SOUTHCENTRAL DISTRICT I-10 CORRIDOR RAMP OPERATIONS STUDY

TWIN PEAKS ROAD TO 22ND STREET

Final Report

July 2019

PREPARED FOR:

Arizona Department of Transportation

ADOT

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AECOM

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List of Acronyms/Abbreviations

ADT	Average Daily Traffic
ADOT	Arizona Department of Transportation
ALISS	Accident Location Identification Surveillance System
AUX	Auxiliary Lane
BOG	Back of Gore
BOR	Body of Ramp
EB	Eastbound
MPD	Multimodal Planning Division
mph	Miles per hour
NB	Northbound
SB	Southbound
TI	Traffic Interchange
vpd	Vehicles per day
WB	Westbound

1.0 INTRODUCTION

Interstate 10 (I-10) within the Southcentral District has undergone a number of changes over the past ten years. Between Twin Peaks Road and 22nd Street, there have been several reconstruction projects along the corridor, including I-10 mainline reconstruction from 29th Street to Prince Road and newly reconstructed traffic interchanges including Twin Peaks Road, Prince Road, and Ina Road (underway). In the near future, the Ruthrauff Road interchange will also be reconstructed, along with I-10 mainline widening from Ina Road to southeast of Ruthrauff Road.

The section of I-10 between 22nd Street and Twin Peaks Road has been reviewed as separate pieces (under separate projects), but not as a system, particularly with regard to ramp metering and frontage road operations. A study to evaluate the frontage road traffic control devices and operations was completed in 2003, which predated the major reconstruction of I-10 in 2009. The traffic operations of these facilities have changed significantly due to the change in roadway geometrics and increased traffic volumes.

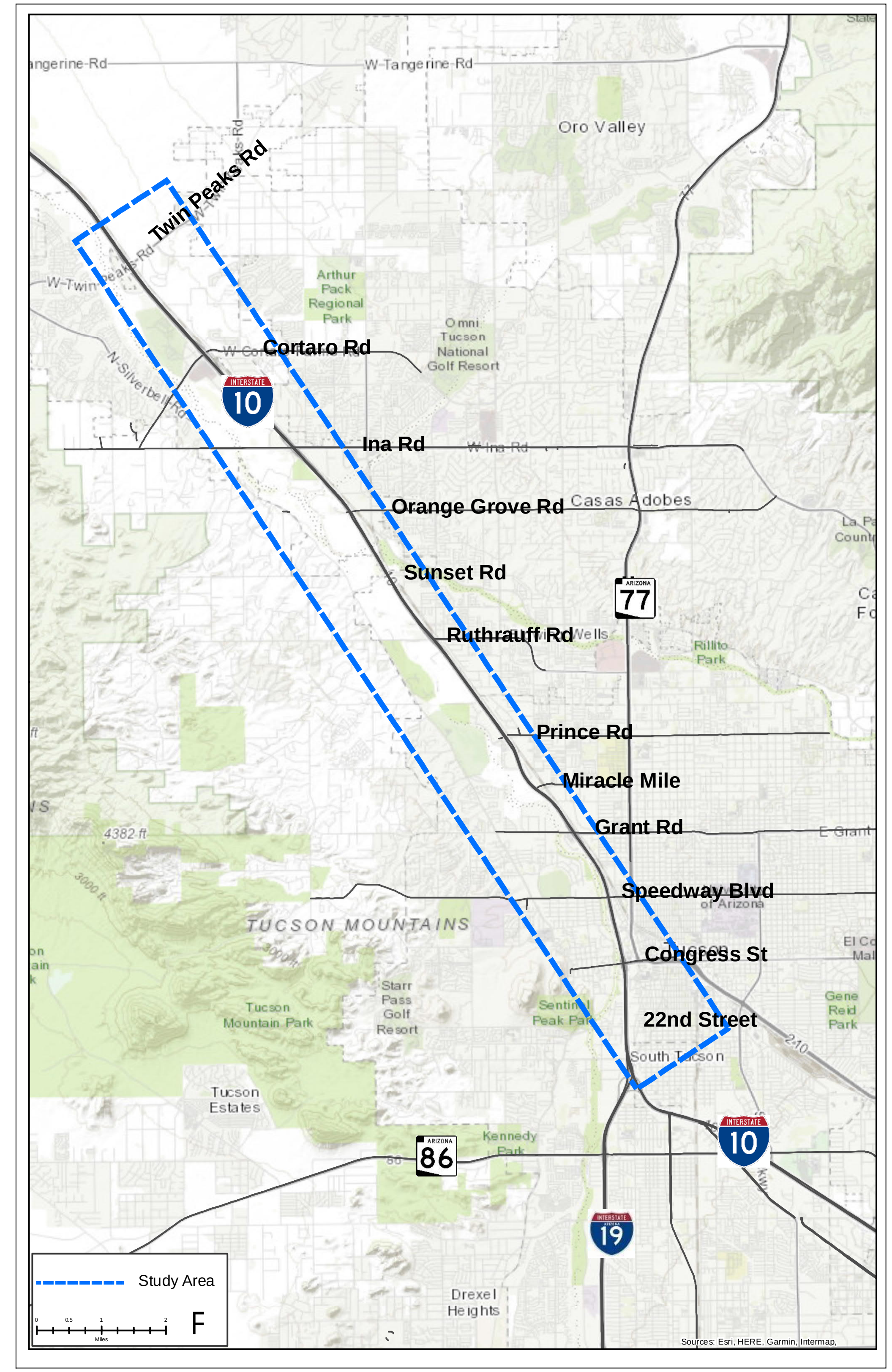
1.1 Study Area

The study area for the I-10 Corridor Ramp Operations Study encompasses the 14-mile section of I-10 from Twin Peaks Road to 22nd Street. The study area is shown in **Figure 1**. The corridor limits include twelve traffic interchanges. The entire length of the study corridor is a divided, access-controlled freeway facility with one-way frontage roads in each direction of travel.

1.2 Study Goals & Objectives

The primary goal of this study is to determine current and future traffic control needs for the I-10 corridor between Twin Peaks Road and 22nd Street. This study will determine if and when the ramp metering infrastructure should be utilized and how it would operate. In addition, this study will re-evaluate the traffic control at the frontage road junctions to determine if the systematic "yield" control is appropriate or if "stop" control should be provided. The result of this study will provide the basis for future ramp metering design projects and provide operational insight and direction on the frontage road operational controls.

Figure 1: Study Area



2.0 EXISTING CONDITIONS

This section of the report focuses on the existing conditions along the study corridor and documents the physical/geometric conditions, traffic volumes, lane arrangement, crash data, and previous studies related to ramp metering and the frontage roads. Subsequent sections will evaluate this data and investigate improvement alternatives.

2.1 Summary of Relevant Plans and Studies

The following sections summarize relevant plans and studies that have been completed by various agencies which are relevant to the potential implementation of ramp metering and/or frontage road operations along the I-10 corridor.

Traffic Control Devices for the I-10 Corridor Frontage Roads

Completion Date: 2003
Sponsoring Agency: ADOT

The purpose of this study was to evaluate the use of different traffic control devices along the I-10 frontage roads between Cortaro Road and 22nd Street. An evaluation was conducted using a point system based on several factors including accident history, traffic volumes, vehicle gap, vehicle speeds, and roadway geometrics. This evaluation was used to determine if stop-control or yield-control should be used at each exit ramp/frontage road junction along the corridor. The traffic volumes that were used in this study were from 2003 and no future horizon years were considered. A traffic operational analysis was not conducted.

The recommendations from this study included converting the exit ramp/frontage road junctions from Miracle Mile Road to the northwest to yield-control, and utilizing stop-control at the junctions from Grant Road to the southeast.

Intelligent Transportation Systems Strategic Deployment Plan

Completion Date: 2004
Sponsoring Agency: Pima Association of Governments

The Intelligent Transportation Systems Strategic Deployment Plan documented the history, current status and future of intelligent transportation infrastructure in the greater Tucson metropolitan area. It provided a roadmap for deploying Intelligent Transportation Systems (ITS) within the region until the year 2030.

This plan does discuss the deployment of a Freeway Management System (FMS) along I-10, and does discuss including ramp meters as part of the long-term vision along I-10.

Ramp Meter Design Guidelines

Completion Date: 2013
Sponsoring Agency: ADOT

This document provides guidelines for the design of ramp metering on the ADOT system. It provides information on warrants for the installation of ramp metering based on traffic volumes and speeds, and acknowledges other factors that could be considered such as roadway geometry, safety, and maintenance. It also provides guidance for the design of the metering system including acceleration distance, queue storage, signing, pavement marking, and ramp metering hardware.

System-Wide Ramp Metering Evaluation

Completion Date: 2013
Sponsoring Agency: ADOT

This project included a study of the existing ramp metering operation and recommended new operation to more effectively manage the flow of traffic entering the freeway system within the Phoenix metropolitan area. It included a state-of-practice review of 20 state departments of transportation to identify ramp metering practices throughout the nation. Ramp metering simulation was performed to assist in developing the recommended ramp metering time of day and metering rate. These simulations included using VISSIM modeling software which were calibrated to actual loop detector speed data.

This report recommends fixed time of day operations coupled with local traffic responsive metering rates for every ramp meter. Initially, the study tested dynamic on/off times. However, this was not recommended due to limitations of the ramp metering software.

I-10 Design Concept Report, Ina Road to Ruthrauff Road

Completion Date: 2013
Sponsoring Agency: ADOT

The purpose of this study was to develop a long-term master plan for the segment of I-10 from Ina Road to Ruthrauff Road. The study included a Design Concept Report, Traffic Report, and other associated technical reports. A 2040 horizon year was used for the traffic analysis. The study also included an Environmental Assessment (EA).

The Recommended Alternative included:

- Widening the I-10 mainline to provide five general-purpose lanes in each direction of travel
- Reconstructing the Ina Road TI
- Reconstructing the Sunset Road TI
- Reconstructing the Ruthrauff Road TI

The traffic analysis included the analysis of the frontage road capacity (between interchanges), but did not specifically address the exit ramp/frontage road junctions. This report did not make any specific recommendations for the operation of the frontage roads or for ramp metering.

I-10 Corridor Study, Tangerine Road to Ina Road

Completion Date: 2014
Sponsoring Agency: ADOT

The purpose of this study was to develop a long-term master plan for the segment of I-10 from Tangerine Road to Ina Road. The study included a Design Concept Report, Traffic Report, and other associated technical reports. A 2040 horizon year was used for the traffic analysis. The study also included an Environmental Assessment (EA).

The Recommended Alternative included:

- Widening the I-10 mainline to provide five general-purpose lanes in each direction of travel
- Reconstructing the Avra Valley Road TI
- Reconstructing the Cortaro Road TI

The traffic analysis did not include the frontage roads (between interchanges). This report did not make any specific recommendations for the operation of the frontage roads or for ramp metering.

2045 Regional Mobility and Accessibility Plan

Completion Date: 2016
Sponsoring Agency: Pima Association of Governments

The 2045 Regional Mobility and Accessibility Plan (RMAP) provides a vision for the future transportation network and includes goals and implementation strategies to help reach the vision. The 2045 RMAP identifies the region's long-range transportation needs and anticipated revenues during the plan period, and contains a list of roadway, transit, bicycle and pedestrian projects.

The "In-Plan" (funded) project list includes the widening of I-10 from Ruthrauff Road to Ina Road, and the reconstruction of the Ruthrauff Road, Orange Grove Road, Ina Road, and Sunset Road interchanges.

The RMAP does mention the implementation of a Freeway Management System along I-10 and includes $50,000,000 in funding.

This plan did not make any specific recommendations for the operation of the frontage roads or for ramp metering.

Strategic Transportation Safety Plan

Completion Date: 2016
Sponsoring Agency: Pima Association of Governments

The PAG Strategic Transportation Safety Plan (STSP) establishes the regional vision, goals, objectives, strategies, countermeasures, and performance measures for making systematic improvements in transportation safety. Network screening was conducted to analyze intersections and segments in the region to determine which intersections and segments could be potential priority locations for future safety projects.

This plan did not make any specific recommendations for the operation of the frontage roads or for ramp metering, nor did it contain any safety recommendations along the I-10 mainline or frontage roads.

2.2 Corridor Conditions

2.2.1 Roadway Characteristics

I-10 between I-19 and Twin Peaks Road is a controlled access divided freeway. There are twelve grade separated traffic interchanges throughout the corridor. The posted speed limit is 65 mph.

In the westbound direction of travel, I-10 contains three general-purpose lanes through the I-10/I-19 system interchange. Ramp N-W (from I-19) is a two lane ramp that creates five general-purpose lanes in the westbound direction of travel departing the I-10/I-19 system interchange. Just west of the I-10/I-19 system interchange, the outside lane drops to provide four general-purpose lanes over 22nd Street. Four general-purpose lanes are provided in the westbound direction of travel with auxiliary lanes between:

- Westbound 22nd Street entrance ramp and the westbound Congress Street exit ramp
- Westbound Congress Street entrance ramp and the westbound Speedway Boulevard exit ramp
- Westbound Speedway Boulevard entrance ramp and the westbound Grant Road exit ramp
- Westbound Grant Road entrance ramp and the westbound Miracle Mile exit ramp
- Westbound Miracle Mile entrance ramp and the westbound Prince Road exit ramp
- Westbound Prince Road entrance ramp and the westbound Ruthrauff Road exit ramp

Immediately south (east) of the Ruthrauff Road exit ramp, the inside (median) lane drops in the westbound direction of travel to provide three westbound lanes under Ruthrauff Road. Three travel lanes continue to the west past Twin Peaks Road.

In the eastbound direction of travel, I-10 contains three general-purpose lanes from Twin Peaks Road to Ruthrauff Road. Immediately south (east) of the eastbound Ruthrauff Road entrance ramp, a fourth general-purpose lane is added on the inside (median) of I-10. Four general-purpose lanes are provided in the eastbound direction travel with auxiliary lanes between:

- Eastbound Ruthrauff Road entrance ramp and the eastbound Prince Road exit ramp
- Eastbound Prince Road entrance ramp and the eastbound Miracle Mile exit ramp
- Eastbound Miracle Mile entrance ramp and the eastbound Grant Road exit ramp
- Eastbound Grant Road entrance ramp and the eastbound Speedway Boulevard exit ramp
- Eastbound Speedway Boulevard entrance ramp and the eastbound Congress Street exit ramp
- Eastbound Congress Street entrance ramp and the eastbound 22nd Street exit ramp

Ramp E-S (to I-19) is a two-lane exit ramp with a forced exit from the outside general-purpose lane and an optional exit from the adjacent general-purpose lane. Therefore, three general-purpose lanes are provided in the eastbound direction of travel through the I-10/I-19 system interchange.

I-10 is elevated over 22nd Street, Cushing Street/Granada Avenue, Congress Street, 6th Street/St. Mary's Road, Speedway Boulevard, Grant Road, Ruthrauff Road, Orange Grove Road, Ina Road (under construction), and Cortaro Road. I-10 crosses under Miracle Mile, Prince Road, and Twin Peaks Road.

2.2.1.1 Entrance Ramp Characteristics

The existing entrance ramps were inventoried to determine the geometric characteristics of each ramp. The following features were inventoried:

- Origin – description of the interface between the local road and the entrance ramp/frontage road
- Number of origins – description of the number of turn lanes from local road onto the entrance ramp/frontage road
- Type of entrance ramp – taper-type ramp (no lane added to freeway), a parallel-type (lane added and then dropped), or an auxiliary lane (lane addition extends from entrance ramp to next downstream exit ramp)
- Length of lane addition – distance along freeway (feet) from the nose of the striped entrance gore to the end of the lane line (for parallel ramps) or the striped gore for next downstream exit ramp (for auxiliary lane)
- Lane drop on entrance ramp – whether the number of lanes on the entrance ramp reduces along its length
- Width of entrance ramp at back of gore
- Number of freeway lanes upstream of the entrance ramp merge
- Number of freeway lanes downstream of the entrance ramp merge
- Entrance ramp length to the tip of the nose – both the length of the main section of the ramp location from the frontage road gore to the back of the freeway physical gore, and the length of the striped gore (from back of freeway gore to the end of the striped gore)
- Entrance ramp curve – description of whether the ramp is straight, slightly curved or tightly curved
- Entrance ramp grade – description of whether the entrance ramp is level, uphill or downhill (in direction of travel)
- Entrance ramp shoulder – description of whether there is shoulder, discontinuous shoulder, or no shoulder on the entrance ramp
- Freeway shoulder – description of whether there is shoulder, discontinuous shoulder, or no shoulder on the freeway
- Current ramp metering infrastructure for entrance ramps (based on record drawings)
- Current traffic control devices for the frontage road and exit-ramp junctions

The results of this inventory are shown in **Table 1** (Eastbound Entrance Ramps) and **Table 2** (Westbound Entrance Ramps).

2.2.1.2 Exit Ramp Characteristics

The existing exit ramps were inventoried to assess the characteristics of the junction between the exit ramp and the frontage road. **Figure 2** shows the operational control (stop or yield), and signing and pavement marking at each exit ramp/frontage road junction.

All of the existing exit ramp/frontage road junctions are yield control. However, the advance signing is not consistent and the location of the signing is not consistent.

Table 1: Eastbound Entrance Ramp Characteristics

ID	Eastbound Characteristic	Interchange						Notes
		Twin Peaks Rd	Cortaro Rd	Ina Rd	Orange Grove Rd	Sunset Rd	Ruthrauff Rd	
	Construction Complete	2014	2004	Under Construction Info from Plans	-	2001	Under Design Info from Stage III Plans	
A	Origin	90 Deg Signalized Diamond TI	90 Deg Signalized Diamond TI	Skewed Signalized Diamond TI	Skewed Signalized Diamond TI	90 Deg Stop Controlled Diamond TI	Skewed Signalized Diamond TI	
B	Number of Origins (Turn Lanes on Local Road)	2 EB Rt & 2 WB Lt	2 EB Rt & 2 WB Lt	2 EB Rt & 2 WB Lt	1 EB Rt & 2 WB Lt	1 EB Rt & 1 WB Lt	1 EB Rt & 2 WB Lt	
C	Type of Entrance Ramp	Parallel	Taper-Type	Parallel	Taper-Type	Taper-Type	Auxiliary Lane	
D	Length of Lane Addition	340'	NA	660'	NA	NA	5600'	
E	Lane Drop on Entrance Ramp	2 to1 at BOG	2 to1 at BOG	2 to1 at BOG	2 to1 in BOR	NA	2 to1 at BOG	BOG = back of gore BOR = body of ramp # = estimated from aerial image
F	Total Pavement Width at BOG	29'	32'	24'	19'	18'	23'	
G	Number of Freeway Lanes Upstream	3	3	3	3	3	3	
H	Number of Freeway Lanes Downstream	3	3	3	3	3	4 + AUX	
I-A	Ramp Length from Frontage Road BOG to Freeway BOG	830'	430'	700'	720'	980'	160'	
I-B	Length of Striped Freeway Gore from BOG	600'	940'	700'	690'	630'	780'	
I-C	Length of Striped Frontage Road Gore to BOG	260'	350'	290'	240'	290'	210'	
J	Entrance Ramp Curve	Slightly Curved	Slightly Curved	Slightly Curved	Slightly Curved	Straight	Slightly Curved	
K	Entrance Ramp Grade	Level	Level	Downhill/Uphill	Level	Level	Downhill/Uphill	
L	Entrance Ramp Shoulder	Shoulder (8')	Shoulder (6') #	Shoulder (2')	Shoulder (4') #	Shoulder (4') #	Shoulder (2')	
M	Freeway Shoulder	Shoulder (10')	Shoulder (10') #	Shoulder (12')	Shoulder (10') #	Shoulder (10') #	Shoulder (12')	
N	Current Ramp Metering Infrastructure	Conduit and Pull boxes	None	Conduit and Pull boxes	None	None	Conduit and Pull boxes	
O	Layout Description for Exit Ramps	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	

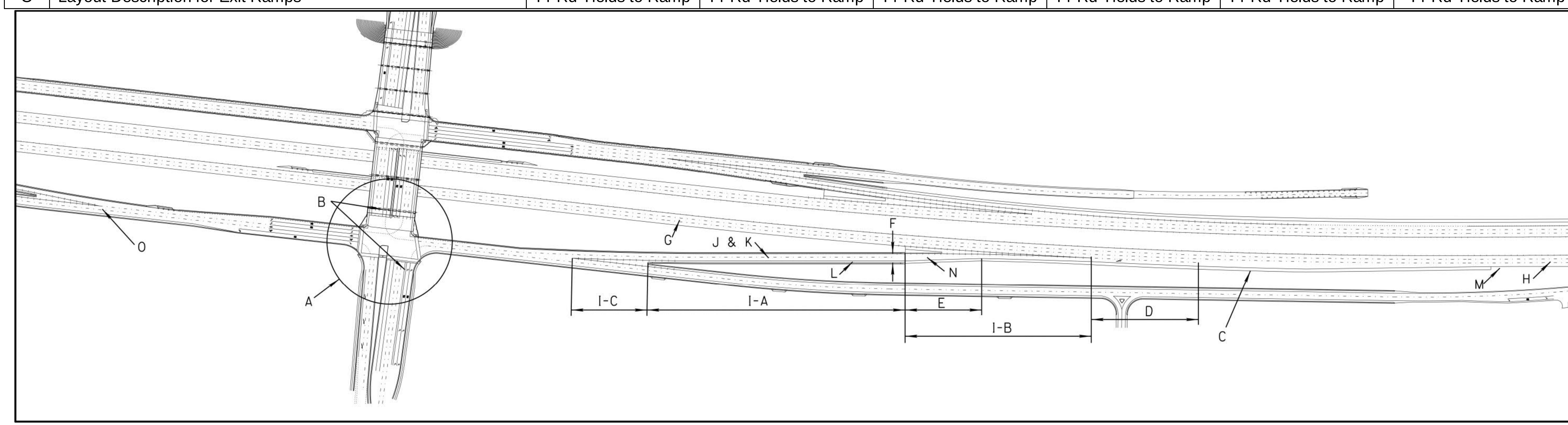


Table 1: Eastbound Entrance Ramp Characteristics - continued

ID	Eastbound Characteristic	Interchange						Notes
		Prince Rd	Miracle Mile Rd	Grant Rd	Speedway Blvd	Congress St	22nd St	
	Construction Complete	2016	2010	2010	2010	2010	2010	
A	Origin	Skewed Signalized Diamond TI	Skewed Signalized T Diamond TI	Skewed Signalized Diamond TI	Slight Skew Signalized Diamond TI	90 Deg Signalized Diamond TI	NA	
B	Number of Origins (Turn Lanes on Local Road)	1 EB Rt & 2 WB Lt	2 WB Lt	1 EB Rt & 1 WB Lt	1 EB Rt & 1 WB Lt	1 EB Rt & 1 WB Lt		
C	Type of Entrance Ramp	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane		
D	Length of Lane Addition	1040'	510'	1800'	1260'	410'		
E	Lane Drop on Entrance Ramp	2 to1 in BOR	2 to1 at BOG	2 t 1 in BOR	2 to1 at BOG	2 t 1 at BOG		BOG = back of gore BOR = body of ramp # = estimated from aerial image
F	Total Pavement Width at Back-of-Gore (BOG)	23'	23'	23'	23'	23'		
G	Number of Freeway Lanes Upstream	4	4	4	4	4		
H	Number of Freeway Lanes Downstream	4 + AUX	4 + AUX	4 + AUX	4 + AUX	4 + AUX		
I-A	Ramp Length from Frontage Road BOG to Freeway BOG	720'	490'	130'	330'	780'		
I-B	Length of Striped Freeway Gore from Back-of-Gore	510'	770'	800'	880'	660'		
I-C	Length of Striped Frontage Road Gore to Back-of-Gore	180'	350'	380'	210'	330'		
J	Entrance Ramp Curve	Slightly Curved	Slightly Curved	Slightly Curved	Straight	Slightly Curved		
K	Entrance Ramp Grade	Downhill/Uphill	Downhill/Uphill	Downhill/Uphill	Uphill	Uphill		
L	Entrance Ramp Shoulder	Shoulder (4')	Shoulder (2')	Shoulder (2')	Shoulder (2')	Shoulder (4')		
M	Freeway Shoulder	Shoulder (12')	Shoulder (12')	Shoulder (12')	Shoulder (12')	Shoulder (12')		
N	Current Ramp Metering Infrastructure	Conduit and Pull boxes	Conduit and Pull boxes	Conduit and Pull boxes	Conduit and Pull boxes	Conduit and Pull boxes		
O	Layout Description for Exit Ramps	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp		

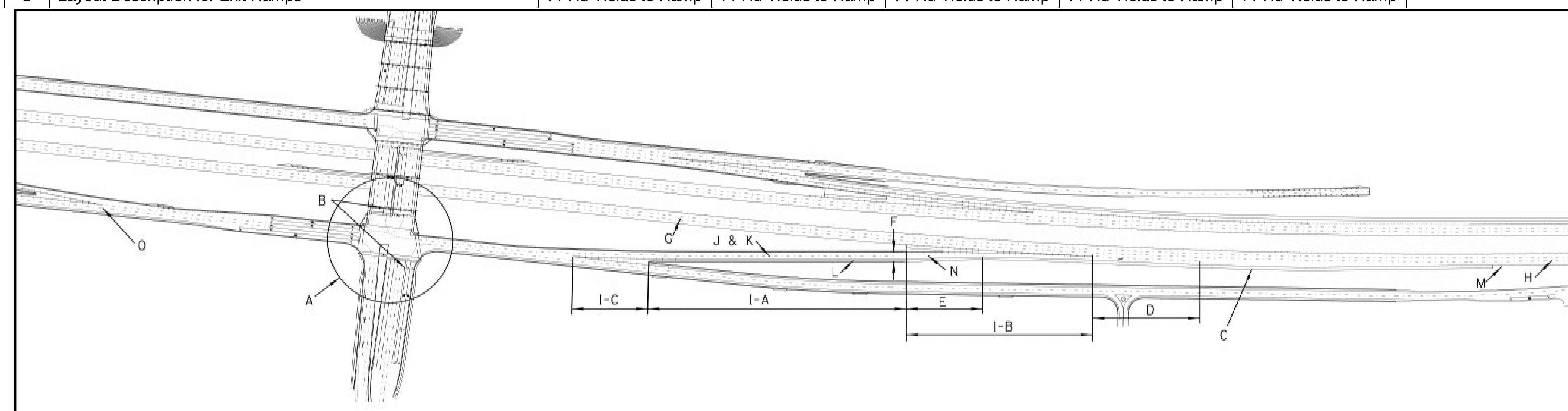


Table 2: Westbound Entrance Ramp Characteristics

ID	Westbound Characteristic	Interchange						Notes
		Twin Peaks Rd	Cortaro Rd	Ina Rd	Orange Grove Rd	Sunset Rd	Ruthrauff Rd	
	Construction Complete	2014	2004	Under Construction Info from Plans	-	2001	Under Design Info from Stage III Plans	BOG = back of gore BOR = body of ramp # = estimated from aerial image
A	Origin	90 Deg Signalized Diamond TI	90 Deg Signalized Diamond TI	Skewed Signalized Diamond TI	Skewed Signalized Diamond TI	90 Deg Stop Controlled Diamond TI	Skewed Signalized Diamond TI	
B	Number of Origins (Turn Lanes on Local Road)	2 EB Rt & 2 WB Lt	2 EB Rt & 2 WB Lt	2 EB Rt & 2 WB Lt	1 EB Rt & 2 WB Lt	1 EB Rt & 1 WB Lt	1 EB Rt & 2 WB Lt	
C	Type of Entrance Ramp	Parallel	Taper-Type	Parallel	Taper-Type	Taper-Type	Auxiliary Lane	
D	Length of Lane Addition	340'	NA	650'	NA	NA	5600'	
E	Lane Drop on Entrance Ramp	2 to1 at BOG	2 to1 at BOG	2 to1 at BOG	2 to1 in BOR	NA	2 to1 at BOG	
F	Total Pavement Width at Back-of-Gore (BOG)	29'	32'	24'	19' #	18' #	23'	
G	Number of Freeway Lanes Upstream	3	3	3	3	3	3	
H	Number of Freeway Lanes Downstream	3	3	3	3	3	3	
I-A	Ramp Length from Frontage Road BOG to Freeway BOG	830'	430'	700'	720'	980'	160'	
I-B	Length of Striped Freeway Gore from Back-of-Gore	600'	940'	700'	690'	630'	780'	
I-C	Length of Striped Frontage Road Gore to Back-of-Gore	260'	350'	290'	240'	280'	210'	
J	Entrance Ramp Curve	Slightly Curved	Slightly Curved	Slightly Curved	Slightly Curved	Straight	Slightly Curved	
K	Entrance Ramp Grade	Level	Level	Downhill/Uphill	Level	Level	Downhill/Uphill	
L	Entrance Ramp Shoulder	Shoulder (8')	Shoulder (6') #	Shoulder (2')	Shoulder (4') #	Shoulder (4') #	Shoulder (2')	
M	Freeway Shoulder	Shoulder (10')	Shoulder (10') #	Shoulder (12')	Shoulder (10') #	Shoulder (10') #	Shoulder (12')	
N	Current Ramp Metering Infrastructure	Conduit and Pull boxes	None	Conduit and Pull boxes	None	None	Conduit and Pull boxes	
O	Geometric Layout Description for Exit Ramps	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	

