313 Price Place, Suite #5
Madison, WI 53705
Office: 608.238.5000
Fax: 866.846.5552
www.mtjengineering.com

# Technical Memorandum

**TO:** B. Finley Vinson, PE, PTOE

Director – Street & Engineering Dept., City of Conway, Arkansas

**FR:** Mark T. Johnson, (PE pending in AR), MTJ Engineering, LLC

**RE:** Highway 286/Dave Ward Dr. Roundabout Review

**DT:** February 11, 2015

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As requested by the City of Conway, MTJ Engineering, LLC has completed an initial review of the three proposed roundabouts located along Dave Ward Drive.

This horizontal design review is aimed at identifying potential design deficiencies that may produce poor safety performance, and provide recommendations for design improvements to optimize operations and safety performance through improved driver comprehension, slower speed environment, and fewer conflict points consistent with roundabout, traffic and roadway engineering principles. The review is broken into two stages as outlined below. This memo is a summary of Stage I at this time and is focused on the two closely spaced roundabouts.

## OVERVIEW

### Review and Analysis

**STAGE I – Review:**
- Proposed Horizontal Geometric Designs
- Perform an Operational Analysis
- Develop Concept Sketch Level Design Recommendations

**STAGE II: (to follow)**
- Develop Preliminary Geometric CAD format Recommendation
- Complete Written Summary

## Design Composition

Multi-lane high-flow roundabouts require correct composition for optimal safety and operations. Poor composition will equate to poor performance, lower safety performance, and public acceptance concerns. Design details are inexpensive and easy to correct, but it can be very expensive and difficult to correct poor composition once constructed

Poor roundabout performance is less about the individual components (e.g., too big or too small) and more accurately attributed to the arrangement and relationship of all the geometric design elements; i.e., composition. The composition of geometric design elements is the most important factor when optimizing safety and operations of a roundabout. Therefore, consistent with the design principles in the *FHWA Roundabout Guide,* we have reviewed this project for conformance to design criteria within available context, operational objectives, and traffic planning objectives.

The outline shown below reflects the primary framework for this design review and the Essential Design Elements for Optimal Safety and Operations. This review has identified many compositional issues with the currently proposed design. We have developed graphics illustrating the Stage I review finding for the two closely space roundabouts and these are attached and referenced within this memo.

## ESSENTIAL DESIGN ELEMENTS FOR OPTIMAL SAFETY AND OPERATIONS

The following outline frames the essential design components for designing for optimal roundabout safety and operations.

### 1. Operations/Geometrics: Avoid Over-Design

a. **Match Capacity to Demand** – Meeting operational requirements and objectives that allow for safe operations for near- to long-term traffic demand.
b. Minimize lanes = reduce conflict points
c. Simplify decision-making
d. Evaluate potential future expandability if necessary

### 2. Design Principles

a. Safety – U.S. and U.K. Safety Research

- Fast Path Criteria
- Maximize angle between arms: 90-degree angles preferred

b. Entry Angles/Angles of Visibility

- The U.K.'s Transportation Research Lab (TRRL) determined that entry angle for multi-lane roundabouts should be in the range of 20-40 degrees.
- Small (flat) 'entry angles' promote:
    - Higher entry speeds
    - Merging driver behavior (vs. yield to circulating traffic)
    - Difficult left view angle making it difficult to see circulating traffic

### 3. Improving Driver Messaging and Information Processing

a. Pavement Markings

## REVIEW

### 1. Operations/Geometrics

Safety research indicates that the entering-circulating conflict is a primary contributor to crashes for multi-lane roundabouts. Therefore, safety benefits can be derived from limiting the number of entry and circulating lanes to the minimum necessary while still meeting acceptable operational objectives of delay and queues.

To understand the necessary laneage for these two roundabouts and determine if opportunities exist for reduced laneage from what is currently proposed, we have conducted an operational analysis with Rodel v1.88 on the long-range 2036 traffic provide by AHTD. Figure #1 below, called "Sketch Level Lane Recommendations," reflects the necessary laneage for acceptable operations based upon the Long Range 2036 traffic data. This Lane Sketch Graphic reflects reduced laneage and the associated conflicts, simplifies decision-making, and reduces the need for future expansion as compared to what is currently proposed.

