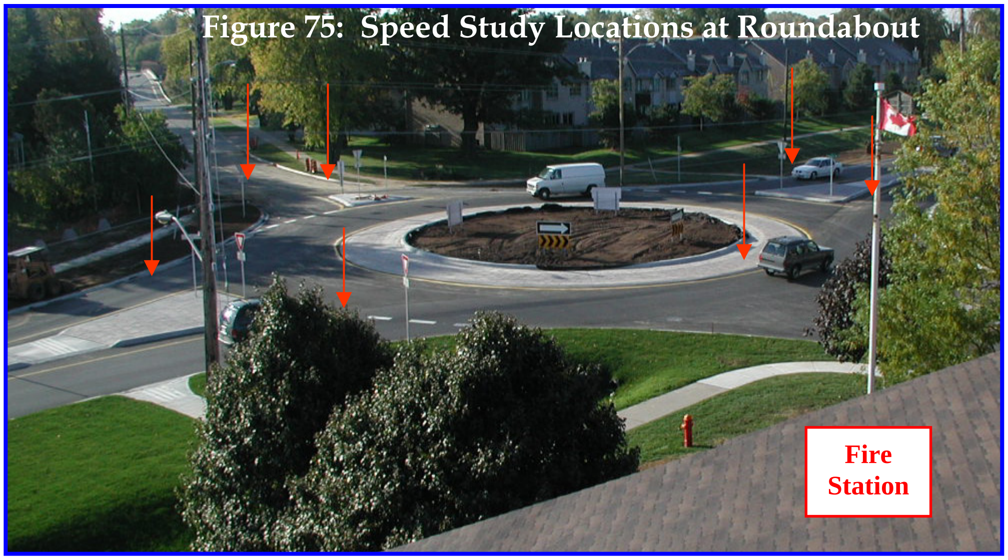
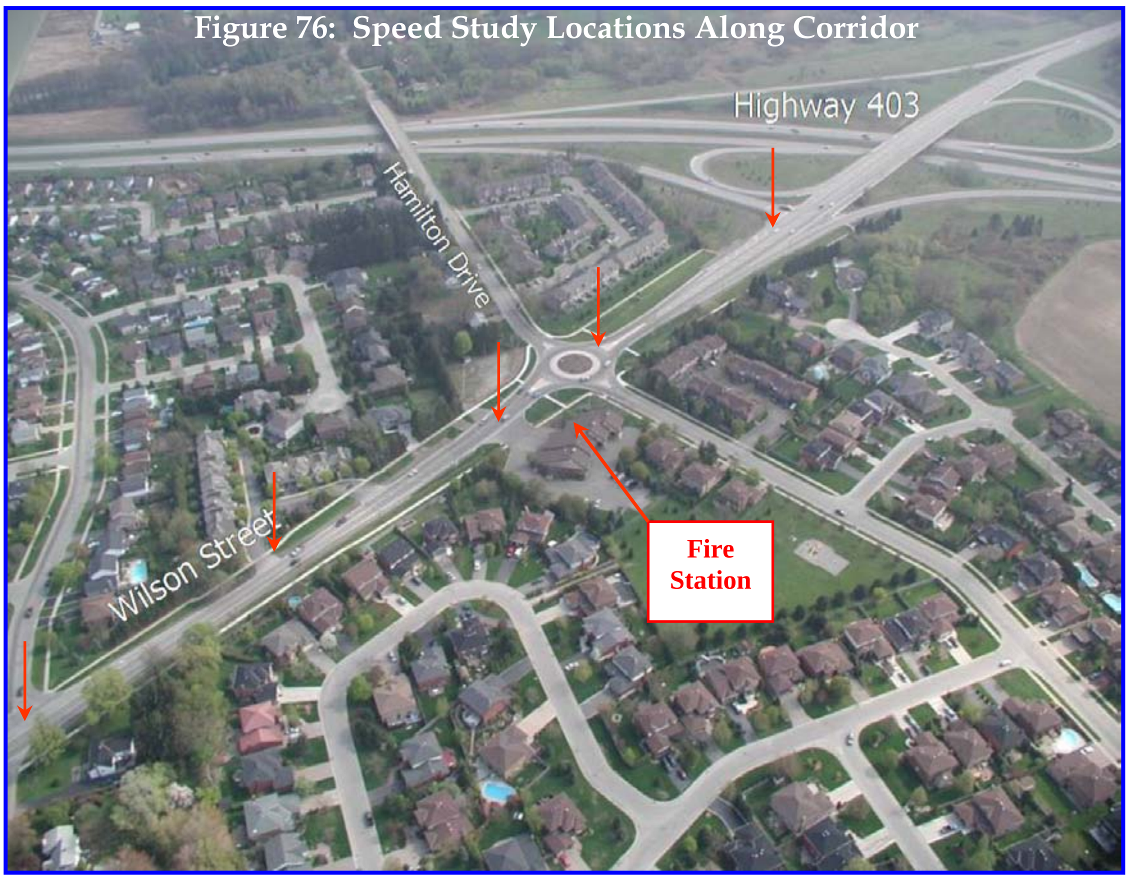