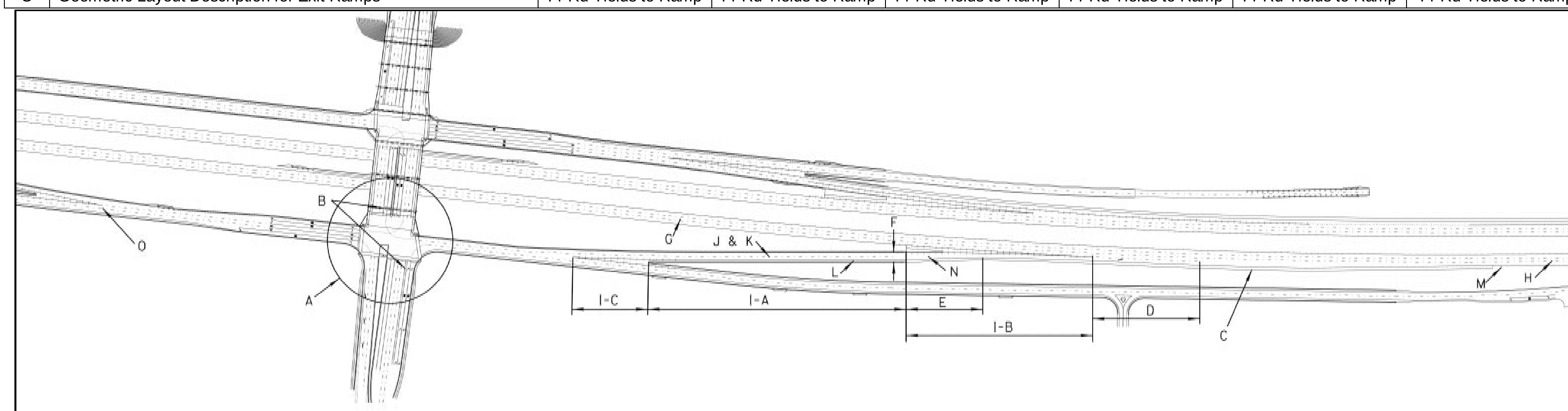


Table 2: Westbound Entrance Ramp Characteristics - continued

ID	Westbound Characteristic	Interchange						Notes
		Prince Rd	Miracle Mile Rd	Grant Rd	Speedway Blvd	Congress St	22nd St	
	Construction Complete	2016	2010	2010	2010	2010	2010	
A	Origin	Skewed Signalized Diamond TI	Skewed Signalized Diamond TI	Skewed Signalized Diamond TI	Slight Skew Signalized Diamond TI	90 Deg Signalized Diamond TI	90 Deg Fr Rd	
B	Number of Origins (Turn Lanes on Local Road)	1 EB Lt & 1 WB Rt	1 EB Lt & 1 WB Rt	1 EB Lt & 1 WB Rt	1 EB Lt & 1 WB Rt	1 EB Lt & 1 WB Rt	1 EB Lt & 1 WB Rt	
C	Type of Entrance Ramp	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane	Auxiliary Lane	
D	Length of Lane Addition	5090'	670' #	470' #	625' #	650' #	415' #	BOG = back of gore BOR = body of ramp # = estimated from aerial image
E	Lane Drop on Entrance Ramp	NA	NA	2 to 1 at BOG	2 to 1 at BOG	2 to 1 at BOG	2 to 1 at BOG	
F	Total Pavement Width at Back-of-Gore (BOG)	23'	23'	23'	23'	23'	23'	
G	Number of Freeway Lanes Upstream	4	4	4	4	4	4	
H	Number of Freeway Lanes Downstream	4 + AUX	4 + AUX	4 + AUX	4 + AUX	4 + AUX	4 + AUX	
I-A	Ramp Length from Frontage Road BOG to Freeway BOG	380' #	555' #	195' #	545' #	425' #	710' #	
I-B	Length of Striped Freeway Gore from Back-of-Gore	420' #	525' #	635' #	750' #	930' #	510' #	
I-C	Length of Striped Frontage Road Gore to Back-of-Gore	295' #	230' #	275' #	325' #	365' #	250' #	
J	Entrance Ramp Curve	Straight	Slightly Curved	Slightly Curved	Slightly Curved	Slightly Curved	Straight	
K	Entrance Ramp Grade	Downhill	Downhill	Downhill/Uphill	Downhill/Uphill	Downhill/Uphill	Uphill	
L	Entrance Ramp Shoulder	Shoulder (10')	Shoulder (8') #	Shoulder (2')	Shoulder (2')	Shoulder (3') #	Shoulder (4')	
M	Freeway Shoulder	Shoulder (14')	Shoulder (12')	Shoulder (12')	Shoulder (12')	Shoulder (12')	Shoulder (12')	
N	Current Ramp Metering Infrastructure	Conduit and Pull boxes	Conduit and Pull boxes	Conduit and Pull boxes	Conduit and Pull boxess	Conduit and Pull boxes	Conduit and Pull boxes	
O	Layout Description for Exit Ramps	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	Fr Rd Yields to Ramp	

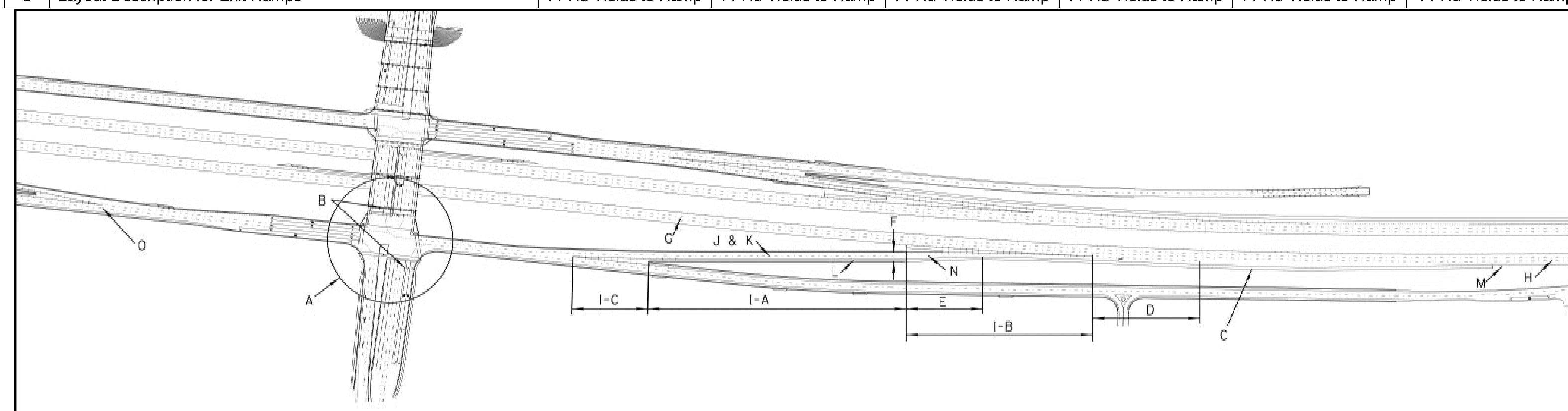
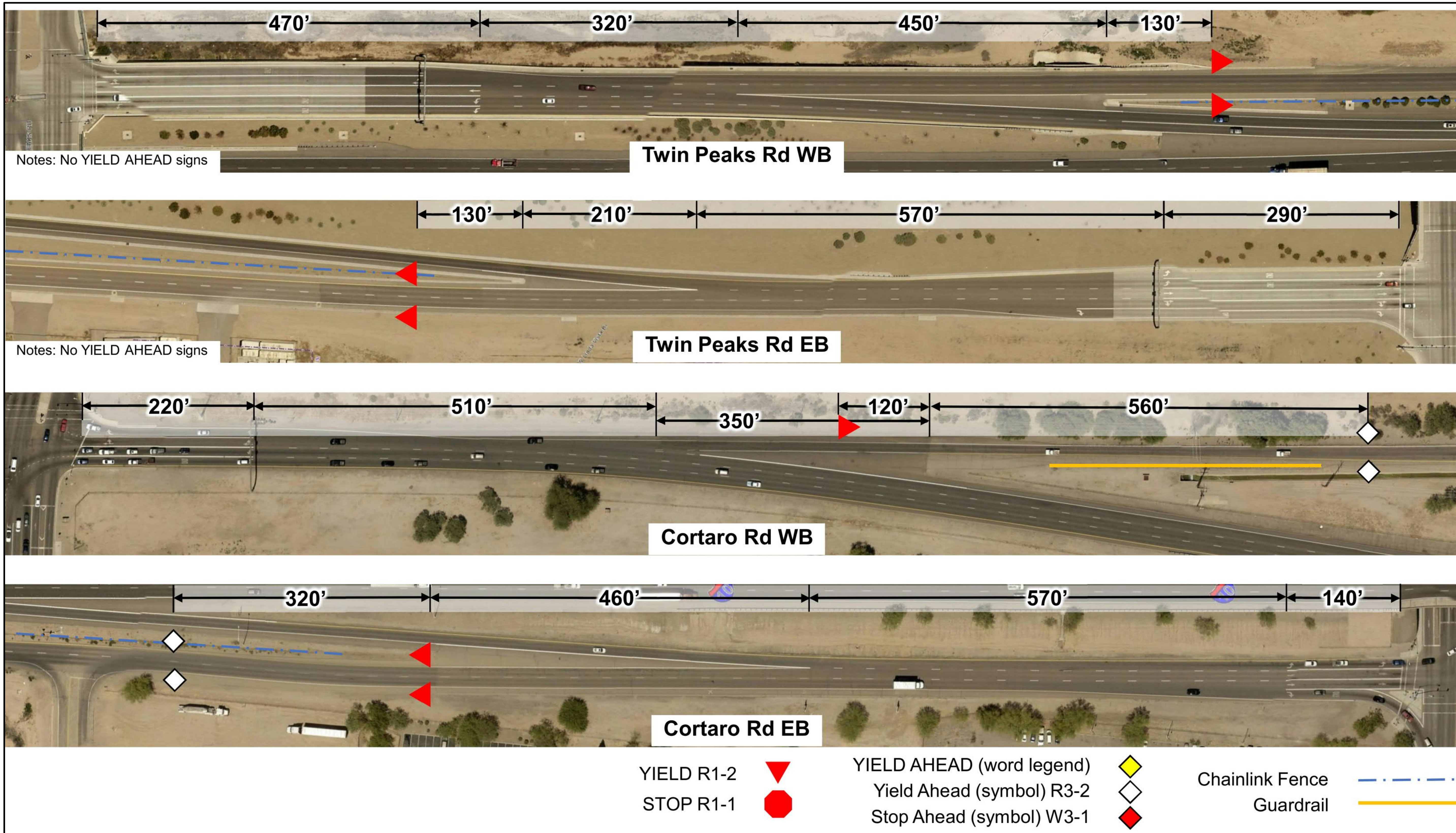


Figure 2: Exit Ramp Characteristics



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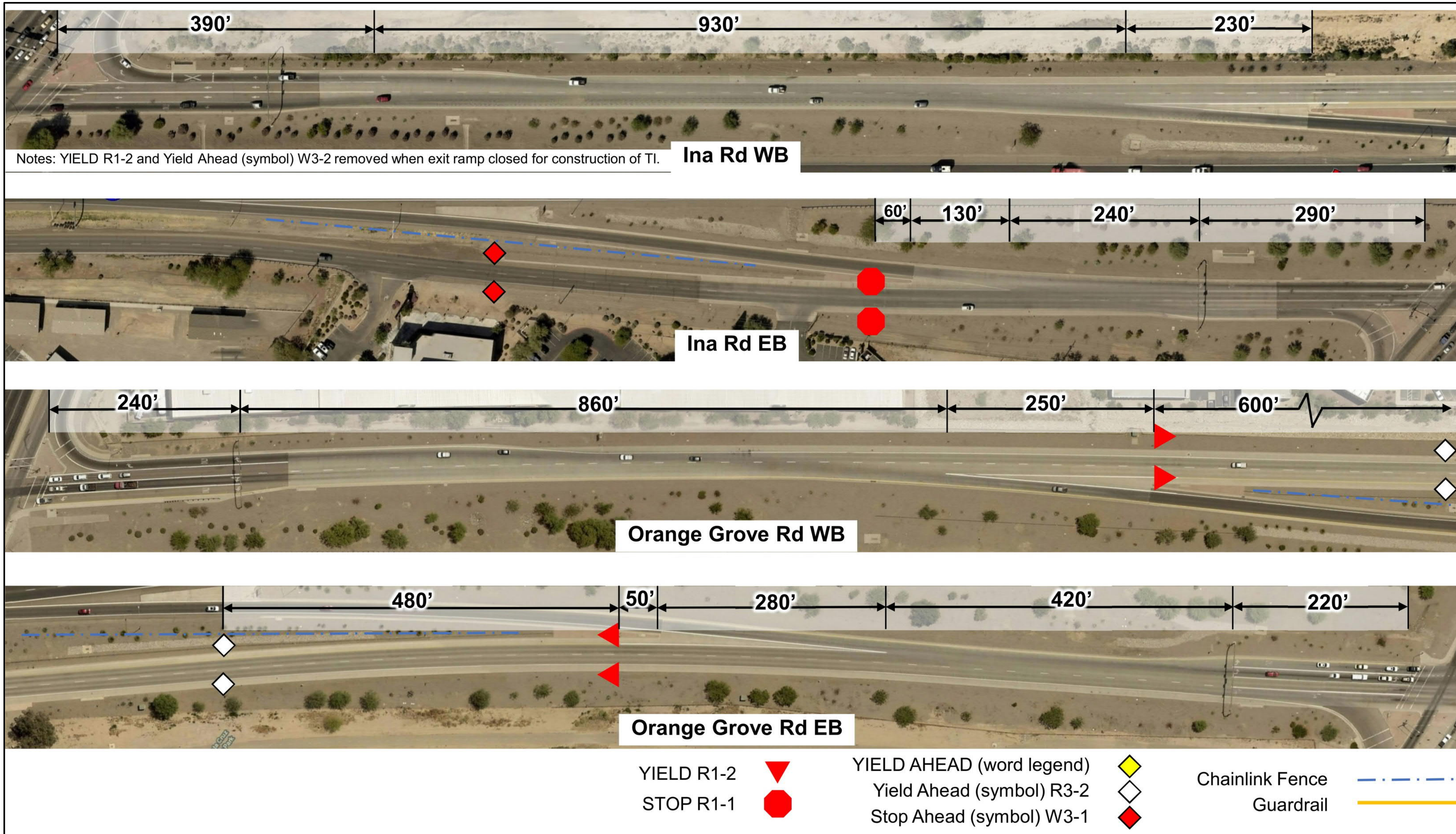

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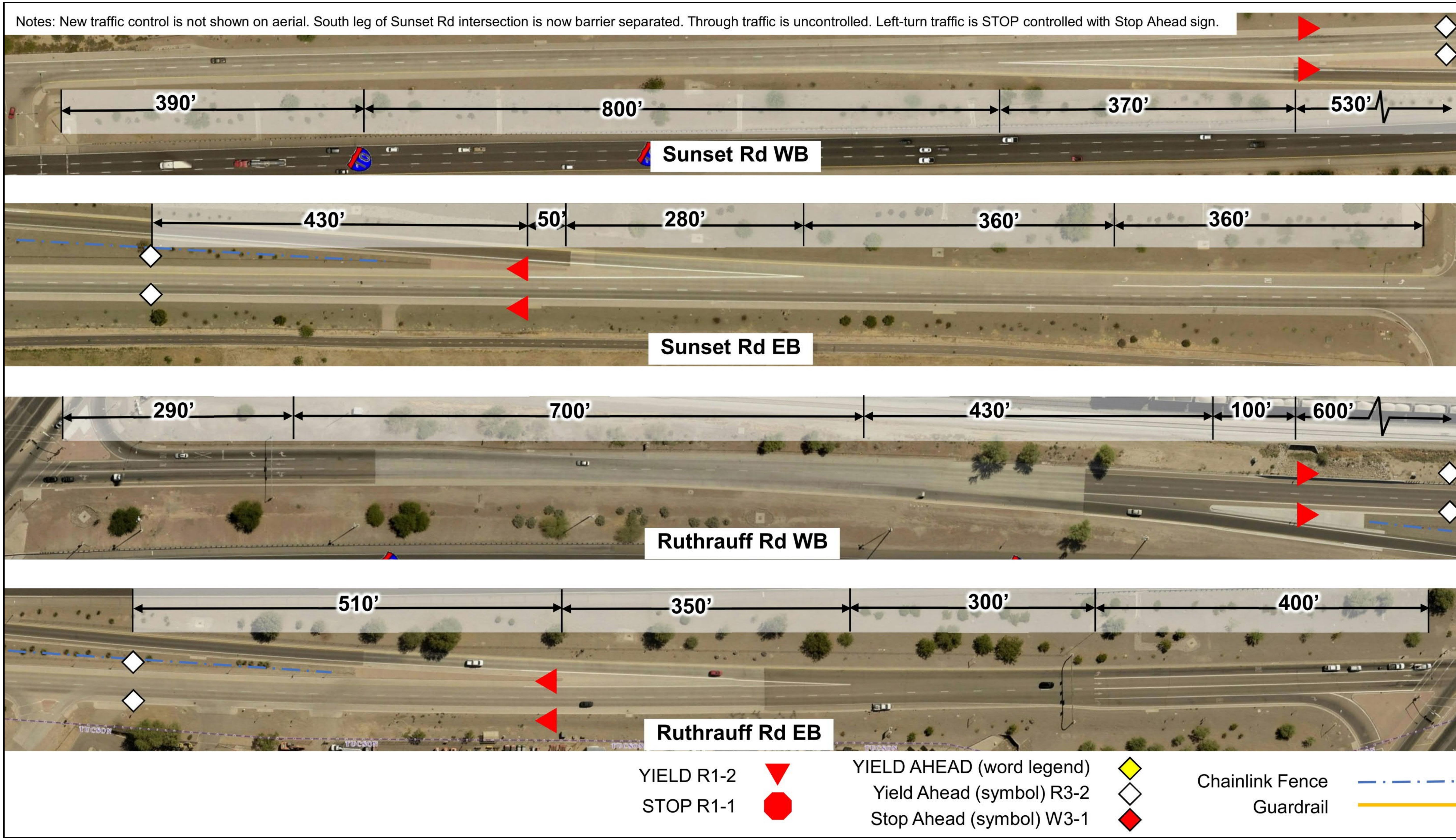

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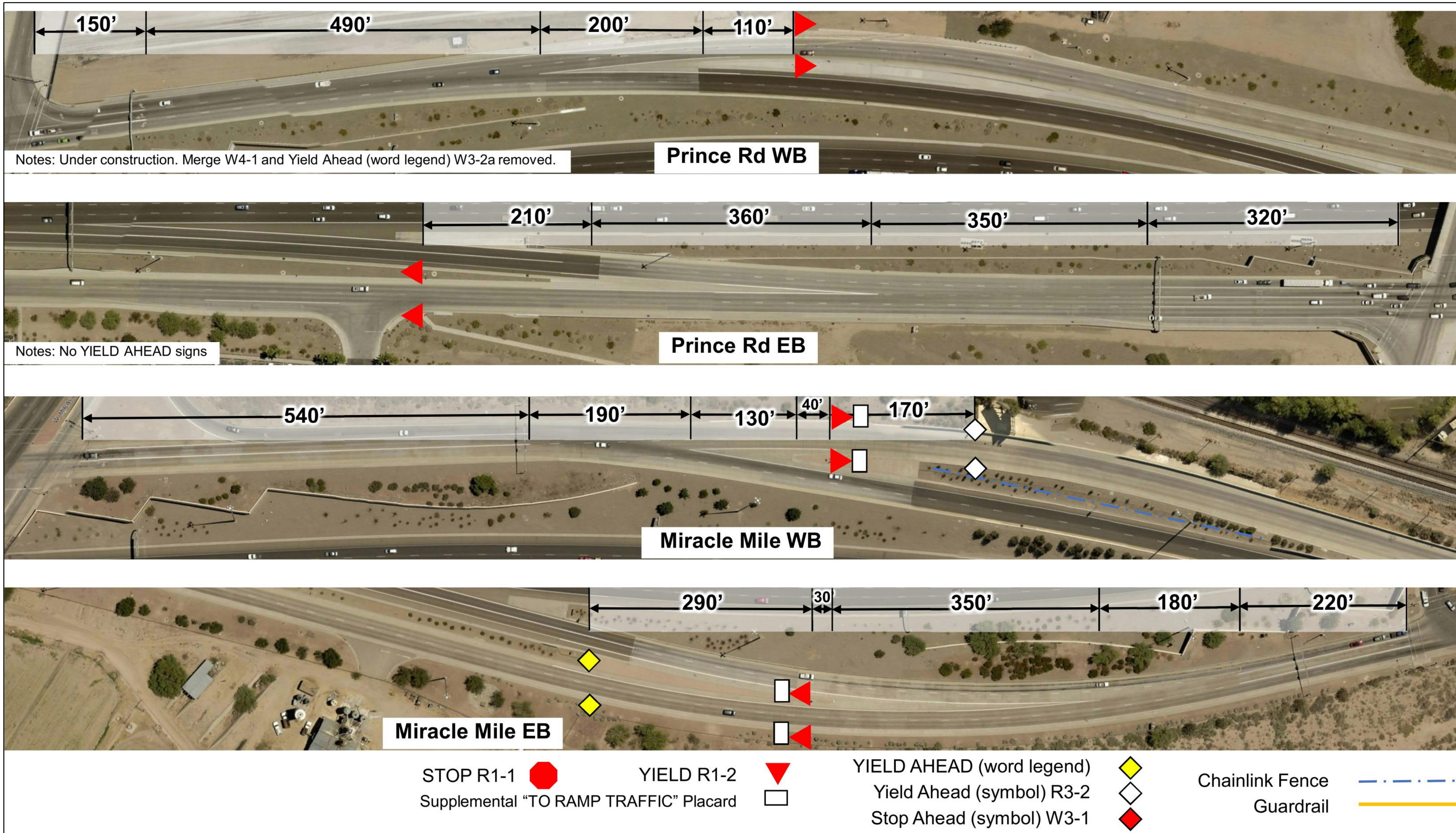

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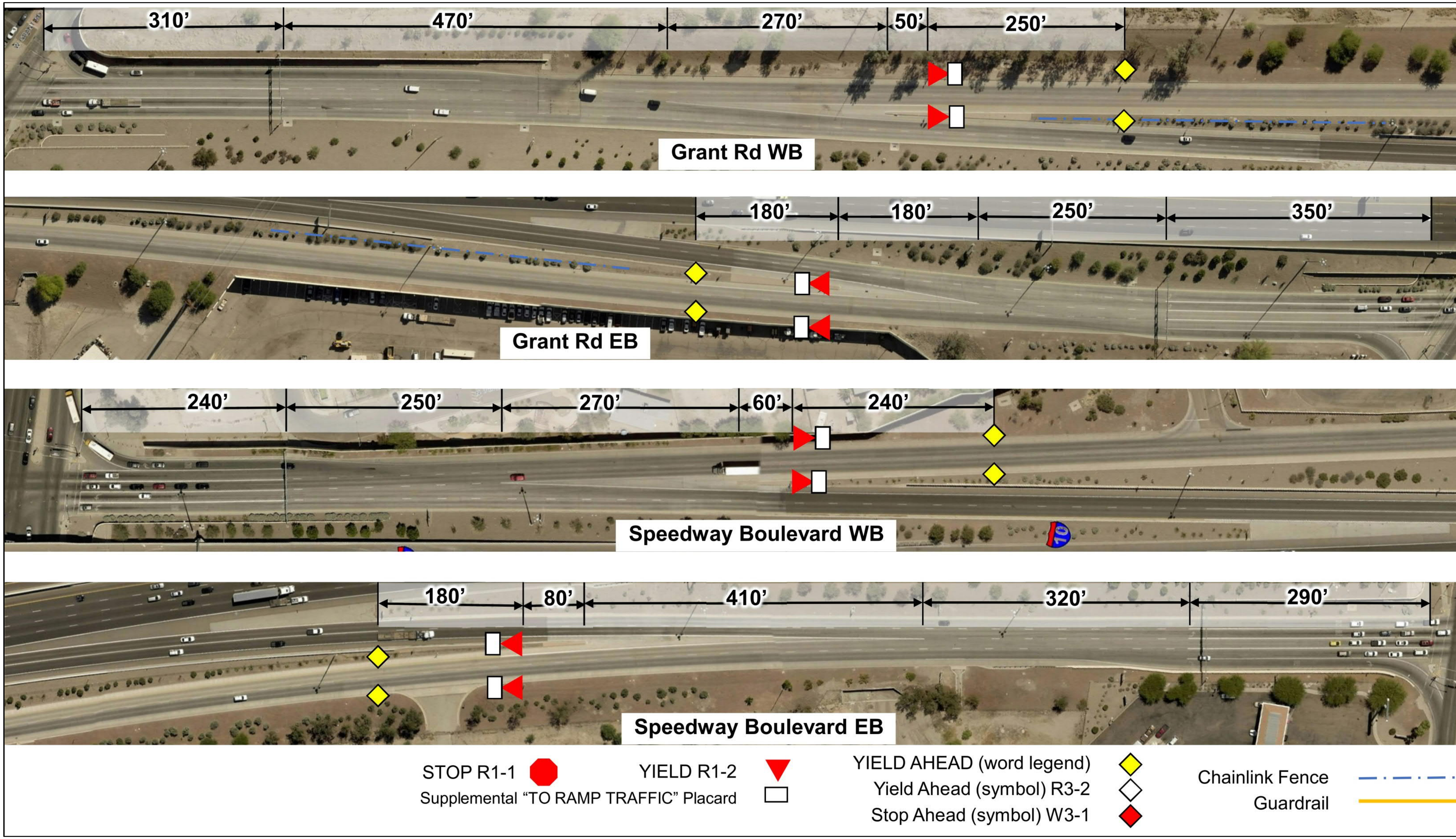

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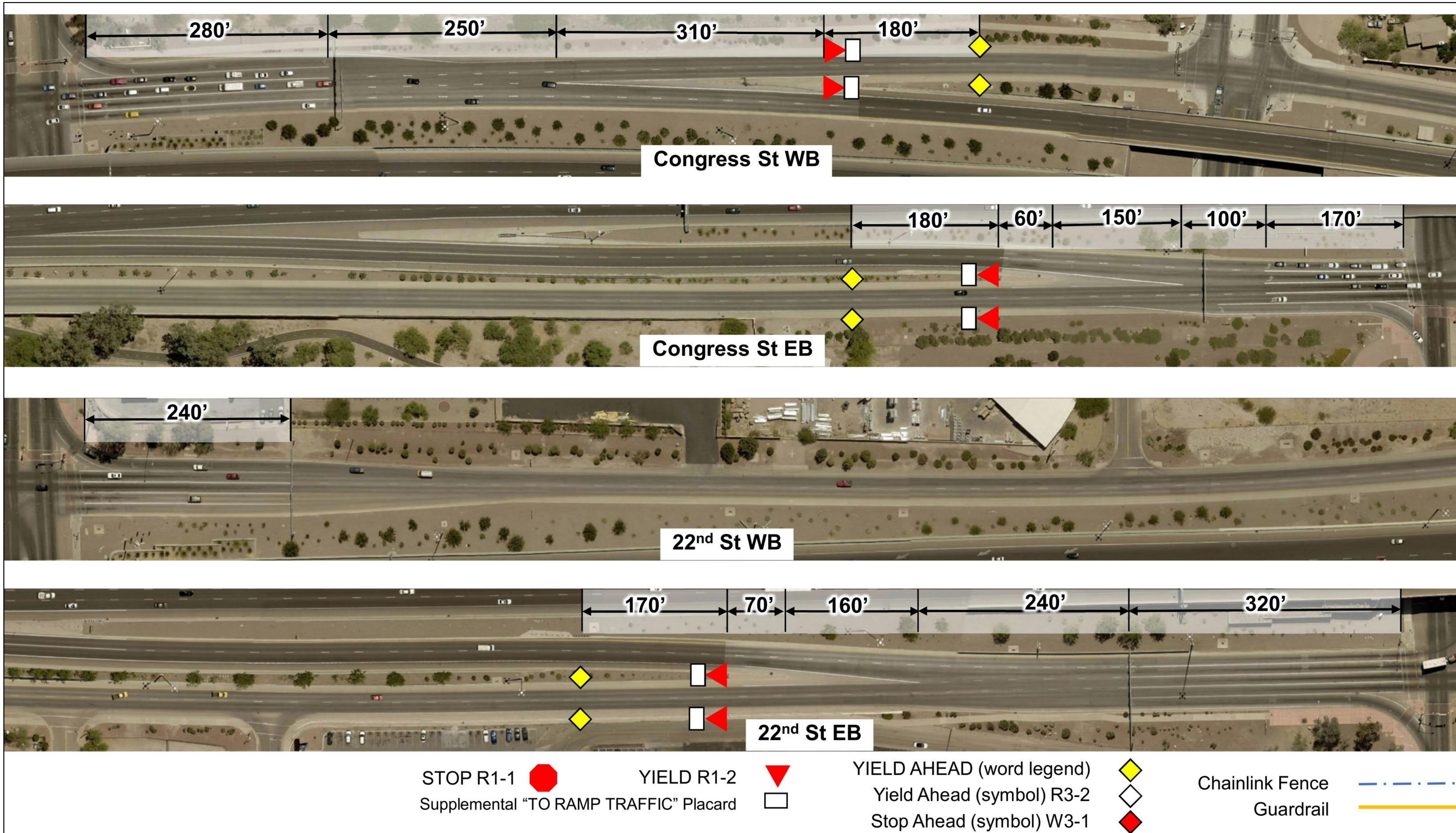


2.2.2 Traffic Conditions

2.2.2.1 Crash Data

Records of traffic crashes in the study area along I-10 were assembled from ADOT's Accident Location Identification Surveillance System (ALISS) database. Crashes were reviewed for the 5-year period from November 2012 through November 2017, the most recent 5-year period for which complete crash data is available. The corridor experienced 3,531 crashes during this period, including crashes on the mainline, ramps, frontage roads and crossroads in the vicinity of the study-area interchanges.