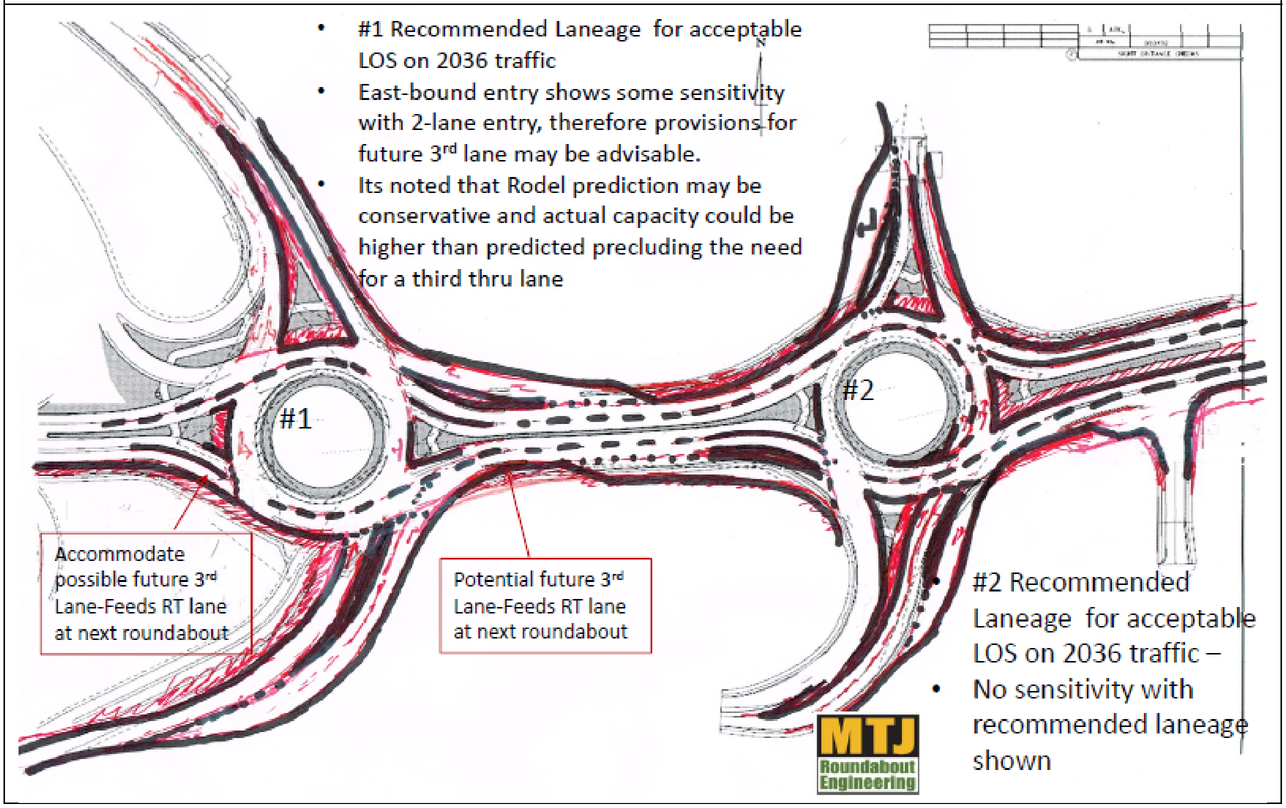
**Rodel Analysis – Accurate for U.S. Capacity Predictions**
Rodel is a high definition, robust and accurate roundabout analysis program that utilizes the U.K. Empirical Capacity Model. Rodel v1.88 extends the application of the U.K. capacity equations to U.S./North American design practices and principles.

It has been reported that the U.K.-derived capacity predictions may over-predict capacity on U.S. roundabouts since U.K. drivers are more accustomed to roundabouts. However, review of U.S. field-measured capacity data collected by FHWA in 2012 demonstrates that there is strong correlation to Rodel's capacity predictions. Additionally it's important to note that Rodel utilizes U.S.-based Queuing and Delay theory equations. Consequently, nothing in this respect is different from U.S.-based methodologies.

Based upon the strong correlation of Rodel capacity prediction to US data the recommended laneage as shown below in Figure #1 provides a high level of confidence to meet acceptable levels of service for the project design-year traffic volumes.

The full operational analysis output is provided separately.

Figure #1 MTJ Sketch Level Lane Recommendations



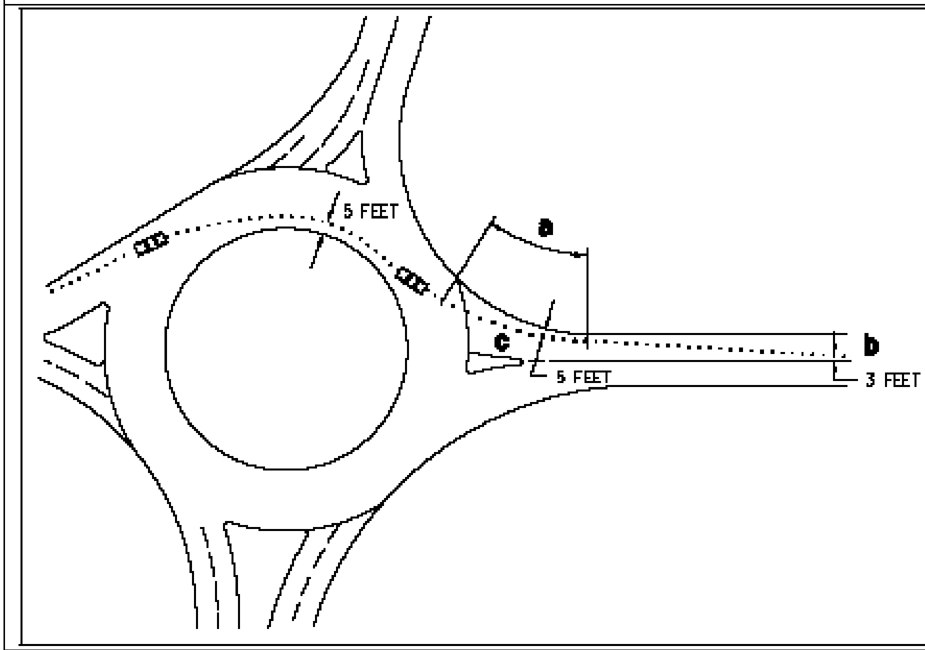

## 2. Design Principles – (a) Fast Paths/Speed Control

The FHWA guide recommends that fast path speeds not exceed 25 mph for single-lane, and 30 mph for multi-lane entries of roundabouts.

Fastest path speeds are an important measure of relative safety predicated on U.K. research and adopted into U.S. guidance as reflected in NCHRP 672. Quantification of the fast path speeds in a consistent manner ensures adherence to this primary safety criteria, and this is incorporated into U.S. roundabout design guidance as reflected in NCHRP 67 and is illustrated below.

Fastest vehicle paths are developed via the smoothest, fastest path possible for a single vehicle, in the absence of other traffic and ignoring all lane line markings, traversing through the entry, around the central island, and out the exit.

Figure #2 Fast Path Construction Method




*a - The radius should be measured over a distance of 65 to 80 feet. It is the minimum that occurs along the approach entry path near the yield point but not more than 165 feet in advance of it.*

*b - Beginning point is 3 feet from a pavement marking with no curb face present and is 5 feet from the left curb face (if raised curb median) at a point not less than 165 feet from the yield point. This point is a continuation of a vehicle path, not a point with deflection.* *Source: WIDOT FDM*

**Review Findings -** (Attached Exhibits 1 and 2)
Our review found that the fast path analysis conducted on the currently proposed geometrics do not follow the correct method for the fast path constructs. Therefore, the measurements made from these erroneous fast path constructs are not accurate and are substantially non-compliant with FHWA fast path safety criteria. This is illustrated in the attached graphics, Exhibits 1 and 2.

