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2nd Street/Flume Street/1st Street Roundabout Design Report

for the

City of Chico

Draft Report

January 10, 2011

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A Intersection Level of Service Calculations and Queuing Calculations

draft

Introduction and Background

Introduction

The following report summarizes the anticipated operation and suggested design for a modern roundabout at the intersection of 2nd Street/Flume Street/1st Street in the City of Chico. The potential benefits and constraints associated with installing a roundabout were evaluated. This report supplements the *1st Street/ 2nd Street Circulation Modification Study* completed in April 2010. This roundabout is one component of the proposed transportation modifications to downtown Chico that includes converting 1st Street and 2nd Street to a one-way couplet between Broadway and Flume Street, as well as completing a four-lane to three-lane road diet on 2nd Street from Orange Street to Broadway. The intent of this project is to enhance pedestrian and bicycle circulation while maintaining or improving vehicle circulation and better utilizing existing transportation infrastructure.

This report summarizes the characteristics of the roundabout design for this intersection. It includes an analysis of the intersection operation with the existing configuration as well as with a roundabout, and indicates how the roundabout could affect adjacent properties. A summary of the design features of the roundabout alternative, as well as some background information on roundabouts, are also included.

Project Goals

The following goals were applied to the design.

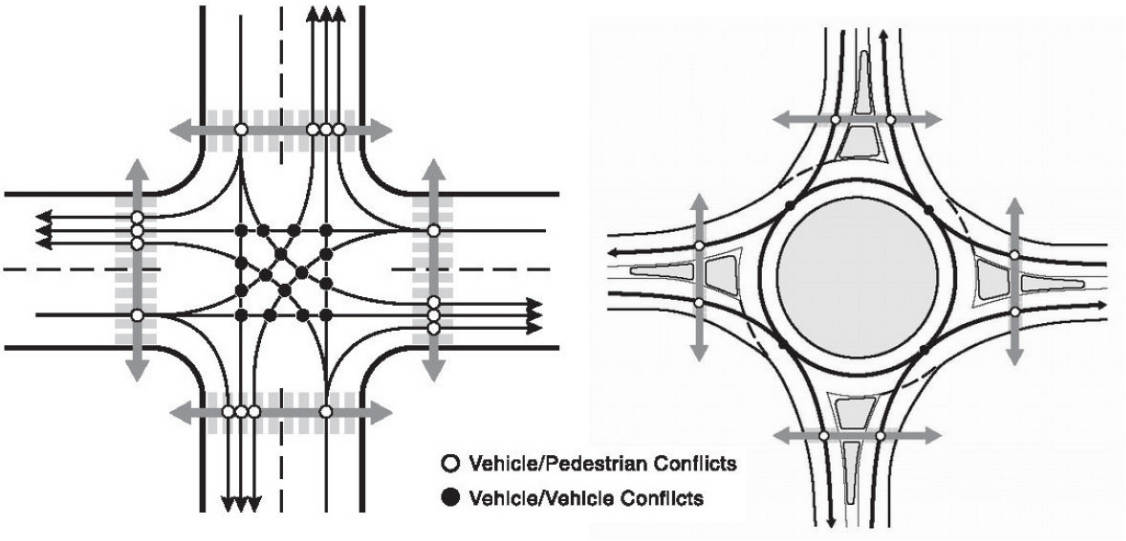
- Determine an intersection configuration that can safely accommodate traffic expected with future growth under buildout of the General Plan.
- Provide improved circulation for pedestrians and bicyclists.
- Evaluate how access to adjacent streets and parcels will function in the future.
- Ensure that the largest City of Chico fire trucks as well as transit vehicles can easily negotiate the intersection, and that the occasional large semi truck can be accommodated for through travel on the corridor.
- Improve safety at this awkward intersection of several streets.
- Provide an efficient transition between a one-way couplet and bi-directional streets.

Background on Modern Roundabouts in the United States

Modern roundabouts are relatively new to the United States, though in the past several years their use has been growing rapidly as decision makers, the public, and the development community have come to realize their benefits. In March 2000 the Federal Highway Administration (FHWA) published *Roundabouts: An Informational Guide*, which provides design guidelines as well as discussions of the operational impacts of roundabouts. Following is a synthesis of the benefits typically associated with modern roundabouts based on discussion in the FHWA guide, as well as safety-related findings from the Insurance Institute for Highway Safety (IIHS) and National Cooperative Highway Research Program (NCHRP).

1. Safety – The IIHS has found that installation of modern roundabouts, on average, results in a 39 percent decrease in total crashes, 76 percent decreases in injury-producing crashes, and 90 percent decreases in fatal crashes. The IIHS also reports significant reductions in pedestrian-related incidents after roundabout installation. The recent NCHRP Report 579 *Roundabouts in the United States* indicates that

overall collisions decrease by 35 percent when intersections are converted to roundabouts, with a 76 percent decrease in injury-producing collisions. There are multiple characteristics of roundabouts that lead to their notable safety performance. Perhaps the most influential are related to speed moderation and reduction in conflict points. Properly-designed roundabouts are configured to regulate all vehicle speeds to the 15-20 mph range, and collisions in roundabouts tend to be low-speed incidents that often result only in property damage. The most severe types of accidents, head-on and broadside, do not occur at roundabouts. Another major difference between roundabouts and other intersections is a substantial reduction in the number of potential conflict points. At four-way intersections roundabouts have eight vehicle-to-vehicle conflict points versus 32 at a conventional intersection, and eight vehicle-to-pedestrian conflict points in comparison to 16. Diagrams showing conflict point locations are provided below.



Source: FHWA Roundabout Guide

2. Capacity and Delay Times – For a given number of entering lanes, roundabouts are capable of handling a higher volume of vehicles than other types of intersection controls. At many intersections, and in particular those that are all-way stop-controlled, roundabouts will have lower average vehicle delay and better Levels of Service.

3. Aesthetics and "Gateway" Effect – Roundabouts provide an excellent opportunity for landscaping and/or public art, work well as transition points between higher-speed and lower-speed environments, and work effectively as a transition between one- and two-way streets. Roundabouts also create "gateways" into urban areas that visually alert drivers that they are entering a different type of street environment.

4. Speed Moderation – Roundabouts are carefully designed to moderate traffic speeds through maneuverability restrictions, with all traffic flowing through the roundabout at design speeds of 15 to 20 miles per hour. This also results in moderated traffic speeds on the roundabout approaches and exits without creating the stop-and-start conditions associated with stop signs and traffic signals.

5. Fuel Consumption, Air Quality, and Energy – By reducing the amount of rapid acceleration and deceleration associated with other types of intersection controls, roundabouts typically cause vehicles

to consume less fuel and correspondingly lead to lower vehicle emissions. Roundabouts also use no electricity other than street lighting, and have a longer expected service life than signalized intersections.

6. U-turns – The ability to make U-turns is relatively easy and safe at roundabout-controlled intersections. This can facilitate parking circulation, and can improve access from driveways along adjacent street segments where left turns are difficult or prohibited.

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Roundabout Concept Design

Site Description

The study intersection is located east of Downtown Chico and is the convening point for two major downtown routes as well as a crossing of Big Chico Creek. Two adjacent intersections come together to connect 1st Street, 2nd Street, Flume Street and Camellia Way with the northern and southern legs of 1st Street being offset. Immediately to the east, Camellia Way connects to Vallombrosa Avenue. Due to physical constrains related to the Creek, 1st Street and the Camellia Way Bridge intersect at severely skewed angles while 2nd Street and Flume Street intersect at right angles. Additionally, due to offset of the 1st Street approaches, these two intersections essentially operate as one large, awkward intersection. A channelization island separates westbound right turn movements from though movements onto 2nd Street; however, despite this island, the turn has a large radius and is often taken at high speeds. The intersection is located at a transition point between commercial areas and an established residential neighborhood. Additionally, between Camellia Way and the southern leg of 1st Street to the east of the intersection is the Annie's Glen Picnic Area which is the westernmost entrance to Bidwell Park.

Existing traffic volumes were obtained at the intersection by the City of Chico during the weekday p.m. peak hour. Future volumes were projected based upon a redistribution of traffic along likely routes with the implementation of the one-way couplet on 1st and 2nd Streets.

The speed limit on 1st Street, 2nd Street and Flume Street in the vicinity of the intersection is 25 mph. To the east of the Camellia Way Bridge, an advisory speed limit of 15 mph is posted.

Layout Constraints

Site constraints influence the roundabout's layout and limit its overall size. Following are the primary constraints.

- The alignment of intersecting roadways and topography to the east of Flume Street limit the placement of the roundabout.
- There is a Pacific Gas & Electric (PG&E) electricity substation on the northeast side of the intersection that cannot be relocated. Access must be maintained for general maintenance (large pick-up trucks), and occasional major maintenance would require access for large equipment.
- Full access must be maintained to two parcels on 1st Street directly opposite of Flume Street (Sierra Central Credit Union and Chico Creek Wellness and Chiropractic).
- The building on the southeast corner is built to the back of the sidewalk (Chico News & Review), which limits the position of the roundabout.

There are also trees that could be impacted by a roundabout, as follows.