Table 3 shows the severity of the study-area crashes. Of the 3,531 crashes, 16 (0.5 percent) involved a fatality.

Table 3: Crash Severity by Year

Year	Reported Crash Severity					
	No Injury	Possible Injury	Suspected Minor Injury	Suspected Serious Injury	Fatal	Total
2012 (2 months)	91	14	18	7	1	131
2013	487	82	79	11	2	661
2014	449	79	61	18	2	609
2015	481	82	86	5	6	660
2016	597	104	73	13	3	790
2017 (10 months)	518	78	70	12	2	680
Total	2,623	439	387	66	16	3,531

Table 4 shows which facility the crashes occurred on over the 5-year period.

Table 4: Crash Locations

Location	Number of Crashes
Ramps	172
Frontage Roads	665
Mainline	2,171
Crossroads	451
Other Intersections	72
Total	3,531

2.2.2.2 Existing Traffic Volumes

Existing traffic volumes were collected from ADOT MPD, PAG, and the City of Tucson for the I-10 mainline, ramps, frontage roads, and interchanges. The mainline and ramp volumes were balanced to represent an access-controlled facility. **Figure 3** displays the existing mainline lane configurations along with the balanced mainline and ramp volumes. **Figure 4** shows the turning movement volumes at the intersections and traffic interchanges.

The traffic volumes displayed in Figure 3 and Figure 4 are balanced volumes which take into account the method of data collection, and eliminate the traffic dissipated from the network between intersections. In other words, these volumes represent "balanced" conditions. The average daily traffic (ADT) on I-10 ranges from approximately 70,000 vehicles per day (vpd) northwest of Twin Peaks Road to 180,000 vpd near Speedway Boulevard.

Using the data obtained from ADOT, PAG, and the City of Tucson, the existing K, D, and T factors were calculated. The 'K' factor represents the portion of daily traffic which occurs during the peak hours and is expressed as a percentage, inclusive of both directions of travel. The 'D' factor represents the directional distribution of traffic during the peak hour and is expressed as a percentage. The 'T' factor represents the percentage of traffic that would be classified as heavy vehicles/commercial trucks. According to ADOT MPD, the 2017 T factor along I-10 varies between 12.1% and 18.9% within the study area.

Representative traffic factors for the study area are shown in **Table 5**. Along the mainline, the portion of the ADT occurring within the peak hour (K value) is approximately 7 to 9% and the directional distribution (D value) is approximately 50 to 60% in the peak direction of travel, except at Cortaro Road.

Table 5: Traffic Factors

Location	AM Peak Hour			PM Peak Hour		
	K value	D value		K Value	D value	
		WB	EB		WB	EB
I-10 Mainline near 22nd St	7.7%	49%	51%	7.8%	53%	47%
I-10 Mainline near Miracle Mile Rd	7.6%	39%	61%	7.8%	59%	41%
I-10 Mainline near Ruthruaff Rd	6.9%	35%	65%	7.9%	58%	42%
I-10 Mainline near Cortaro Rd	7.0%	35%	65%	7.7%	58%	42%
22nd Street, west of I-10	6.8%	49%	51%	8.7%	58%	42%
22nd Street, east of I-10	8.9%	38%	62%	7.4%	52%	48%
Miracle Mile Rd, east of I-10	7.3%	44%	56%	8.3%	53%	47%
Ruthrauff Rd, west of I-10	8.3%	25%	75%	8.3%	62%	38%
Ruthruaff Rd, east of I-10	6.5%	45%	55%	7.4%	54%	46%
Cortaro Rd, west of I-10	6.8%	34%	66%	9.1%	61%	39%
Cortaro Rd, east of I-10	7.1%	61%	39%	8.4%	43%	57%

2.2.2.3 Future Traffic Volumes

PAG maintains a regional traffic forecasting model to develop future traffic volume projections based on projected socioeconomic, population, employment, origin-destination, and other regionally based data. The 2045 PAG travel demand model includes all transportation system improvements identified through year 2045. While the PAG model inputs were not reviewed as part of this study, it was assumed to include improvements to the Ina Road and Ruthrauff Road traffic interchanges and mainline widening between Ruthrauff Road and Ina Road. PAG provided traffic volume projections for year 2018 and for year 2045 for use in this study. The output from the model includes daily and peak period traffic volumes. The 2045 traffic volume projections that were received from PAG were compared to the 2018 PAG model to determine a growth rate. This growth rate was applied to the existing traffic volume data to estimate future volumes for the 2025 Design Year.

Figure 5 displays the resulting 2025 mainline and ramp volumes. **Figure 6** shows the 2025 turning movement volumes at the intersections and traffic interchanges.

2.2.2.4 Signal Phasing

Signal timing and phasing information was obtained from ADOT, the City of Tucson, Town of Marana, and Pima County.

Figure 7 displays the traffic interchanges, adjacent signalized intersections (that are within ½ mile) and the phasing information.