## 2. Design Principles – (b) Entry Angles/Angles of Visibility

Small (flat) 'entry angles' produce visual cues promoting 'merging driver behavior' versus the desired priority message of 'yield' at entry to circulating traffic. This can also encourage higher entry speeds. Flat entry angles also force drivers to strain to look over their left shoulders, creating poor view angles that make it difficult to see circulating traffic.

**Review Findings** – (Attached Exhibits 3 and 4)
The currently proposed design does not meet minimum design standards for entry angles and angles of visibility. This issue is illustrated in the attached graphics, Exhibits 3 and 4.

## 3. Improving Driver Messaging and Information Processing

Multi-lane roundabouts in high flow conditions involve high visual and perceptual demands arising from information acquisition and processing requirements. When signing and pavement marking information are presented in a manner not consistent with driver expectancy, this can create confusion and excessive crashes. Therefore, from an information processing perspective, workload demands for these tasks should be reduced by making it easier for drivers to understand how to drive the roundabout.

Signing and pavement marking guidelines must:

1. Provide clear and easily understood information
2. Minimize detection, reading, and processing time
3. Maximize comprehension

**Review Findings -** (Attached Exhibit 5)
Line types, weight, and arrangement of pavement marking information are very important. The proposed design and pavement markings apply a blend of "Turbo" style raised dividers, with widened lane markings and skips. This arrangement of line types and raised dividers creates substantial concerns with respect to driver comprehension and safety for vehicular, motorcycle, and non-motorized traffic (pedestrian safety). Therefore, modifications are necessary to achieve more consistency with currently recognized pavement marking design principles in order to optimize driver comprehension. Please see attached graphics, Exhibit 5. After the Stage I Review is completed, pavement marking recommendations will be finalized.

## Stage I Review Summary:

U.S. and international safety research concludes roundabouts are proven to have the least amount of serious and fatal crashes compared to signalized intersections. However, many U.S. multi-lane roundabouts are experiencing higher than anticipated or desired minor crashes caused by less than optimal design elements.

For optimal operations and safety of roundabouts, the visual information must be presented (designed) to simplify decision making, and provide clear and concise information as to the correct way to drive the roundabout. If the information presented is contradictory or doesn't send the correct message to drivers, then less than optimal safety performance will result. The primary roundabout design elements – geometrics, signing, and marking – all play a role in how drivers interact with multi-lane roundabouts. Therefore, the safety performance of a multi-lane roundabout emerges from the whole system interaction of these design elements.

## Expected Outcomes of Existing Design

Based on this review of the currently proposed design the expected safety outcomes are as follows:

- The proposed horizontal geometrics and pavement markings are anticipated to create chronic crash problems to include:
  - Side swipes and failure-to-yield crashes due to driver confusion and lack of lane discipline at both entry and exit. This is based on recent case studies with similar design issues and outcomes within the U.S.

- Reduced pedestrian safety is expected due to:
  - Exit conflicts associated with the geometrics
  - Higher speeds at entry and exit pedestrian crossing locations.

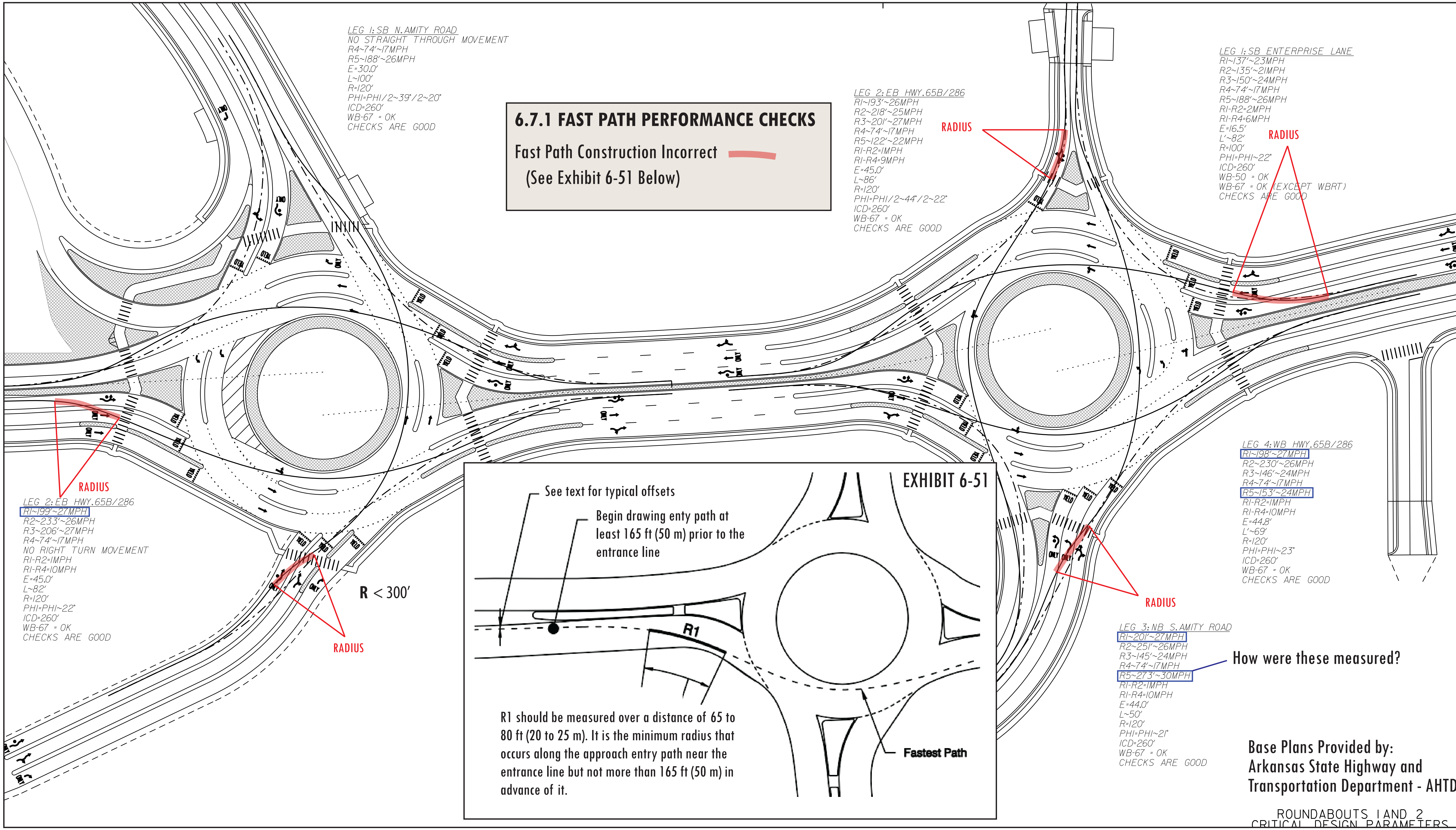
- As currently proposed (with large ICDs and Fast Path Deficiencies) the design does not adhere to Pedestrian Facilitation goals and objectives as discussed and outlined in NCHRP 674 – Speeds, Refuge area deficiencies, Pedestrian Beacons (e.g., RRFB, Hawk, for multi-lane entry/exits designs).