- One large tree on the corner of the western triangle between 1st Street and 2nd Street (on the US Bank Property)

- One medium-sized tree on the easterly side of the northbound Flume Street approach (in sidewalk tree-wells adjacent to the Chico News & Review building)
- Two medium-sized trees on south side of the eastern leg (in sidewalk tree-wells adjacent to the Chico News & Review building)

General Roundabout Configuration

Analysis using the 20-year forecast peak hour traffic volumes indicates that a single-lane roundabout would be expected to operate acceptably at LOS A. There is insufficient space to fully incorporate the minor southeast leg of East 1st Street (that runs alongside Bidwell Park) into the roundabout intersection. It was determined, however, that it would be possible to convert the leg to carry traffic one-way southbound only, connecting to Orient Street. Westbound left-turn moments from Camellia Way onto this leg would also need to be prohibited. Drivers wishing to make this westbound left-turn movement from Camelia Way onto the southern leg of 1st Street would instead need to make a U-turn through the roundabout followed by a right turn. Drivers who currently exit northbound on the southern leg of 1st Street would need to divert their route by one to two blocks. While this is a slightly longer distance, it will reduce delay and turning conflicts associated with the current offset intersection. By converting this segment of 1st Street to a one-way street it is possible to replace parallel parking on the Park side of the street with angled parking, increasing the total on-street parking supply. This, coupled with a bicycle path that would provide direct access from the roundabout to the Annie's Glenn trail, could reinforce the location as an entry point to Bidwell Park. The configuration also maintains full access for the driveway on 1st Street.

There are two parcels that have access either within the intersection or very near the intersection. These are Sierra Central Credit Union, which has its sole driveway on the northwest leg of 1st Street just west of the intersection, and Chico Creek Wellness and Chiropractic, which has two driveways located within the intersection. The access to Sierra Central Credit Union would not be affected; however, the location of the crosswalk would be slightly modified to maintain this access. Access to the Chico Creek Wellness and Chiropractic office would be modified, but full access from all directions will be maintained. The parking lot would be converted to a one-way loop with the entrance driveway located directly on the roundabout, and the right-out only exit on the westbound approach. While the exit maneuver would be limited to a right turn only, a driver wishing to go another direction would be able to enter the roundabout to change directions. Entering drivers would travel through the roundabout from any approach and then enter the parking lot. This is expected to improve access to the parking lot as it will reduce turning conflicts while serving all movements.

These fundamental assumptions were used in the process of designing an appropriate layout for the roundabout and each of its approach legs. The resulting roundabout layout is shown in Figures 1 and 2.

Design Elements

Roundabouts have geometric elements that are unique among traffic control devices. The combination of various design elements must be customized to each roundabout intersection, and specifically configured to achieve the desired balance of safety, capacity, and speed regulation. A discussion regarding how each of these elements is treated at the proposed roundabout design for 2nd Street/Flume Street/1st Street is provided below. A diagram showing the terminology associated with each component of a roundabout is provided in Plate 2.

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FIRST ST/SECOND ST/FLUME ST
ROUNDABOUT LAYOUT

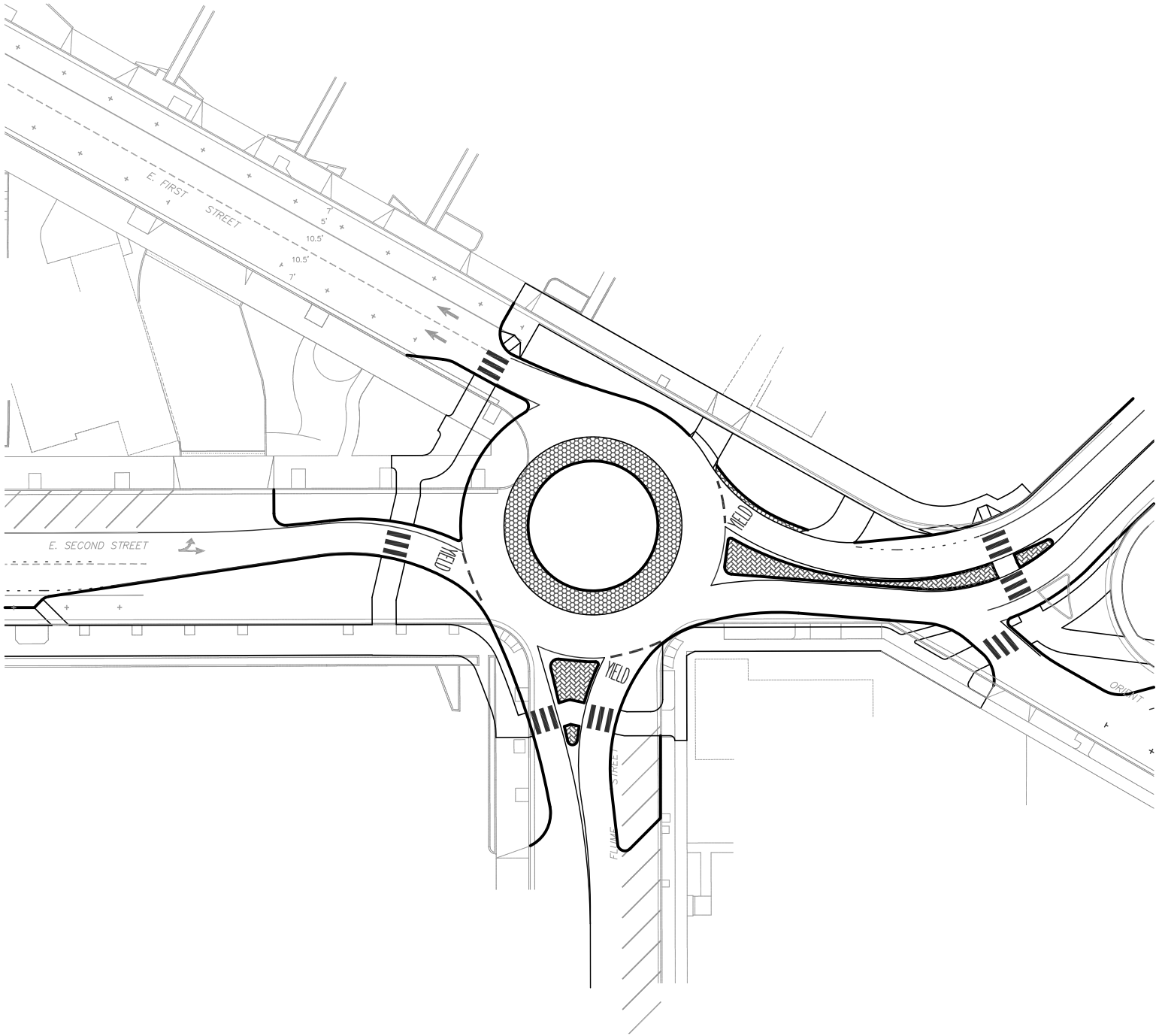

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FIGURE 1
ROUNDABOUT LAYOUT

SCALE 1" = 60'

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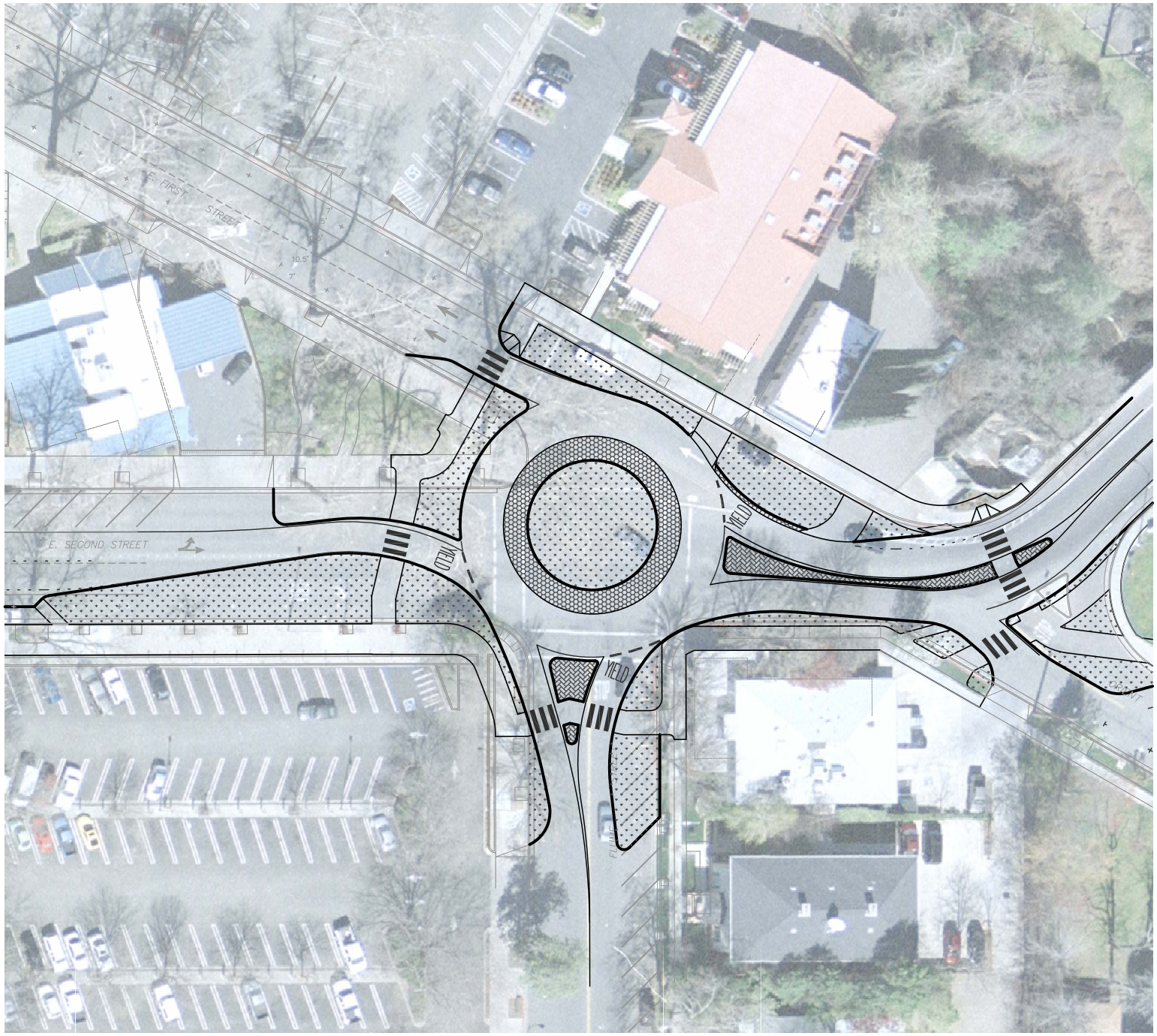