Figure 3: Existing Mainline Lane Configurations and Volumes

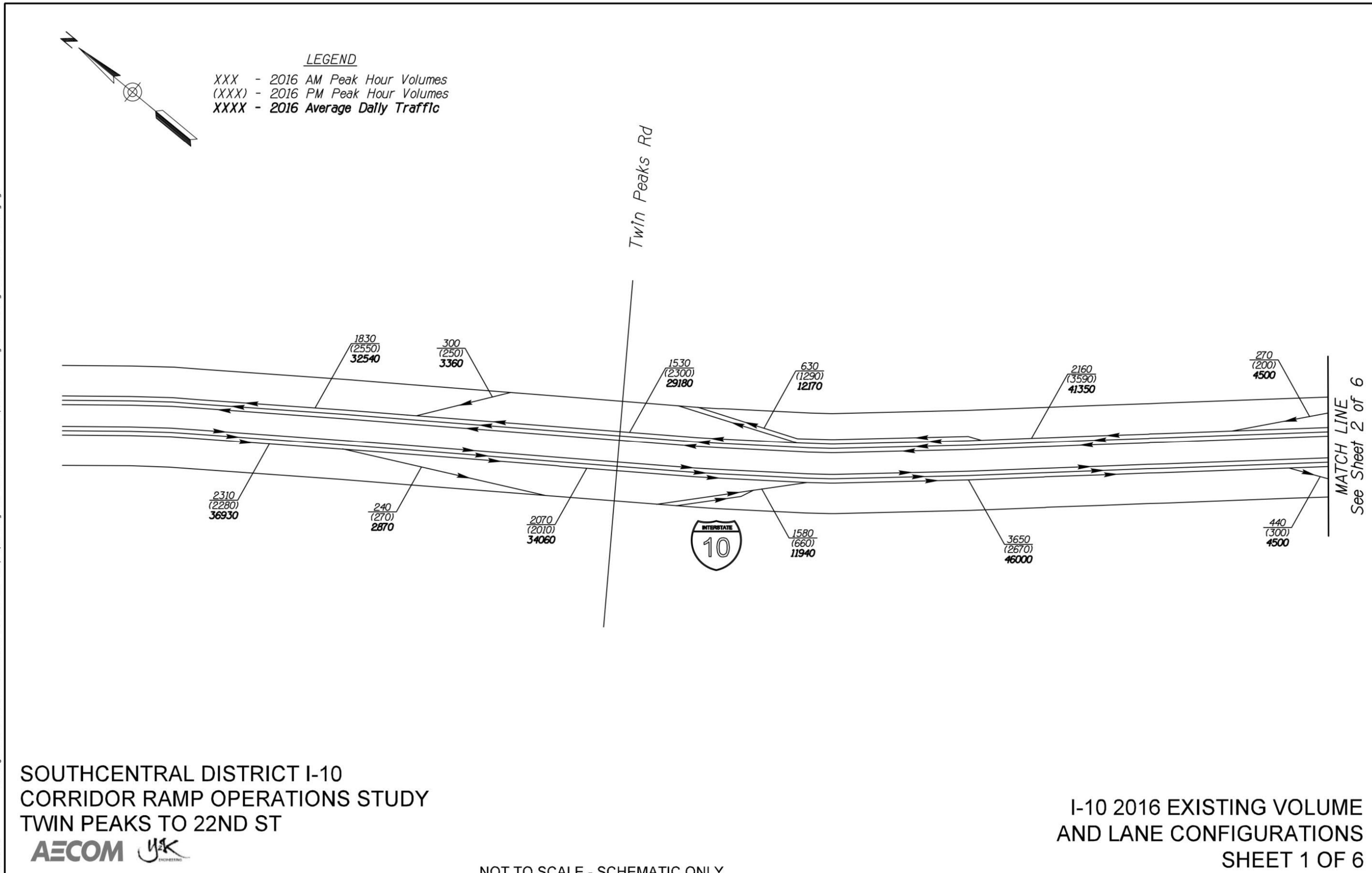


Figure 3: Existing Mainline Lane Configurations and Volumes - continued

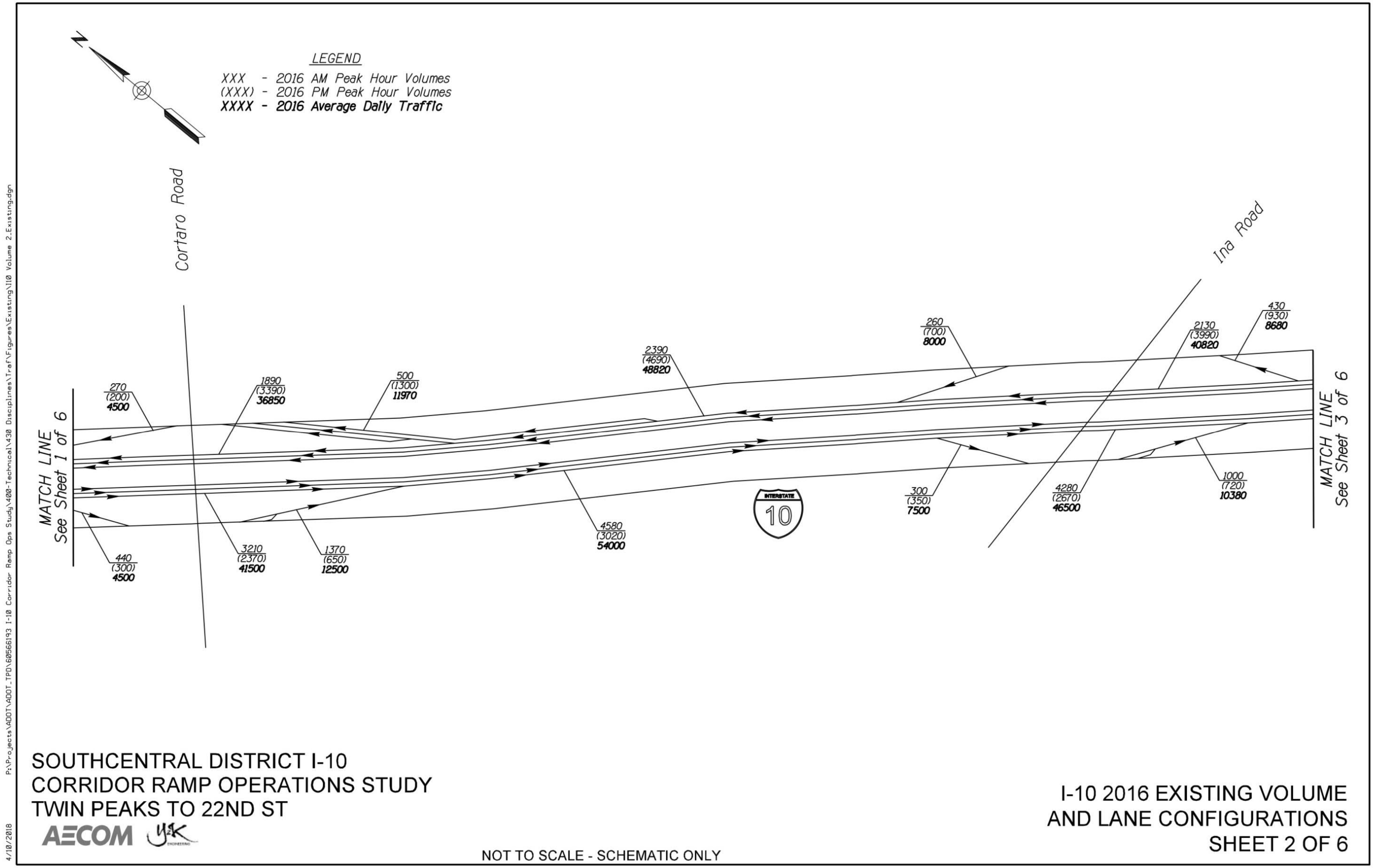


Figure 3: Existing Mainline Lane Configurations and Volumes - continued

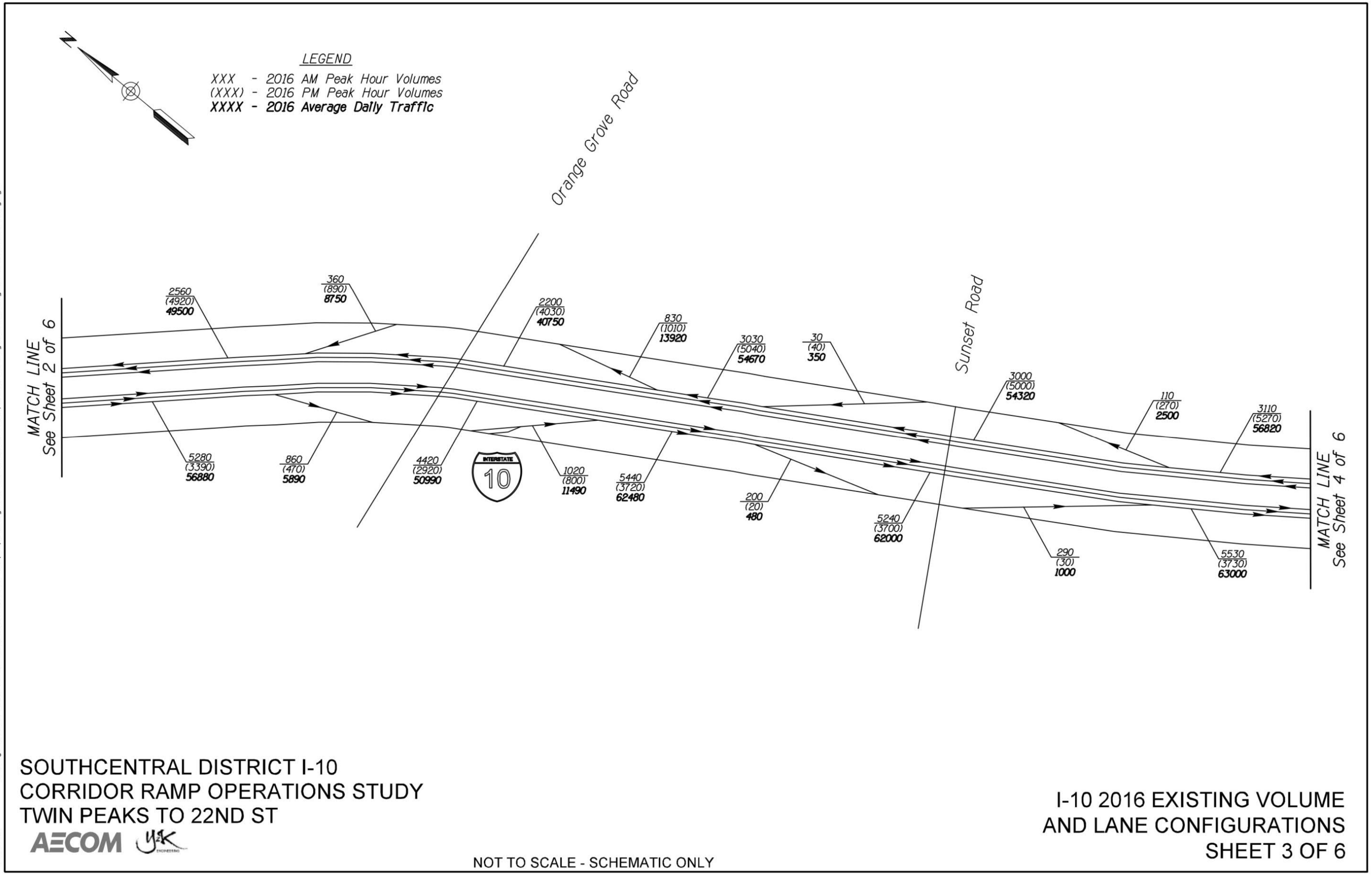


Figure 3: Existing Mainline Lane Configurations and Volumes - continued

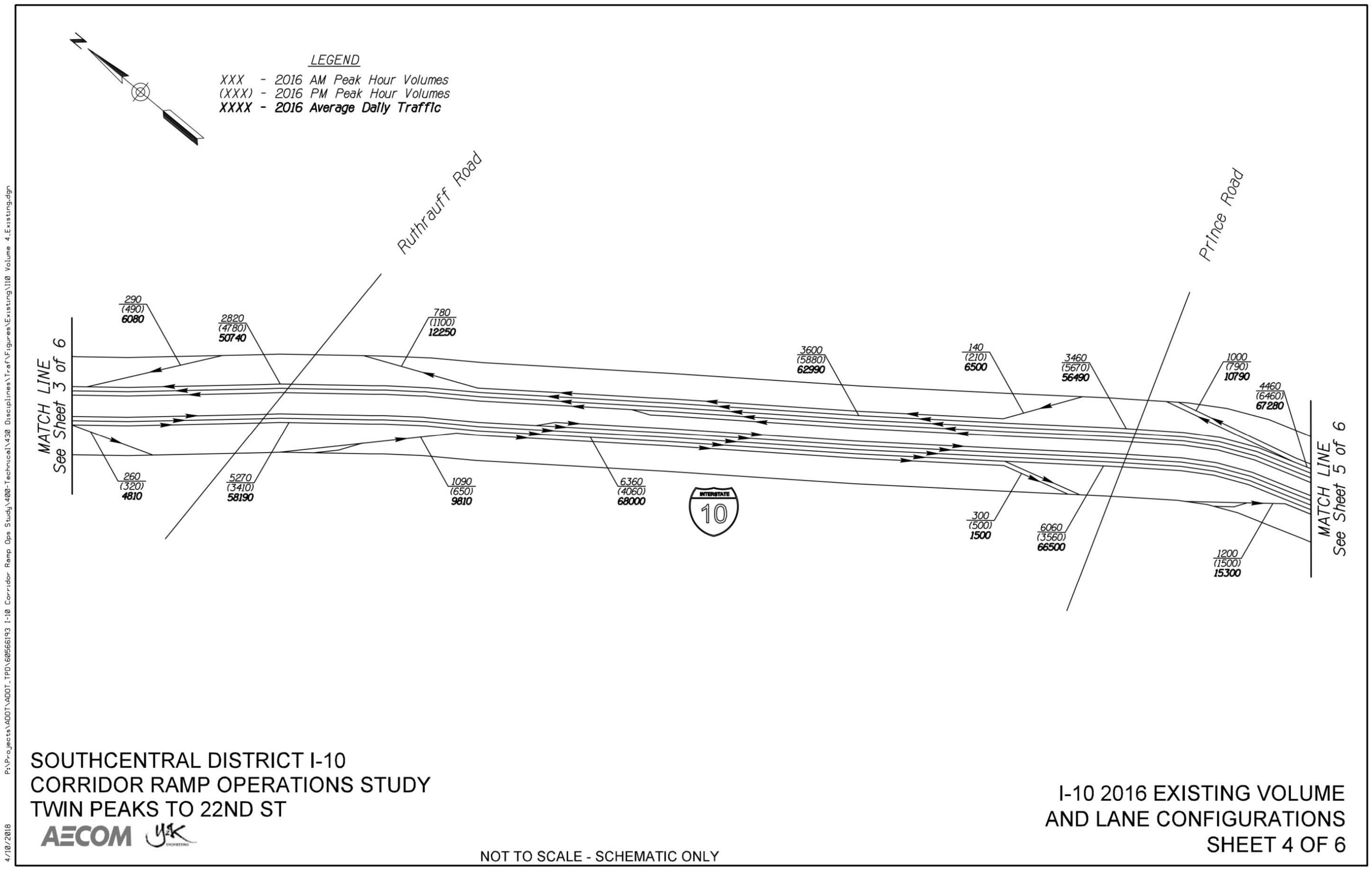


Figure 3: Existing Mainline Lane Configurations and Volumes - continued

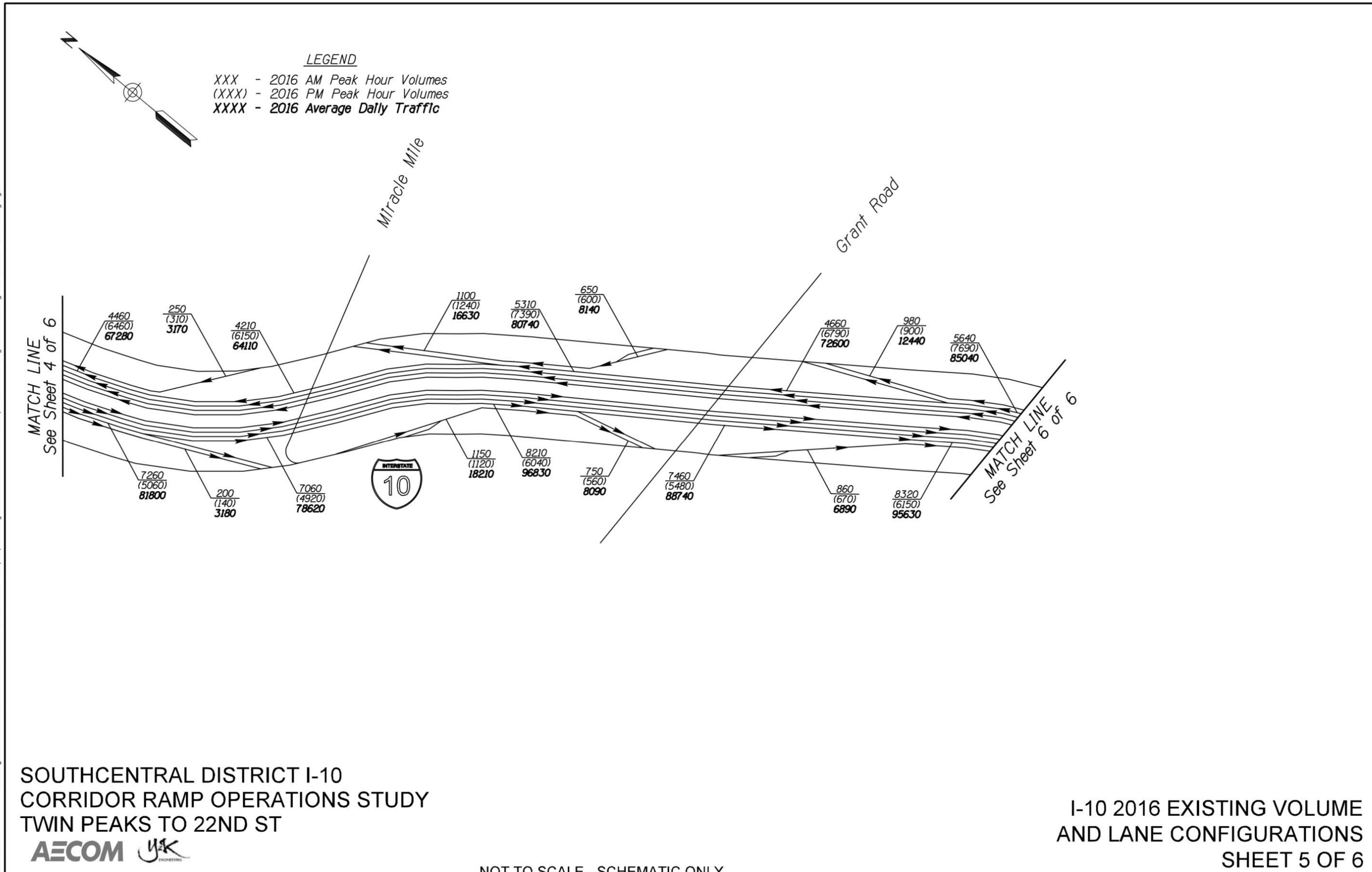


Figure 3: Existing Mainline Lane Configurations and Volumes - continued

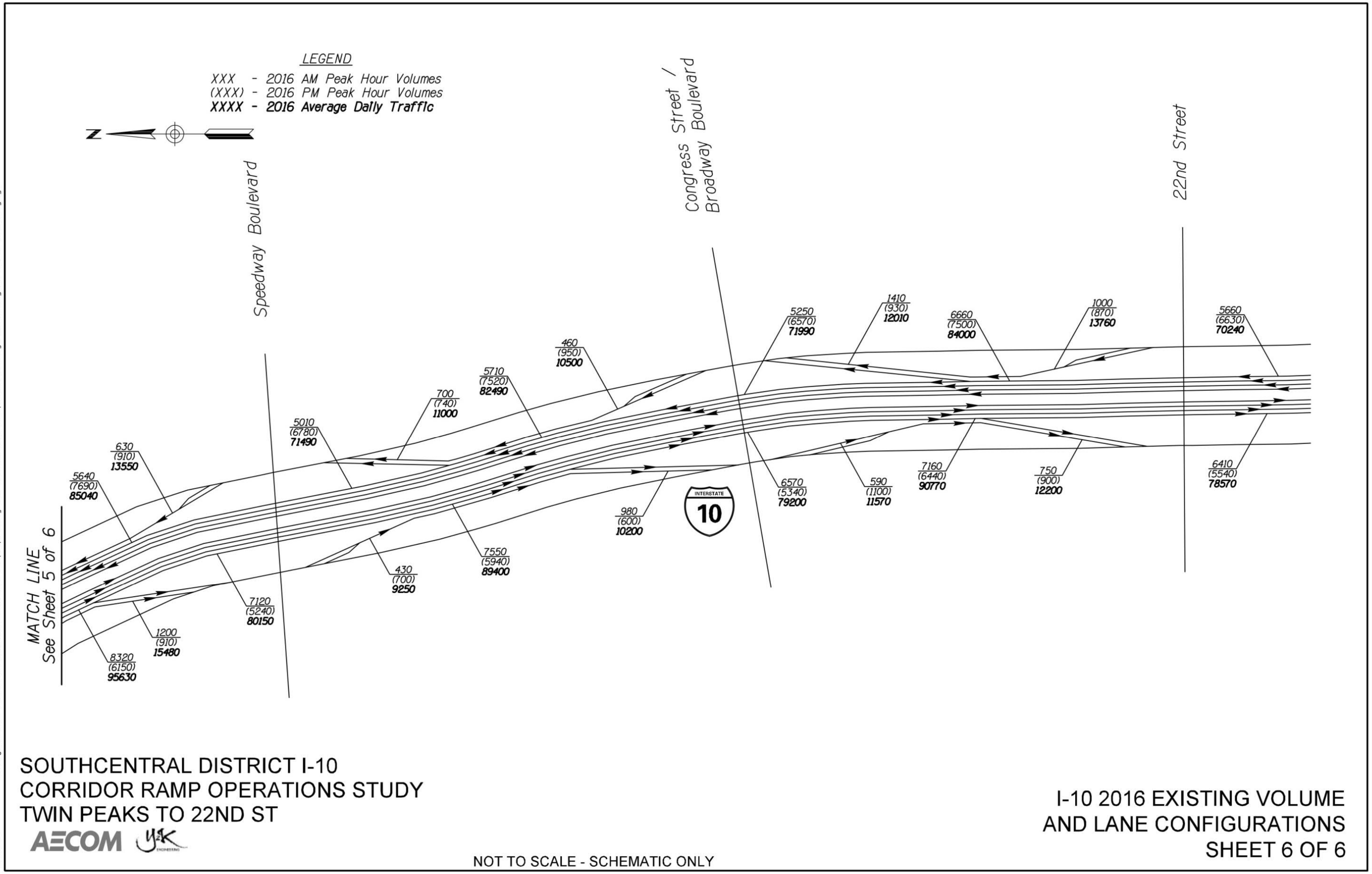


Figure 4: Existing Interchange Volumes

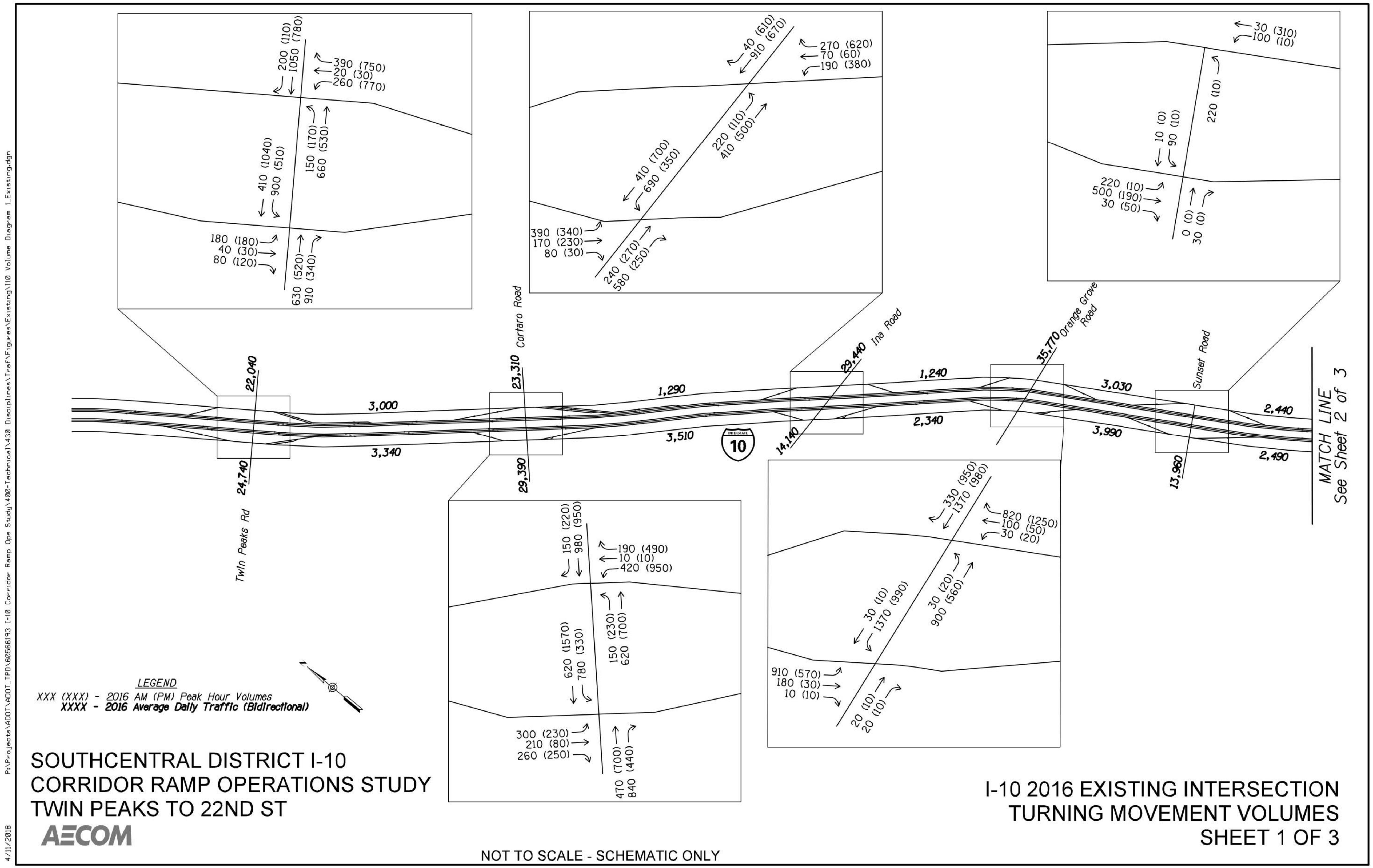


Figure 4: Existing Interchange Volumes - continued

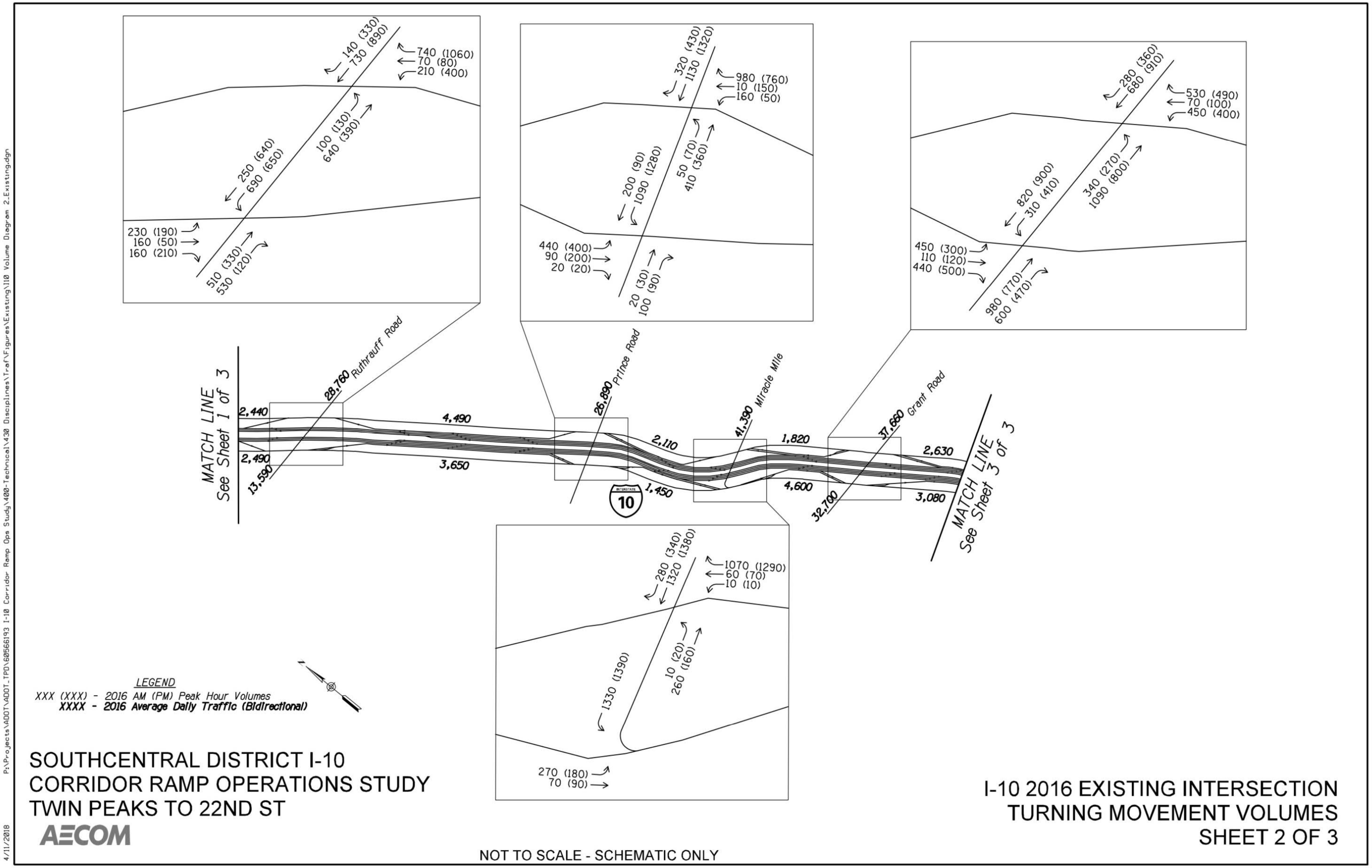


Figure 4: Existing Interchange Volumes - continued

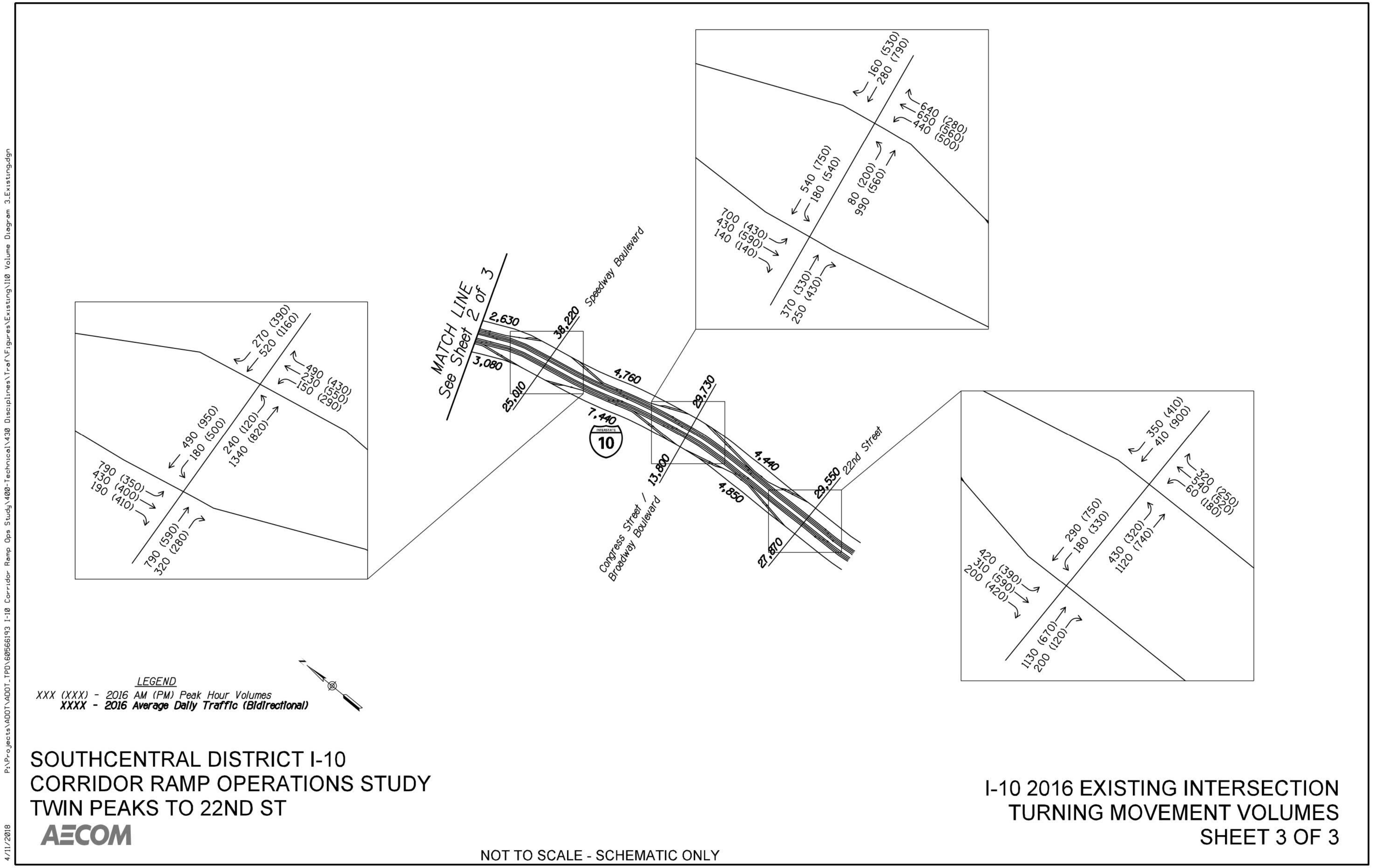


Figure 5: 2025 Mainline Lane Configurations and Volumes

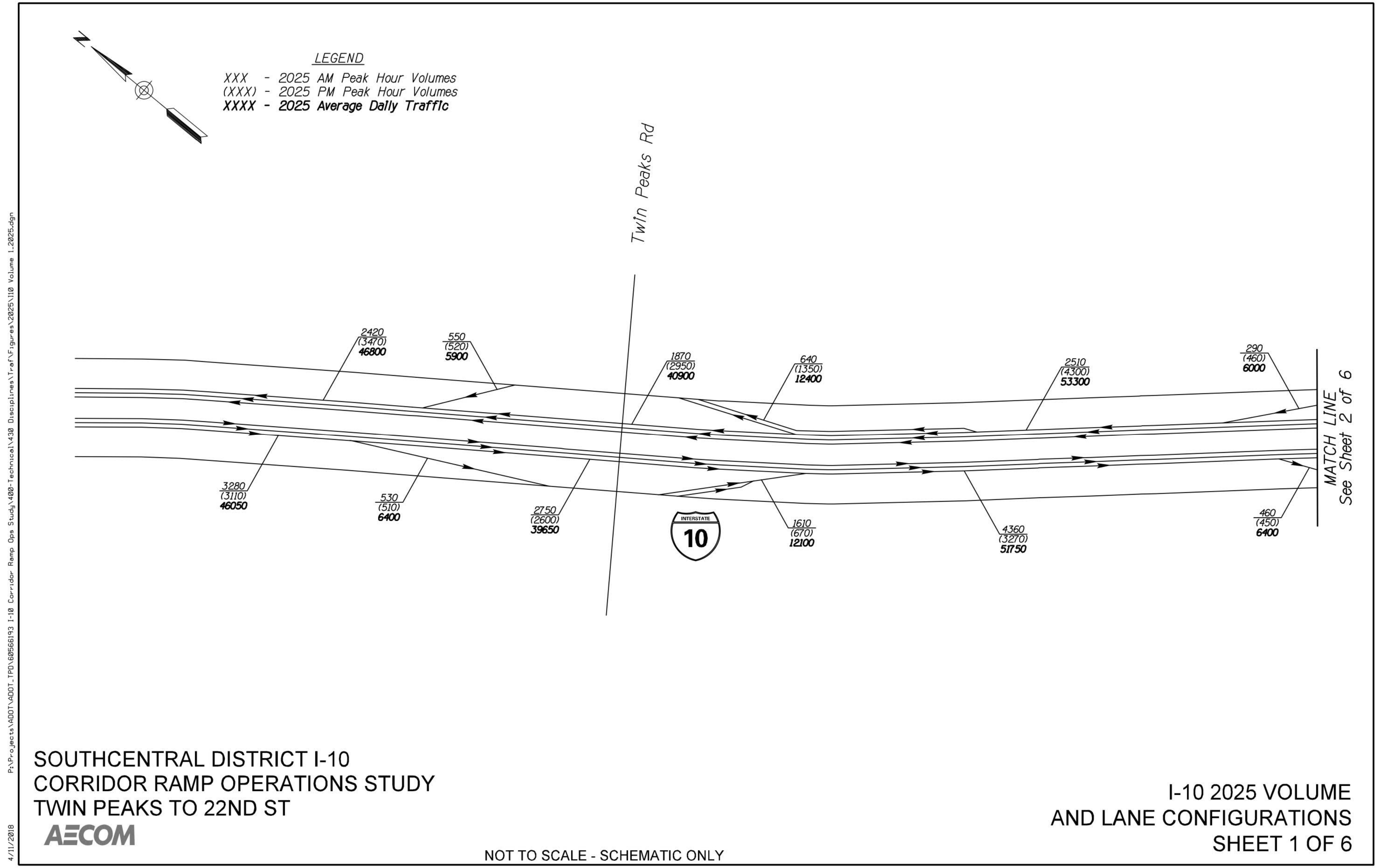


Figure 5: 2025 Mainline Lane Configurations and Volumes - continued

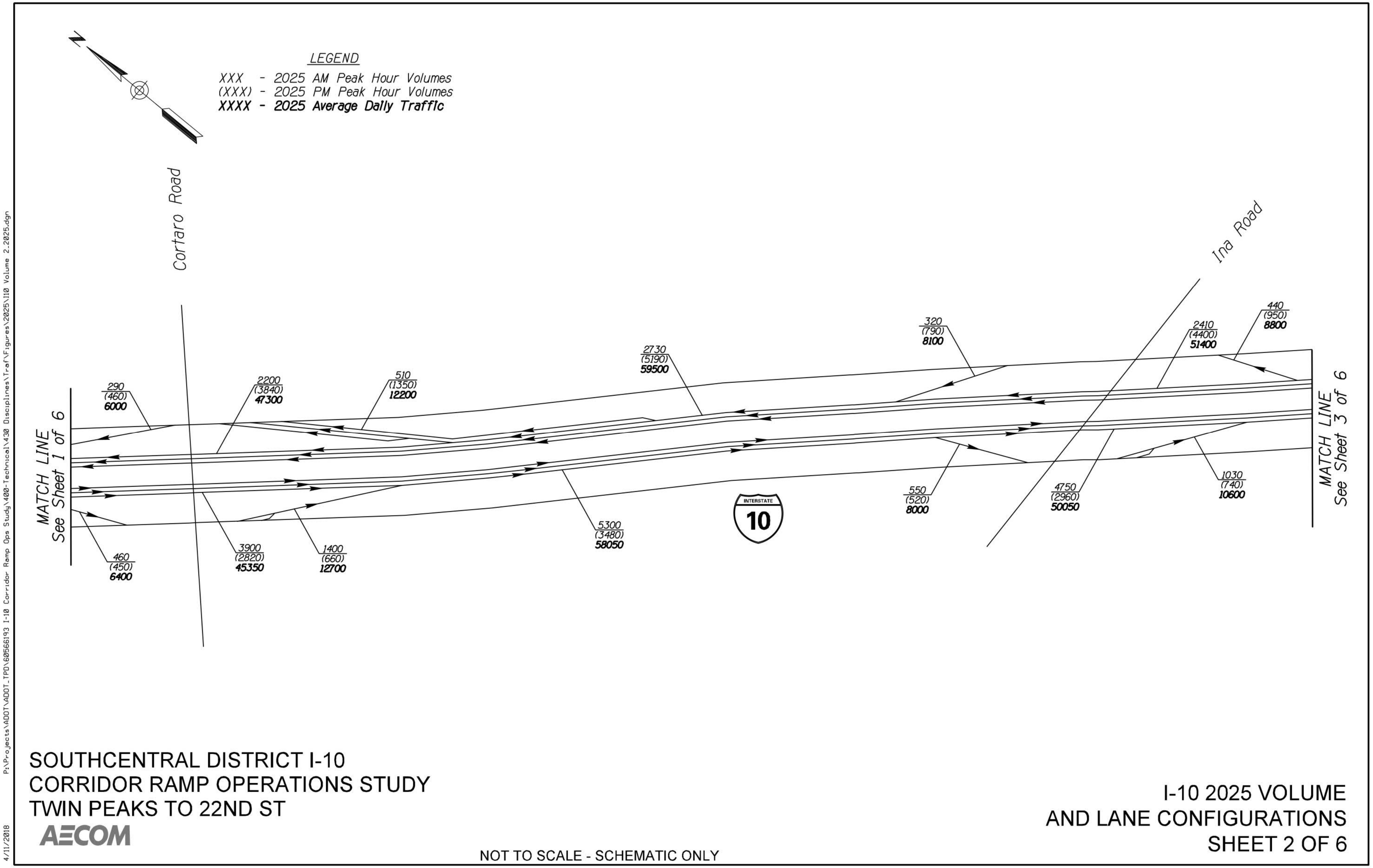


Figure 5: 2025 Mainline Lane Configurations and Volumes - continued

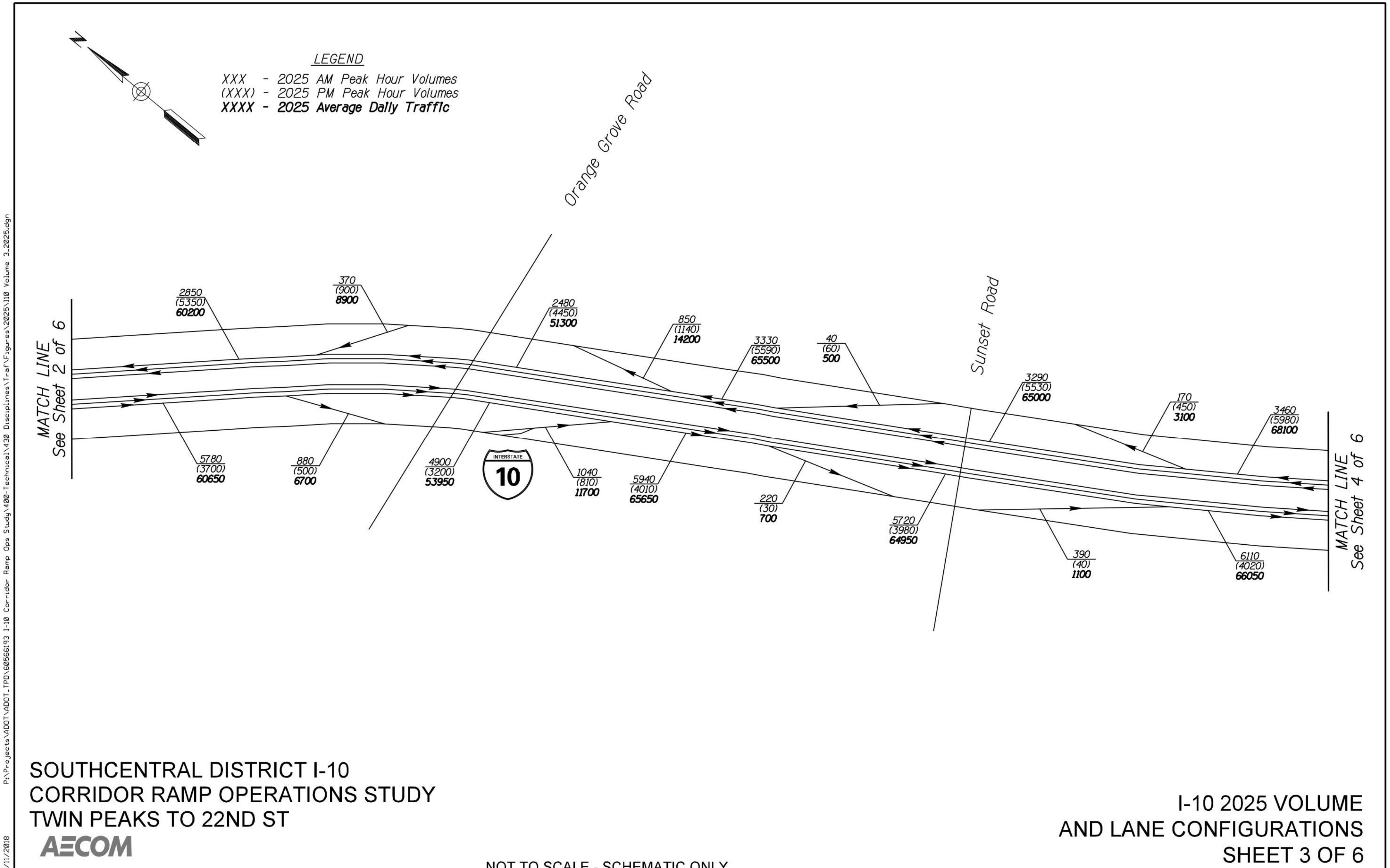


Figure 5: 2025 Mainline Lane Configurations and Volumes - continued

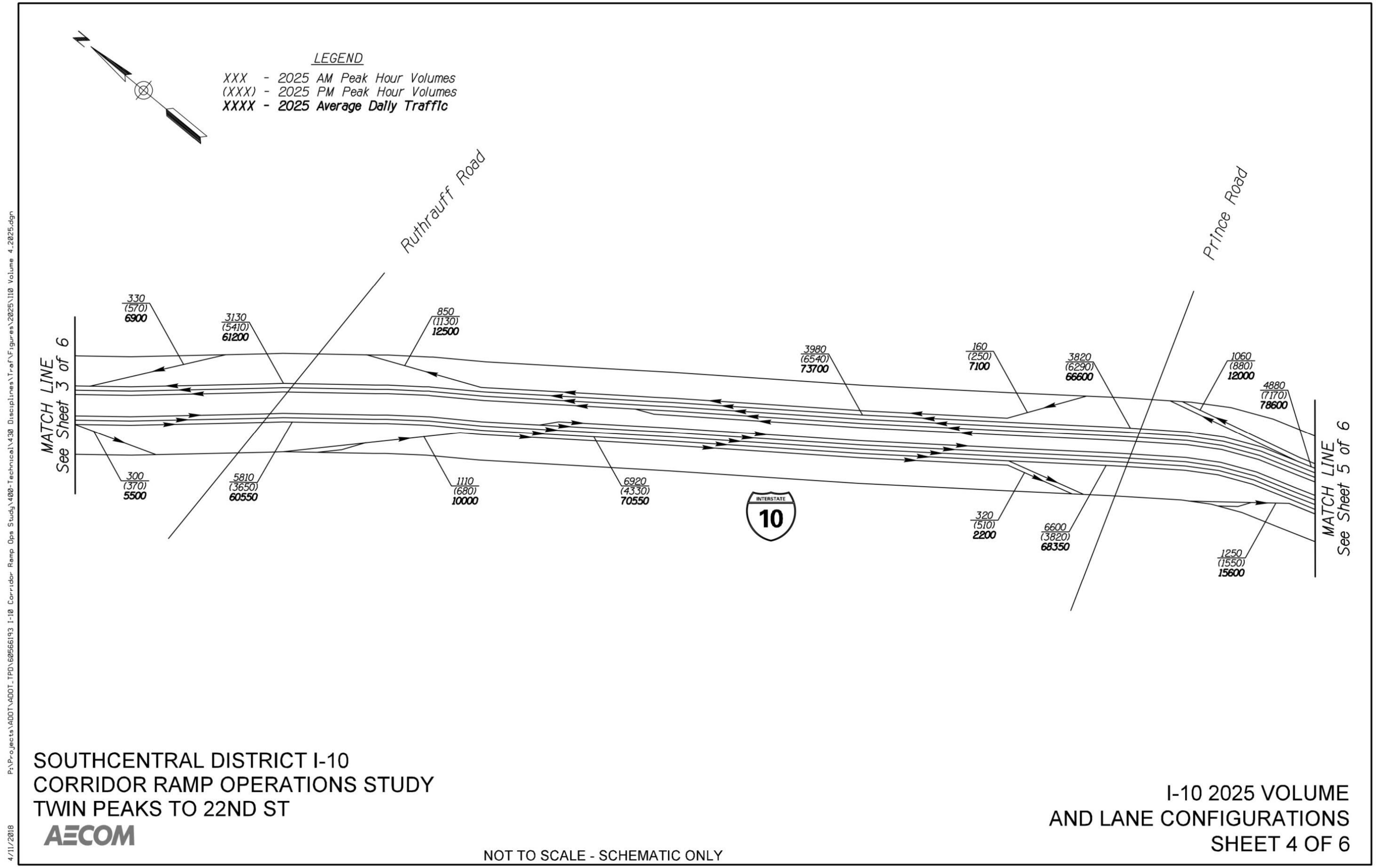