Based on this geometric and pavement markings review, this project requires modifications to adhere to proven and established design principles and criteria as outlined in NCHRP 672 *(FHWA Roundabout Guide 2010)*. The sketch level optimized design concept presented earlier in the Tech Memo (Figure #1) provides a concept sketch level design reflecting the laneage and geometric foundation from which to develop a revised preliminary design.

A revised design is necessary to correct deficiencies of the current design and to apply design principles to optimize this design such that the expected and desired operational outcomes will match the actual outcomes. These proposed modifications will provide substantial improvements in the safety performance, operations, and public/driver acceptance of these roundabouts.

Please see attachments.

# EXHIBIT #1




HWY 286 / DAVE WARD DR.
CONWAY, AR

MTJ REVIEW - GEOMETRIC DESIGN PRINCIPLES - FAST PATHS CHECKS
2.3.2015

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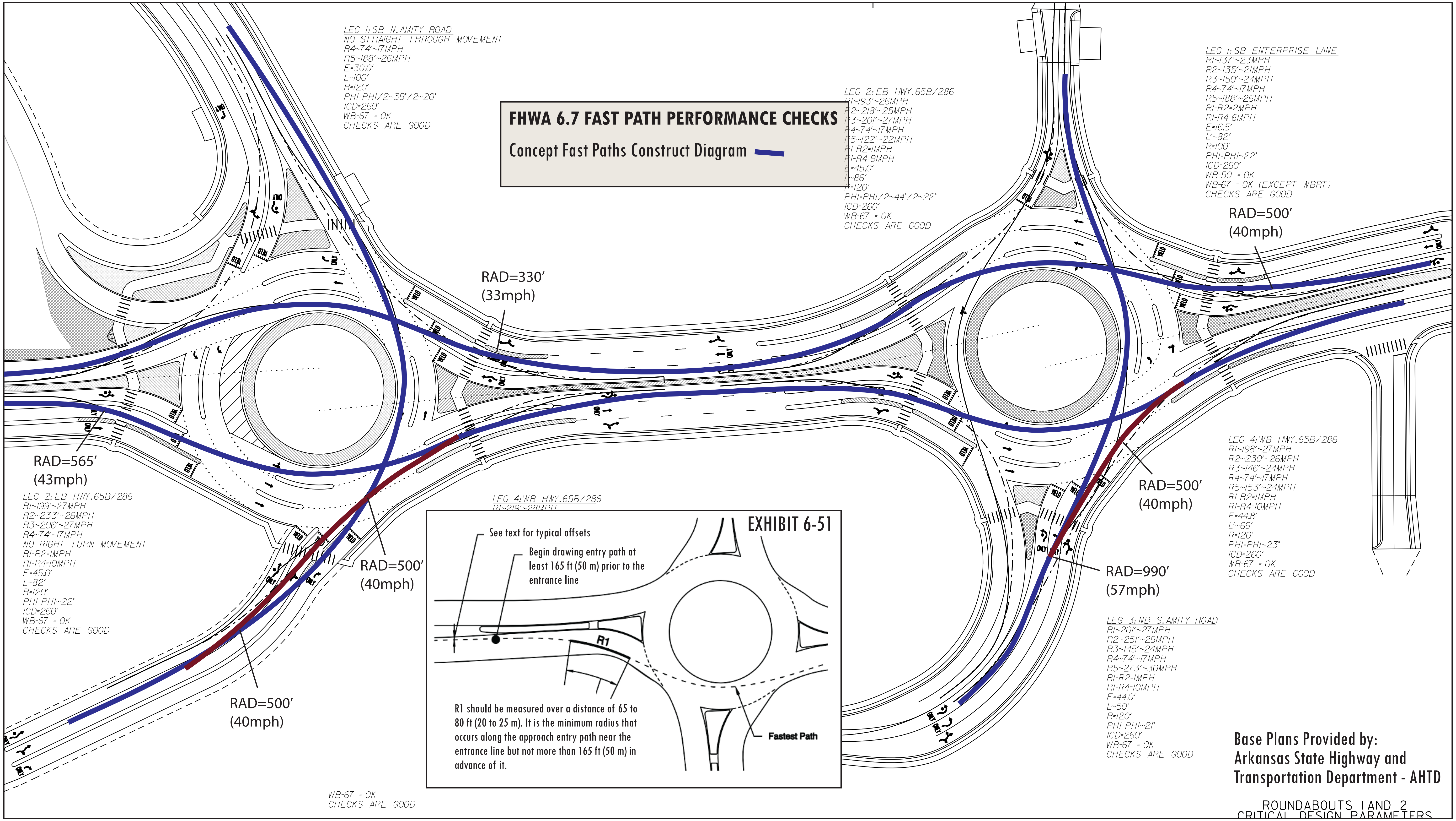
# EXHIBIT #2

