

# Reconstructing a Six-Leg Intersection into Mohave County's First Roundabout

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**Abstract:** Mohave County, Arizona maintains a six-leg intersection in the Golden Shores area bisected by an uncontrolled regional County highway, County Route 1, where two STOP-controlled section line local roads converge. The two-lane, rural CR 1 serves commuter and visitor traffic traveling between population centers of Lake Havasu City, AZ and Bullhead City, AZ/Laughlin, NV on the Colorado River and its desert lakes. The intersection features 180 total vehicle-to-vehicle conflict points inclusive of 126 crossing conflicts. This paper presents the County's technical and administrative approach and techniques in planning and developing the CR 1 "Six Points" roundabout given the (1) absence of fatal and incapacitating injury crash history and (2) backdrop of this improvement representing the County's first roundabout. Project initiation entailed the County securing a Federal share of Highway Safety Improvement Program funding at 100-percent. Project design commenced with a preliminary engineering study to identify, evaluate, and solicit public input on alternative improvement solutions as part of validating the roundabout improvement as superior for traffic operations, community and business function, sitting, and constructability. Public input targeted preference for maintaining CR 1 uninterrupted flow versus interrupted flow introduced under roundabout circulation. This simple decision tree enabled the County to understand existing operational and access conditions important to the public, business owners, and public safety providers for purpose of configuring a roundabout improvement satisfying local motorist and community needs, which stoked stakeholder buy-in on the project.

**Key words:** Roundabout, thru-about, safety, skewed intersections, predictive modeling, benefit-cost.

## 1. Introduction

This paper presents Mohave County's (Arizona) success in delivering the first roundabout construction, inclusive of State and city roadways, across its 13,311 square-mile jurisdictional area, the fifth-largest in the contiguous United States. The project improves County Route 1 (CR 1), a former State highway. The 12-mile CR 1/Oatman Highway (Historic Route 66) corridor serves important industrial and agricultural areas in Mohave Valley, Arizona and Fort Mojave Indian Reservation through access to Interstate 40 and its reach to Southern California, Port of Los Angeles, and CANAMEX Corridor (future Interstate 11). The facility further represents an important thoroughfare for commuters and visitors traveling adjacent the Colorado River and frequenting commercial and

recreational attractions central to Lake Havasu City, Bullhead City, and Laughlin, Nevada casino resort area.

The CR 1 intersection at Powell Lake Road and Golden Shores Parkway (a.k.a. "Six Points" intersection) in central Golden Shores, Arizona requires consolidation and realignment of its six approaches to promote efficient traffic flow. This intersection serves approximately 3,000 entering vehicles per day, and CR 1 through traffic comprises about one-quarter of all intersection entering traffic. The four local, section line road approaches maintain steady activity in circulating traffic to/from area residential and business uses, but CR 1 through traffic represents the dominant movement.

The present configuration shown in Fig. 1 creates line-of-sight challenges attributed to the skewed approaches and particularly for visiting winter and weekend motorists, confusion on understanding which

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vehicles have the right-of-way. These shortcomings under modern highway design policy were not exposed through crash history as a 12-year intersection crash history, January 2000 through February 2012, yielded 19 total crashes inclusive of 14 property-damage-only crashes, 5 injury crashes, and zero fatal and incapacitating injury crashes. Despite such history, the County achieved a 100-percent federally funded intersection improvement project developed and designed within an aggressive one-year period against a Federal Fiscal Year 2016 (construction) appropriation authorization deadline with full community and local elected official participation and support.

Fig. 2 highlights key project milestones toward bringing roundabout construction to fruition. The following sections delve into the County's technical and administrative approach and techniques applied in achieving these milestones and delivering the project to

the Golden Shores community.

## 2. Funding Pursuit

Mohave County programmed the Six Points Roundabout Project through the Western Arizona Council of Governments (WACOG) in January 2011. The project was initially programmed under a nominal design concept study proposal to determine traffic operation and safety deficiencies and candidate improvements. However in March 2012, available WACOG allocated Highway Safety Improvement Program (HSIP) Federal-aid funds enabled the County to secure merit-based project programming in the WACOG 5-Year Transportation Improvement Program (TIP) at \$1.15 million subject to Federal Highway Administration (FHWA) approval.