Figure 5: 2025 Mainline Lane Configurations and Volumes - continued

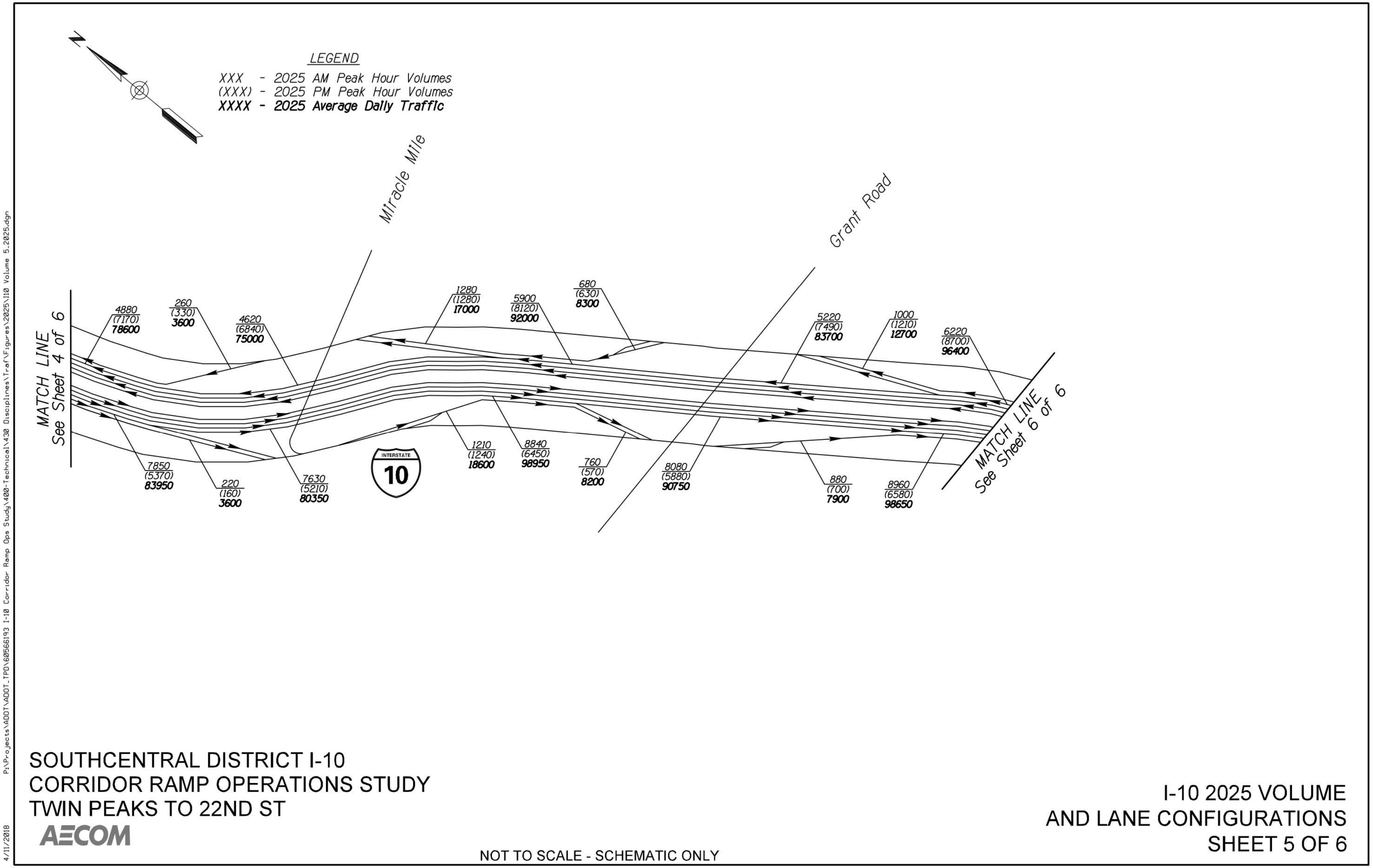


Figure 5: 2025 Mainline Lane Configurations and Volumes - continued

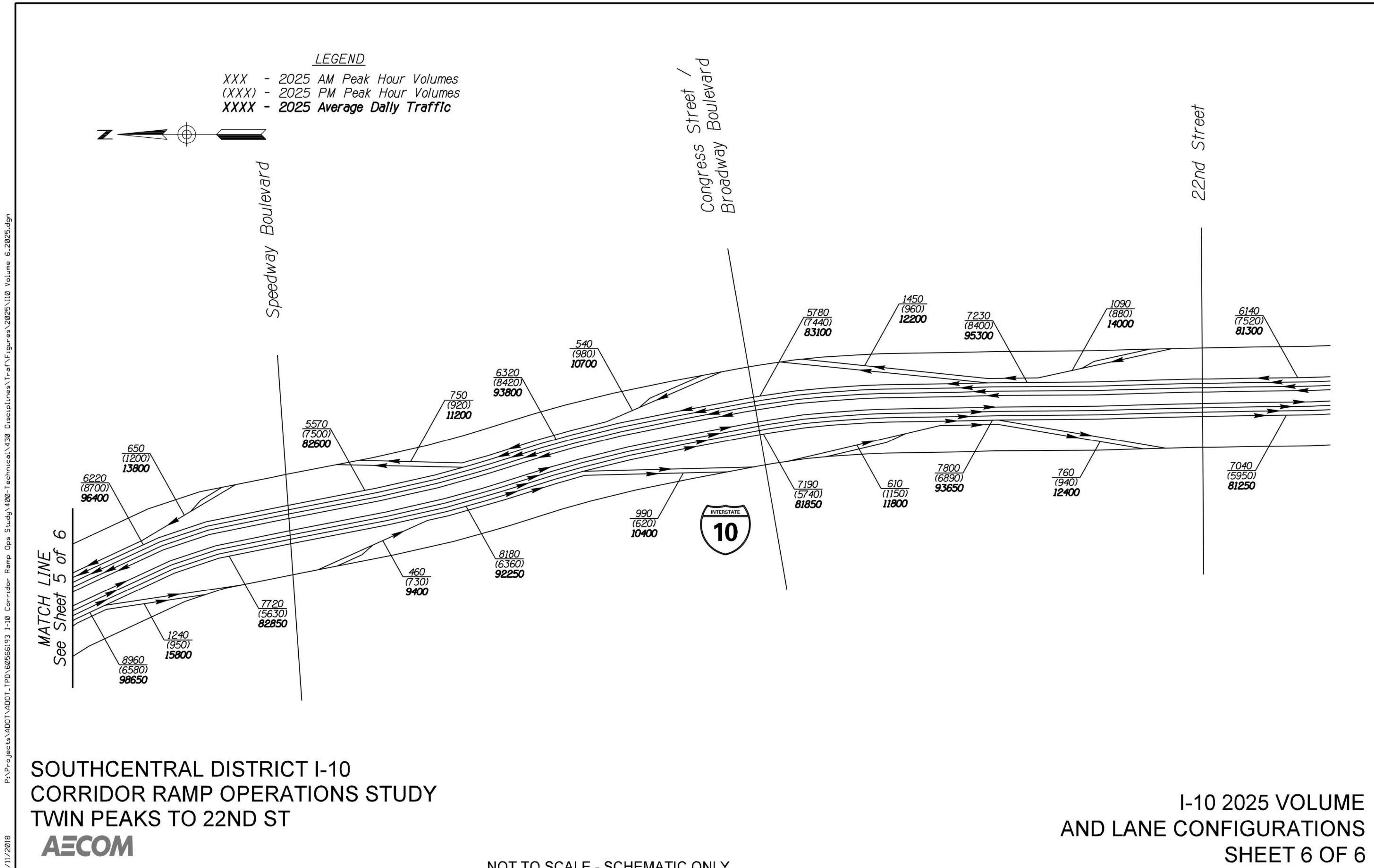


Figure 6: 2025 Interchange Volumes

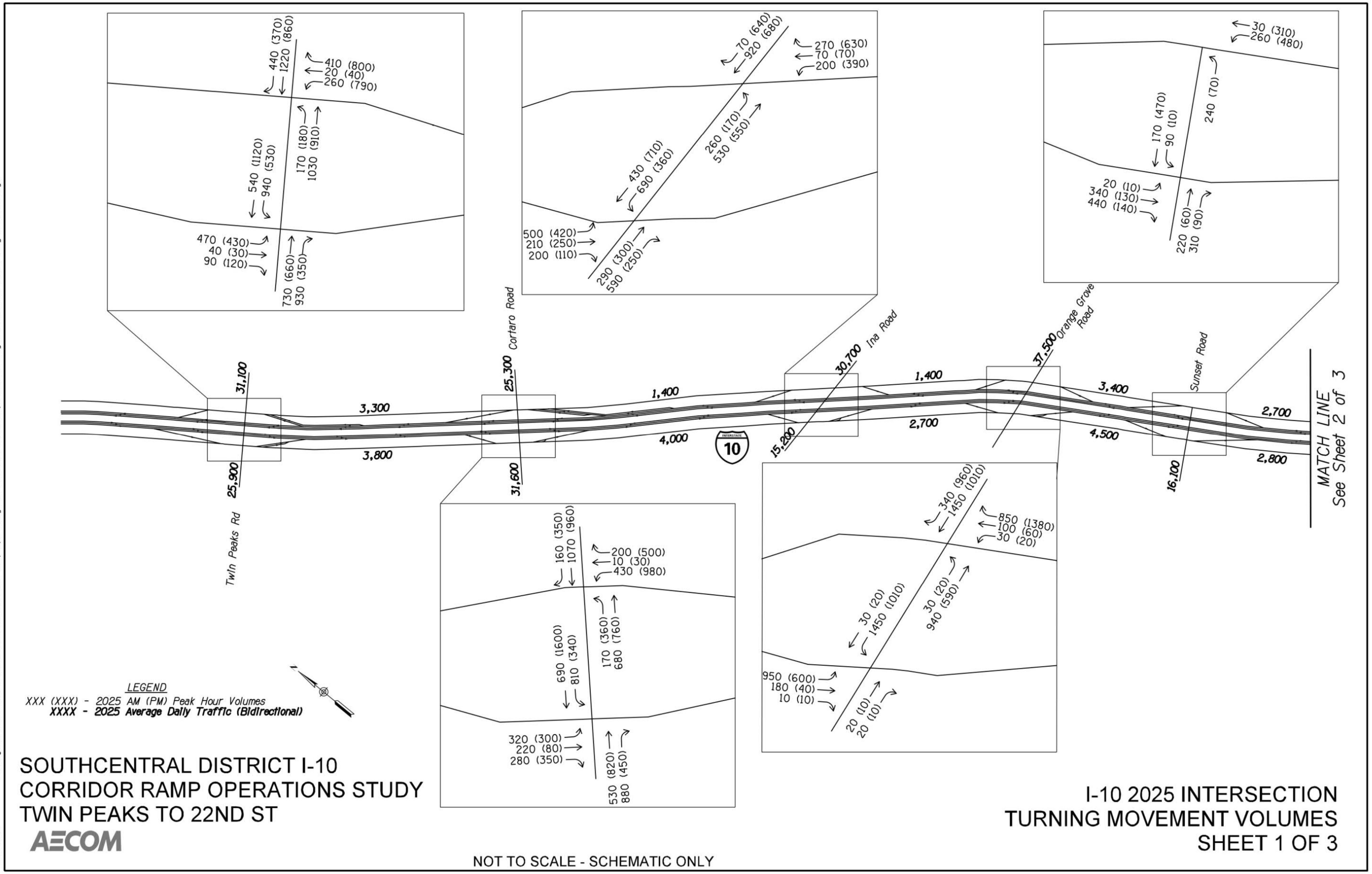


Figure 6: 2025 Interchange Volumes - continued

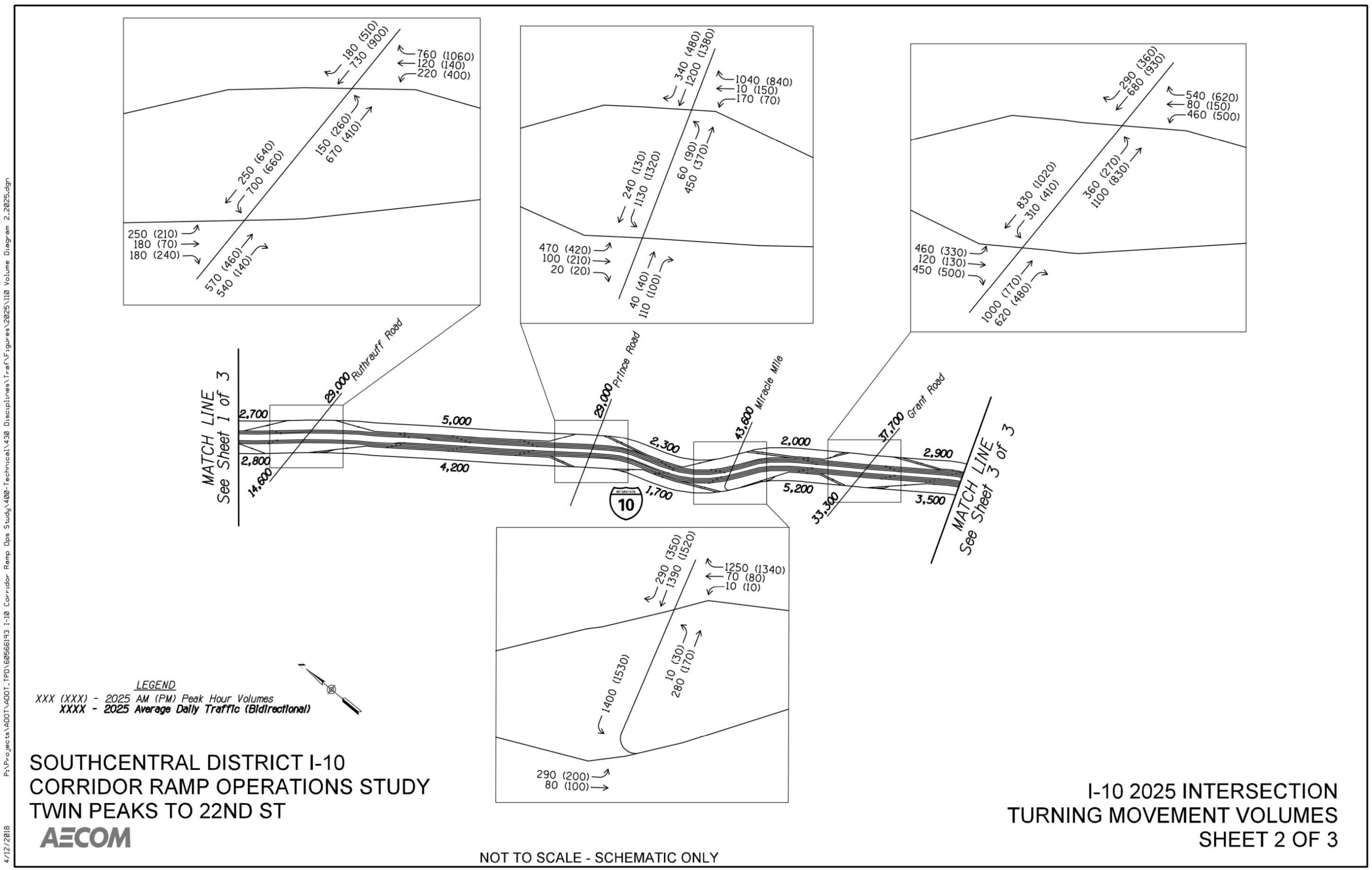


Figure 6: 2025 Interchange Volumes - continued

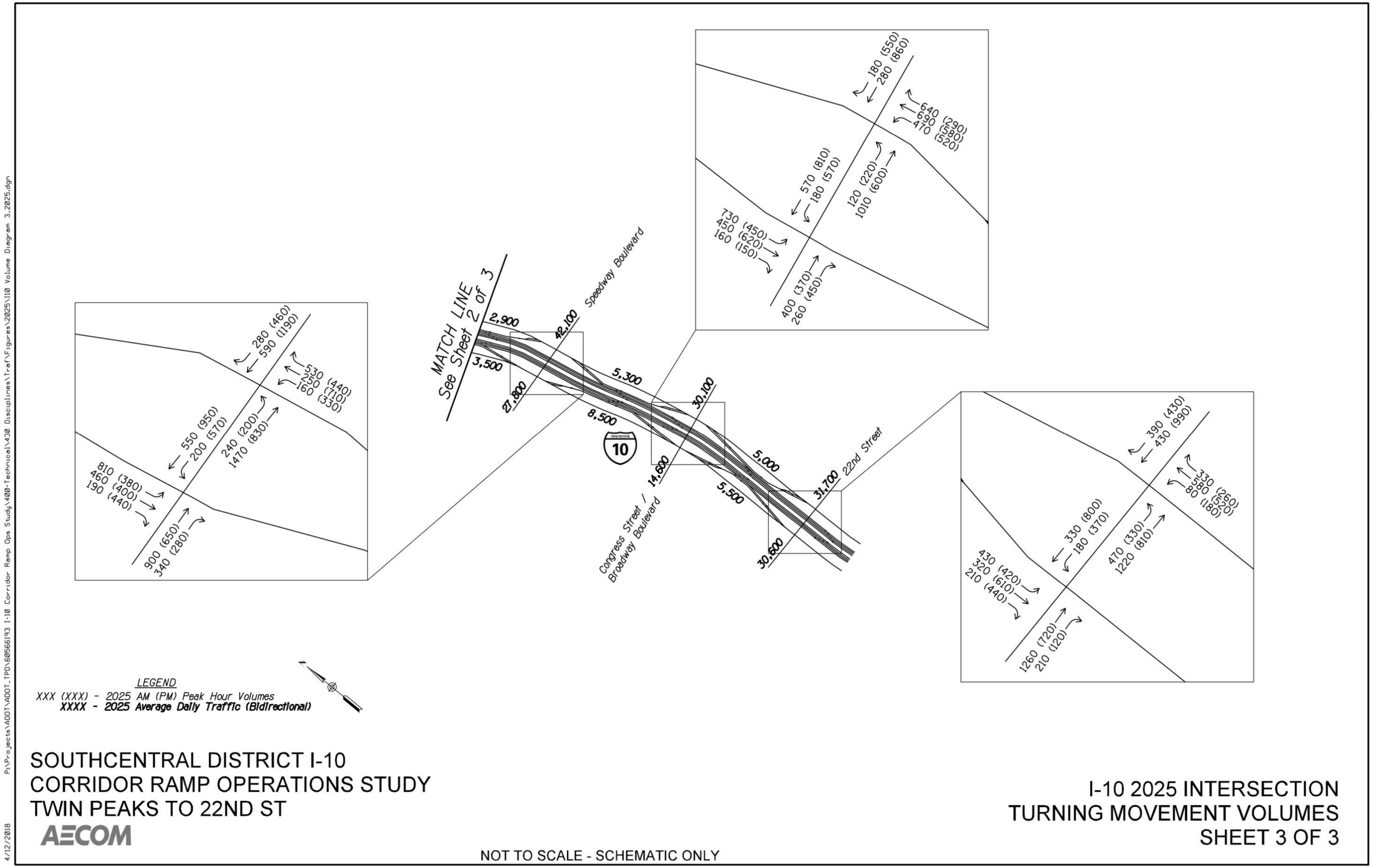
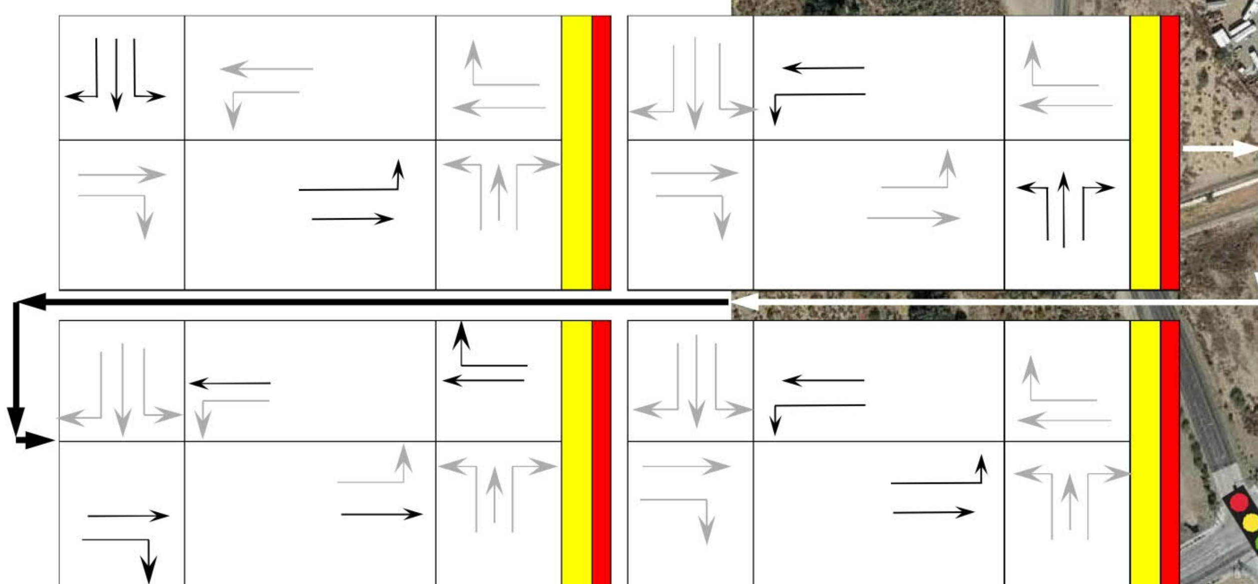


Figure 7: Existing Signal Phasing

LOCATION: Twin Peaks Rd & I-10				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1	EB	15	35	0
2	WB LT PROT	7	30	0
3	SB	7	25	0
4	NB	7	30	0
5	WB	15	35	0
6	EB LT PROT	7	30	0
7				
8				

PHASING DIAGRAM



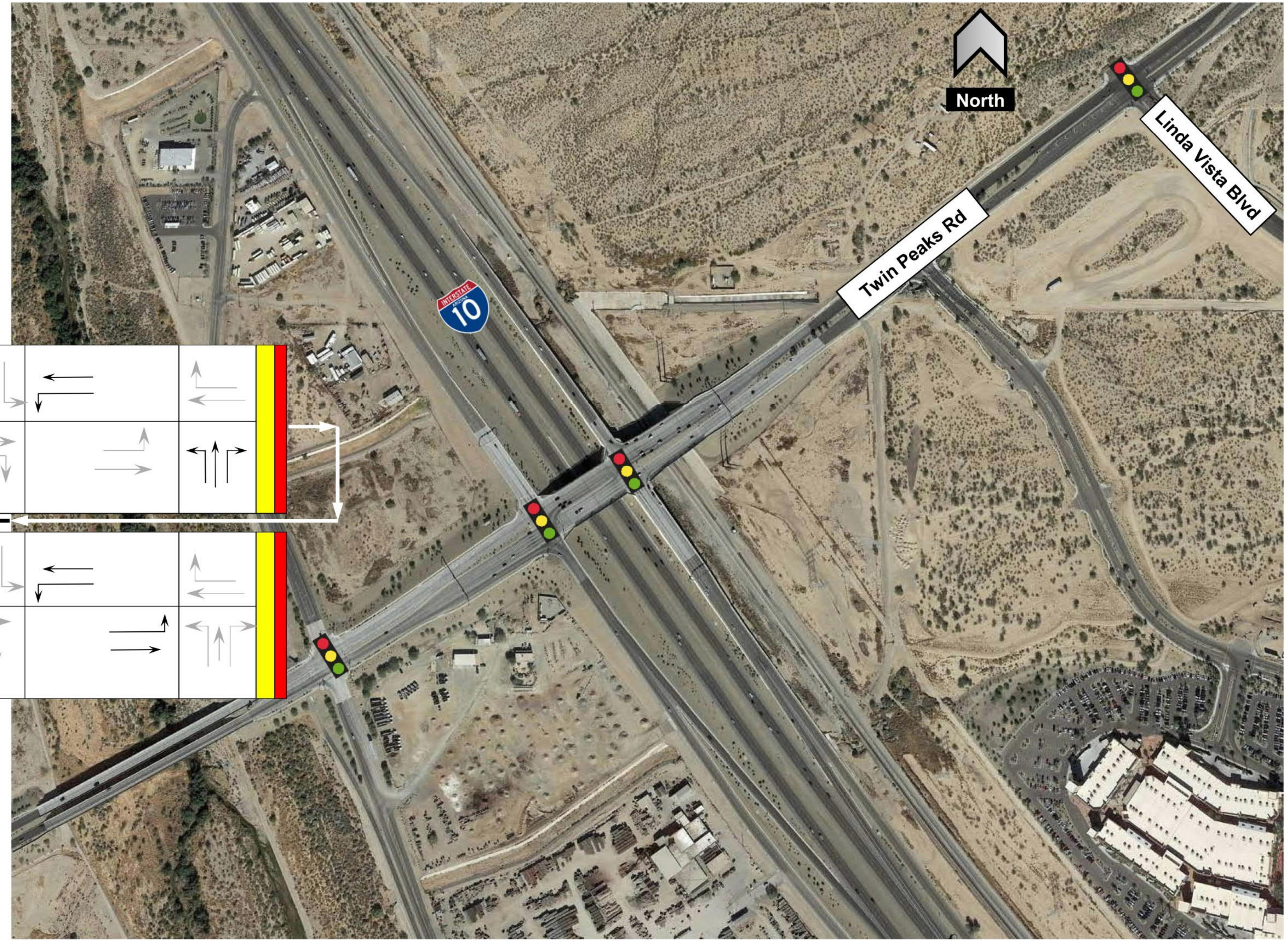


Figure 7: Existing Signal Phasing - continued

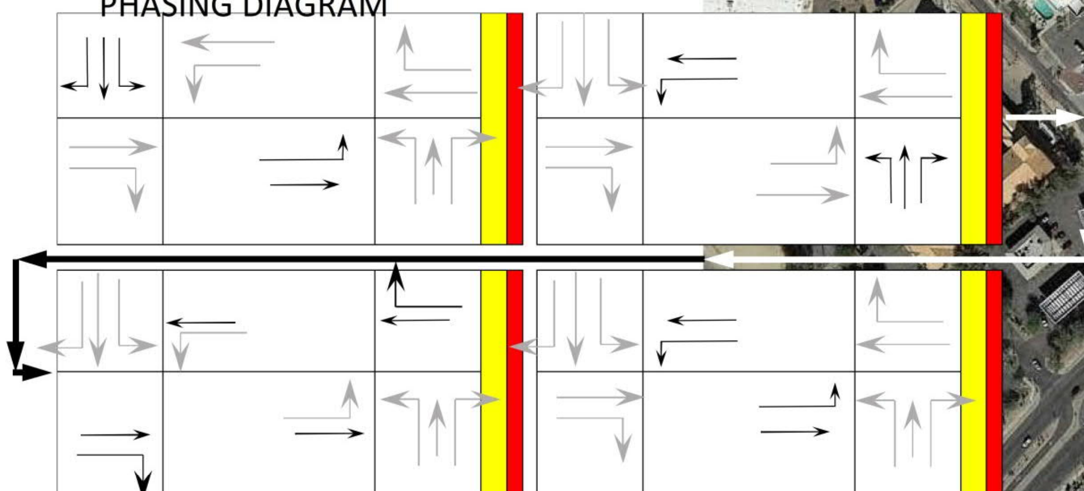
LOCATION: Cortaro Rd & I-10

VIDEO: ✓

LOOPS:

PHASE	Movement	Min Green	Max 1	Max 2
1				
2	WB	20	40	55
3	NB	8	60	60
4	SB/E LT	10	30	0
5	EB	10	30	0
6	WB LT	8	15	0
7				
8				

PHASING DIAGRAM



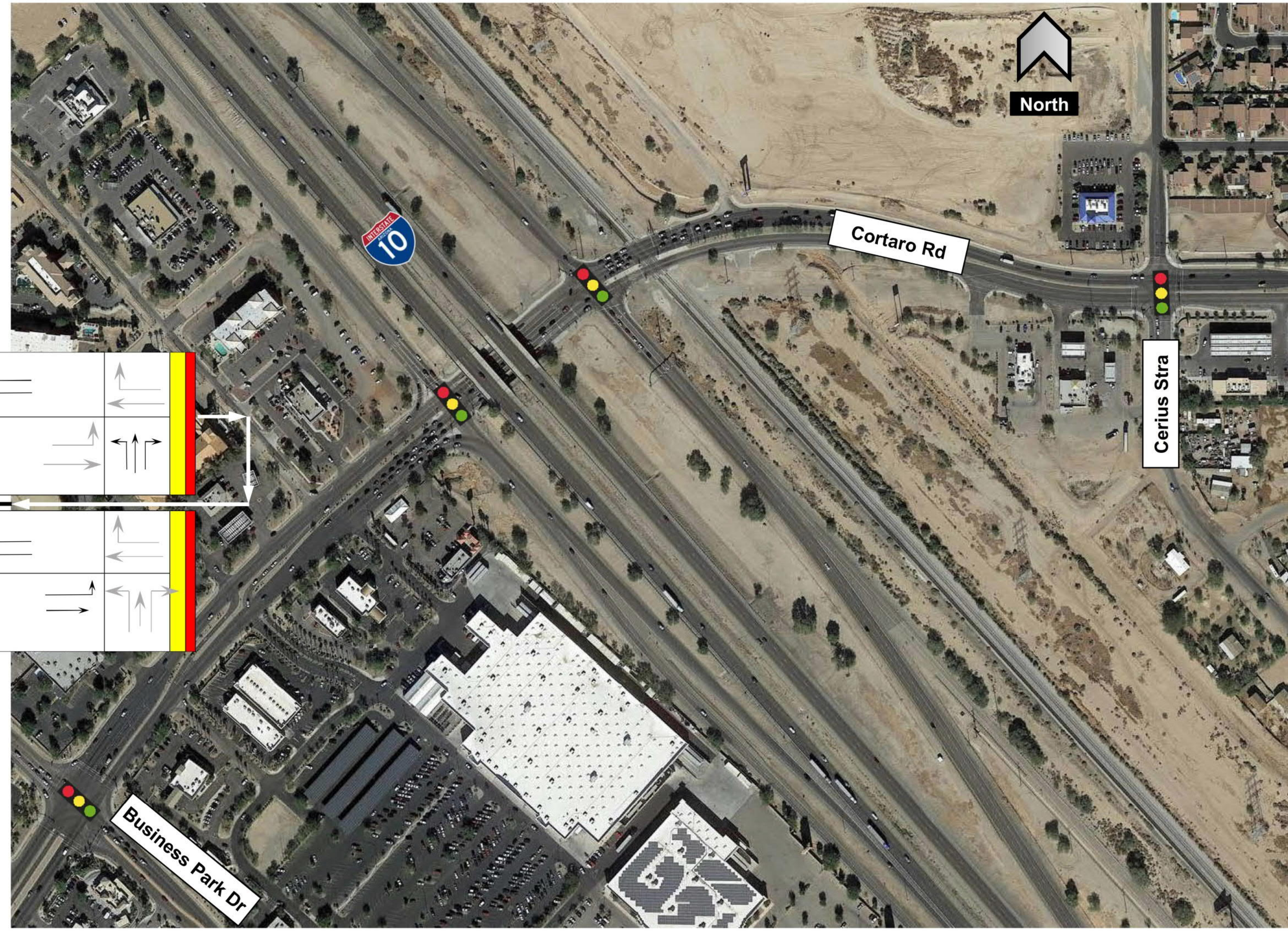


Figure 7: Existing Signal Phasing - continued

LOCATION: Orange Grove Rd & I-10

VIDEO:
LOOPS: ✓

PHASE	Movement	Min Green	Max 1	Max 2
1	EB	5	35	0
2	SB	25	60	0
3				
4	WB LT	25	45	60
5				
6	EB LT	15	10	0
7	WB	25	45	65
8	NB	6	20	0