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MTJ REVIEW - GEOMETRIC DESIGN PRINCIPLES - FAST PATHS MODIFIED
2.3.2015


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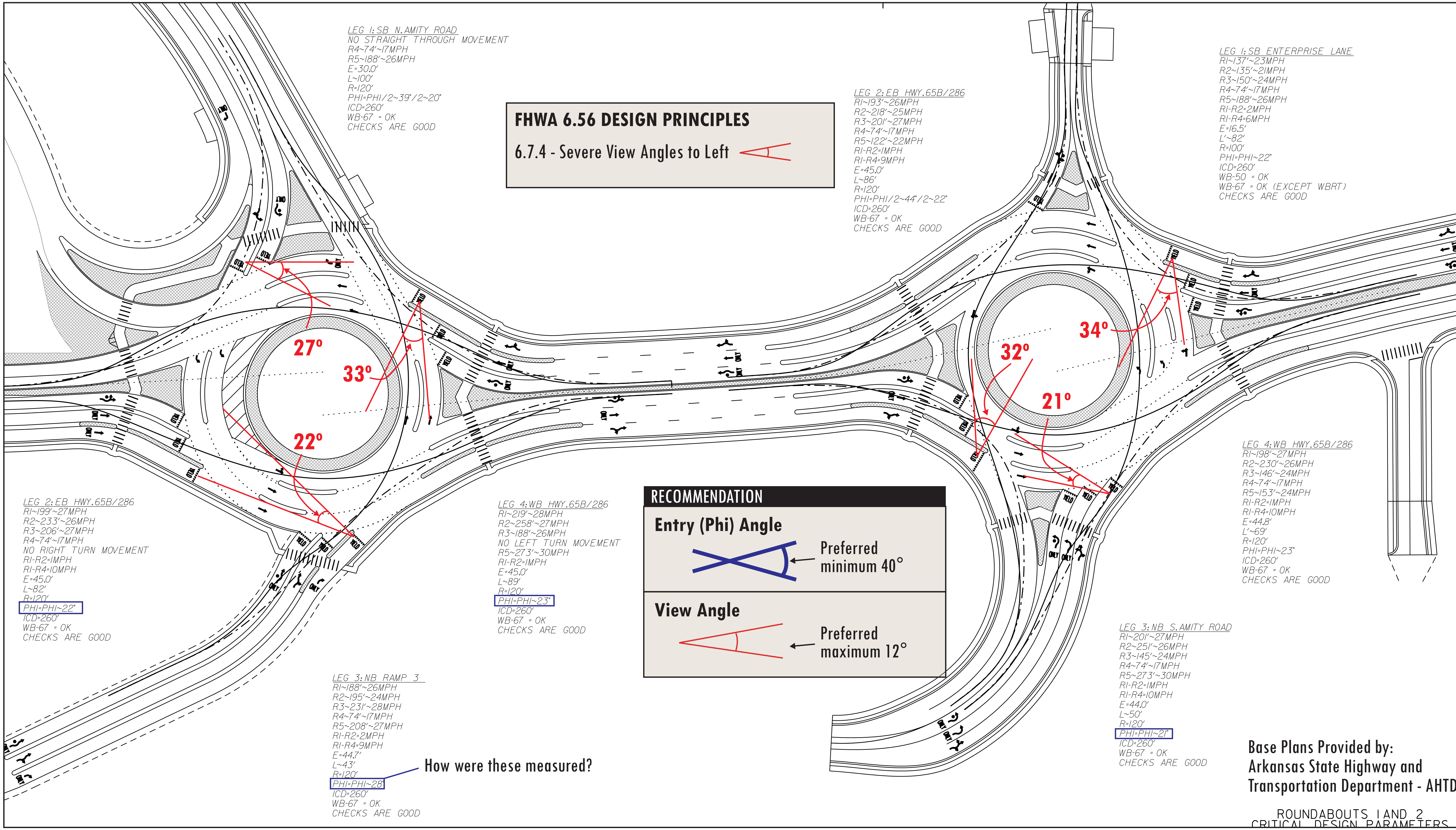
# EXHIBIT #3