The County made its first application to FHWA for HSIP funding approval in April 2012. In conferring with FHWA and finding no occurrence of recent,

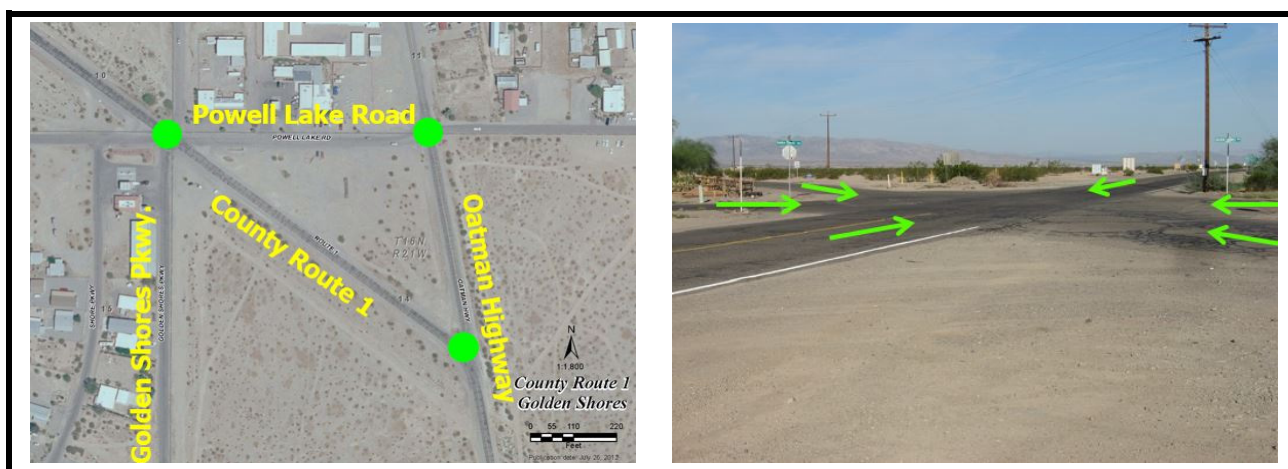


Fig. 1 Project site and intersection configuration.

| Phase                        | 2011 | 2012 | 2013 | 2014 | 2015    | 2016 |
|------------------------------|------|------|------|------|---------|------|
| Project Programming          | ★    | §    | §    |      |         |      |
| Road Safety Audit            |      | ★    |      |      |         |      |
| Federal-Aid Funding Approval |      |      | ★    |      |         |      |
| Design Development           |      |      |      |      | M M § M | ★    |

★ Milestone    § Federal Funding Programmed    M Public Meeting    § County Board of Supervisors Approval

Fig. 2 Project development timeline.

historical fatal or incapacitating injury crashes, the County secured a no-cost Road Safety Audit (RSA) through the Arizona Department of Transportation (ADOT) Road Safety Assessment Program [1]. ADOT performed the study in June 2012 with support of a multi-jurisdictional stakeholder team including engineers and law enforcement. It extended to encompass adjacent intersections at (1) Oatman Highway at Powell Lake Road and (2) CR 1 at Oatman Highway as shown in Fig. 1. The collective 12-year crash history, January 2000 through February 2012, at these additional intersections included 8 property-damage-only crashes, 3 injury crashes, and 2 incapacitating injury crashes.

The RSA found the Six Points intersection geometry rendering motorist confusion and line-of-sight deficiencies among conflicting traffic movements. It further cited general lack of cues to motorists approaching Six Points from the high speed CR 1 northerly approach. In framing a long-term solution for Six Points, the RSA recognized the underlying need to reduce intersection conflict points by restricting or removing movements. The RSA long-term recommendation for Six Points targeted intersection realignment/reconstruction including roundabout consideration. The RSA offered approach realignment/reconstruction as long-term solutions for Oatman Highway at Powell Lake Road and CR 1 at Oatman Highway.