Figure 76: Speed Study Locations Along Corridor



CASE STUDY: MARYLAND STATE HIGHWAY ADMINISTRATION [7]

Within the later part of the past decade the Maryland State Highway Administration has implemented modern roundabouts to resolve a number of traffic engineering and urban design dilemmas. Edward Myers published a report *Accident Reduction with Roundabouts* with accident statistics at five sites where the Maryland State Highway Administration (MSHA) has installed modern roundabouts. All of the roundabout sites can be classified as high-speed rural locations. The following intersections were analyzed in the study:

1. MD 94 / MD 144, Howard County (Lisbon Roundabout)
2. MD 63 / MD 58-MD 494, Washington County (Cearfoss Roundabout)
3. MD 213 / Leads Road- Elk Mills Road, Cecil County (Leeds Roundabout)
4. MD 2 / MD 408-MD 422, Anne Arundel County (Lothian Roundabout)
5. MD 140/ MD 832-Antrim Blvd., Carroll County (Taneytown Roundabout)

The accident data was gathered three years before as well as three years after the roundabouts were installed. The before and after accident results are shown in the summary table below (Reference A) by accident type. The table also shows the reported average annual accidents and the injury crash rates three years before and three years after construction of the roundabouts.

REF. A: Maryland Before & After Accidents

3 Years Before and After Data for All Roundabouts

	Lisbon Roundabout		Cearfoss Roundabout		Leads Roundabout		Lothian Roundabout		Taneytown Roundabout	
Crash Type	Before	After	Before	After	Before	After	Before	After	Before	After
Angle	23	3	6	2	8	2	13	1	12	0
Rear-End	0	1	1	0	1	0	2	8	2	1
Sideswipe	1	0	0	0	0	1	1	0	1	0
Left-turn	0	1	1	0	1	0	8	0	1	0
Opposite Direction	0	0	0	0	0	0	1	0	1	0
Single Vehicle	0	10	1	0	0	14	0	3	2	2
Overturned	0	0	0	0	0	0	0	1	0	0
Avg. Annual Crashes	**7.4**	**2.3**	**3.0**	**0.67**	**3.9**	**3.2**	**8.2**	**4.1**	**5.3**	**1.25**
Avg. Injury Crashes	**4.3**	**0.53**	**0.78**	**0.29**	**0.78**	**0.29**	**5.4**	**1.25**	**2.8**	**0.42**

Source: Accident Reduction With Roundabouts, Myers *RTE High Speed Approach Tables.xls*

[7] High Speed Approaches At Roundabouts, Scott Ritchie, PE, RTE, 2005, Published By The TRB

In addition, the report used statistics for average accident costs compiled by the MHSA to determine the average cost per accident at each intersection location in both the before and after conditions. The next table (Reference B) presents a summary of the accident severity comparison of the intersections before and after the roundabouts as reported in the *Accident Reduction with Roundabouts* study.