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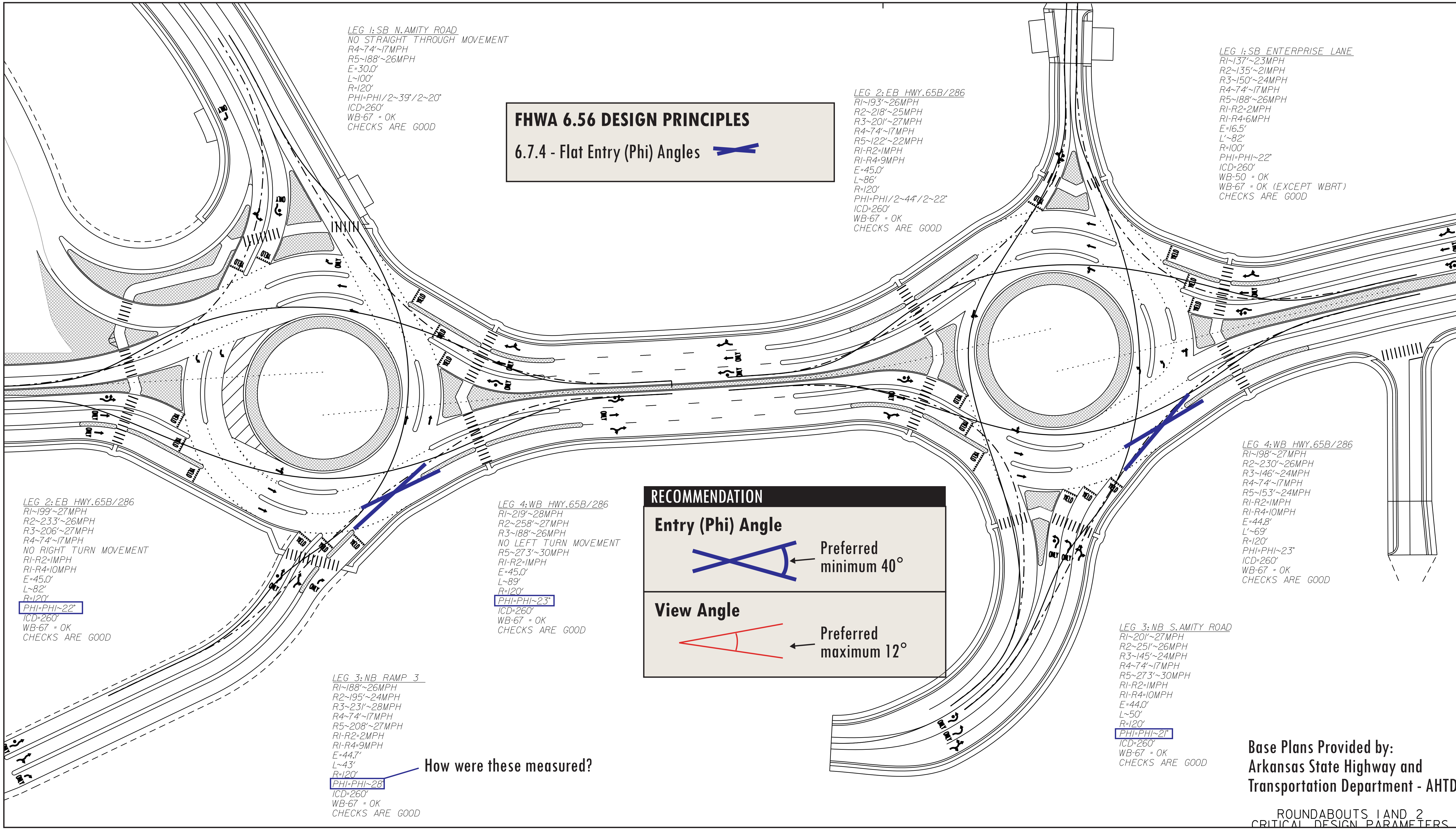
# EXHIBIT #4

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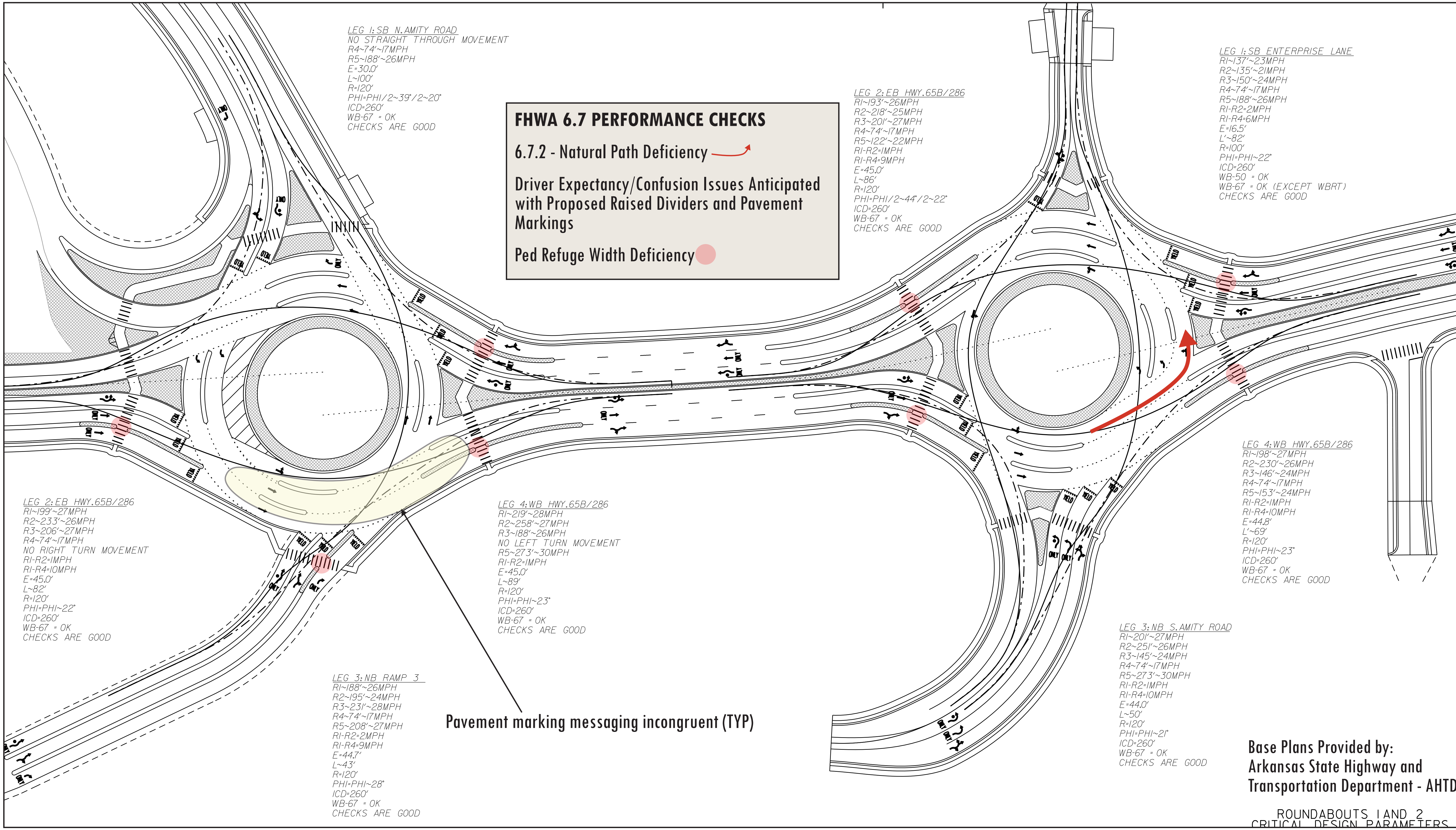
# EXHIBIT #5