PHASING DIAGRAM

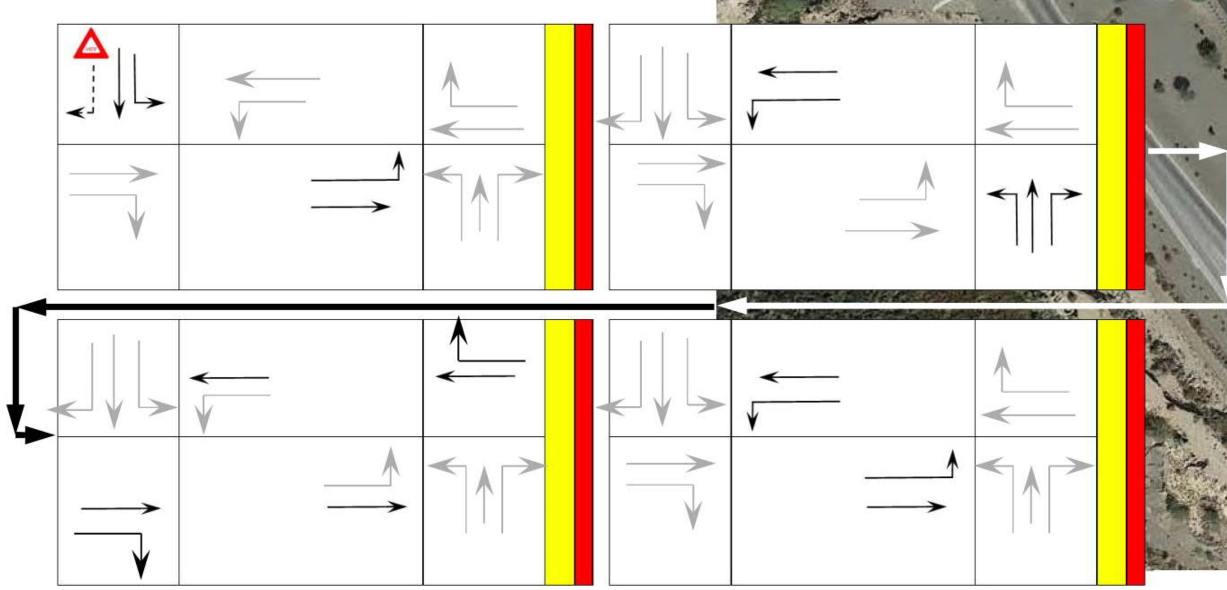
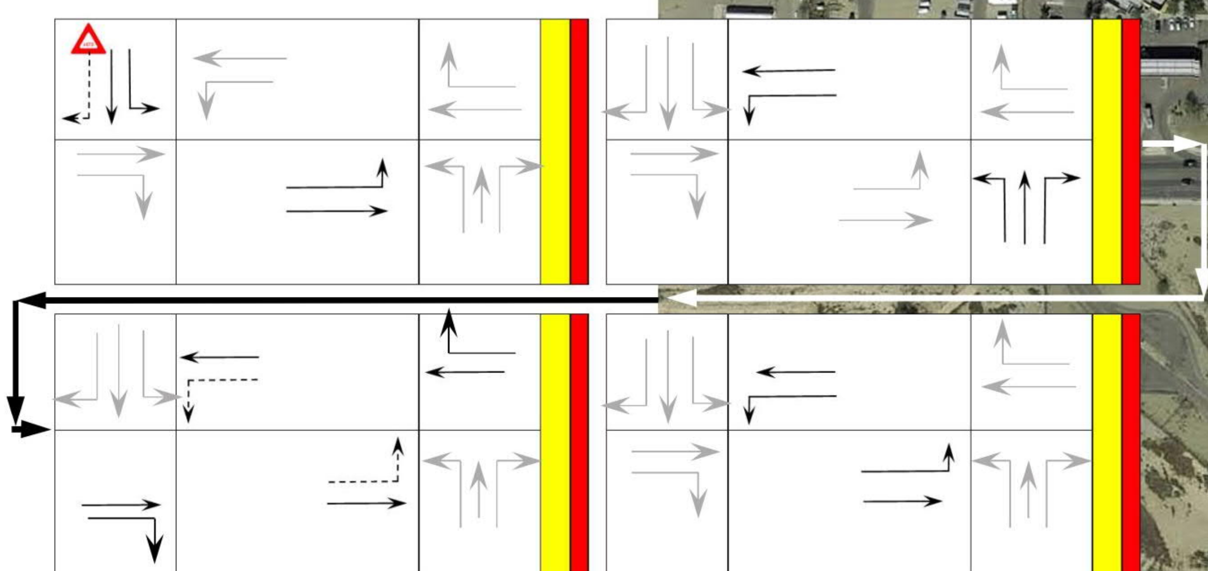


Figure 7: Existing Signal Phasing - continued

LOCATION: Ruthrauff Rd & I-10 West				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1	WB L	5	25	35
2	EB	15	60	60
3				
4	SB	10	45	60
5				
6	WB	15	60	60
7				
8				

LOCATION: Ruthrauff Rd & I-10 East				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1				
2	EB	15	60	60
3				
4				
5	EB LT	2	25	35
6	WB	15	60	60
7				
8	NB	10	45	60

PHASING DIAGRAM



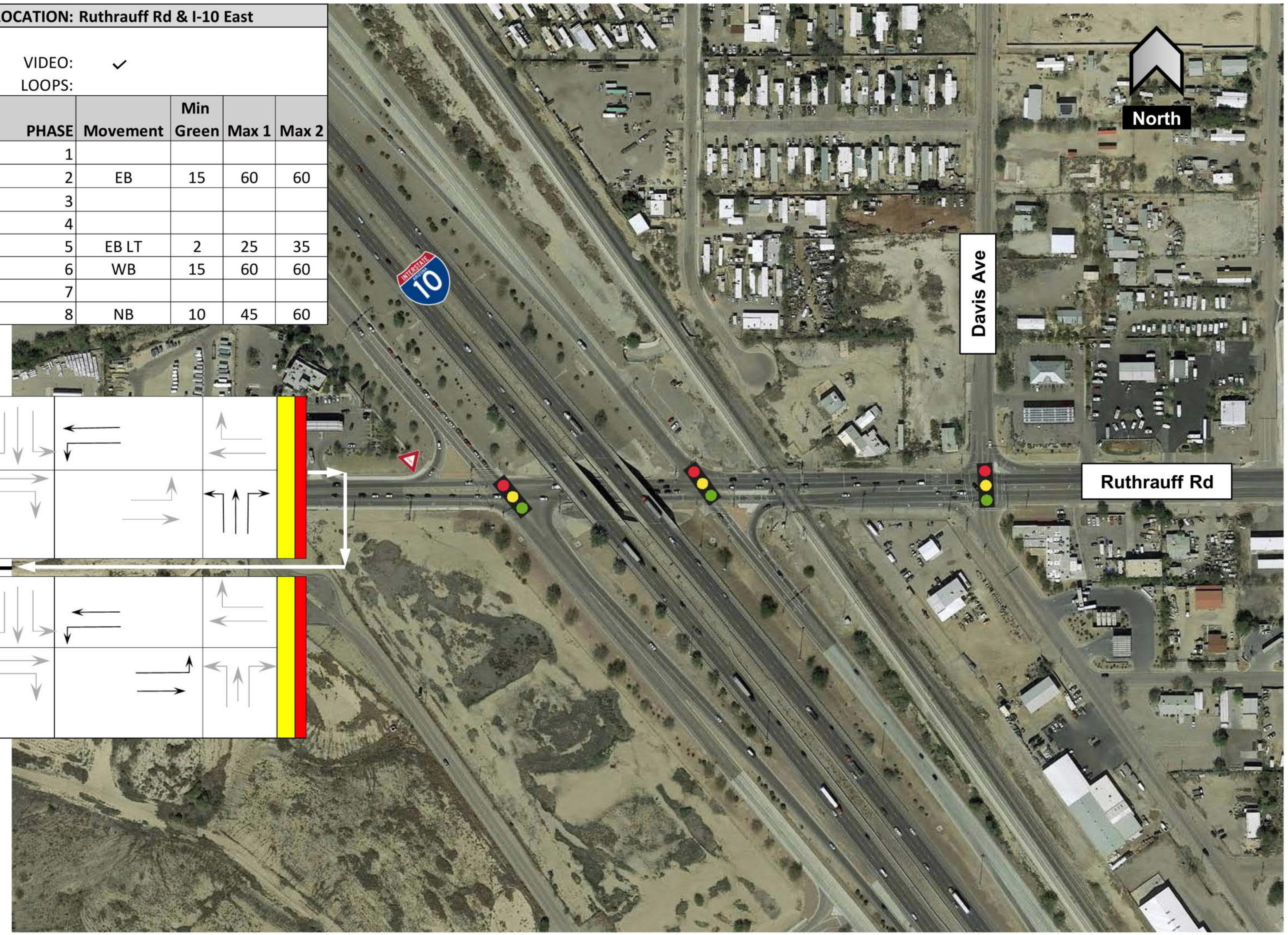


Figure 7: Existing Signal Phasing - continued

LOCATION: Prince Rd & I-10 West

VIDEO: ✓
LOOPS:

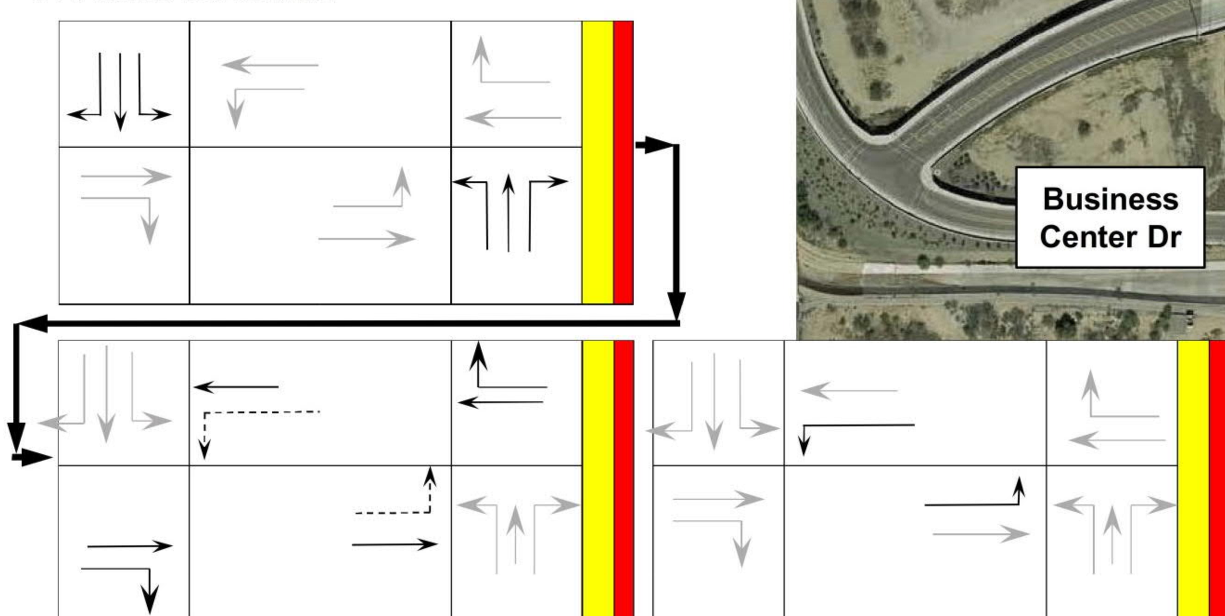
PHASE	Movement	Min Green	Max 1	Max 2
1	WB L	5	25	35
2	EB	15	60	60
3				
4	SB	10	45	60
5				
6	WB	15	60	60
7				
8				

LOCATION: Prince Rd & I-10 East

VIDEO: ✓
LOOPS:

PHASE	Movement	Min Green	Max 1	Max 2
1				
2	EB	15	60	60
3				
4				
5	EB LT	2	25	35
6	WB	15	60	60
7				
8	NB	10	45	60

PHASING DIAGRAM



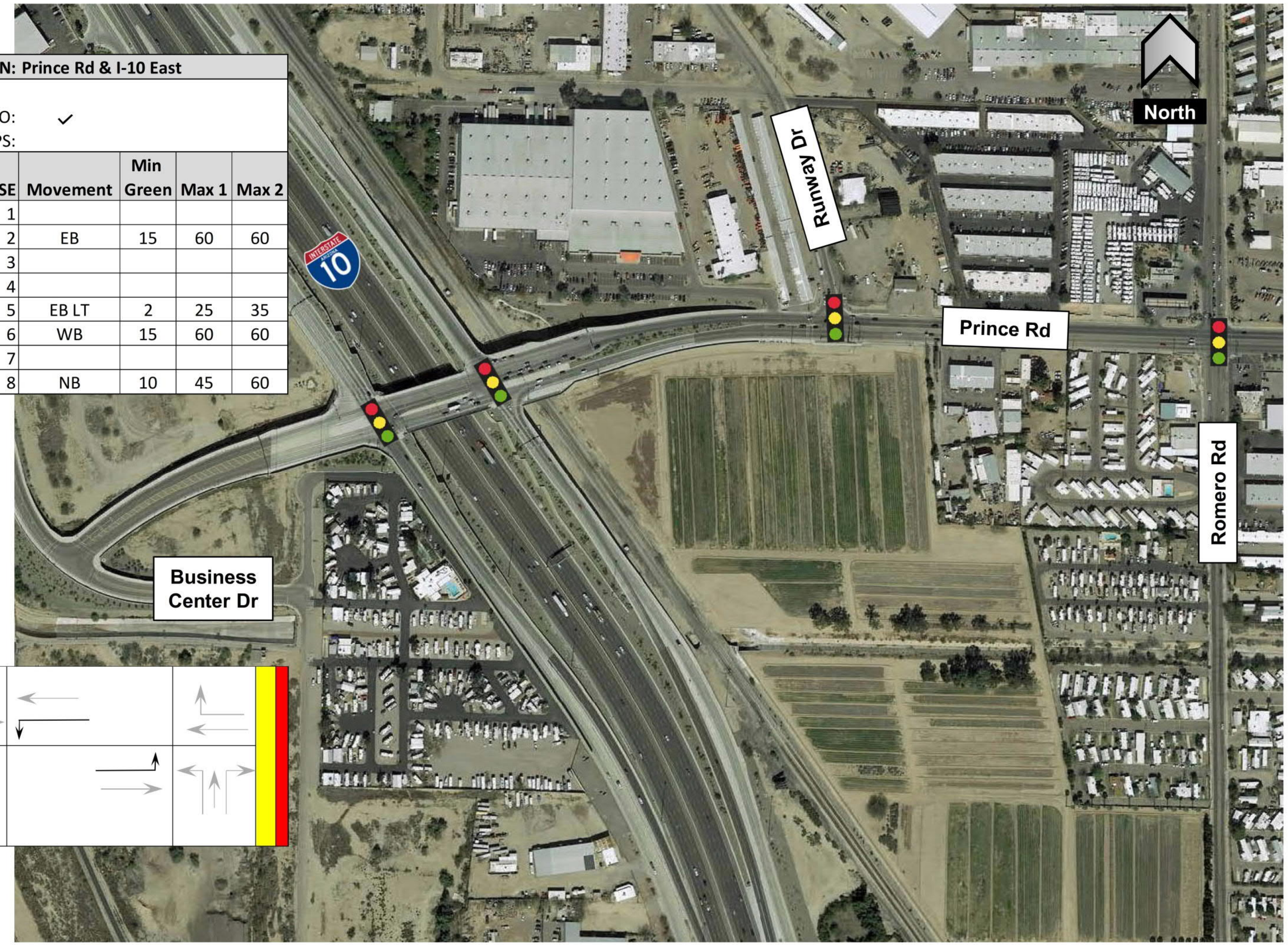


Figure 7: Existing Signal Phasing - continued

LOCATION: Miracle Mile & I-10				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1				
2	EB	15	60	
3				
4	SB	10	45	
5	EB L	2	25	
6	WB	15	60	
7				
8	NB	10	45	

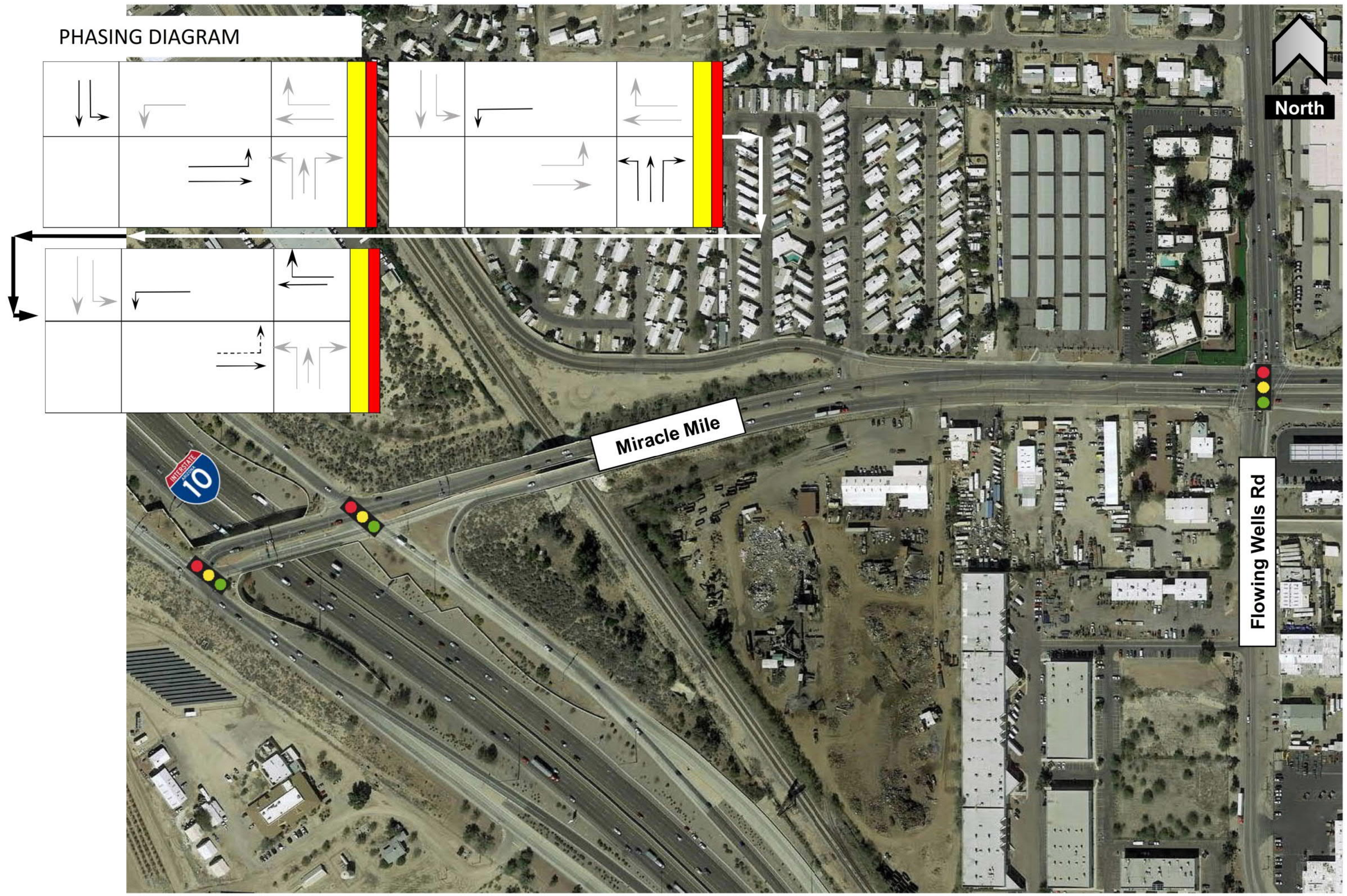


Figure 7: Existing Signal Phasing - continued

LOCATION: Grant Road & I-10				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1	WB L	2	25	0
2	EB	15	60	0
3				
4	SB	10	45	0
5	EB L	2	25	0
6	WB	15	60	0
7				
8	NB	10	45	0

PHASING DIAGRAM

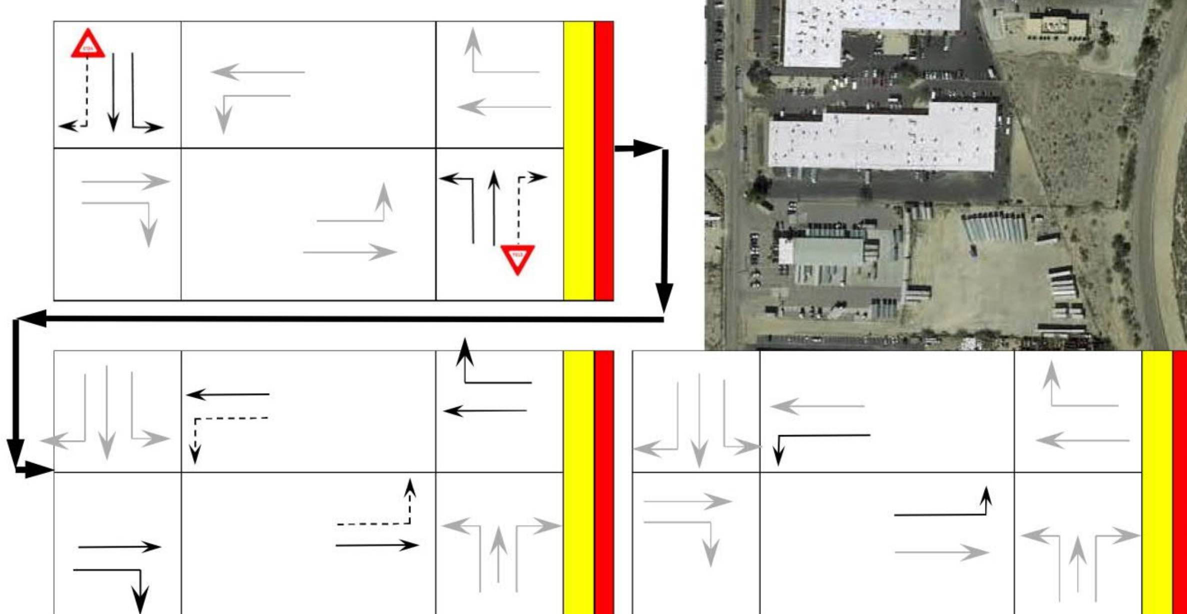


Figure 7: Existing Signal Phasing - continued

LOCATION: Speedway Boulevard & I-10				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1	WB L	2	25	0
2	EB	15	60	0
3				
4	SB	10	45	0
5	EB L	2	25	0
6	WB	15	60	0
7				
8	NB	10	45	0

PHASING DIAGRAM

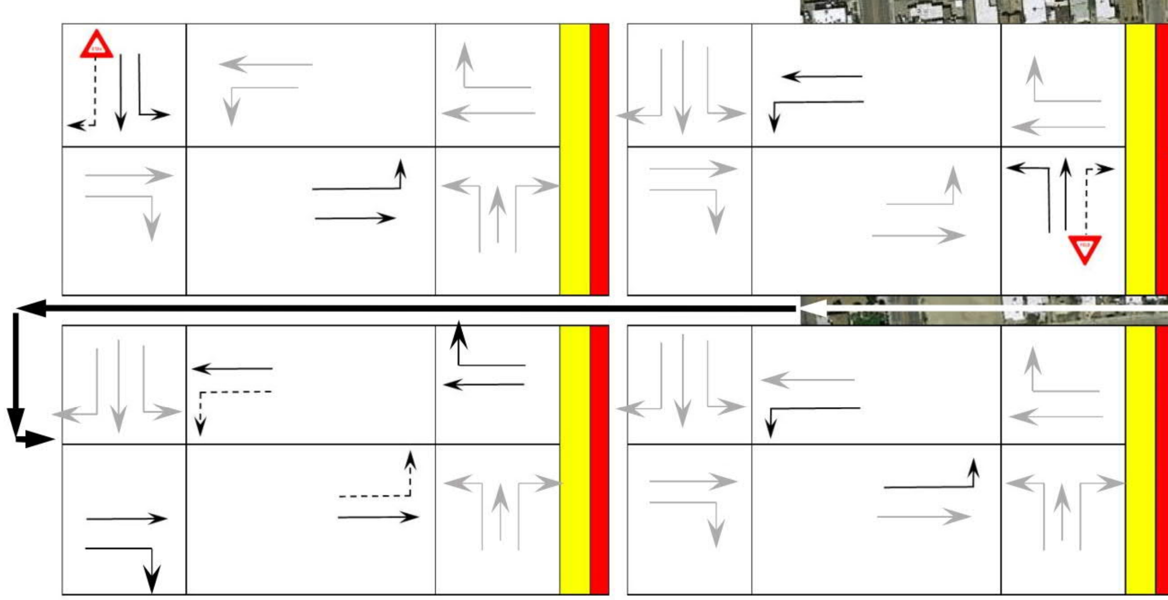


Figure 7: Existing Signal Phasing - continued

LOCATION: Congress Street & I-10				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1	WB L	2	25	0
2	EB	15	60	0
3				
4	SB	10	45	0
5	EB L	2	25	0
6	WB	15	60	0
7				
8	NB	10	45	0

PHASING DIAGRAM

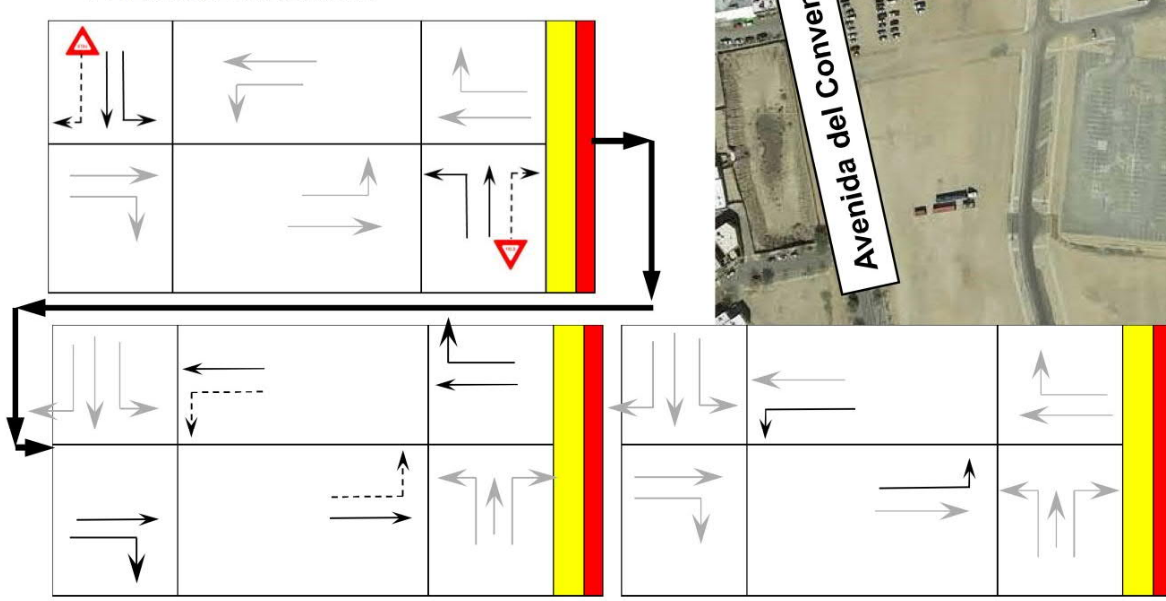
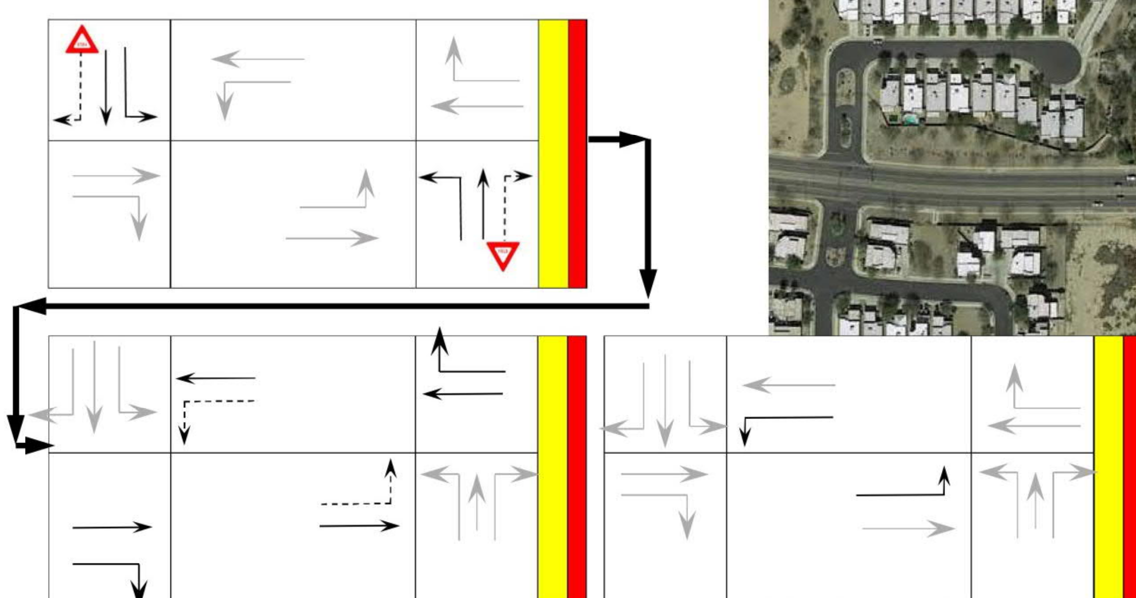


Figure 7: Existing Signal Phasing – continued

LOCATION: 22nd Street & I-10 West				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1	WB L	2	25	0
2	EB	15	60	0
3				
4	SB	10	45	0
5				
6	WB	15	60	0
7				
8				

LOCATION: 22nd Street & I-10 East				
VIDEO: ✓				
LOOPS:				
PHASE	Movement	Min Green	Max 1	Max 2
1				
2	EB	15	60	0
3				
4				
5	EB L	2	25	0
6	WB	15	60	0
7				
8	NB	10	45	0

PHASING DIAGRAM



3.0 ANALYSIS OF EXISTING AND FUTURE CONDITIONS

3.1 Crash Analysis

Records of traffic crashes in the study area along I-10 were assembled from ADOT's Accident Location Identification Surveillance System (ALISS) database. Crashes were reviewed for the 5-year period from November 2012 through November 2017.