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FIGURE 2
ROUNDABOUT LAYOUT

SCALE 1" = 60'

Images: 2nd st aerial.jpg; w-trans_150dpi.jpg; w-trans_300dpi.jpg; Xrefs: City Base.dwg; Topo Combined.dwg; Couplet Design 3-29-10 2007.dwg; Camelia _ vallombrosa _ mangrove 2007.dwg
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Layout: Layout a Plot Date: Oct 27, 2010
DWG File: Second-Flume Fall 2010-Bid.dwg Plotting Time: Wed - 01:43 pm

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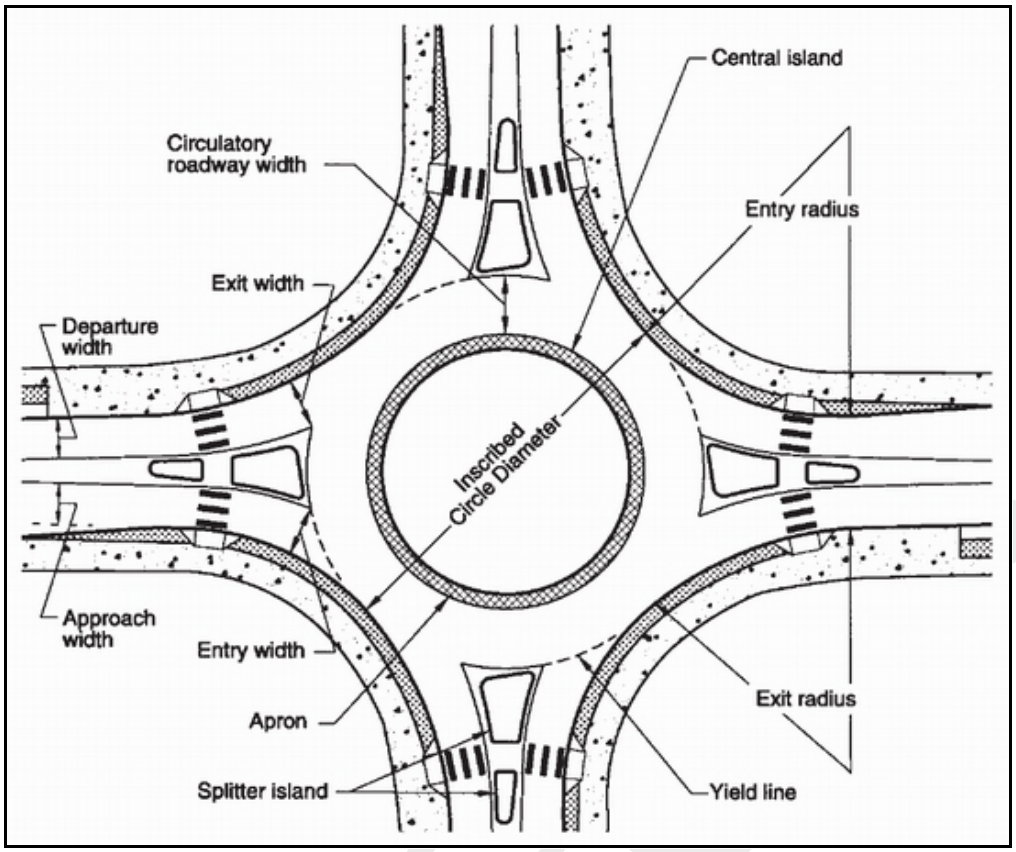

Plate 2 - Roundabout Design Elements *(Source: FHWA Roundabout Guide)*

Size and Positioning

In the initial design phase, various diameters and placement of the inscribed circle were examined. Through this process it was determined that an appropriate roundabout size given existing constraints would be a circle with an inscribed diameter of 110 feet. In terms of placement, the circle has been located to provide adequate deflection and speed control while minimizing right of way impacts.

Central Island and Truck Apron

The "central island" of a roundabout is the innermost area; it is raised and typically landscaped. No vehicles pass through the central island area. Roundabouts are designed to accommodate the largest design vehicle anticipated to pass through the intersection, while still moderating speeds for passenger vehicles. A "truck apron" is generally incorporated into the design of single-lane roundabouts to provide additional traversable area around the raised central island for large vehicles.

The dimensions of the roundabout's central island and mountable truck apron were determined through a combination of large vehicle maneuverability testing (described in more detail below) and the need to regulate vehicle speeds. The current concept includes a 10-foot wide truck apron, which is constructed of structural concrete that is raised 3 inches above the circulating travel lane, colored, and given an aggressive texture (such as small cobbles) that deters passenger car drivers while still being traversable by semi truck trailers. Additionally, a two-foot wide mountable curb is provided on the westbound approach just prior

to the roundabout entry in order to accommodate large semi trucks. Such mountable curbs are referred to as "outside truck aprons." The central island of the roundabout would be 44 feet in diameter and landscaped. This landscaping could be used to create a gateway entry to Downtown Chico. Figure 3 shows the location of these mountable curbs as well as the locations of typical 6-inch curbs.

Splitter Islands

Splitter islands are generally provided on the entry legs of all roundabouts. Their purpose is to provide shelter for pedestrians, regulate speeds, guide traffic into the roundabout in a smooth manner, physically separate entering and exiting traffic streams, and deter wrong-way movements. Additionally, splitter islands can be used as a place for mounting signs and occasionally for landscaping.

Splitter island configurations are determined by the widths of entry and exit roadways as well as striping offsets. The lengths of the splitter islands are influenced by the need to slow vehicle speeds as drivers proceed toward the roundabout, and they can also be used to channel and restrict turning movements at adjacent driveways and streets. On bi-directional approaches, the splitter islands would include a minimum 6-foot wide break through which the pedestrian crosswalk passes; crosswalks would generally be set back approximately 20 feet (one vehicle length) from the circulatory roadway. On the eastern leg, the pedestrian crossing will not be provided adjacent to Flume Street, but further back at the southeast leg of 1st Street (adjacent to Bidwell Park). This adds about 175 feet of additional walking distance to cross the eastern approach, but this was necessary to provide driveway access and locate the crosswalk where a full 6-foot wide refuge area and adequate sight distance could be achieved. Splitter islands are typically 6 inches high, formed by concrete curbs and filled with a colored hardscape.

One-way Transition

Since all roundabout entrances and exits are channelized it would be very difficult for a driver to accidentally enter the wrong direction of traffic. This is beneficial for the proposed one-way couplet as it will provide a smooth transition between one-way and bi-directional traffic.

Landscaping

Landscaping in the central island of roundabouts plays an important safety role, helping to focus drivers' attention only on circulating traffic rather than activity on adjacent approaches. The center of the roundabout should include landscaping and/or monuments that reach a minimum of six feet in height. Small shrubs are typically planted between sidewalks and the circulating roadway to help guide pedestrians to the crosswalks (rather than entering into the roundabout itself). A similar effect can be created by installing a rough cobble-like hardscape between sidewalks and the circulating roadway.

Design for Pedestrians and Bicyclists

Pedestrian ramps and marked crosswalks exist on all four corners of the intersection. Continuous sidewalks currently exist along all sides of the intersection and will continue to be provided with the roundabout, though with some modifications. As previously discussed, the eastern Camilla Way leg would be moved to immediately east of the southeast leg of East 1st Street, with no crossing provided adjacent to Flume Street. This would increase walking distances for some pedestrians, but was the only way to provide adequate refuge space on the splitter island where both sight distance and driveway access could be maintained.