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MTJ REVIEW - GEOMETRIC DESIGN PRINCIPLES - FHWA 6.7
2.3.2015


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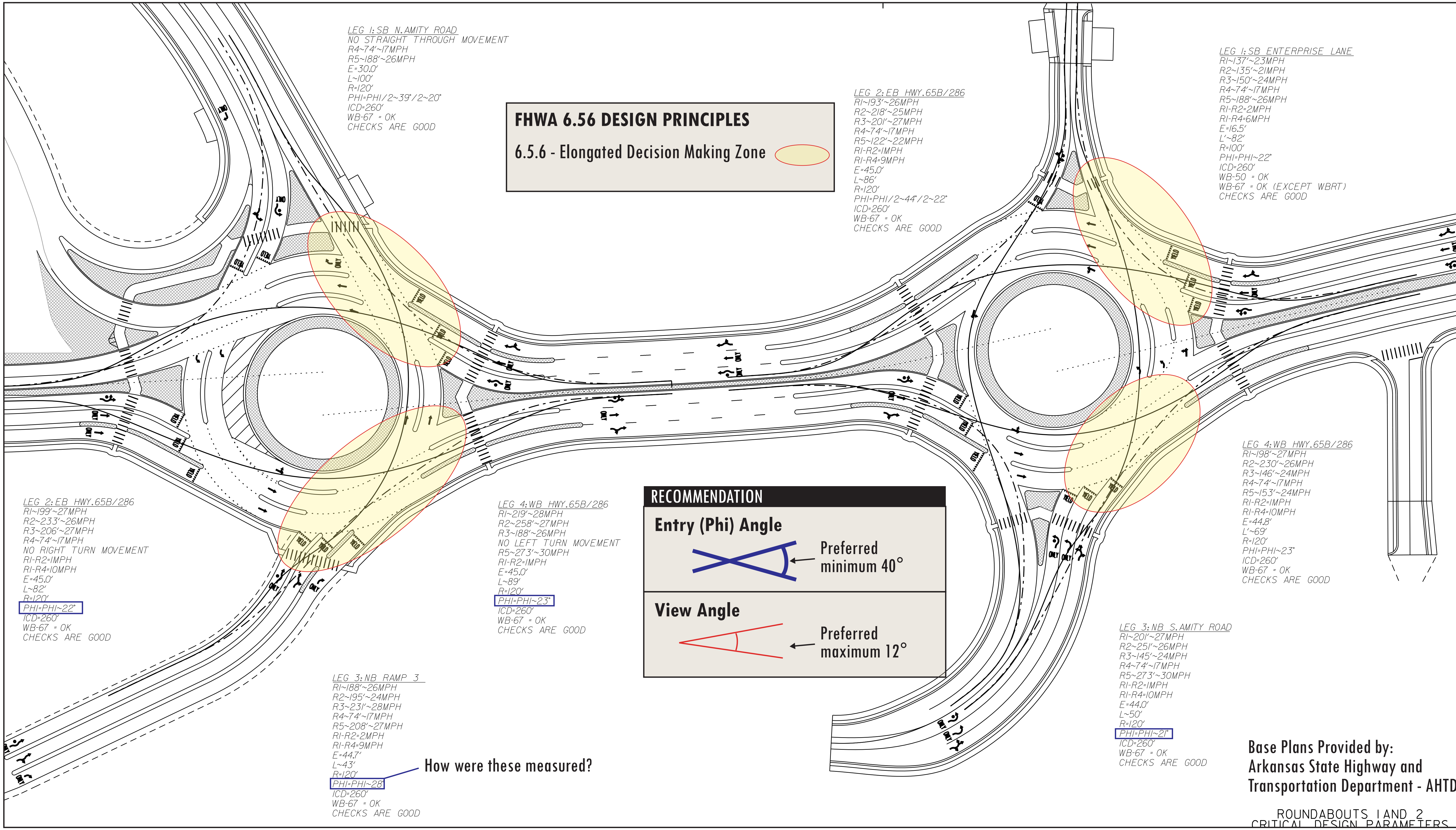