In order to assess the crash trends related to ramp metering, the I-10 mainline was broken into segments and classified as either "weaving" or "non-weaving". The weaving segments include areas between an entrance ramp and the downstream exit ramp where vehicles entering and exiting the freeway would be conducting weaving maneuvers. A majority of these locations within the study area contain auxiliary lanes connecting the entrance ramp to the downstream exit ramp. The non-weaving segments include areas between an exit ramp and the downstream entrance ramp where weaving maneuvers would be minimal.

Table 6 shows the severity of mainline crashes between the weaving and non-weaving areas and **Table 7** shows the manner of collision between weaving and non-weaving areas.

Table 6: Mainline Crash Severity by Location

Location	No Injury	Possible Injury	Suspected Minor Injury	Suspected Serious Injury	Fatal	Total
Eastbound Non-weaving	371	36	43	7	1	458
(Approx. 39,000 ft)	81.0%	7.9%	9.4%	1.5%	0.2%	
Eastbound Weaving	503	43	51	7	7	611
(Approx. 31,000 ft)	82.3%	7.0%	8.3%	1.1%	1.1%	
Westbound Non-weaving	382	50	29	8	2	471
(Approx. 47,000 ft)	81.1%	10.6%	6.2%	1.7%	0.4%	
Westbound Weaving	505	61	58	6	3	633
(Approx. 26,000 ft)	79.8%	9.6%	9.2%	0.9%	0.5%	

Table 7: Mainline Manner of Collision by Location

Location	Angle	Rear End	Sideswipe Same Direction	Single Vehicle	Other/ Unknown	Total
Eastbound Non-weaving	9	192	98	118	41	458
(Approx. 39,000 ft)	2.0%	41.9%	21.4%	25.8%	9.0%	
Eastbound Weaving	8	202	134	221	46	611
(Approx. 31,000 ft)	1.3%	33.1%	21.9%	36.2%	7.5%	
Westbound Non-weaving	5	185	114	142	25	471
(Approx. 47,000 ft)	1.1%	39.3%	24.2%	30.1%	5.3%	
Westbound Weaving	17	236	149	195	36	633
(Approx. 26,000 ft)	2.7%	37.3%	23.5%	30.8%	5.7%	

As shown in Tables 6 and 7, there were a total of 1,069 crashes in the eastbound direction and 1,104 in the westbound direction. The following observations were made related to this data:

- There is no significant difference in crash frequency between eastbound and westbound
- More crashes occur in the weaving areas than in the non-weaving areas
- Rear-end crashes were a greater percentage of the total crashes in the non-weaving areas than in the weaving areas

Additional information related to the crash frequencies along the mainline is contained in **Appendix A**.

In order to assess the crash trends near the frontage road/exit ramp junction, crash records were reviewed for the segment of each frontage road from the crossroad to an upstream point 500' beyond the gore at the exit ramp/frontage road junction. The crashes in these areas would be influenced by the weaving between the exit ramp traffic and the frontage road traffic, and the stop/yield control at the exit ramp/frontage road junction. **Table 8** through **Table 11** show the severity of crashes and manner of collision for these locations along the eastbound and westbound frontage roads.

Table 8: Eastbound Frontage Road Crash Severity by Location

Eastbound Frontage Road, Approaching:	No Injury	Possible Injury	Suspected Minor Injury	Suspected Serious Injury	Fatal	Total
Twin Peaks Rd	0	0	0	0	0	0
Cortaro Rd	5	0	0	0	0	5
Ina Rd	10	4	2	0	0	16
Orange Grove Rd	14	3	0	0	0	17
Sunset Rd	0	0	0	0	1	1
Ruthrauff Rd	4	3	0	0	0	7
Prince Rd	14	3	0	1	0	18
Miracle Mile Rd	3	1	0	0	0	4
Grant Rd	9	3	0	0	0	12
Speedway Blvd	4	2	0	0	0	6
Congress St	5	2	0	0	0	7
22nd St	7	2	1	1	0	11
Total	75	23	3	2	1	104

Note: Approach length varies and is measured from the nearest side of the cross street to 500 feet upstream of the physical gore of the exit ramp.

Table 9: Eastbound Frontage Road Manner of Collison by Location

Eastbound Frontage Road, Approaching:	Rear-End	Left-Turn	Sideswipe Same Direction	Single Vehicle	Angle	Other	Total
Twin Peaks Rd	0	0	0	0	0	0	0
Cortaro Rd	4	0	0	1	0	0	5
Ina Rd	14	0	1	1	0	0	16
Orange Grove Rd	13	0	2	1	0	1	17
Sunset Rd	0	0	0	0	0	1	1
Ruthrauff Rd	7	0	0	0	0	0	7
Prince Rd	2	13	1	1	1	0	18
Miracle Mile Rd	2	0	1	1	0	0	4
Grant Rd	9	0	0	1	2	0	12
Speedway Blvd	3	0	2	0	0	1	6
Congress St	6	0	0	1	0	0	7
22nd St	7	0	2	2	0	0	11
Total	67	13	9	9	3	1	104

Note: Approach length varies and is measured from the nearest side of the cross street to 500 feet upstream of the physical gore of the exit ramp.

Table 10: Westbound Frontage Road Crash Severity by Location

Westbound Frontage Road, Approaching:	No Injury	Possible Injury	Suspected Minor Injury	Suspected Serious Injury	Fatal	Total
Twin Peaks Rd	1	0	0	0	0	1
Cortaro Rd	12	2	2	1	0	17
Ina Rd	9	2	0	0	0	11
Orange Grove Rd	17	0	0	1	1	19
Sunset Rd	0	0	1	0	0	1
Ruthrauff Rd	10	2	2	0	0	14
Prince Rd	4	1	0	0	0	5
Miracle Mile Rd	16	3	0	1	0	20
Grant Rd	5	2	0	0	0	7
Speedway Blvd	8	4	0	0	0	12
Congress St	0	0	0	0	0	0
22nd St	0	0	0	0	0	0
Total	82	16	5	3	1	107

Note: Approach length varies and is measured from the nearest side of the cross street to 500 feet upstream of the physical gore of the exit ramp.

Table 11: Westbound Frontage Road Manner of Collison by Location

Westbound Frontage Road, Approaching:	Rear-End	Left-Turn	Sideswipe Same Direction	Single Vehicle	Angle	Other	Total
Twin Peaks Rd	0	0	0	1	0	0	1
Cortaro Rd	10	0	4	2	1	0	17
Ina Rd	8	0	1	2	0	0	11
Orange Grove Rd	16	0	2	1	0	0	19
Sunset Rd	0	0	0	0	1	0	1
Ruthrauff Rd	10	0	2	2	0	0	14
Prince Rd	2	0	2	0	1	0	5
Miracle Mile Rd	10	0	0	10	0	0	20
Grant Rd	6	0	0	1	0	0	7
Speedway Blvd	10	0	2	0	0	0	12
Congress St	0	0	0	0	0	0	0
22nd St	0	0	0	0	0	0	0
Total	72	0	13	19	3	0	107

Note: Approach length varies and is measured from the nearest side of the cross street to 500 feet upstream of the physical gore of the exit ramp.

As shown in **Table 8** through **Table 11**, there were a total of 211 crashes along both frontage roads in the vicinity of the exit ramp/frontage road junction. The following observations were made related to this data:

- There is no significant difference in crash frequency between eastbound and westbound
- A majority of the crashes were rear-end crashes (66%)
- On the westbound frontage road, the highest crash frequency occurs approaching the Miracle Mile, Orange Grove, and Cortaro TI's
- On the eastbound frontage road, the highest crash frequency occurs approaching the Prince, Orange Grove, and Ina TI's

3.2 Traffic Operational Analysis

3.2.1 Analysis Methodology

An operational analysis was performed for the mainline including the general-purpose lanes, ramp junctions, and weave sections for the existing conditions and future No-Build conditions. The VISSIM computer program was used to provide a simulation of the entire system within the study area. VISSIM is a microscopic traffic simulation program that uses roadway geometry and traffic volume inputs to simulate operations of an entire freeway or arterial network. VISSIM has the ability to provide various measures of effectiveness for each link within the system. The vehicle density and speed outputs from VISSIM were used as the measure of effectiveness to relate to a level-of-service as established by the Highway Capacity Manual (HCM) for the freeway and ramp facilities.

The concept of level-of-service (LOS) uses qualitative measures that characterize operational conditions within a stream of traffic. The descriptions of individual levels-of-service characterize these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience. Six levels of service are defined for each type of facility for which the analytical procedures are available. They are given letter designations from ‘A’ to ‘F’, with each condition describing a gradually worsening level of congestion, as described below:

- **LOS A:** Best, free flow operations (on uninterrupted flow facilities) and very low delay (on interrupted flow facilities). Freedom to select desired speeds and to maneuver within traffic is extremely high.
- **LOS B:** Flow is stable, but presence of other users is noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within traffic.
- **LOS C:** Flow is stable, but the operation of users is becoming affected by the presence of other users. Maneuvering within traffic requires substantial vigilance on the part of the user.
- **LOS D:** High density but stable flow. Speed and freedom to maneuver are severely restricted. The driver is experiencing a generally poor level of comfort and convenience.
- **LOS E:** Flow is at or near capacity. All speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within traffic is extremely difficult. Comfort and convenience levels are extremely poor.
- **LOS F:** Worst, facility has failed, or a breakdown has occurred.

Table 12 describes levels-of-service and corresponding vehicle densities (vehicles per mile per lane) for freeway and ramp facilities or vehicle delays (seconds) for intersections as established in the HCM.

Table 12: Vehicle Levels-of-Service and Corresponding Measures of Effectiveness

Level-of-Service	Density Range (pc/mi/ln)	Signal Control Delay (sec)
A	0-11	0-10
B	>11-18	>10-20
C	>18-26	>20-35
D	>26-35	>35-55
E	>35-45	>55-80
F	>45	>80

Source: *Highway Capacity Manual* (2010)

The following VISSIM model input assumptions were used for the operational analysis:

- Free flow speed of 65 mph for the mainline general-purpose lanes
- Commercial vehicle percentage was assumed to be 2% during the peak hours

In order to replicate the existing peak hour travel conditions, the AM and PM peak hour VISSIM models were calibrated based on measured field data. Travel time measurements were performed during both AM and PM peak hours in March, 2018. The field travel time measurements were conducted along the eastbound and westbound directions of travel on I-10 (mainline and frontage roads) from the Twin Peaks Road TI to the I-19 TI. The travel time measurements were recorded and averaged over multiple trips. Existing field measured traffic volumes, speeds, and travel times were utilized as calibration data. Following the calibration process, the VISSIM model output closely replicated the existing congestion conditions observed in the study area. The lane changing and driver behavior parameters from the calibration process were then used in the future condition VISSIM models. The models were run ten times with varying random number seeds and the model output was averaged to determine the density and delay.

3.2.2 Operational Analysis Results

Existing Conditions

The 2016 peak hour traffic volumes, lane configurations, and LOS results are shown in **Appendix B**. The LOS results are shown in **Table 13** for eastbound I-10 and **Table 14** for westbound I-10.

During the 2016 AM peak hour, all sections of the westbound I-10 mainline and all ramps operate at level-of-service (LOS) ‘C’ or better except for:

- Westbound exit ramp at Congress Street which operates at LOS ’F’

During the 2016 AM peak hour, a majority of the eastbound I-10 mainline operates at LOS ‘C’ or ‘D’ with the exception of:

- Eastbound mainline between Orange Grove Road and Sunset Road which operates at LOS ‘F’

During the 2016 PM peak hour, all sections of the eastbound I-10 mainline and all ramps operate at level-of-service (LOS) ‘C’ or better except for:

- Eastbound entrance ramp at Prince Road which operates at LOS ’F’

During the 2016 PM peak hour, a majority of the westbound I-10 mainline operates at LOS ‘C’ or ‘D’, except for:

- Westbound mainline between Sunset Road and Orange Grove Road which operates LOS ‘E’
- Westbound exit ramps at Ruthrauff Road and Orange Grove Road which operate at LOS ‘F’

2025 No-Build Conditions

The 2025 No-Build model includes improvements that are already underway or are programmed for construction prior to 2025, including the Ina Road TI, Ruthrauff Road TI, and mainline widening from Ruthrauff Road to Ina Road. The 2025 No-Build peak hour traffic volumes, lane configurations, and LOS results are shown in **Appendix B**. The LOS results are shown in **Table 13** for eastbound I-10 and **Table 14** for westbound I-10.

During the 2025 AM peak hour, all sections of the westbound I-10 mainline and ramps operate at level-of-service (LOS) ‘C’ or better, except for:

- Westbound mainline between Granada Avenue and the southern study limit (near 22nd Street) which operates at LOS ‘D’

During the 2025 AM peak hour, all sections of the eastbound I-10 mainline and ramps operate at LOS ‘C’ or better, except for:

- Eastbound mainline between Cortaro Road entrance ramp and Ina Road which operates at LOS ‘D’
- Eastbound mainline between Prince Road exit ramp and Miracle Mile exit ramp which operates at LOS ‘D’
- Eastbound mainline between Miracle Mile exit ramp and the Grant Road exit ramp which operates at LOS ‘E’

- Eastbound mainline between Grant Road exit ramp and 22nd Street which operates at LOS ‘D’
- Eastbound exit ramp at Orange Grove Road which operates at LOS ‘D’
- Eastbound entrance ramps at Twin Peaks Road, Cortaro Road, and Prince Road which operate at LOS ‘E’ or ‘F’

During the 2025 PM peak hour, all sections of the eastbound I-10 mainline and ramps operate at level-of-service (LOS) ‘C’ or better, except for:

- Eastbound entrance ramp at Prince Road which operates at LOS ‘F’
- Eastbound exit ramp at Congress Street which operates at LOS ’E’

During the 2025 PM peak hour, all sections of the westbound I-10 mainline and ramps operate at LOS ‘C’ or better, except for:

- Westbound mainline between Congress Street exit ramp and 22nd Street which operates at LOS ‘D’
- Westbound mainline between Miracle Mile exit ramp and Congress Street exit ramp which operates at LOS ‘E’ or ‘F’
- Westbound mainline between Prince Road entrance ramp and Miracle Mile exit ramp which operates at LOS ‘D’
- Westbound mainline between Ina Road entrance ramp and Cortaro Road exit ramp which operates at LOS ‘D’
- Westbound exit ramps at Orange Grove Road and Speedway Boulevard which operate at LOS ‘D’
- Westbound entrance ramp at Grant Road which operates at LOS ‘F’

In both the 2025 AM and PM peak hours, additional congestion in the westbound direction at the southern end of the corridor results in slight operational improvements downstream (to the northwest) since the additional congestion creates an upstream bottleneck (between Miracle Mile and 22nd Street in the PM, for example) resulting in less vehicles reaching the downstream area.

<u>2032 No-Build Conditions</u>

The 2032 No-Build model includes the same roadway network as the 2025 model. The 2032 No-Build traffic volumes, lane configurations, and LOS results are shown in **Appendix B**. The LOS results are shown in **Table 13** for eastbound I-10 and **Table 14** for westbound I-10.

During the 2032 AM peak hour, all sections of the westbound I-10 mainline and ramps operate at level-of-service (LOS) ‘C’ or better, except for:

- Westbound mainline between Congress Street entrance ramp and 22nd Street which operate at LOS ‘D’
- Westbound exit ramps at Congress Street and Grant Road which operate at LOS ’E’ or ‘F’

During the 2032 AM peak hour, all sections of the eastbound I-10 mainline and ramps operate at LOS ‘C’ or better, except for:

- Eastbound mainline between Twin Peak entrance ramp and Ina Road which operates at LOS ‘D’
- Eastbound mainline between Sunset Road entrance ramp and Ruthrauff Road exit ramp which operates at LOS ‘D’
- Eastbound mainline between Prince Road exit ramp and Prince Road entrance ramp which operates at LOS ‘D’
- Eastbound mainline between Prince Road entrance ramp and the Grant Road entrance ramp which operates at LOS ‘E’ or ‘F’
- Eastbound mainline between Grant Road entrance ramp and 22nd Street which operates at LOS ‘D’
- Eastbound Twin Peaks, Cortaro Road, and Prince Road entrance ramps which operate at LOS ‘E’ or ‘F’

During the 2032 PM peak hour, all sections of the eastbound I-10 mainline and ramps operate at level-of-service (LOS) ‘C’ or better, except for:

- Eastbound mainline from the northern study limit to the Twin Peaks Road exit ramp which operates at LOS ‘D’
- Eastbound mainline from Congress Street entrance ramp to the 22nd Street which operates at LOS ‘D’
- Eastbound entrance ramps at Prince Road and Congress Street which operate at LOS ’E’

During the 2032 PM peak hour, all sections of the westbound I-10 mainline and ramps operate at LOS ‘C’ or better, except for:

- Westbound mainline between Miracle Mile exit ramp and 22nd Street which operates at LOS ‘E’ or ‘F’
- Westbound mainline between Prince Road entrance ramp and Miracle Mile exit ramp which operates at LOS ‘D’
- Westbound mainline between Orange Grove exit ramp and Ruthrauff Road entrance ramp which operates at LOS ‘D’
- Westbound exit at Orange Grove Road which operates at LOS ‘F’
- Westbound mainline between Twin Peaks Road exit ramp and Ina Road entrance ramp which operates at LOS ‘D’
- Westbound Grant Road entrance ramp and Orange Grove exit ramp which operate at LOS ‘F’

Increased traffic volumes in 2032 result in additional congestion along the corridor compared to the 2025 No-Build conditions.

Table 13: Eastbound Existing and No-Build LOS Results

Location	AM Peak Hour			PM Peak Hour		
	Existing	2025 No-Build	2032 No-Build	Existing	2025 No-Build	2032 No-Build
Project Begin to Twin Peaks Off Ramp	B	B	C	B	C	D
Twin Peaks Off Ramp	A	A	B	A	A	B
Twin Peaks Off Ramp to Twin Peak On Ramp	B	B	C	B	B	C
Twin Peak On Ramp	D	E	E	B	B	B
Twin Peak On Ramp to Cortaro Off Ramp	C	C	D	B	C	C
Cortaro Off Ramp	A	A	A	A	A	B
Cortaro Off Ramp to Cortaro On Ramp	C	C	D	B	B	C
Cortaro On Ramp	B	F	F	A	A	A
Cortaro On Ramp to Ina Off Ramp	C	D	D	B	C	C
Ina Off Ramp	A	A	B	A	A	A
Ina Off Ramp to Ina On Ramp	C	D	D	B	B	C
Ina On Ramp	B	B	B	A	A	A
Ina On Ramp to Orange Grove Off Ramp	D	C	C	C	B	B
Orange Grove Off Ramp	B	D	B	A	A	A
Orange Grove Off Ramp to Orange Grove On Ramp	D	C	C	C	B	B
Orange Grove On Ramp	B	A	B	A	A	A
Orange Grove On Ramp to Sunset Off Ramp	F	C	C	C	B	B
Sunset Off Ramp	A	A	A	A	A	A
Sunset Off Ramp to Sunset On Ramp	D	C	C	C	B	B
Sunset On Ramp	A	A	A	A	A	A
Sunset On Ramp to Ruthrauff Off Ramp	D	C	D	C	B	B
Ruthrauff Off Ramp	A	A	A	A	A	A
Ruthrauff Off Ramp to Ruthrauff On Ramp	D	C	C	C	B	B
Ruthrauff On Ramp	C	C	C	B	B	B
Ruthrauff On Ramp to Prince Off Ramp	C	C	C	B	B	B
Prince Off Ramp	A	A	A	A	A	A
Prince Off Ramp to Prince On Ramp	C	D	D	B	B	B
Prince On Ramp	D	E	E	F	F	E
Prince On Ramp to Miracle Mile Off Ramp	D	D	F	C	C	C
Miracle Mile Off Ramp	A	A	A	A	A	A
Miracle Mile Off Ramp to Miracle Mile On Ramp	D	E	F	C	C	C
Miracle Mile On Ramp	B	C	C	B	B	B
Miracle Mile On Ramp to Grant Off Ramp	D	E	E	C	C	C
Grant Off Ramp	B	B	A	A	A	A
Grant Off Ramp to Grant On Ramp	D	D	E	C	C	C
Grant On Ramp	A	A	A	A	A	A
Grant On Ramp to Speedway Off Ramp	D	D	D	C	C	C
Speedway Off Ramp	B	B	A	A	A	A
Speedway Off Ramp to Speedway On Ramp	D	D	D	C	C	C
Speedway On Ramp	A	A	A	A	A	A
Speedway On Ramp to Congress Off Ramp	D	D	D	C	C	C
Congress Off Ramp	A	A	A	C	E	E
Congress Off Ramp to Congress On Ramp	D	D	D	C	C	C
Congress On Ramp	A	A	A	B	B	B
Congress On Ramp to 22nd Off Ramp	C	D	D	C	C	D
22nd Off Ramp	A	A	A	A	A	A
22nd Off Ramp to End Project	C	D	D	C	C	D

Table 14: Westbound Existing and No-Build LOS Results

Location	AM Peak Hour			PM Peak Hour		
	Existing	2025 No-Build	2032 No-Build	Existing	2025 No-Build	2032 No-Build
Project Begin to 22nd On Ramp	C	D	D	D	D	E
22nd On Ramp	A	B	A	A	A	A
22nd On Ramp to Congress Off Ramp	C	D	D	D	D	F
Congress Off Ramp	F	C	E	A	A	A
Congress Off Ramp to Congress On Ramp	C	C	D	D	E	F
Congress On Ramp	A	A	A	A	A	A
Congress On Ramp to Speedway Off Ramp	C	C	C	D	E	F
Speedway Off Ramp	A	A	A	A	D	A
Speedway Off Ramp to Speedway On Ramp	C	C	C	D	F	F
Speedway On Ramp	A	A	A	A	B	B
Speedway On Ramp to Grant Off Ramp	C	C	C	D	F	F
Grant Off Ramp	A	C	F	A	B	B
Grant Off Ramp to Grant On Ramp	C	C	C	D	E	E
Grant On Ramp	A	A	B	A	F	F
Grant On Ramp to Miracle Mile Off Ramp	B	C	C	D	F	F
Miracle Mile Off Ramp	A	A	A	B	B	B
Miracle Mile Off Ramp to Miracle Mile On Ramp	B	C	C	C	D	D
Miracle Mile On Ramp	A	A	A	A	A	A
Miracle Mile On Ramp to Prince Off Ramp	B	B	C	C	D	D
Prince Off Ramp	A	C	C	A	A	A
Prince Off Ramp to Prince On Ramp	B	B	C	C	D	D
Prince On Ramp	A	A	A	A	A	A
Prince On Ramp to Ruthrauff Off Ramp	B	B	B	D	C	C
Ruthrauff Off Ramp	B	B	B	F	C	C
Ruthrauff Off Ramp to Ruthrauff On Ramp	B	B	B	D	C	C
Ruthrauff On Ramp	A	A	A	A	A	B
Ruthrauff On Ramp to Sunset Off Ramp	B	B	B	D	C	D
Sunset Off Ramp	A	A	A	A	A	A
Sunset Off Ramp to Sunset On Ramp	B	B	B	D	C	D
Sunset On Ramp	A	A	A	A	A	A
Sunset On Ramp to Orange Grove Off Ramp	B	A	B	E	C	D
Orange Grove Off Ramp	B	B	B	F	D	E
Orange Grove Off Ramp to Orange Grove On Ramp	B	A	B	C	C	C
Orange Grove On Ramp	A	A	A	B	C	C
Orange Grove On Ramp to Ina Off Ramp	B	A	B	C	C	C
Ina Off Ramp	A	A	A	B	A	A
Ina Off Ramp to Ina On Ramp	B	A	B	C	C	C
Ina On Ramp	A	A	A	B	B	B
Ina On Ramp to Cortaro Off Ramp	B	B	B	C	D	D
Cortaro Off Ramp	A	A	A	A	A	A
Cortaro Off Ramp to Cortaro On Ramp	B	B	B	C	C	D
Cortaro On Ramp	A	A	A	A	A	A
Cortaro On Ramp to Twin Peaks Off Ramp	B	B	B	C	C	D
Twin Peaks Off Ramp	A	A	A	B	B	B
Twin Peaks Off Ramp to Twin Peaks On Ramp	A	A	B	B	C	C
Twin Peaks On Ramp	A	B	B	A	A	B
Twin Peaks On Ramp to End Project	A	A	B	A	C	C

4.0 RAMP METER STRATEGIES

Ramp metering is the deployment of traffic signals on a ramp to control the rate at which vehicles enter a freeway facility. The overall goal of ramp metering is to reduce freeway congestion and/or freeway crashes by reducing the vehicle platooning/flow at entrance ramps. Overall challenges for the implementation of ramp metering include:

- Geometry of Existing Infrastructure - Not all ramps will have adequate acceleration length, some ramps may be too closely spaced
- Costs and Funding - Costs for deploying and maintaining ramp metering systems
- Public Opposition – Can be rooted in misconceptions about ramp metering and effectiveness
- Heavy Ramp Volume – Long ramp meter queues could spill onto arterials resulting in inefficient arterial operations
- Local Agency Opposition – Can be concerned that the ramp metering strategies will negatively impact traffic operations in local jurisdictions

Ramp metering has been implemented at numerous locations within the United States including California, Minnesota, Texas, Florida, Oregon, Washington, Wisconsin, and Illinois. Within the Phoenix metro area, ADOT has ramp meters installed on over 200 entrance ramps. **Table 15** shows benefits associated with the deployment of ramp meters.

Table 15: Ramp Meter Benefits

Location	Safety Benefits	Travel Time & Speed Benefits
Denver, CO	50% reduction in rear-end and side swipe crashes	Average vehicle speed increased from 43 mph to 50 mph
Portland, OR	43% reduction in crashes in peak period	Average vehicle speed increased from 16 mph to 41 mph
Minneapolis, MN	26% reduction in crashes in peak period	Average vehicle speed increased from 40 mph to 43 mph
Seattle, WA	34% reduction in crash rate	Average travel time reduced from 22 minutes to 11.5 minutes

Source: FHWA Ramp Management and Control Handbook, 2006

There are three primary ramp metering strategies: local fixed time; local traffic responsive; and system-wide traffic responsive. The characteristics of these strategies are shown in **Table 16**. Additional information related to ramp metering is contained in **Appendix C**.