REF. B: Maryland Accident Severity Comparison

3 Years Before and After Data for All Roundabouts

Crash Type	Number Of Accidents Before	Number Of Accidents After	Average Accident Cost	Total Accident Cost Before	Total Accident Cost After
Angle	62	8	$125,971	$7,810,202	$1,007,768
Rear-End	6	10	$80,231	$481,386	$802,310
Sideswipe	2	1	$60,819	$121,638	$60,819
Left-turn	11	1	$95,414	$1,049,554	$95,414
Opposite Direction	1	0	$307,289	$307,289	$0
Single Vehicle	3	20	$59,851	$179,553	$1,197,020
TOTALS	**85**	**40**	**3.0**	**$9,949,622**	**$3,163,331**

Source: Accident Reduction With Roundabouts, Myers *RTE High Speed Approach Tables.xls*

VII. COST COMPARISONS

This chapter compares the proposed roundabout alternatives to the proposed signal alternatives with respect to the general cost related issues for each intersection. The City of Prescott derived both the signal and roundabout costs based on general costs from other signal and roundabout projects. These costs are not detailed engineering cost estimates, rather initial rudimentary costs for feasibility study purposes and do not include right of way acquisition costs.

CONSTRUCTION COST ESTIMATES OF ALTERNATIVES

Although the costs for both the signal and roundabout alternatives are undeveloped, the cost estimates are based on the capacity calculations derived above, the conceptual intersection exhibits of each intersection, and the currently available unit costs. The City of Prescott provided the cost estimates for both intersection alternatives. **Table 5** summarizes the total construction costs for both alternatives for each intersection. As shown, the estimated project costs for the signal alternatives are lower than the anticipated roundabout alternative costs for nearly every intersection.

Table 5: Cost Comparison[1,2]

Highlighted Values Identifies Lowest Cost 'Winner'

Intersection	Signal[1]	Roundabout[1]
SR 89 / Ruger Road	$690,000	$950,000
SR 89 / Side Rd Connector	$840,000	$920,000
Willow Creek Rd / Park West	$830,000	$1,110,000
SR 89A / Side Rd TI North	N/A	$1,050,000
SR 89A / Side Rd TI South	N/A	$1,050,000
Prescott Lakes Pkwy/Sundog Ranch Rd	$695,000	$746,000
Prescott Lakes Pkwy/Sundog Connector	$1,100,000	$1,310,000

Note 1: The Cost Values Herein Are Rudimentary Cost Estimates Only Derived From Other Local Projects Which May or May Not Have Similar Sizes, Constraints, or Backgrounds. Actual Construction Costs May Vary Significantly. These Undeveloped Costs Are For Feasibility Study Purposes Only.

Note 2: The Estimates Herein Do Not Include Right of Way Acquisition Due to Uncertainty of Development Arrangements.

Source: RTE — Prescott Feasibility Tables.xls

Considering all of the projects cumulatively, the signal alternatives would provide approximately a 20% average cost savings at initial construction. However, this does not include maintenance costs, emergency services' pre-emption devices, or cost-safety impacts of the signal alternatives. It should be noted that additional costs might occur for any scenario and estimate.

MAINTENANCE COSTS

Traffic signals require ongoing maintenance costs for the signal poles, controller cabinet, loop or video detectors, signal heads, emergency vehicle pre-emption devices, fiber optic / coordination systems, or the like. These costs typically add up to an annual average of $5,500 per year per signal. Roundabouts typically do not incur such maintenance costs unless annual flowers or foliage need replacement or upkeep in the central island or outside the roundabout. The required obstructions in the roundabout designs can usually be accommodated with perennial foliage, statues, native plants/trees, or rocks that requires little to no maintenance, as seen at the existing SR 89 / Willow Lake Road roundabout in Prescott. Other costs, such as curb/pavement repair and lighting maintenance are similar between the two alternatives.