Project need as argued through the RSA findings and recommendations positioned the County in January 2013 to obtain on merit additional WACOG assigned HSIP Federal-aid funding for project design and construction. Hence, WACOG reprogrammed the project in its TIP at \$1.87 million HSIP funding plus Arizona standard 5.7% local match netting cumulative project budget at \$1.98 million.

### *2.1 Project Justification by Predictive Modeling*

Upon reprogramming the revised, final HSIP funding allocation for the project, attaining FHWA

project eligibility approval remained. Project context proved compelling: (1) Six Points features 180 total vehicle-to-vehicle conflict points and 126 crossing conflicts versus 32 and 16, respectively, under a traditional four-leg intersection and (2) Six Points operates under markedly skewed and misaligned approaches. But, a glaring—albeit it positive—shortcoming existed in the site not exhibiting a history of fatal and incapacitating injury crashes. This encumbered the County's ability to demonstrate fatal and incapacitating injury crash reduction, and in turn formulate positive project return on Federal-aid funding investment, through a roundabout at Six Points.

The County turned to a new approach on engineering justification, predictive crash modeling under methods set forth in the Highway Safety Manual (HSM) [2]. Recognizing Six Points operated under the same geometric and operating characteristics for decades, the finite period of historical crashes are not necessarily representative of past crash frequency and severity distribution as well as that in future years under status quo condition. Predictive modeling evaluates statistical likelihood of crash frequency under site as-constructed and operating characteristics influencing crash causal factors. FHWA endorses HSM predictive models, which have been tested and proven to estimate crash likelihood. This approach represents a best practice method toward computing project benefit-cost in evaluating existing versus proposed intersection improvements.

The project and eligibility approval request expanded from Six Points to include the intersections at Oatman Highway at Powell Lake Road and CR 1 at Oatman Highway. Project improvements coincided to eliminate, thus representing 100 percent crash reduction, the Oatman Highway at CR 1 intersection by abandoning the diagonal CR 1 section between Powell Lake Road and Oatman Highway. The improvements also contemplated roundabouts at Six Points and Oatman Highway at Powell Lake Road to promote

north/south through traffic flow continuity in transitioning between CR 1 and Oatman Highway. Later in project design, the Historic Route 66 status precluded consideration on realigning and/or widening any part of Oatman Highway.

Table 1 summarizes the approach in carrying out the HSM-based predictive modeling analysis [3]. It encompasses an overall conservative estimate on crash frequency prediction given available safety performance functions for maximum four-leg intersections only whereas Six Points represents six legs. The analysis maintains the predictive model calibration factor at 1.00 given absence of State or local developed calibration factors for jurisdiction/area-specific intersections. It finds the

project site intersection characteristics and traffic conditions yield 5.57 predicted crashes per year inclusive of 1.94 fatal and injury crashes. This compares to 2.63 historical crashes per year including zero fatal and 0.82 injury crashes. Roundabout conversion at Six Points and Oatman Highway at Powell Lake Road, coupled with CR 1 at Oatman Highway intersection elimination, nets a cumulative 0.40 fatal crash reduction and 4.36 incapacitating injury crash reductions over the 25-year project horizon. Project benefit-cost computes to 1.35 under nominal/fixed crash unit cost values and increases are to 3.15 when considering that both monetary benefit of crash reduction and project development cost as real,