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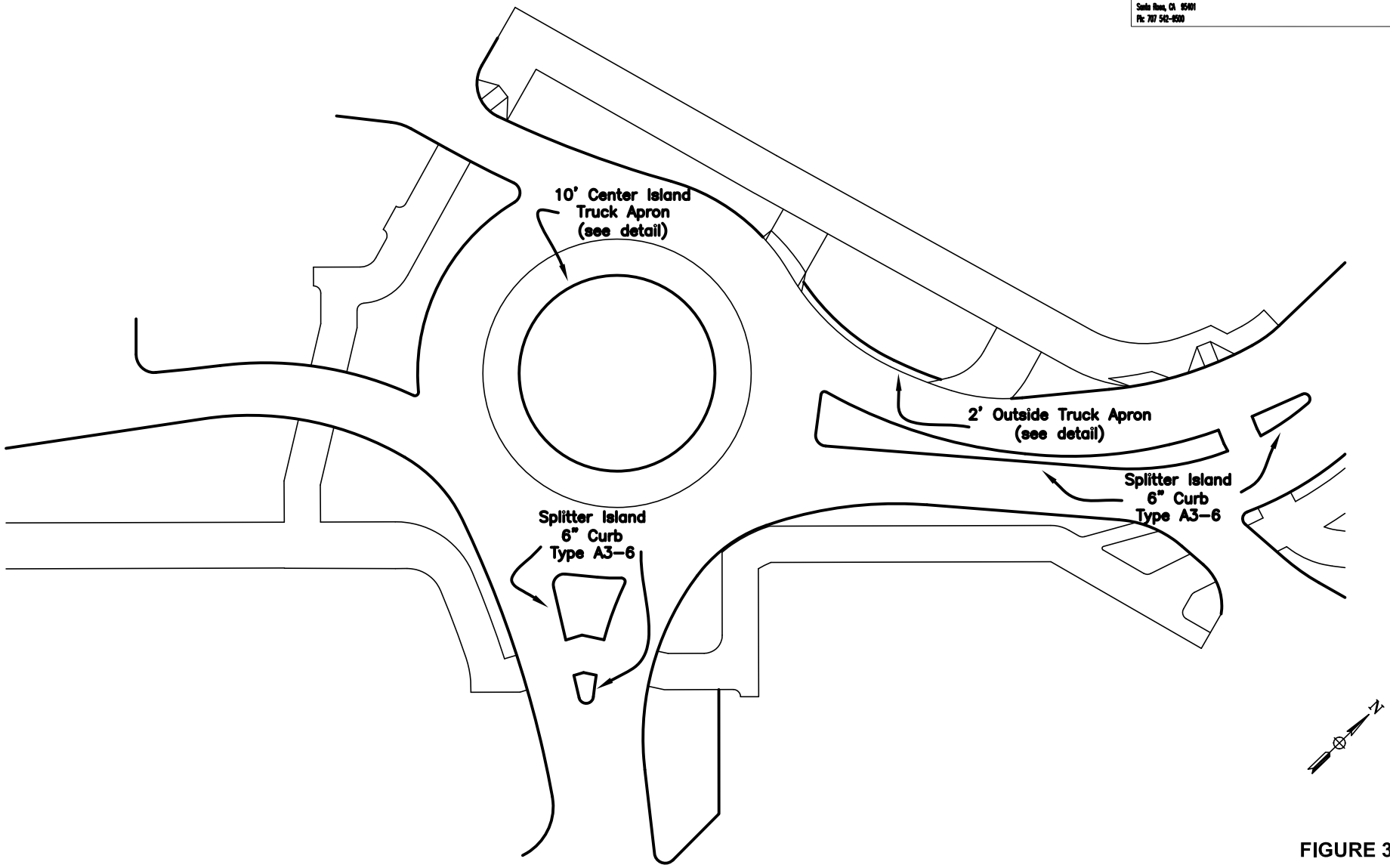

FIGURE 3
CURB DETAIL

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FIRST ST/SECOND ST/FLUME ST
ROUNDABOUT LAYOUT

Images: 2nd st aerial.jpg; w-trans_150dpi.jpg; w-trans_300dpi.jpg; Xrefs: City Base.dwg; Topo Combined.dwg; Couplet Design 3-29-10 2007.dwg; Camelia _ vallombrosa _ mangrove 2007.dwg
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Pedestrians would also have the option of making a shorter crossing via the other side of the roundabout. To prevent pedestrians from crossing at an inappropriate location adjacent to Flume Street, guide signs directing pedestrians to the marked crossing may be necessary. All crosswalk openings through the raised splitter islands would be 10 feet wide and have a minimum length of six feet, which is sufficient to shelter both pedestrians and those walking bicycles.

The roundabout would include 10-foot wide multi-use path on its periphery. The paths would connect to existing sidewalks, and would be of sufficient width to allow for bicycle travel. In order to construct a 10-foot wide path along the Chico News & Review building on the southeast corner it will be necessary to remove three trees.

Currently, on-street bicycle lanes are only provided on the eastern leg, but bicycle lanes would be installed on 1st Street and 2nd Street with the completion of the proposed Downtown modifications. At single-lane roundabouts, most bicyclists are comfortable "claiming the lane" and proceeding through the roundabout with vehicles, which are traveling at low speeds in the 15-20 mph range. Cyclists would mix with traffic as they currently do at the intersection but would have the benefit of not having to stop. Inexperienced, slower, or less-confident cyclists would have the option of riding on the peripheral multi-use path. Bicycle ramps to and from this path would be provided on 1st Street, 2nd Street, and Camellia Way.

Vehicle Maneuverability

The roundabout has been designed to accommodate a large single-unit ladder fire truck. It will be possible to maneuver the fire truck between intersection legs without using the center truck apron. Butte County B-Line Bus Route 2 currently travels east-west through the intersection, so the roundabout has been designed to accommodate a large 45-foot long bus on east-west movements, but not to and from Flume Street since it is unlikely that transit service would extend to this street. School buses were also considered; they will be able to make all movements within the roundabout.

The roundabout has also been designed to accommodate a California Legal semi truck on east-west movements (1st Street, 2nd Street, and Camellia Way). A driver of this size of truck would need to make use of the truck apron as well as the mountable curb on the westbound approach. A truck of this size could not negotiate the a right turn from Flume Street onto Camelia Way; however, it is unlikely that such a truck would be making this movement (alternative routes are available). A truck of this size would be able negotiate a left-turn from Flume Street to East 1st Street, so if a driver inadvertently enters the roundabout from Flume Street, they will still be able to exit the roundabout. A 30-foot single-unit box truck, such as those commonly used for local deliveries, was found to be able to navigate the roundabout to and from all legs without needing to use the mountable curb. The drive-paths of these critical movements are shown on Figures 4 through 6.

PG&E owns and maintains an electrical substation at the northeast corner of the intersection that cannot be relocated as part of the roundabout installation. Access to the substation is generally not needed except for routine maintenance, emergency response and rare major maintenance. For routine maintenance, a large pick-up truck would need to access the site, but for major maintenance large equipment, including a crane, would need access. Access for large equipment cannot be accommodated within the roundabout, so alternative access will be provided on the westbound approach adjacent to the pedestrian ramp. A mountable curb would be provided that would allow large trucks to drive onto the sidewalk to get to the substation, but would not be confused as a driveway to be used by other drivers. Both the ramp and

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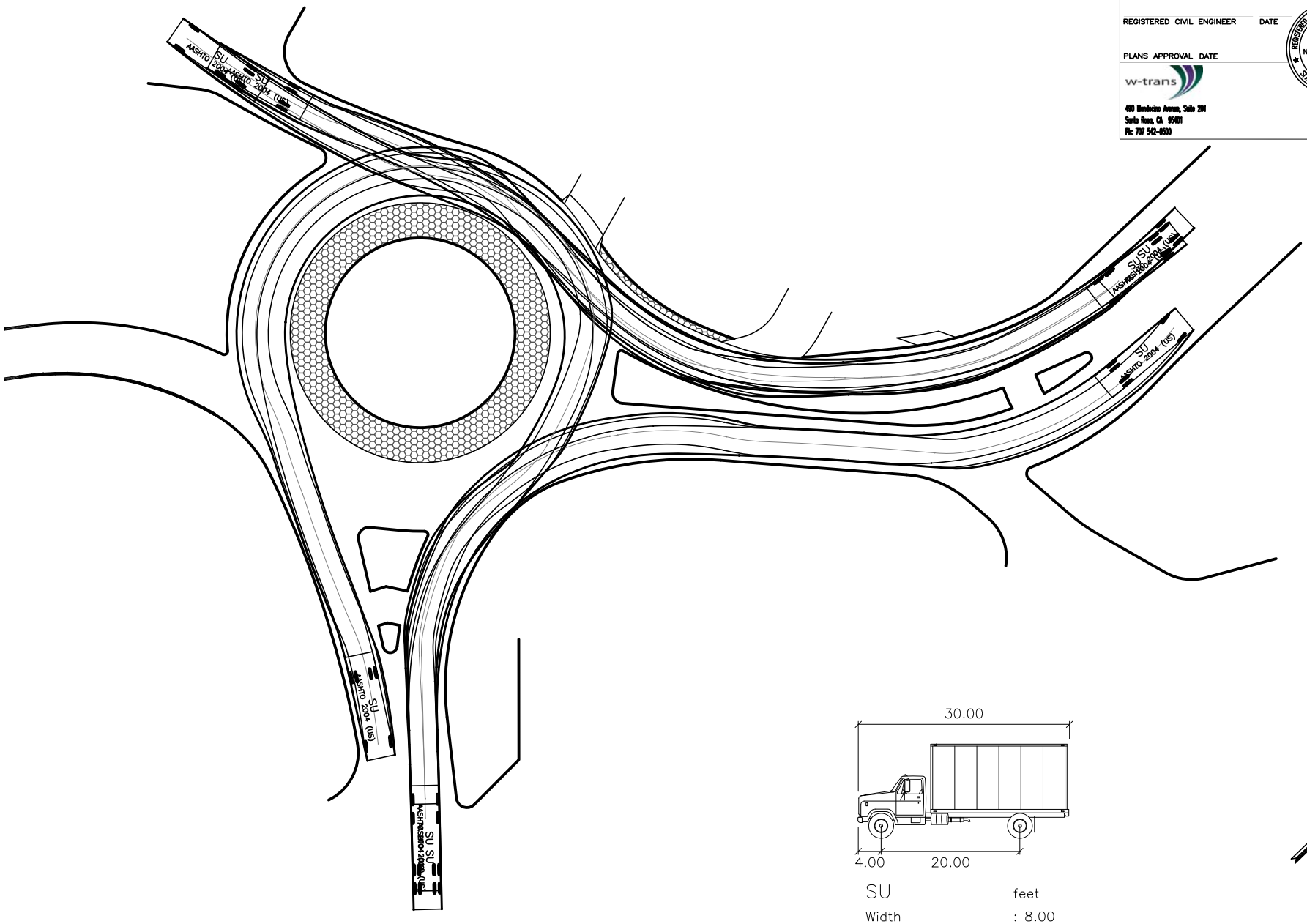