COST-SAFETY IMPACTS

As shown at the end of the previous chapter, there are also associated costs to the public directly related to the safety of an intersection. These cost-safety impacts are proportional to the number of existing accidents at an intersection. As shown in the Maryland State Highway Administration's *Accident Reduction with Roundabouts* study, the tabulated data in **Reference B** in the previous chapter (page 76), showed an average annual cost savings/difference with the roundabouts implemented of $6,786,291 in addition to the reduction in accident severity. Hence, the public should have a considerable cost savings with roundabouts implemented versus the signal alternative at these locations as well.

VIII. CONCLUSIONS & RECOMMENDATIONS

CONCLUSIONS

The preceding three sections of this report compared the capacity, safety, and cost of each intersection with either a roundabout or signal alternative. The following summarizes the comparative analysis sections of this report.

- With respect to the overall cumulative analyses, the roundabouts provide superior capacity for all intersections over the signal alternatives based on the collective overall operations, design year achieved, level of service, delay, and queue lengths for the intersection.

- The "before" and "after" safety statistics conducted in the United States and worldwide provide substantiating evidence of the superior safety performance of roundabouts versus signals and other intersection types for both vehicles and pedestrians.

- The construction cost estimates of the roundabout alternatives illustrate an average of 20% higher costs versus the traffic signals. The average additional cost for a roundabout versus a signal equates to approximately $176,200. However, the modern roundabouts would require less annual maintenance costs.

In addition to the capacity, safety, and costs of each alternative, the importance of a proper functioning traffic control device for each existing site's constraints are critical to the safety operations and public acceptance of either traffic control device. As a result of the analyses herein as well as the conceptual designs, the proposed modern roundabouts would function superior to the traffic signals.

Comparison Matrix: The Comparison Matrix is designed for use by the decision makers and project development team. It assists in a comparative analysis that measures and weighs a various number of major design decision options. RTE has compiled the results of a variety of comparison factors into a matrix that includes key decision measures, assigned percentages, and weighted values based on the capacity, safety, emergency design vehicles, and cost results completed in this feasibility study. The comparison matrix merely provides a tool for the design team and decision makers to aid in the selection of a preferred alternative. **Table 6** provides the items considered and the summary results of the analyses herein.

Table 6: Decision Matrix

Comparison of Key Elements of Alternatives

Highlighted Values Identifies Decision 'Winner'

Legend:
0=Very Poor, 1=Poor, 2=Below Avg,
3=Average, 4=Above Avg, 5=Excellent

Intersection Alternative[1]	Delay /LOS[3]	Vehicle Safety[4]	Const. Cost	EMS & Ped Safety[4]	O & M Costs[4]	Aesth-etics[5]	Score: Higher is Better
Weight[2]	35%	30%	10%	15%	5%	5%	
SR 89 / Ruger Road - **Signal**	3.5	2.8	3.0	3.3	3.0	2.2	**3.1**
SR 89 / Ruger Road - **Roundabout**	3.8	4.8	2.5	4.8	4.5	4.8	**4.2**
SR 89 / Side Rd Connector - **Signal**	3.3	2.8	3.0	3.3	3.0	2.2	**3.0**
SR 89 / Side Rd Connector - **Roundabout**	5.0	4.8	2.8	4.8	4.5	4.8	**4.7**
Willow Creek / Park West - **Signal**	2.0	2.8	3.0	3.3	3.0	2.2	**2.6**
Willow Creek / Park West - **Roundabout**	2.8	4.8	2.4	4.7	4.5	4.8	**3.8**
SR 89A / Side Rd TI North - **Signal**	2.0	2.2	3.0	2.4	2.0	2.2	**2.2**
SR 89A / Side Rd TI North - **Roundabout**	3.8	4.7	3.0	4.5	4.2	4.8	**4.1**
SR 89A / Side Rd TI South - **Signal**	1.8	2.2	3.0	2.4	2.0	2.2	**2.1**
SR 89A / Side Rd TI South - **Roundabout**	2.3	4.7	3.0	4.5	4.2	4.8	**3.6**
Prescott Lakes/Sundog Ranch - **Signal**	3.5	2.5	3.0	3.0	2.5	2.2	**3.0**
PLP / Sundog Ranch - **Roundabout**	4.8	4.8	2.9	4.7	4.4	4.8	**4.6**
Prescott Lakes/Sundog Cnctor - **Signal**	2.0	2.5	3.0	3.0	2.5	2.2	**2.4**
PLP / Sundog Cnctor - **Roundabout**	4.8	4.8	2.4	4.7	4.4	4.8	**4.5**