**Table 1 Predictive modeling approach.**

| Task   | Action  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
|--|---|----------------|------------------|-------|------|-----------------------|------|---------------------------|-------|-----------------|-------|----------------------|-------|
| Project analysis period and input data   |   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Determine project service life   | 25 years (2017-2042)  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Collect and forecast intersection approach daily Traffic volumes   | Mohave County Traffic Volume Counts   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Site pre-improvement crash frequency prediction  |   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select HSM predictive model  | HSM Equation 10-3 for Rural two-lane, two-way intersections<br>$N_{predicted\ int} = N_{spf\ int} \times C_i \times (CMF1_i \times CMF2_i \times \dots \times CMF4_i)$  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select safety performance function for Six Points and Oatman Highway at Powell Lake Road   | HSM Equation 10-9 for Four-Leg STOP-controlled intersections<br>$N_{spf4ST} = \exp[-8.56 + 0.60 \times \ln(AADT_{maj}) + 0.61 \times \ln(AADT_{min})]$  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select safety performance function for CR 1 at Oatman Highway  | HSM Equation 10-8 for Three-Leg STOP-controlled intersections<br>$N_{spf3ST} = \exp[-9.86 + 0.79 \times \ln(AADT_{maj}) + 0.49 \times \ln(AADT_{min})]$   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select crash modification factor (s) for Six Points and Oatman Highway at Powell Lake Road   | HSM Equation 10-23 for Effect of intersection skew on total crashes<br>$CMF1_i = e^{(0.0054 \times skew)}$  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select crash modification factor (s) for CR 1 at Oatman Highway  | HSM Equation 10-22 for Effect of intersection skew on total crashes<br>$CMF1_i = e^{(0.004 \times skew)}$   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Site improvement crash reduction and project benefit analysis  |   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select crash modification factor (CMF) for roundabout conversion at Six Points and CR 1 at Oatman Highway  | NCHRP Report 572 Roundabouts in the United States [4]<br>Rural area/all crash severities: CMF = 0.29<br>Rural area/serious and minor injury: CMF = 0.13<br>Mohave County Query and Severity Distribution Analysis of Arizona Statewide Intersection Crashes 2006-2010   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Select crash severity distribution to disaggregate total predicted crashes to discrete severity levels for CMF application and monetary benefit estimation | <table> <tr> <th>Severity level</th><th>Percent of total</th></tr> <tr> <td>Fatal</td><td>0.4%</td></tr> <tr> <td>Incapacitating injury</td><td>3.6%</td></tr> <tr> <td>Non-incapacitating Injury</td><td>12.5%</td></tr> <tr> <td>Possible Injury</td><td>18.4%</td></tr> <tr> <td>Property damage only</td><td>65.1%</td></tr> </table> | Severity level | Percent of total | Fatal | 0.4% | Incapacitating injury | 3.6% | Non-incapacitating Injury | 12.5% | Possible Injury | 18.4% | Property damage only | 65.1% |
| Severity level   | Percent of total  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Fatal  | 0.4%  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Incapacitating injury  | 3.6%  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Non-incapacitating Injury  | 12.5%   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Possible Injury  | 18.4%   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Property damage only   | 65.1%   |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |
| Compute project benefit-cost   | Apply Arizona Highway Safety Improvement Program Application Guidance on benefit/cost ratio tabulation [5]  |                |                  |       |      |                       |      |                           |       |                 |       |                      |       |

inflation-indexed values. This comprehensive engineering approach and need-based justification by means of crash likelihood gained project eligibility approval by FHWA in March 2013 whereby the agency assigned 100% Federal-aid funds at \$1.98 million sans local match per 23 U.S.C. 120(c) for roundabouts.

### 3. Community Centered Project Development

In connection with project eligibility approval by FHWA, Mohave County further secured the agency's approval to perform and expend HSIP funds on a preliminary engineering study phase under project design to determine the most cost-effective preferred alternative including roundabout evaluation. Study context recognized any change in project scope from the eligible Six Points roundabout safety improvement would demand FHWA review for HSIP eligibility and percent Federal-aid funding commitment. ADOT administered this local government project. Upon initiating project preliminary engineering and design, Mohave County in its executing an intergovernmental agreement with ADOT on agency responsibilities, asserted a unique project milestone: County (elected official) acceptance of the Study's preferred alternative as "accepted". Moreover, the County secured waiver on funding reimbursement if the County and FHWA failed to agree on a project alternative for design. This marked the cornerstone of the County's philosophy on a community centered project development being on

the cusp of its first roundabout in Golden Shores and the County at large.