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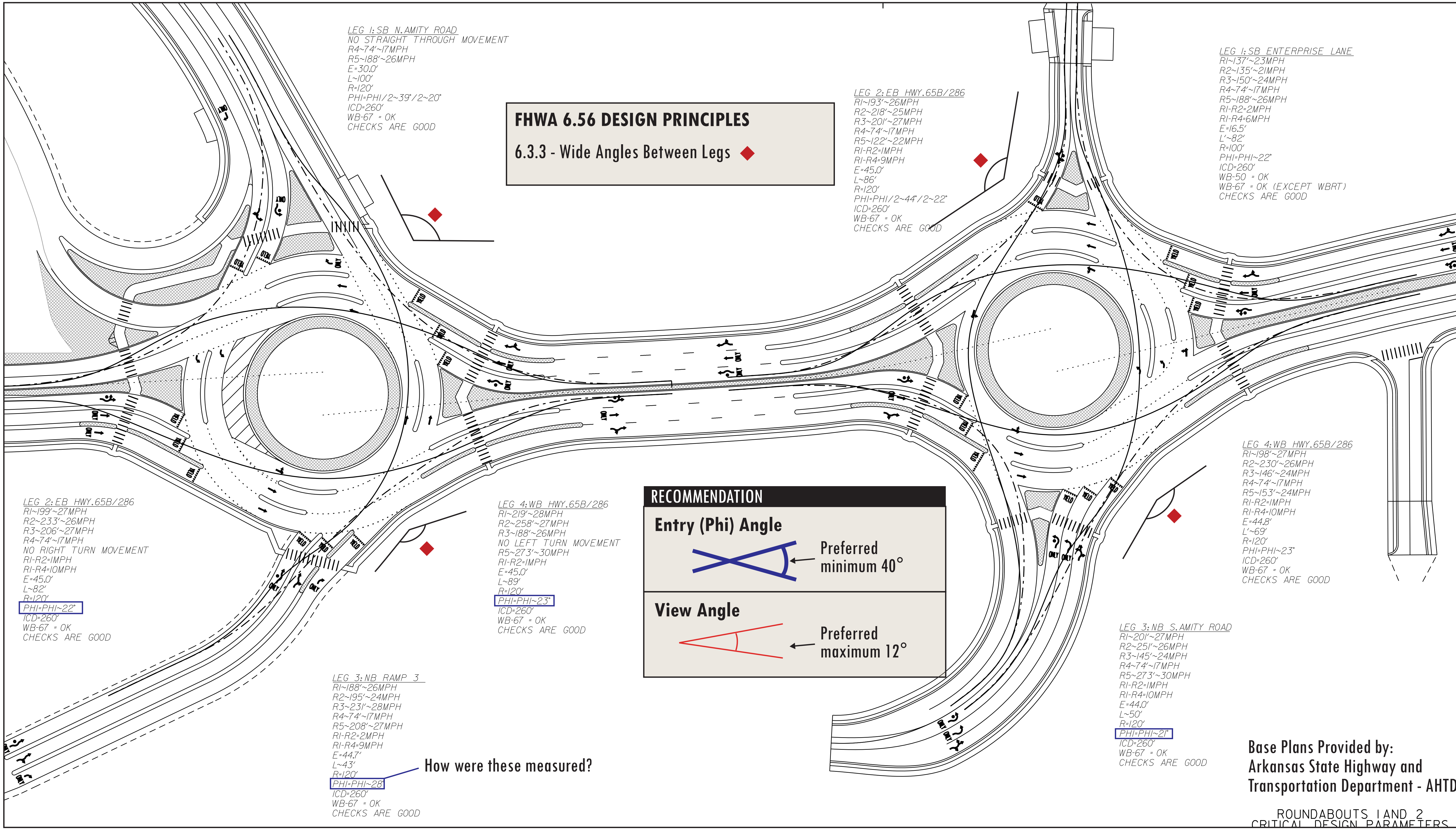


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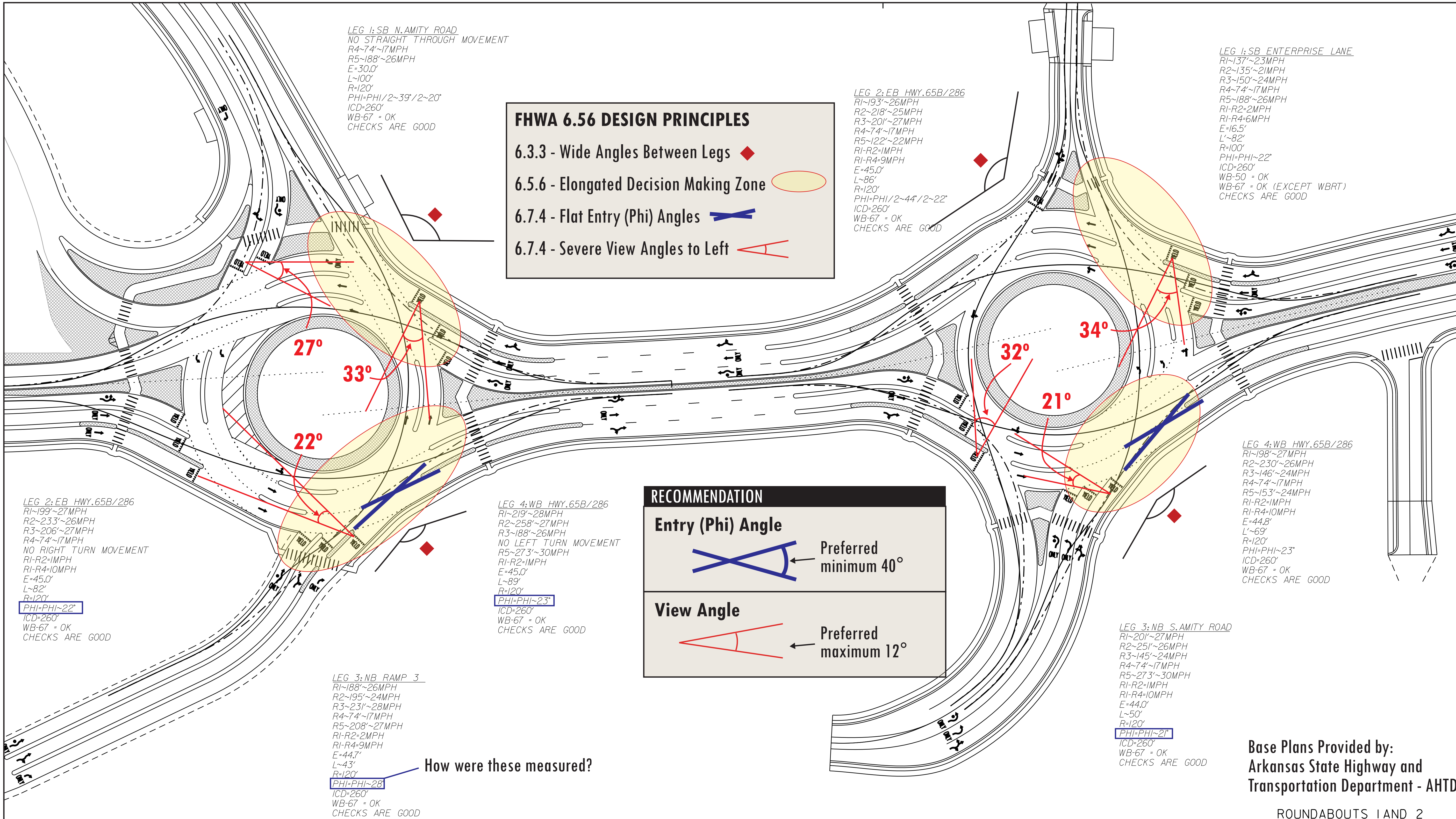


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