Legend: 0=Very Poor, 1=Poor, 2=Below Avg, 3=Average, 4=Above Avg, 5=Excellent

Note 1: Each Alternative is an Averaged Composite of Both AM and PM Peak Hours Studied in the Feasibility Report and Pertains to the Intersections as a Whole.
Note 2: Weights Are Based on National Averages From Like Comparison Projects Derived From Public Input.
Note 3: Delay / LOS Are also Weighted Based on the Design Year Achieved.
Note 4: Values Are Based on National Averages
Note 5: Values Are Based on Public Input at Meetings and Conferences.

Source: RTE

Prescott Feasibility Tables.xls

As shown above, the modern roundabouts have significantly higher ratings than the signal alternatives for all of the key elements for each intersection. In fact, the roundabout alternatives had a higher rating in nearly every category with the exception of construction costs for each intersection. When all factors are analyzed, weighed, and reported, the tabulated results allow decision makers to see the **net** impact of each alternative as a whole. In the case of the intersections studied for this report, the roundabout alternatives are clearly identified as the preferred option.

Although nearly all of these factors are based on calculated engineering results, it is understood that each jurisdiction could have slightly differing weights and factors included for each design project. However, the intent of the comparison matrix is to provide a cumulative insight and general rational behind the conclusions of this report. The results of each numeric factor are based on either public input, calculated results within this report, available averages, nationwide statistics, and RTE's professional judgment for this particular project. The provided weights of each key element or factor is a derivative and average of public decision makers with similar roundabout versus signal projects RTE has dealt with throughout North America. For example, the cost analyses weighted every $100,000 difference between a standard signal and a roundabout as a 0.2 point change with a 3.0 base value. In the case of the LOS, a standard rating system of LOS A equaling 5 points and LOS F equaling 0 points was used with the AM and PM peak hours averaged. As shown in the comparison matrix, the total score for the roundabout alternative is better than the score of the signal alternative for all intersections.

Although this report provides comparisons and information primarily focusing on the capacity analyses, safety analyses, and cost analyses of each alternative, a number of other comparisons could be made between the two alternatives for each intersection. However, this report does not provide additional comparisons or explanation on these additional issues such as aesthetics, driver behavioral characteristics, benefit-to-cost ratios, predicted accident safety costs, predicted societal accident costs, life-cycle maintenance costs, and delay costs to road users. However, the simplified comparison matrix provided accounts for the major decision-making factors between the signal and roundabout alternative for each intersection.

Other Comments: The first few roundabouts in a community also require a "learning period" for the public. This time frame typically lasts 90 to 180 days depending on the complexity of the design. Places like Vail, Colorado or Truckee, California with a high amount of tourism and visitors with roundabouts in operation since 1993 and 1997 have not experienced any notable problems or accidents with their roundabouts. In fact, the first Truckee roundabout has not had a single injury accident after final construction in 15 years. Public education is a critical key to shortening the learning period of roundabouts in a new area.