#### 3.1 Preliminary Engineering Study

The Six Points and adjacent project intersections exhibit no existing and forecast capacity deficiencies; therefore, alternatives development targeted modern Six Points function and performance measures pinned to safety and mobility. Alternative evaluation criteria encompassed project cost, right-of-way requirements, traffic/truck operations, and property/business access. The latter two criteria framed community existing issues and project input toward traffic speed, circulation, truck maneuvering, and access. The County identified maintenance of business access, the northwest CR 1 approach, the east and west Powell Lake Road approaches, and the south Golden Shores Parkway approach at Six Points as fatal flaw criteria for vetting candidate alternatives. The Powell Lake Road and south Golden Shores Parkway approaches represent collector roads serving densely developed Golden Shores residential areas. Table 2 presents focus areas under three public meetings staged in Golden Shores to solicit community input and ideas.

#### 3.2 Thru-about Alternative

Conventional, non-roundabout intersection improvements represented a de facto alternative to the Federal-aid eligible roundabout alternative at Six Points. However, with traffic safety rooted in benefit-cost

**Table 2 Project public meetings.**

| Meeting   | Focus Areas   |
|---|---|
| First Public Forum  | Present no alternatives.<br>Provide project introduction and technical need.<br>Invite community perspectives on existing Six Points intersection operation and deficiencies.                                       |
| Second Public Forum<br>(29 days after First Forum)  | Present three candidate Six Points improvement alternatives with identification of two Study recommended alternatives for final evaluation.<br>Invite community perspectives on two Study recommended alternatives. |
| Mohave County Board of Supervisors consideration and approval of Study preferred alternative (83 days after Second Forum) |   |
| Third Public Forum<br>(78 days after County acceptance)   | Present County accepted alternative.<br>Invite community perspectives and ideas for improving accepted alternative layout, access, and function.  |

based project eligibility, conventional improvements including realignment and traffic movement channelization proved impractical on premise of (1) pursuing revised project eligibility and (2) curing substantial new right-of-way acquisition and utility impacts in squaring up the CR 1 approaches. This opened the County's introduction of an innovative variant to roundabout configuration, termed a "thru-about", for maintaining uncontrolled CR 1 through traffic flow through Six Points [6].

Fig. 3 presents the thru-about schematic. This design concept and second of two Study recommended alternatives took to existing Six Points shortcomings: six skewed and misaligned approaches to a regional County highway. It establishes two perpendicular-aligned, circulatory approaches to CR 1 that collect and distribute local road turning movements in a counterclockwise manner. Thru-about contrast to

roundabout operation lies in maintaining CR 1 free flow through circulatory road STOP control. Such CR 1 operating condition—interrupted versus uninterrupted flow—represented the decision tree in soliciting public input on desired traffic operational conditions.

Thru-about circulatory approach capacity does not meet that of modern roundabouts, but Six Points sufficiently low existing and forecast traffic demand enabled its consideration. It offers compelling vehicle-to-vehicle conflict point consolidation from 180 to 26 total conflict points under the existing Six Points intersection configuration coupled with crossing conflicts dropping from 126 to 6, a 95 percent reduction. When limiting circulatory approach turning movements to right-turn or through/crossing only at CR 1, the thru-about alternative contains 20 total vehicle-to-vehicle conflict points inclusive of 4 crossing conflicts.