SU	feet
Width	: 8.00
Track	: 8.00
Lock to Lock Time	: 6.0
Steering Angle	: 31.8

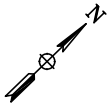

FIGURE 4
TRUCK TURNING
SINGLE UNIT TRUCK

Images: 2nd st aerial.jpg; w-trans_150dpi.jpg; w-trans_300dpi.jpg; Xrefs: City Base.dwg; Topo Combined.dwg; Couplet Design 3-29-10 2007.dwg; Camelia _ vallombrosa _ mangrove 2007.dwg
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Layout: Truck 1 Plot Date: Oct 27, 2010
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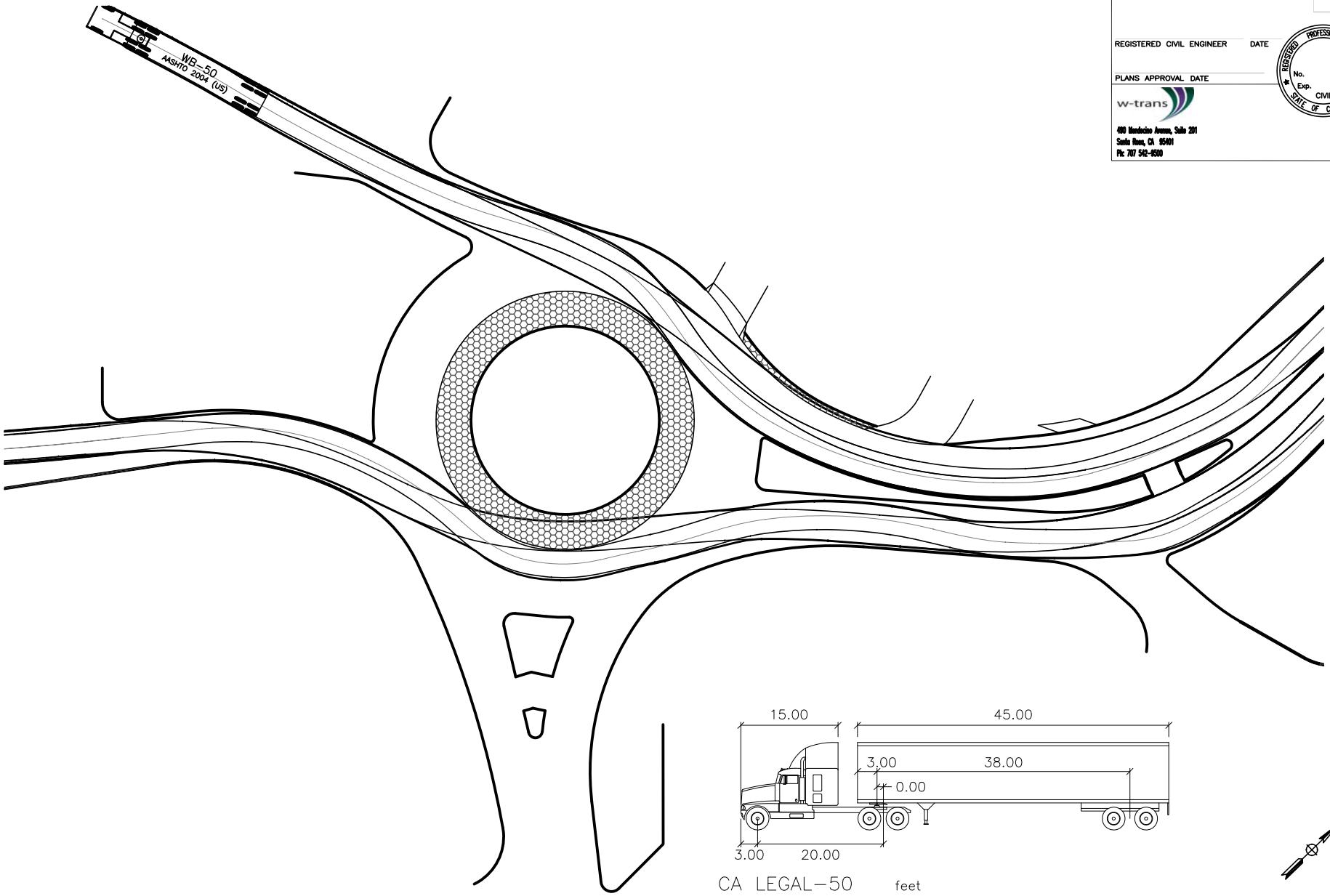

CA LEGAL-50 feet

Tractor Width	: 8.50	Lock to Lock Time	: 6.0
Trailer Width	: 8.50	Steering Angle	: 26.3
Tractor Track	: 8.50	Articulating Angle	: 70.0
Trailer Track	: 8.50		

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FIGURE 5
TRUCK TURNING
CALIFORNIA LEGAL-50 TRUCK

Images: 2nd st aerial.jpg; w-trans_150dpi.jpg; w-trans_300dpi.jpg; Xrefs: City Base.dwg; Topo Combined.dwg; Couplet Design 3-29-10 2007.dwg; Camelia _ vallombrosa _ mangrove 2007.dwg
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Layout: Truck 2 Plot Date: Oct 27, 2010
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FIRST ST/SECOND ST/FLUME ST
ROUNDABOUT LAYOUT

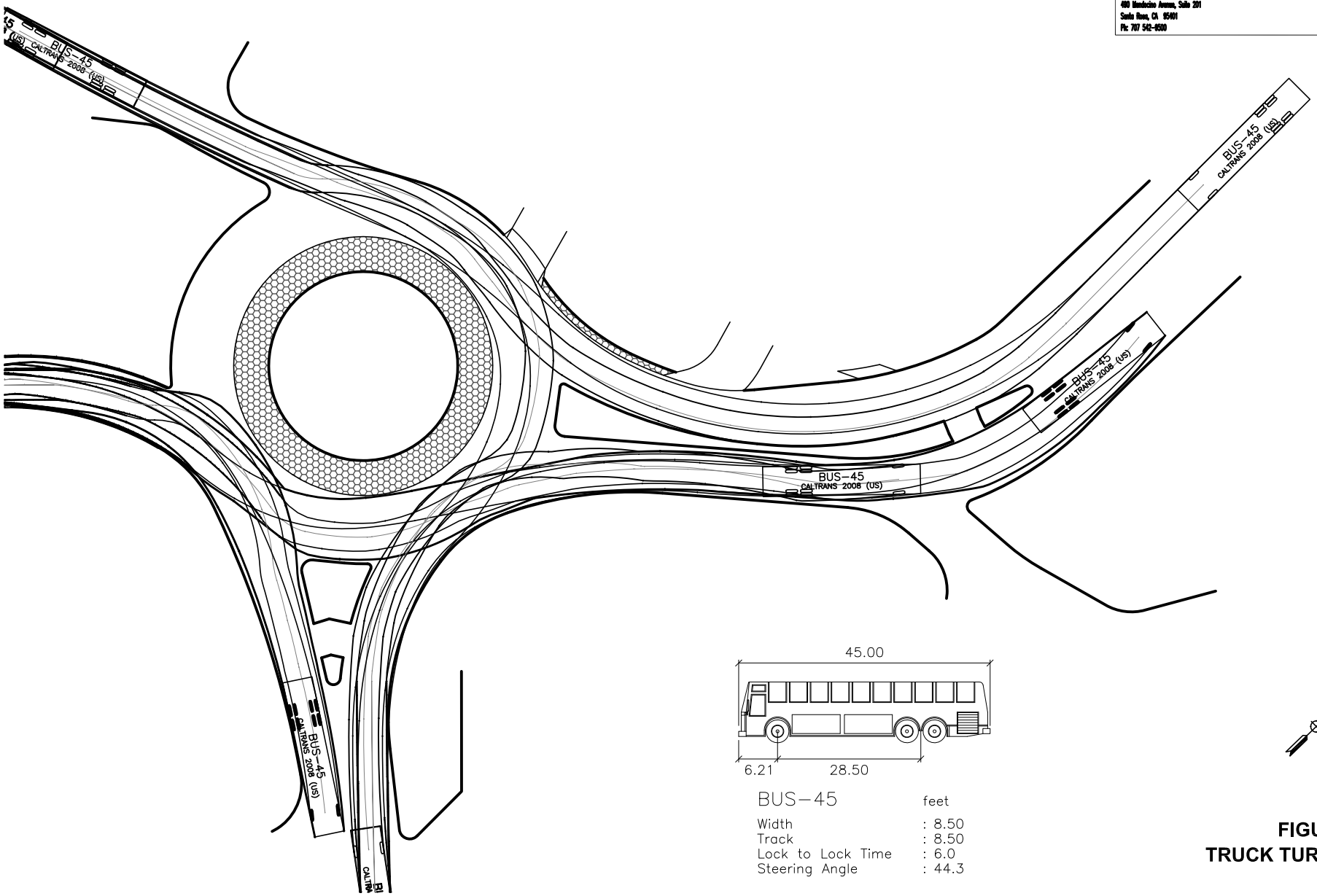

FIGURE 6
TRUCK TURNING
BUS

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Layout: Truck 3 Plot Date: Oct 27, 2010
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sidewalk, as well as an existing electrical vault in the existing sidewalk, may need to be reinforced to accommodate this equipment.

Speed Moderation

Upon satisfying the various requirements indicated above, the resulting configuration was tested to ensure that appropriate vehicle speeds would be maintained for passenger vehicles at the entry, within the roundabout and upon exiting. The "Fastest Path" represents the path that the most aggressive drivers could take through the roundabout, assuming no other traffic within the intersection. The *Informational Guide* indicates that vehicle entry speeds along the fastest path should be no greater than 20 mph at urban single-lane roundabouts. The *Informational Guide* also indicates that the differential between the fastest and slowest projected speeds within the roundabout should be no more than 12 mph.