Emergency vehicle response times are also worth noting in the conclusions. Discussions with fire department and police department chiefs in jurisdictions throughout the nation where RTE has roundabouts constructed or where modern roundabouts have replaced traffic signals or stop control have reported either a decrease in emergency response times or no reported problems with roundabouts implemented. RTE has observed and videotaped the traffic behavior of emergency vehicles in route to an incident where little to no hindrances to the emergency vehicles was experienced. In general, traffic moves to the curb near or within the roundabout or exits the roundabout before pulling over. Emergency officials state that drivers infrequently pull over in a manner that does not permit the emergency vehicle to proceed through the intersection. In these infrequent cases where vehicles block the circulating roadway, the emergency vehicle utilizes the truck apron or the adjacent exit to bypass traffic. This ease of emergency response and reduced response times is due to the continuous traffic flows, wider entry lanes at roundabouts, and wide circulating lanes for large trucks to maneuver in the roundabout, which provides enough room for an emergency vehicle to pass by passenger vehicles.

Air emissions and construction traffic impacts are additional topics that could be discussed at great length where roundabouts provide positive results over traffic signals. In addition, the aesthetic benefit of roundabouts is understated in most instances. As a civic feature, roundabouts provide a gateway to a town entry or city focal point. The local environment at the intersections could be significantly improved with proper landscaping at and around roundabouts.

Summary Conclusion: As a final conclusion, **Table 7** on the following page provides general items from the above analyses for comparison between the proposed roundabouts and traffic signals in a very simple format. As shown in the contents of this feasibility study, the modern roundabout alternative has shown to be superior to the traffic signal at all of the analyzed intersection locations.

RECOMMENDATIONS

The key points this study established were that the roundabout alternative provides the most amounts of capacity and operational safety for each project location. This was demonstrated in the capacity analyses, the safety discussions, the proposed roundabout conceptual designs, and the comparative analyses between the signals and the roundabouts. In addition, the roundabouts function superior to the signals for pedestrians, cyclists, and emergency vehicles.

Table 7: General Summary Comparison
Modern Roundabouts versus Traffic Signals

FACTOR	ROUNDABOUT	SIGNAL
All Study Area Intersections		
Capacity (Level of Service)	Better LOS	Worse LOS
Capacity (Design Year Achieved)	Higher Year	Lower Year
Lane Geometry	Relatively Similar for Mainline	Can Require Additional Left Turn Lanes
Operations	Free Flow / Yield	Stopped Phases
Avg Stopped Queue Lengths	Typically Shorter	Blocks Business Accesses
Air Emissions	Reduced Air Emissions With Reduced Delays	Stopped / Idling Pollution
Safety (Injury Accidents)	78% Reduced Injuries / 90% Reduced Fatalities	24% of All Intx Injuries Are Red Light Runners
Safety (Speeds)	20 MPH Average / 125' Braking Distance	50 MPH Average / 475' Braking Distance
Safety (Pedestrian / Cycles)	Substantial Reduction in Accident Rates	Nationwide Statistics Find High Accidents
Estimated Project Costs	Higher Cost by 20% Avg	Lower Cost by 20% Avg
Emergency Vehicle Operations	Reduced Response Times / Free Flow	Detectors Recommended / Stopped Delay

Source: RTE | Prescott Feasibility Tables.xls

Therefore, it can be unanimously determined by all the contributing factors within this feasibility study the modern roundabout is the recommended alternative for all six locations (seven intersections). Upon review of the results identified herein, the City of Prescott should consider the design of modern roundabouts at all of the studied intersections by a qualified roundabout design specialist as to ensure a properly designed, well operating modern roundabout that can be easily accepted by our driving citizens.

It is recommended to proceed with the final geometric design layouts of the roundabouts, including geometric design modifications and details still to complete, all of the non-geometric essentials (such as signing, lighting, striping, and landscaping), and the remaining civil components of the design plans including grading, utilities, drainage, and survey information. It is recommended that the geometric layouts of the roundabout designs be revised to the needs and desires of the City of Prescott based on future buildout conditions to ensure right-of-way impacts, turn lanes into nearby access points, and additional information required for the exact points to tie into the existing roadways.