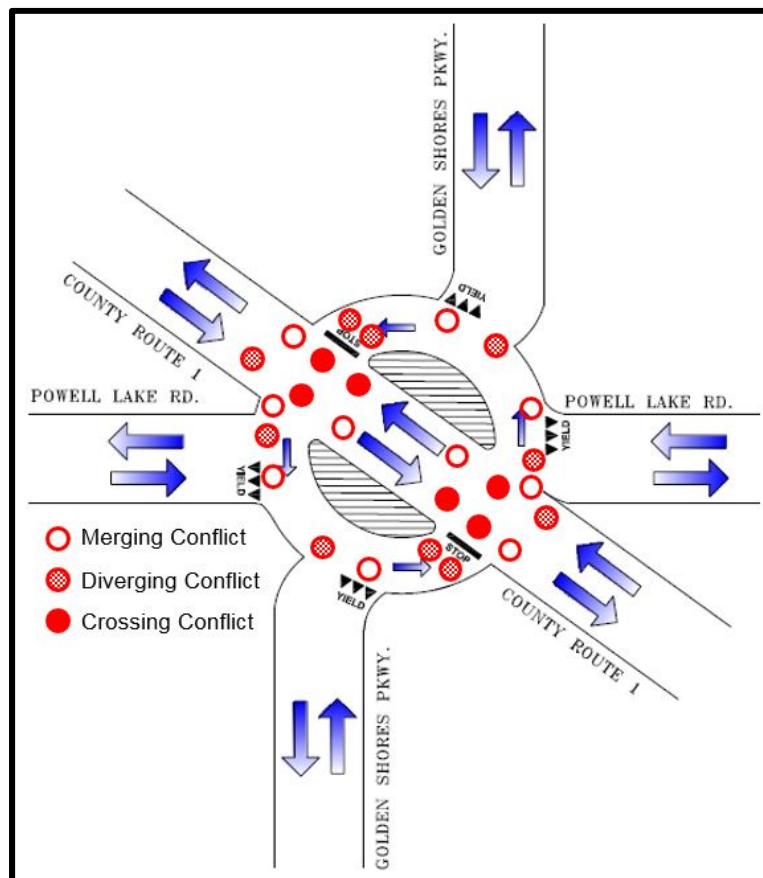


Fig. 3 Thru-about schematic.

### 3.3 Preferred Alternative Selection

The project's WB-67 design vehicle, attributed to CR 1 connecting industrial/agricultural areas to the north and Interstate 40 to the south, drove roundabout selection as the preferred alternative. The thru-about required too significant a footprint to accommodate such heavy vehicle movements. It remains a functional solution for 4-plus approach intersections where the primary road serves through truck traffic, thus lending to a diminished footprint. Thruabouts reduce intersection crossing conflict points, which fuel propensity for fatal and incapacitating crashes, by as much as 75 percent compared to a conventional four-leg intersection with 16 crossing conflicts. With 23 U.S.C. 120(c) establishing increased Federal-aid funding share for roundabouts under the category "traffic circle", site-specific opportunities exist for rendering position and positive benefit-cost toward justifying thru-about funding eligibility.

The preferred roundabout alternative advanced to Mohave County Board of Supervisors consideration and received Board approval as the accepted

alternative. Remarkably, in the period 2000 through mid-2016, no fatal and only 2 incapacitating injury crashes occurred at Six Points. The accepted alternative touts a two-fold safety improvement through (1) eliminating all intersection crossing conflicts and (2) eliminating the skewed, three-leg CR 1 at Oatman Highway intersection and associated intersection crash likelihood. Fig. 4 shows the Six Points single-lane roundabout and adjacent roadway improvements at final design [7]. The roundabout serves two-way traffic movement on the northwest CR 1 approach and the east and west Powell Lake Road approaches. It accepts traffic ingress only from the north Golden Shores Parkway approach for benefit of Powell Lake Road commercial property traffic circulation and motorist access to CR 1 north of Powell Lake Road. The project improvements maintain two-way traffic movement between Powell Lake Road and Golden Shores Parkway south, and the project establishes CR 1—Powell Lake Road—Oatman Highway as the through traffic thoroughfare to Interstate 40 five miles south of the project location.