Fastest path speeds are determined for five locations per approach. These include entry speeds (referred to as R1); through movement circulating speeds (R2); exiting speeds (R3); left turn movement circulating speeds (R4); and right turn speeds (R5). Exhibits showing the fastest-path speeds for various movements are attached. The projected fastest-path speeds for each approach are shown in Table 1.

Table 1
Projected "Fastest-Path" Vehicle Speeds

Movement	Northbound Flume Street	Eastbound 2nd Street	Westbound 1st Street
R1 – Entering	18	19	20
R2 – Circulating	14	15	22
R3 – Exiting	n/a	23	29
R4 – Left Turn	14	n/a	14
R5 – Right Turn	15	17	n/a

Note: all values are in miles per hour

The fastest path speeds for vehicles entering the intersection are projected to range between 18 and 20 mph. The fastest circulating speeds within the roundabout would be in the 14 to 22 mph range. The fastest exiting speeds, measured at the exiting approach's crosswalk, would be approximately 23 to 29 mph. All of the projected speeds fall within acceptable parameters for urban roundabouts, including the differentials among various circulating and entering speeds.

Sight Distance

The *Informational Guide* provides direction on the sight distance criteria that must be analyzed at roundabouts. The areas that must be kept free of vertical obstructions that would impede drivers' visibility of other key vehicles and pedestrians are referred to as "clear-view areas." Tall objects and landscaping that could grow to a height of two feet or greater should be kept out of these clear-view areas. The project's landscaping plans should restrict the use of landscaping and related objects within the necessary sight triangles, ensuring that heights do not exceed these standards. These clear-view areas are shown on Figures 7 through 9.

SHEET No	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

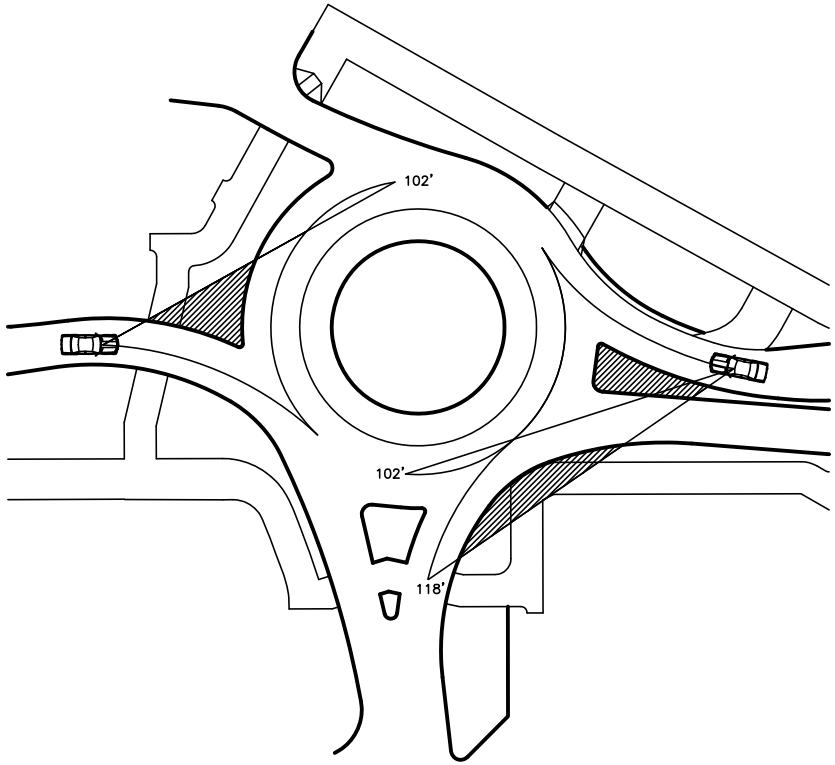
PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

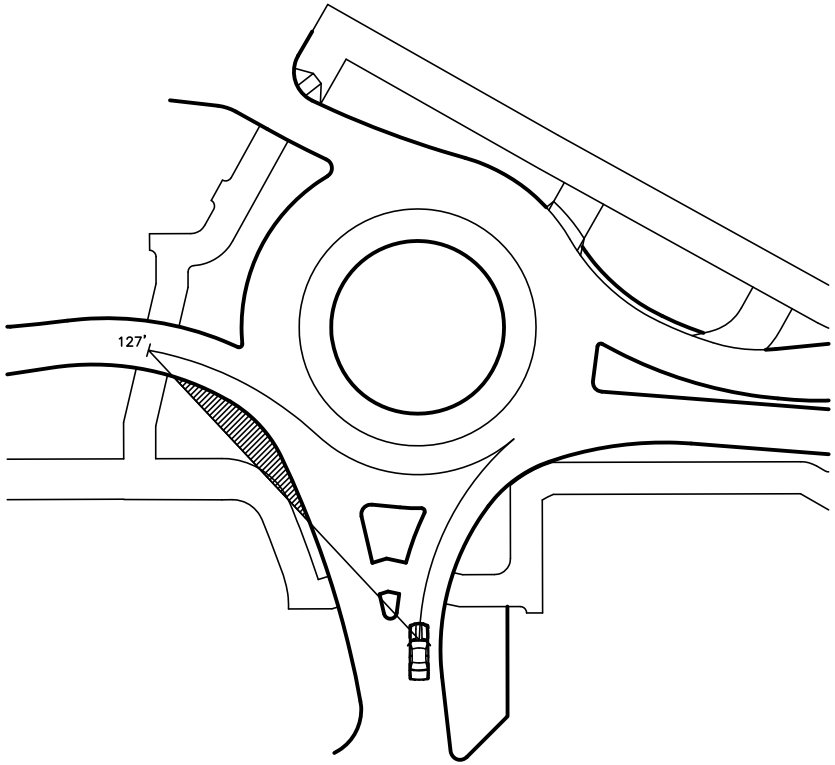
w-trans
490 Mendocino Avenue, Suite 201
Santa Rosa, CA 95401
Ph: 707 542-9500

REVISED BY | DATE

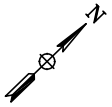
CALCULATED/DESIGNED BY | CHECKED BY



EASTBOUND AND WESTBOUND APPROACHES



NORTHBOUND APPROACH AND CIRCULATING TRAFFIC



Low–Profile Landscaping Possible (2 feet or less)

FIGURE 7
INTERSECTION SIGHT DISTANCE
ENTERING MOVEMENTS

FIRST ST/SECOND ST/FLUME ST
ROUNDABOUT LAYOUT

Images: 2nd st aerial.jpg; w–trans_150dpi.jpg; w–trans_300dpi.jpg; Xrefs: City Base.dwg; Topo Combined.dwg; Couplet Design 3–29–10 2007.dwg; Camelia _ vallombrosa _ mangrove 2007.dwg
Path: N:\AAA\BUX\CHI\900CHI\CHI900–7 First–Second Street\CAD\Plan Finalization\

Layout: Sight 1 Plot Date: Oct 27, 2010
DWG File: Second–Flume Fall 2010–Bid.dwg Time: Wed – 01:45 pm

LAST REVISION 10/21/10

SHEET No	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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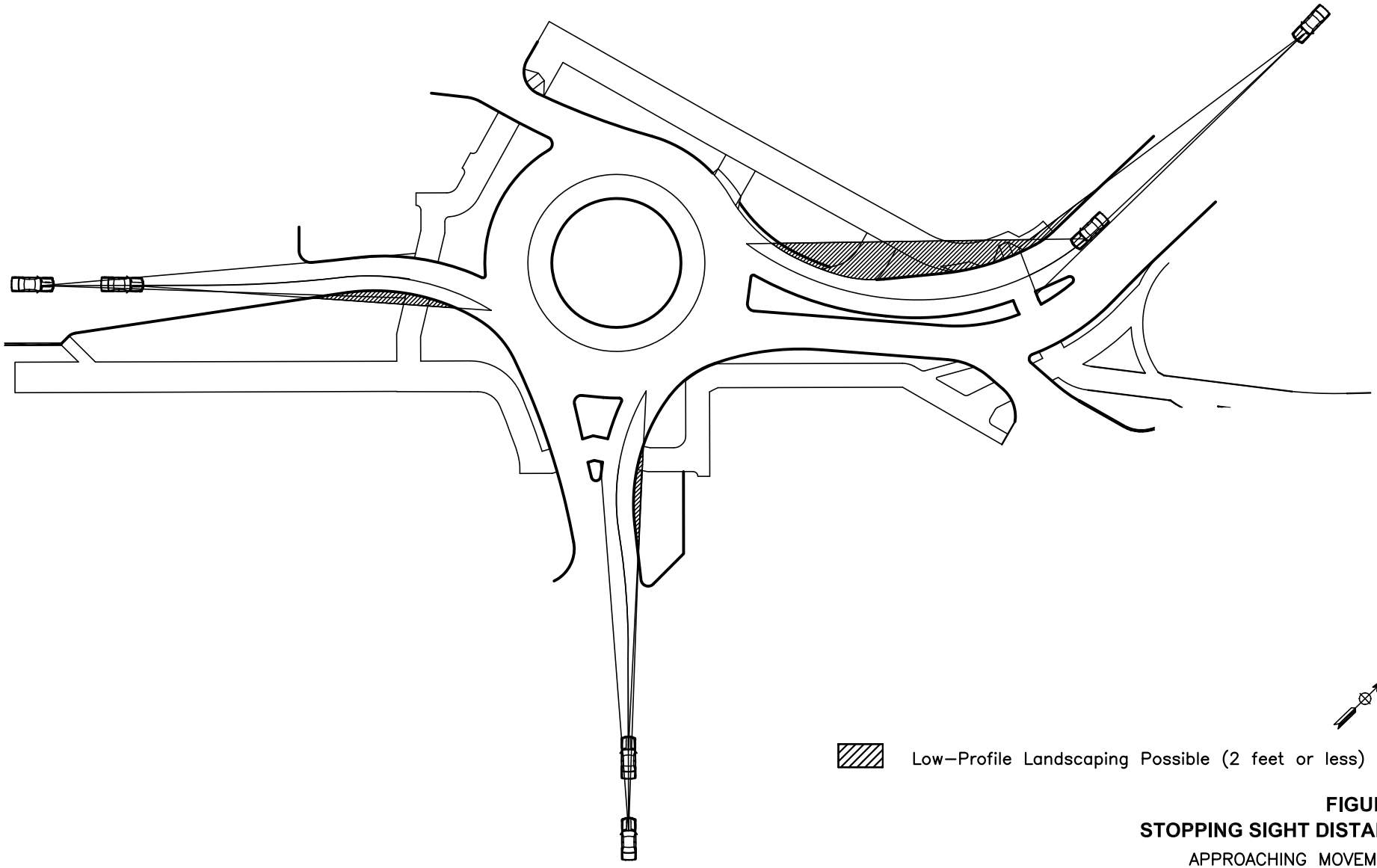