As stated in the introduction of the report, the modern roundabout, coupled with good design practices and additional geometric and non-geometric design measures such as proper signing and landscaping, are the traffic control devices of choice for intersections in most countries. Hence, the conclusions of this report are not unusual. The self-regulating traffic control device creates an environment controlled by roadway and intersection geometric layouts with roadway widths, curves, medians, lighting, signing, striping, and landscaping to regulate traffic speeds and significantly enhance driver safety.

As shown in the conceptual roundabout designs exhibits (**Figure 59 through 65**), the entries are visible to drivers from a safe stopping distance, safe design speeds promote yielding at entry with slow entry and circulating speeds, the splitter islands have been initially designed well, ADA and bike lane appurtenances are present, as well as many other design features.

Additional Implementation Recommendations**:** The following additional items not shown in the conceptual roundabout designs are also recommended:

- Rolled curb is recommended for the roundabout's truck apron.
- Provide at least a 3-4% slope on the truck apron sloping downward towards the circulating roadway with textured or stamped concrete with large chevrons in the concrete to discourage pedestrian usage and driver awareness.
- Provide highly visible and obstructing landscaping in the central islands according to sight distance requirements for each entry and circulating points within the roundabouts.
- Landscaping on the medians and splitter islands in appropriate places as determined by final design.
- Provide post mounted maptype signs as shown in the *Roundabout Signing Guide, A Recommended Practice, 1st Edition,*[8] for driver comprehension of

[8] Roundabout Signing Guide, A Recommended Practice, 1st Edition, Scott Ritchie, P.E., Roundabouts & Traffic Engineering and Phil Weber, P.Eng. Roundabouts Canada, 2005, Published by the Transportation Research Board 2005

destination and repeated display and understanding of a roundabout ahead.

- Provide internally illuminated bollards (new MUTCD compliant[8]) on the splitter islands of all approaches to assist in nighttime visibility of the roadway geometry ahead. These devises are newer and revised from the existing SR 89 / Willow Lake Road roundabout in Prescott.
- Provide roadway, approach, and exit lighting at the roundabouts according to national standards as determined in final design. RTE can identify the specific locations for proper positive contrast lighting at the roundabout.
- Provide detached sidewalks with landscaping between the back of curb and face of walk to provide a tunnel effect or constrained environment for the driver to slow down prior to entry.
- If possible, the use of internally illuminated exit signs is a highly visible method of displaying an intersection with a roundabout. RTE has illustrations of the internally illuminated signs used in Vail, Colorado.
- General conformance to the recommendations found in the *Roundabout Signing Guide, A Recommended Practice* such as the arrow shaped exit signs are recommended for all approaches at both roundabouts.[8]
- Conformance to the DRAFT 2008 MUTCD manual is recommended. Scott Ritchie is a member of the board for the new MUTCD 2008 manual on signing and striping at roundabouts and can provide recommendations on the latest federal and ADA recommendations.
- Provide highly visible crosswalks with the use of recessed thermoplastic in an international style stripe design (a.k.a. "ladder" stripes) or a stamped and colored concrete for high visibility.
- Provide proper advanced and intersection signing and markings to advise of the appropriate speed and lane for approaching drivers.

Advance signage combined with a visible driving situation with appropriate landscaping and a well-illuminated intersection all contribute to the good safety performance currently being observed at roundabout sites. The consequences of an inconspicuous central island and/or splitter islands is mainly loss of control crashes as motorists unfamiliar with the roundabout are not given sufficient visual information to elicit a change in speed and path.

If the City of Prescott or Prescott's citizens have any questions or concerns regarding the results of this report or roundabouts in general, Scott Ritchie with RTE is available to provide public presentations or forums at the convenience of the City of Prescott to assist business owners, general citizens, public officials, City staff, or others with the design, implementation, and public acceptance of roundabouts.

APPENDIX