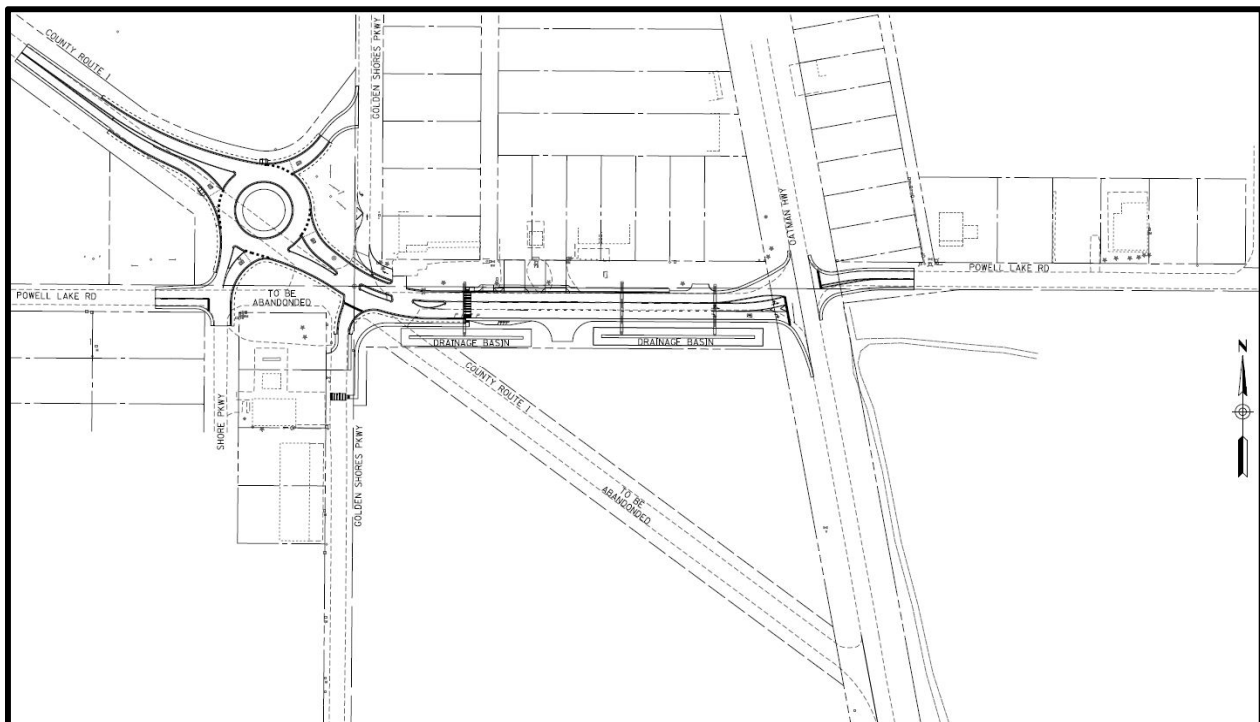


Fig. 4 Six Points roundabout and project improvements.

**Table 3 Roundabout planning and development sequence.**

| Activity                         | Action   |
|----------------------------------|--|
| Prove need                       | Complete Road Safety Audit or related traffic engineering study.<br>Examine engineering-based justification on crash likelihood.   |
| Secure funding                   | Target non-local funding source qualifying for roundabout design and construction.   |
| Engage public participation      | Provide opportunity and public understanding on their participation prior to and during roundabout design.<br>Understand the local community represents the motorist demographic, all motor vehicle users, and all travel modes.<br>Promote active, positive public participation through soliciting input in context of the public's vision and ideas versus reference to "comments" and "concerns", which may hold negative connotation. |
| Memorialize selected alternative | Spotlight the important role local elected officials have in advancing road safety and operations improvements; use their forum in memorializing a selected alternative or roundabout acceptance as that representing community consensus.   |

#### 4. Conclusions

Mohave County's first roundabout development proved soundly successful on many fronts. Table 3 outlines the County's blueprint toward this outcome for the Golden Shores community. Key roundabout design elements understood and ultimately favored by the public include single-lane circulatory road, design vehicle accommodation, and speed management through approach-to-circulatory road transition using proper deflection. The overall project development process garnered unanticipated promotion through public, unsolicited inquiry on and their future anticipation of roundabout center island beautification. Though the project has enabled future irrigation and electric service connections, it has not incorporated center island beautification features such as landscaping or visual art. This initiative will be contemplated post-project and represents an ancillary benefit toward community buy-in for the project.

#### References

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