FIGURE 8
STOPPING SIGHT DISTANCE
APPROACHING MOVEMENTS

FIRST ST/SECOND ST/FLUME ST
ROUNDABOUT LAYOUT

REVISED BY	DATE

CALCULATED/ DESIGNED BY	CHECKED BY

SHEET No	TOTAL SHEETS

REGISTERED CIVIL ENGINEER DATE

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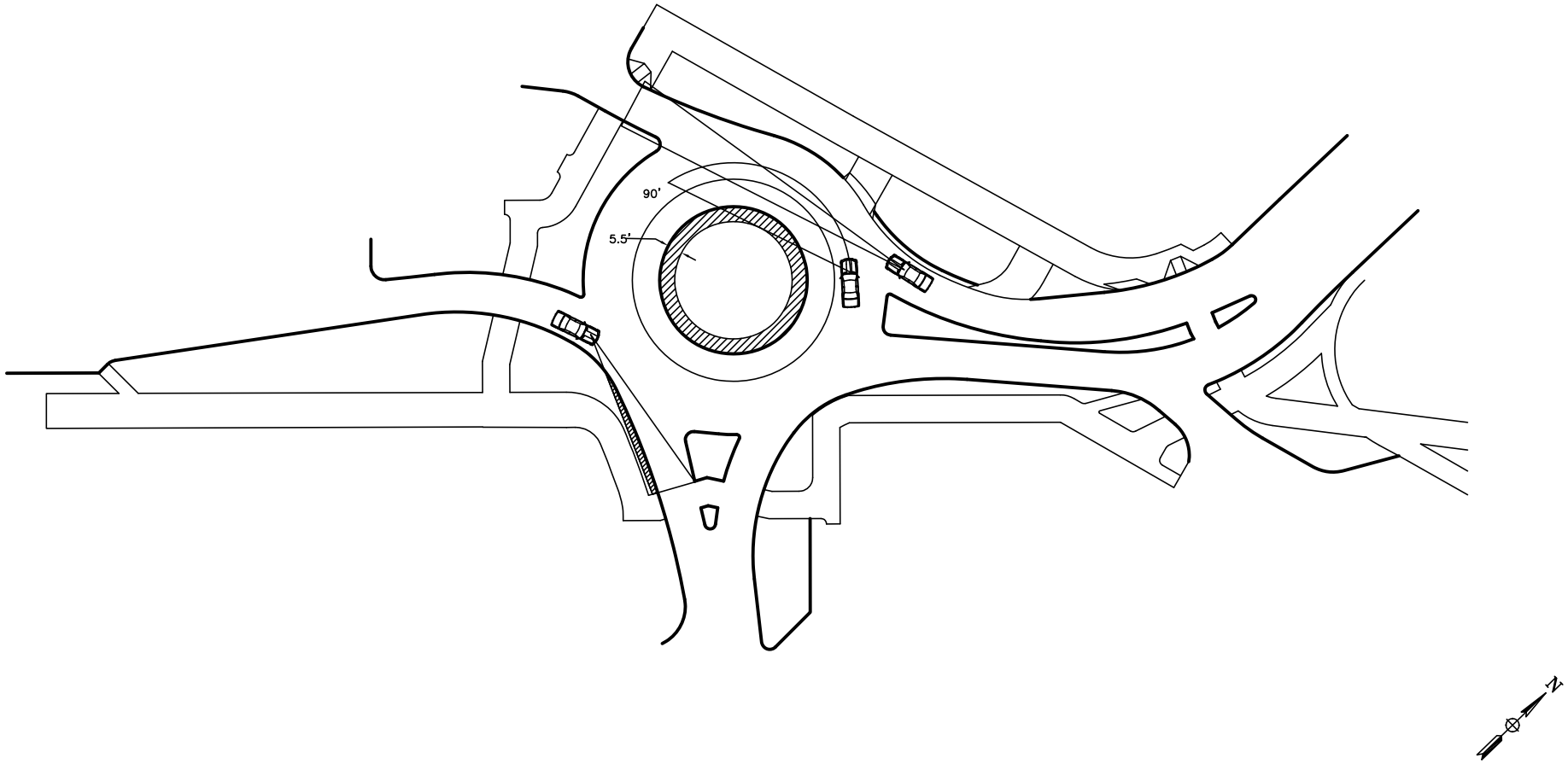

Low–Profile Landscaping Possible (2 feet or less)

FIGURE 9
STOPPING SIGHT DISTANCE
CIRCULATING AND CROSSWALKS

REVISED BY	DATE

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FIRST ST/SECOND ST/FLUME ST
ROUNDABOUT LAYOUT

The inner portion of the roundabout's central island are beyond the required clear-view areas will need to include vertical elements that obstruct sight distance across the roundabout. Such elements need to be six feet or higher than the circulating roadway and may include an earthen mound. Additional elements may include landscaping and decorative monuments. This is a safety technique used to focus drivers' attention only where it is needed, and increase advance visibility of the roundabout to approaching drivers.

Stopping Sight Distance

Sufficient stopping sight distance must be provided at three key roundabout locations: on intersection approaches, on the circulatory roadway, and at pedestrian crossings of roundabout exits. Approach stopping sight distances must be met in advance of roundabout entries (measured from the yield line) as well as in advance of pedestrian crossings (measured from the crosswalk). Stopping sight distances were determined to be acceptable within the roundabout.

Intersection Sight Distance

Intersection sight distance differs at roundabouts versus other intersections. Drivers must only be able to see potentially-conflicting oncoming traffic from the left as they approach the roundabout entry. The *Informational Guide* provides methodologies to establish the required sight distance triangles. Sight distance lengths vary according to vehicle speeds in different areas of the roundabout, and are measured along vehicle drive paths (which at roundabouts are typically arcs). Intersection sight distances were determined to be adequate for all approaches.

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Intersection Level of Service Methodologies

Level of Service (LOS) is used to rank traffic operation on various types of facilities based on traffic volumes and roadway capacity using a series of letter designations ranging from A to F. Generally, Level of Service A represents free flow conditions and Level of Service F represents forced flow or breakdown conditions. A unit of measure that indicates a level of delay generally accompanies the LOS designation.

The study intersection's current and projected future operation were analyzed using methodologies published in the *Highway Capacity Manual* (HCM), Transportation Research Board, 2000. This source contains methodologies for various types of intersection control, all of which are related to a measurement of delay in average number of seconds per vehicle.

Currently, the intersection is side-street stop-controlled so the Levels of Service for the intersection's current configuration were analyzed using the "Two-Way Stop-Controlled" intersection capacity method from the HCM. This methodology determines a level of service for each minor turning movement by estimating the level of average delay in seconds per vehicle. Results are presented for individual movements together with the weighted overall age delay for the intersection.

Intersection operation with a roundabout was determined using the SIDRA Intersection 4.0 analysis software. SIDRA uses the "gap acceptance" roundabout analysis method and utilizes various geometric data and traffic volumes to determine criteria such as vehicle delays and queue lengths, and the associated LOS for each approach. As with the unsignalized and signalized methods, service levels are based on average vehicle delay.

The ranges of delay associated with the various levels of service are indicated in Table 2.

Table 2
Intersection Level of Service Criteria

LOS	Two-Way Stop-Controlled Intersections	Roundabout Intersections
A	Delay of 0 to 10 seconds	Delay of 0 to 10 seconds
B	Delay of 10 to 15 seconds	Delay of 10 to 20 seconds
C	Delay of 15 to 25 seconds	Delay of 20 to 35 seconds
D	Delay of 25 to 35 seconds	Delay of 35 to 55 seconds
E	Delay of 35 to 50 seconds	Delay of 55 to 80 seconds
F	Delay of more than 50 seconds	Delay of more than 80 seconds

Reference: *Highway Capacity Manual,* Transportation Research Board, 2000
SIDRA Intersection 4.0 User Guide, Akcelik & Associates, 2009

Traffic Operation Standards

In the Transportation Element of its General Plan, the City of Chico establishes requirements for

intersection LOS as follows:

T-G-11: Strive to maintain traffic LOS C on residential streets and LOS D or better on arterial and collector streets, at all intersections, and on principal arterials in the CMP during peak hours.

T-G-12: Accept LOS E for built-out areas served by transit after finding that:

- *There is no practical and feasible way to mitigate the lower level of service; and*
- *The uses resulting in the lower level of service are of clear, overall public benefit.*

Since this intersection is adjacent to downtown Chico which is currently serviced by frequent transit service and the nature of the study area is primarily to serve the downtown area, these standards would indicate a minimum requirement of LOS E or better, as described in General Plan Policy T-G-12.

Existing Traffic Control

The intersection at 2nd Street/Flume Street/1st Street is currently controlled by stop signs on the northbound Flume Street and south-eastbound 1st Street approaches. Northbound 1st Street is also controlled by a stop sign. Channelized right turn islands exist on the westbound approach; however, there are no left-turn or right-turn pockets.

The intersection is currently operating acceptably overall at LOS A, with the southbound approach operating at LOS E during the p.m. peak hour. Under projected future volumes, the intersection is expected to operate overall at LOS A , the southbound approach would operate unacceptably at LOS F with 84.2 seconds of average delay. It should be noted that the primary purpose of installing a roundabout is not operations-based, but to better accommodate the awkward approach angles in a safe manner, better accommodate pedestrians and bicyclists, regulate traffic speeds as drivers enter downtown, and provide a transition point between one-way and two-way streets.

Roundabout Performance

Level of Service

Intersection operating conditions with a roundabout were determined using the SIDRA Intersection roundabout analysis program. As a single-lane roundabout the intersection is projected to operate acceptably at LOS A overall with current volumes. The levels of service on each of the individual approaches are also expected to be LOS A or B. With projected future traffic volumes, the intersection is projected to continue to operate acceptably at LOS A with all approaches again at LOS A or B.

Queuing

When considering any type of intersection control it is important to understand the potential effects of queuing, or stacking, created as drivers wait to proceed through the intersection. Peak queues should typically not extend into adjacent intersections, particularly adjacent intersections controlled by a traffic signal or roundabout.

The future 2030 95th percentile roundabout queues at 2nd Street/Flume Street/1st Street are projected to create no adverse impacts on adjacent intersections. The longest queues during the p.m. peak hour would occur on eastbound 2nd Street, extending approximately 190 feet. Unlike the queues created by traffic

signals, these queues would be moving or "rolling," and would not extend to the nearest intersection at 2nd Street/Wall Street. This rolling queue generally reduces fuel consumption and greenhouse gas emissions associated with stop-and-go traffic.

A summary of the roundabout level of service and queuing calculations is presented in Table 3. Copies of the calculations are provided in Appendix A.

Table 3
Summary of Roundabout Level of Service and Queuing Calculations

	2010 PM Peak Hour			2030 PM Peak Hour		
	Delay	**LOS**	**Queue**	**Delay**	**LOS**	**Queue**
Overall Intersection Operation	**3.3**	**A**		**3.5**	**A**	
Northbound Flume Street	*9.2*	*B*	*30.1*	*9.0*	*B*	*34.9*
Eastbound 2nd Street	*3.2*	*A*	*145.1*	*3.5*	*A*	*192.8*
Westbound Camellia Way	*2.4*	*A*	*129.3*	*2.7*	*A*	*168.1*

Notes: Delay is measured in average seconds per vehicle, LOS = Level of Service
Queue is measured in feet and represents the 95th percentile stacking distance

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Conclusions

- Existing and future vehicle, pedestrian, and bicycle traffic could be accommodated at the intersection through installation of a single-lane modern roundabout.

- With the implementation of a modern roundabout the intersection is expected to operate at LOS A under existing and future traffic volumes, with all approaches operating at LOS A or B.

- A roundabout would provide an efficient transition point for the 1st Street and 2nd Street one-way couplet as it will reduce driver confusion and diminish the likelihood of a driver entering a one way street going the wrong way.

- A roundabout could accommodate California Legal semi trucks on all movements except for the northbound right turn from Flume Street; however, alternative routes are available for trucks in the vicinity of Flume Street. A single-unit delivery truck can be accommodated on all movements.

- A roundabout could accommodate a large fire truck as well as school buses on all movements, and can accommodate large 45-foot long transit buses on the 1st Street and 2nd Street approaches.

- A roundabout would be expected to result in less fuel consumption and lower emissions than would result from the currently-proposed two-way stop-controlled alternative or under signalized conditions.

- Access to all adjacent parcels, including the PG&E electrical substation, would be maintained with the proposed roundabout, though some modifications to current access conditions will be required.

- A multi-use path surrounding the roundabout would provide pedestrian access. Pedestrian crossings would be provided on all approaches, though the crossing of the eastern Camilla Way leg would be located at Flume Street to provide an adequate pedestrian refuge area and sight distance.

- Bicyclists would be able to either ride with traffic within the roundabout, or utilize exit ramps to ride on the adjacent multi-use path.

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Study Participants and References

Study Participants

Principal in Charge:	Steve Weinberger, PE, PTOE
Traffic Engineer:	Allan Tilton, PE
Transportation Planner:	Zack Matley, AICP
Assistant Engineer:	Tony Henderson, EIT
Technician/Graphics:	Deborah Mizell
Editing/Formatting:	Angela McCoy
Report Review:	Dalene J. Whitlock, PE, PTOE

References

City of Chico General Plan, City of Chico, 1999
Highway Capacity Manual, Transportation Research Board, 2000
Manual on Uniform Traffic Control Devices for Streets and Highways, Federal Highway Administration, 2009
Roundabouts: An Informational Guide, Federal Highway Administration, 2000
Roundabouts in the United States, NCHRP Report 572, Transportation Research Board, 2007
SIDRA Intersection 4.0 User Guide, Akcelik & Associates, 2009

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Appendix A

Intersection Level of Service Calculations
and Queuing Calculations

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MOVEMENT SUMMARY

Site: PM Existing Volumes

2nd Street/Flume Street/1st Street Roundabout
PM Peak Hour - Existing Volumes
Downtown Chico One-Way Couplet Study
Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate per veh	Average Speed mph
South	Flume Street										
3L	L	54	2.0	0.175	11.0	LOS B	1.2	30.1	0.69	0.82	15.7
8R	R	49	2.0	0.175	7.2	LOS A	1.2	30.1	0.69	0.70	16.5
Approach		103	2.0	0.175	9.2	LOS B	1.2	30.1	0.69	0.76	16.0
East	2nd Street										
1L	L	65	2.0	0.498	7.3	LOS A	5.1	129.3	0.38	0.78	18.5
6R	R	522	2.0	0.496	1.8	LOS A	5.1	129.3	0.38	0.26	20.2
Approach		587	2.0	0.497	2.4	LOS A	5.1	129.3	0.38	0.31	20.0
West	2nd Street										
5L	L	22	2.0	0.543	8.7	LOS A	5.7	145.1	0.39	0.82	19.2
2T	T	565	2.0	0.542	2.9	LOS A	5.7	145.1	0.39	0.34	21.4
2R	R	60	2.0	0.543	4.4	LOS A	5.7	145.1	0.39	0.47	20.9
Approach		647	2.0	0.542	3.2	LOS A	5.7	145.1	0.39	0.37	21.2
All Vehicles		1337	2.0	0.543	3.3	LOS A	5.7	145.1	0.41	0.38	20.1

Level of Service (Aver. Int. Delay): LOS A. Based on average delay for all vehicle movements. LOS Method: Delay (HCM).
Level of Service (Worst Movement): LOS B. LOS Method for individual vehicle movements: Delay (HCM).
Approach LOS values are based on the worst delay for any vehicle movement.
Roundabout LOS Method: Same as Signalised Intersections.
Roundabout Capacity Model: SIDRA Standard.

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MOVEMENT SUMMARY

Site: PM Future Volumes

2nd Street/Flume Street/1st Street Roundabout
PM Peak Hour - Future Volumes
Downtown Chico One-Way Couplet Study
Roundabout

Movement Performance - Vehicles

Mov ID	Turn	Demand Flow veh/h	HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance ft	Prop. Queued	Effective Stop Rate per veh	Average Speed mph
South	Flume Street										
3L	L	63	2.0	0.183	10.8	LOS B	1.4	34.9	0.75	0.82	15.9
8R	R	56	2.0	0.183	7.0	LOS A	1.4	34.9	0.75	0.72	16.6
Approach		119	2.0	0.183	9.0	LOS B	1.4	34.9	0.75	0.77	16.2
East	2nd Street										
1L	L	74	2.0	0.577	7.5	LOS A	6.6	168.1	0.46	0.76	18.5
6R	R	598	2.0	0.577	2.1	LOS A	6.6	168.1	0.46	0.29	19.7
Approach		672	2.0	0.577	2.7	LOS A	6.6	168.1	0.46	0.34	19.5
West	2nd Street										
5L	L	24	2.0	0.628	9.0	LOS A	7.6	192.8	0.49	0.79	19.2
2T	T	647	2.0	0.628	3.1	LOS A	7.6	192.8	0.49	0.38	20.7
2R	R	68	2.0	0.627	4.6	LOS A	7.6	192.8	0.49	0.48	20.5
Approach		740	2.0	0.628	3.5	LOS A	7.6	192.8	0.49	0.41	20.6
All Vehicles		1532	2.0	0.628	3.5	LOS A	7.6	192.8	0.50	0.41	19.7

Level of Service (Aver. Int. Delay): LOS A. Based on average delay for all vehicle movements. LOS Method: Delay (HCM).
Level of Service (Worst Movement): LOS B. LOS Method for individual vehicle movements: Delay (HCM).
Approach LOS values are based on the worst delay for any vehicle movement.
Roundabout LOS Method: Same as Signalised Intersections.
Roundabout Capacity Model: SIDRA Standard.

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