Table 16: Ramp Metering Strategies

Characteristic	Local Pre-Timed/Fixed Time	Local Traffic Responsive	System-Wide Traffic Responsive
Description	• Simplest approach • Runs on fixed cycle lengths and times of day • Does not require traffic detection or communication with TMC	• Adjusts cycle length based on mainline and ramp conditions at specific location • Doesn't account for upstream and downstream conditions at adjacent ramps • Traffic detection is required	• Most complicated approach • Adjusts cycle lengths based on mainline and ramp conditions • Accounts for upstream and downstream conditions at adjacent ramps • Traffic detection is required • Requires communication with TMC or adjacent ramps • Different algorithms are used by agencies
Advantages	• Detection isn't needed • No communication is required • Simple hardware configuration • Breaks up platoon of entering vehicles • Can effectively reduce recurring congestion	• Allows better management of freeway operations, especially for non-recurring congestion • Operating costs can be lower than pre-timed due to automatic rather than manual adjustments	• Can provide metering rates based on real-time conditions along the corridor or within a sub-area • Algorithms can have the ability to address multiple objectives
Disadvantages	• May require frequent observations/monitoring to manually adjust cycle lengths • Often results in overly-restrictive metering rates leading to ramp queuing	• Increased capital and maintenance costs compared to fixed time • Doesn't consider conditions beyond the immediate area	• Requires system of upstream and downstream detection • Requires communication along corridor and/or to TMC • Requires technical expertise to implement and calibrate system
Locations in use			• Seattle, Miami, Minneapolis/St. Paul, Portland, Orange County, Kansas City
ADOT Application	• Used at majority of ramps in Phoenix metro area	• Used at ramps along SR 51	• Algorithm under development

Figure 8 shows the typical configuration of the ramp meter infrastructure. The ramp meters along SR 51 in Phoenix are currently being operated with a local traffic responsive algorithm. The local traffic responsive meters adjust their timing to fit one of six predetermined metering rates based on the speed of the right-most lane. ADOT TSMO is developing a system-wide traffic responsive algorithm that will use detection data from upstream and downstream locations to adjust the meter timing. ADOT TSMO calls this a “corridor-adaptive” strategy. It is envisioned that this system would process the data and run the timing algorithm within the ramp meter cabinet rather than at the Traffic Operations Center. All ADOT ramp meters use an arrangement of detectors consisting of queue detectors, demand detectors, and passage detectors. All ramp meters operating in the fixed time mode are planned to be upgraded in the near future.

Based on discussions with the project team, the local traffic responsive strategy was selected for further evaluation along the I-10 corridor.

4.1 Ramp Meter Warrants

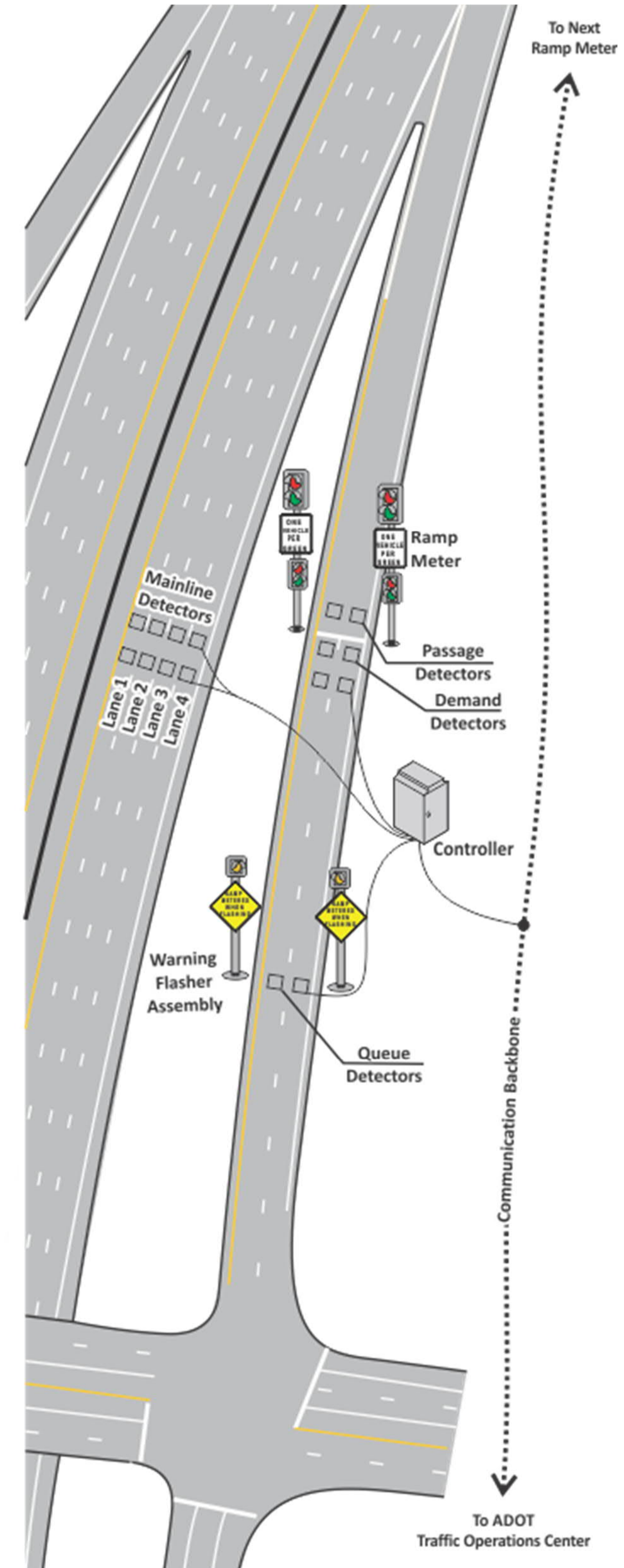
The ADOT *Ramp Metering Design Guide* includes warrants for the installation of ramp meters. The first warrant is based on mainline and ramp traffic volumes while the second warrant is based on mainline speeds. Both warrants must be met to install a ramp meter as follows:

1. Freeway Right-lane and Entrance Ramp Flow Rate: During a typical 15-minute period, the combined flow rate of the entrance ramp and the right-most freeway lane is greater than 2,050 vehicles per hour; and during the same period the entrance ramp flow rate is greater than 400 vehicles per hour.
2. Freeway Speed: During a typical 15-minute period the vehicle speed within the freeway general-purpose lanes (not including HOV, auxiliary, and entrance ramp lanes) is less than 50 mph due to recurring congestion adjacent to or within 2 miles downstream of the entrance ramp.

A warrant analysis was conducted for the 2016 Existing Conditions, 2025 No-Build Conditions, and the 2032 No-Build Conditions. The mainline speeds were taken from the VISSIM model for each year. The results of this analysis are summarized in **Table 17**.

Based on the results shown in Table 17, two of the 23 entrance ramps currently warrant ramp meters, with that number increasing to seven locations in 2025 and eight locations in 2032. While the eastbound Orange Grove entrance currently meets warrants, a future planned project will widen I-10 thus increasing the I-10 travel speeds such that it no longer meets the warrant.

Figure 8: Ramp Meter Configuration



Source: ADOT Ramp Meter Design Guidelines

Table 17: Ramp Meter Warrant Summary

Entrance Ramp	Direction	Warrants Met in 2016	Warrants Met in 2025	Warrants Met in 2032
Twin Peaks Rd	EB	No	No	No
	WB	No	No	No
Cortaro Rd	EB	No	No	No
	WB	No	No	No
Ina Rd	EB	No	No	No
	WB	No	No	No
Orange Grove Rd	EB	**Yes (AM)**	No	No
	WB	No	No	No
Sunset Rd	EB	No	No	No
	WB	No	No	No
Ruthrauff Rd	EB	No	No	No
	WB	No	No	**Yes (PM)**
Prince Rd	EB	No	**Yes (AM)**	**Yes (AM)**
	WB	No	No	No
Miracle Mile	EB	**Yes (AM)**	**Yes (AM)**	**Yes (AM)**
	WB	No	No	No
Grant Rd	EB	No	No	No
	WB	No	**Yes (PM)**	**Yes (PM)**
Speedway Blvd	EB	No	No	No
	WB	No	**Yes (PM)**	**Yes (PM)**
Congress St	EB	No	**Yes (PM)**	**Yes (PM)**
	WB	No	**Yes (PM)**	**Yes (PM)**
22^{nd} St	WB	No	**Yes (AM)**	**Yes (PM)**

4.2 Ramp Meter Queue Analysis

Per the *Ramp Metering Design Guide*, the ramp meter vehicle storage distance is calculated with the following formula:

$$Queue = \left[\frac{\left(Rate_{ramp} - Rate_{meter}\right) \times Time \times \left(L_{car}\left(1 - \frac{T}{100}\right) + L_{trucks}\left(\frac{T}{100}\right)\right)}{Lanes} \right]$$

Where,

- $Queue$: Queue storage distance (ft.)
- $Rate_{ramp}$: Entrance ramp design flow rate (vph).
- $Rate_{meter}$: Design metering rate (vph) (840 vph is the typical design value)
- *Time:* Design period that ramp metering operates at design metering rate (hour) (0.5 hr. is the typical design value)
- *Lanes:* Number of metered lanes
- L_{car}: Average car plus gap length (ft/veh) (28 ft/veh is the typical design value)
- L_{Truck}: Average truck plus gap length (ft/veh) (75 ft/veh is the typical design value)
- T: Percentage of trucks in entrance ramp traffic (percent) (2% trucks may be used as a typical design value)

A ramp meter queue evaluation was conducted for each entrance ramp where the ramp meter met warrants in 2032. A meter rate of 840 vph was used as a default assumption per the ADOT *Ramp Meter Design Guidelines*. The calculations were also refined using higher meter rates (typically 1,200 vph) based on the local traffic responsive algorithm. The results of this analysis are shown in **Table 18**.

Table 18: Calculated Ramp Meter Queue Lengths

Entrance Ramp	Queue Length (feet)		
	ADOT Formula – Default Meter Rate (840 vph)	ADOT Formula - Refined Meter Rate (~1200 vph)	Estimated Currently Available
Prince Rd Eastbound	6,200	1,000	2,000
Miracle Mile Eastbound	5,500	3,800	2,100
Congress Rd Eastbound	4,600	400	2,500
Ruthrauff Rd Westbound	400	400	1,500
Grant Rd Westbound	400	400	1,600
Speedway Blvd Westbound	5,900	4,200	2,200
Congress Rd Westbound	2,600	400	1,800
22^{nd} St Westbound	900	400	2,200

Notes: 1.Queue lengths shown are total storage, regardless of number of lanes.
2. "Refined" meter rate is different for each ramp and is based on local responsive algorithm

4.3 Ramp Meter Alternatives

As discussed in Section 4.0, the local traffic responsive ramp metering strategy was selected for further analysis. Two different Build alternatives were evaluated as follows:

- Alternative 1 – implement local responsive ramp meters (based on warrant analysis) without any roadway improvements. Under this alternative, the ramp metering infrastructure would be installed but no roadway or ramp widening would occur. Therefore, all ramp and mainline lane configurations would remain as-is.
- Alternative 2 – implement local responsive ramp meters (based on warrant analysis) and construct minor roadway improvements on the entrance ramps in locations where ramp meters are installed.

As discussed in Section 2.0, previous Design Concept Reports recommended widening to provide five lanes in each direction of travel between Ruthrauff Road and Tangerine Road but did not make specific recommendations for ramp metering. While the freeway widening may be warranted for design year 2040, this report is investigating potential near-term improvements to improve the operations of I-10.

4.3.1 Traffic Operational Analysis

An operational analysis was performed for the mainline including the general-purpose lanes, ramp junctions, and weave sections for two Build Alternatives. The VISSIM computer program was used to provide a simulation of the entire system within the study area as discussed in Section 3.2.1. The ramp meters and local traffic responsive algorithm were added to the Build Alternatives at entrance ramp locations based on the warrant analysis discussed above. **Table 19** shows the different ramp meter rates based on the adjacent freeway speeds in the right-most travel lane.

Table 19: Local Traffic Responsive Metering Rates

Metering Level	Freeway Speed of Right Lane (Miles/Hour)	Metering Rate (for 2 lanes) (Vehicles/Hour)
1	>65	1,440
2	65 to 56	1,320
3	55 to 46	1,200
4	45 to 36	1,080
5	35 to 11	960
6	10 to 0	840

Both Build Alternatives included the installation of ramp meters and did not include any additional mainline lanes. Build Alternative 2 included minor ramp improvements to provide additional storage. The resulting VISSIM analysis showed the LOS results for both Build Alternatives were identical. Therefore, the LOS results are only shown for one Build Alternative.

<u>2032 Build Alternative</u>

The 2032 Build Alternative model includes the installation of ramp meters at the entrance ramps identified in Table 15. In addition, the Build Alternative includes widening along the Prince Road and Miracle Mile Road eastbound entrance ramps, and the Speedway Boulevard westbound entrance ramp. Improvements were included at these locations to widen the existing entrance ramps to provide additional storage along the entrance ramp. The 2032 Build Alternative traffic volumes, lane configurations, and LOS results are shown in **Figure 9** and **Figure 10**.

During the 2032 AM peak hour, the following improvements in mainline traffic operations were noted when compared to the 2032 No-Build model:

- Eastbound mainline between Prince Road entrance ramp and Grant Road entrance ramp improves from LOS 'E' and 'F' to LOS 'D' and 'E'

During the 2032 PM peak hour, the following improvements in mainline traffic operations were noted when compared to the 2032 No-Build model:

- Westbound mainline between Speedway Boulevard exit ramp and 22nd Street entrance ramp improves from LOS 'F' to LOS 'E'
- Westbound mainline between Miracle Mile exit ramp and Grant Road exit ramp improves from LOS 'E' and 'F' to LOS 'D' and 'E'

<u>Recommended Alternative</u>

Based on the ramp meter queue analysis and the VISSIM analysis, Alternative 1 is not feasible as additional queue storage is needed in some locations. Therefore, Alternative 2 is the Recommended Alternative.

Table 20 shows the 2032 queue lengths estimated from the VISSIM output compared to the Refined Meter Rate approach (described above) and compared to the existing conditions.

Table 20: Ramp Meter Queue Summary

Entrance Ramp	Queue Length (feet)		
	ADOT Formula - Refined Meter Rate	VISSIM Output	Estimated Currently Available
Prince Rd Eastbound	1,000	2,200	2,000
Miracle Mile Eastbound	3,800	3,200	2,100
Congress Rd Eastbound	400	750	2,500
Ruthrauff Rd Westbound	400	250	1,500
Grant Rd Westbound	400	1,000	1,600
Speedway Blvd Westbound	4,200	3,000	2,200
Congress Rd Westbound	400	800	1,800
22nd St Westbound	400	1,000	2,200

Note: 1. Queue lengths shown are total storage, regardless of number of lanes.
2. "Refined" meter rate is different for each ramp and is based on local responsive algorithm

2025 Build Alternative

Following the identification of the Recommended Alternative, VISSIM analysis was conducted for the 2025 horizon year. The 2025 Build Alternative model includes the installation of ramp meters at the entrance ramps identified in Table 15. In addition, the Build Alternative includes widening along the Prince Road and Miracle Mile Road eastbound entrance ramps, and the Speedway Boulevard westbound entrance ramp. Improvements were included at these locations to widen the existing entrance ramps to provide additional storage along the entrance ramp. The 2025 Build Alternative traffic volumes, lane configurations, and LOS results are shown in **Figure 11** and **Figure 12**.

During the 2025 AM peak hour, the following improvements in traffic operations were noted when compared to the 2025 No-Build model:

- Eastbound mainline between Grant Road exit ramp and Miracle Mile exit ramp improves from LOS 'E' to LOS 'D'

During the 2025 PM peak hour, the following improvements in traffic operations were noted when compared to the 2025 No-Build model:

- Westbound mainline between Miracle Mile exit ramp and Speedway Boulevard exit ramp improves from LOS 'E' and 'F' to LOS 'D' and 'E'

Summary

As shown in Table 17, seven of the 23 entrance ramps within the study area are anticipated to meet warrants for the installation of ramp meters by 2025, and eight of the 23 entrance ramps within the study area are anticipated to meet warrants for the installation of ramp meters by 2032.

Table 21 shows a comparison of the mainline travel speeds in 2032 for the No-Build condition and the Build Alternative in the locations were ramp meters were warranted. The speeds represent the average across all travel lanes and were taken from the respective VISSIM models. At all locations of ramp meters, the mainline speeds increase except for at the westbound Ruthrauff and Grant entrance ramps. At these locations, the upstream conditions have improved such that additional traffic is reaching these locations resulting in slower mainline speeds that the ramp meter does not fully mitigate. The installation of a more comprehensive metering system (rather than just at specific locations) and/or a System-Wide Traffic Responsive system could help mitigate freeway congestion.

Table 21: 2032 Mainline Speed Comparison

Entrance Ramp	Peak Hour Travel Speeds (mph)			
	Mainline Adjacent to Ramp		Downstream Mainline	
	No-Build	Build Alternative	No-Build	Build Alternative
Eastbound I-10				
Prince Rd Eastbound (AM)	56	59	41	56
Miracle Mile Eastbound (AM)	36	58	41	57
Congress Rd Eastbound (PM)	58	58	50	54
Westbound I-10				
Ruthrauff Rd Westbound (PM)	58	58	45	43
Grant Rd Westbound (PM)	56	56	48	46
Speedway Blvd Westbound (PM)	36	42	31	33
Congress Rd Westbound (PM)	47	54	40	45
22nd St Westbound	51	53	42	49

Table 22 shows a comparison of the extent of LOS 'E' or 'F' along the I-10 mainline under each alternative. With the addition of ramp meters, the extent of mainline congestion decreases in each horizon year when compared to the No-Build conditions.

Table 22: Miles of Congestion

Alternative	I-10 Mainline Miles of LOS 'E' or 'F'
AM Peak Hour	
2016 AM Peak Hour	0.4
2025 No-Build AM Peak Hour	0.9
2032 No-Build AM Peak Hour	1.8
2025 Build Alternative AM Peak Hour	0.0
2032 Build Alternative AM Peak Hour	0.7
PM Peak Hour	
2016 PM Peak Hour	0.4
2025 No-Build PM Peak Hour	3.0
2032 No-Build PM Peak Hour	3.7
2025 Build Alternative PM Peak Hour	2.2
2032 Build Alternative PM Peak Hour	2.9

Note: The data for the Build Alternative is based on Build Alternative 2.

[text continues on page 80]

Figure 9: 2032 Build Alternative AM Peak Hour LOS Results

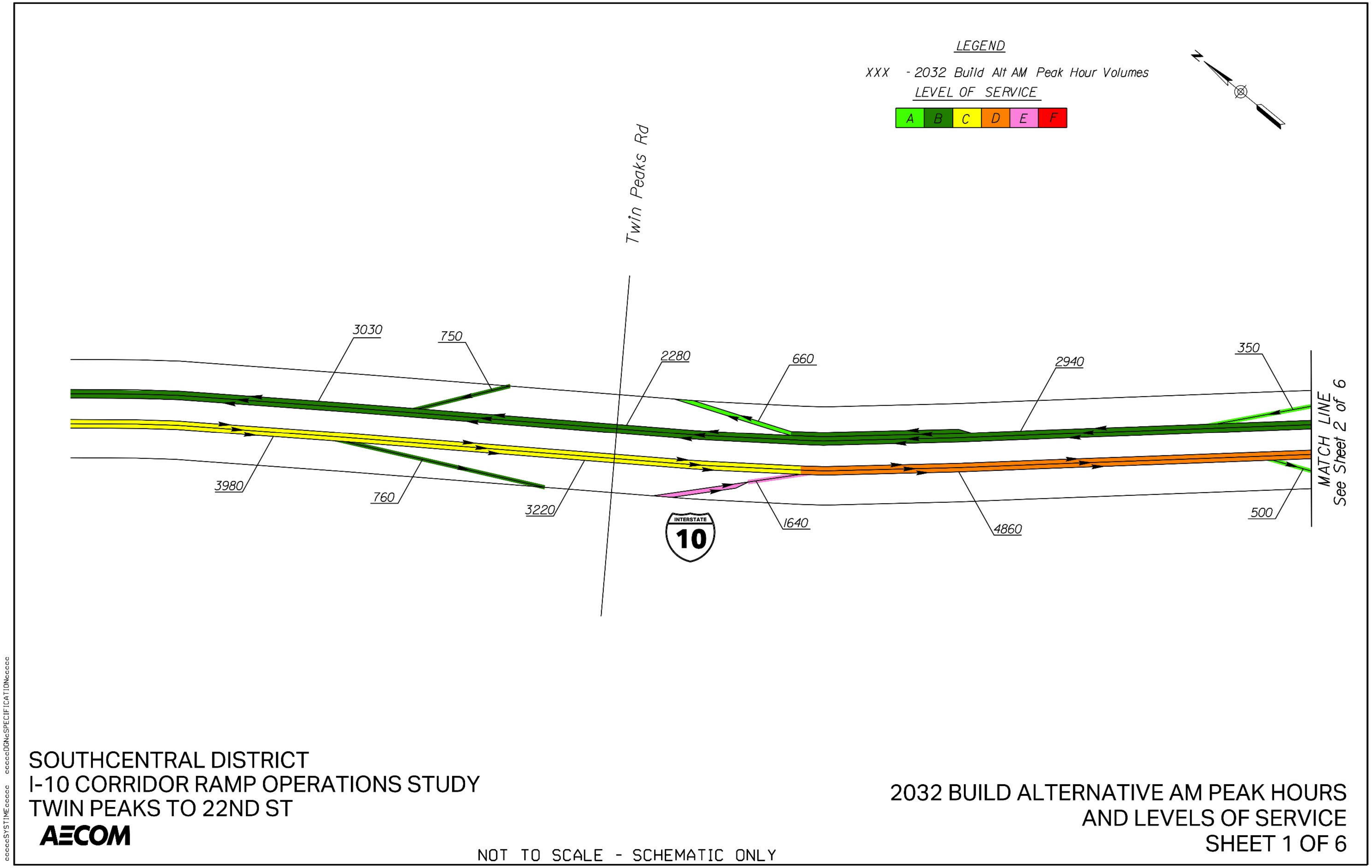


Figure 9 - continued

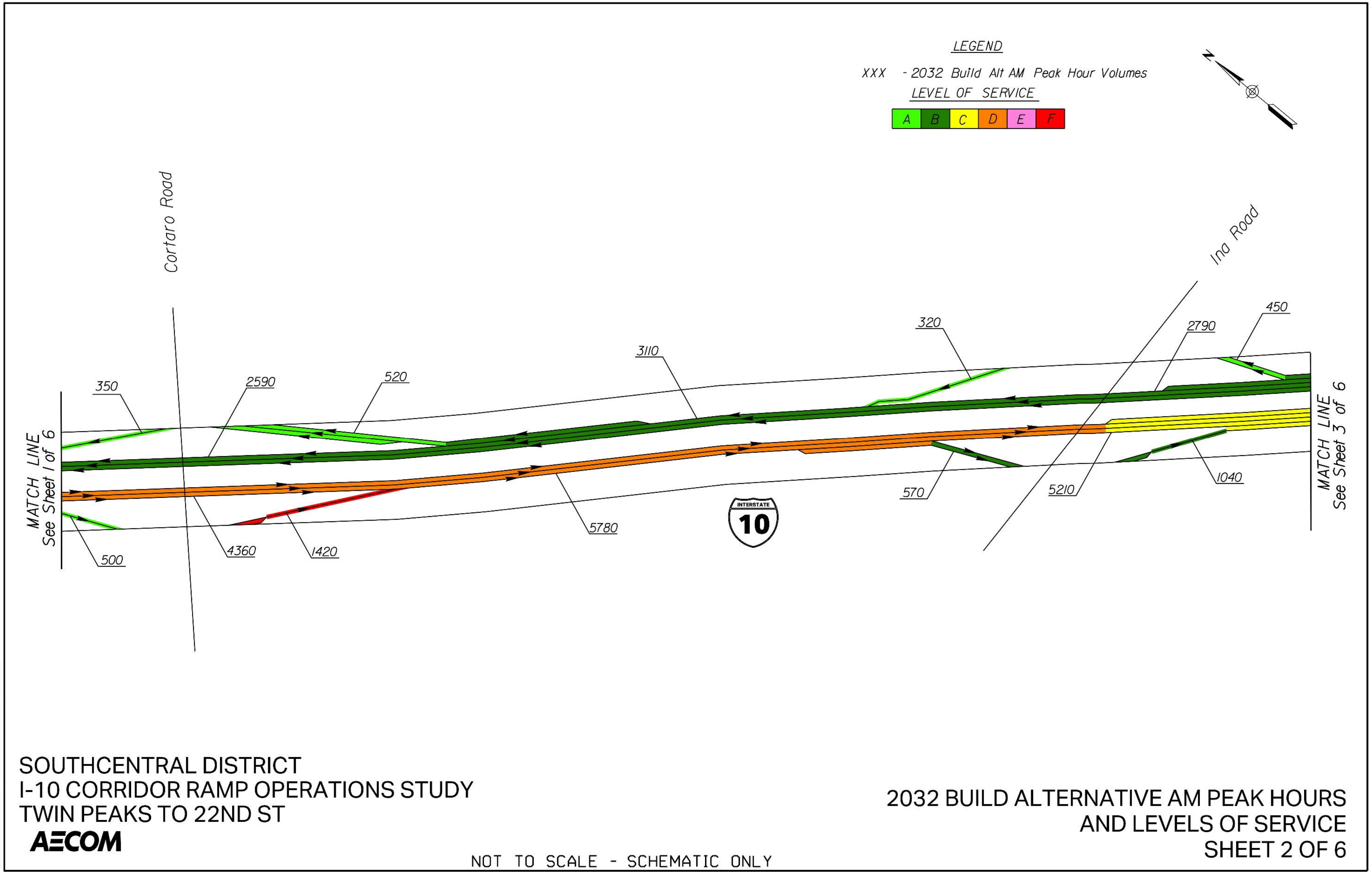


Figure 9 - continued

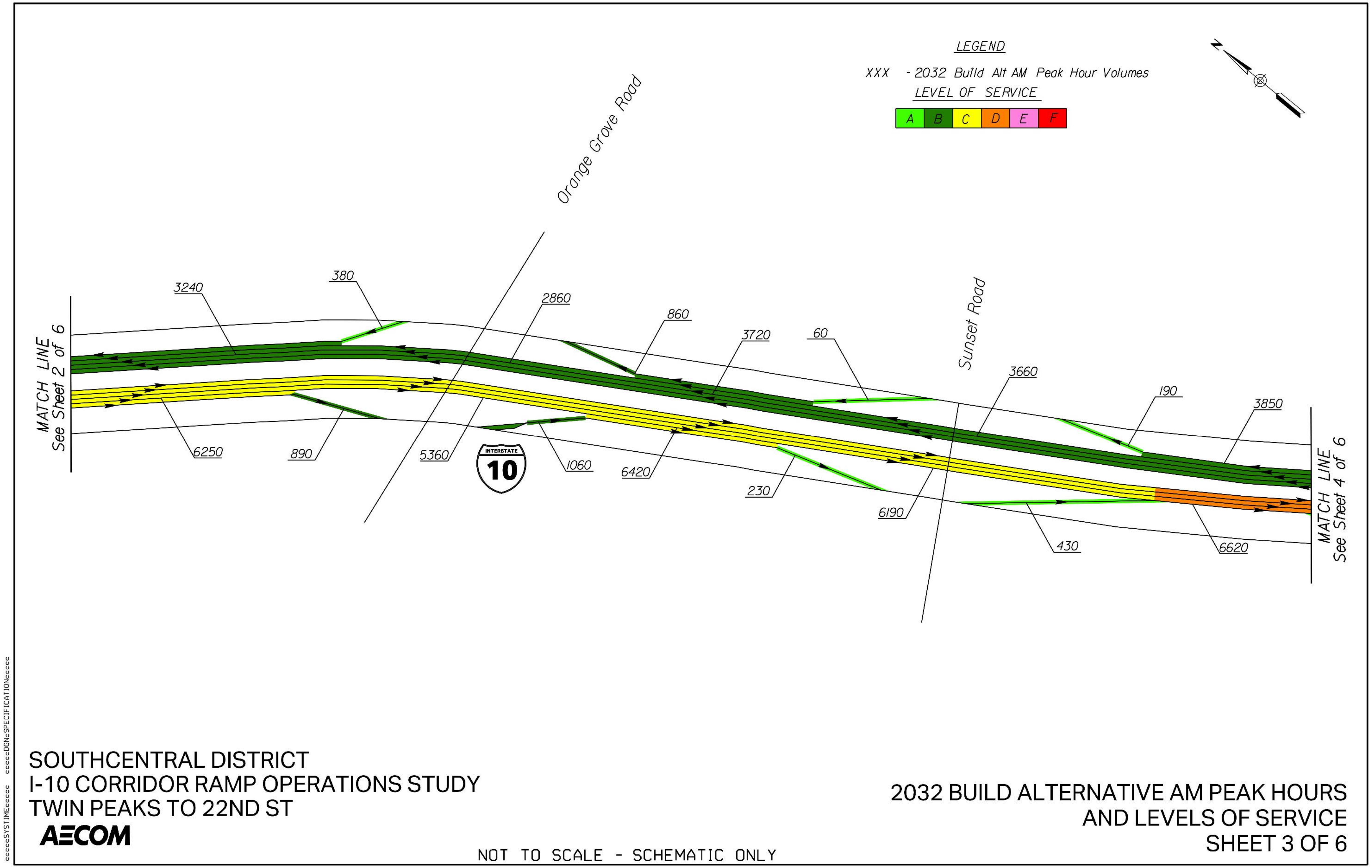


Figure 9 - continued

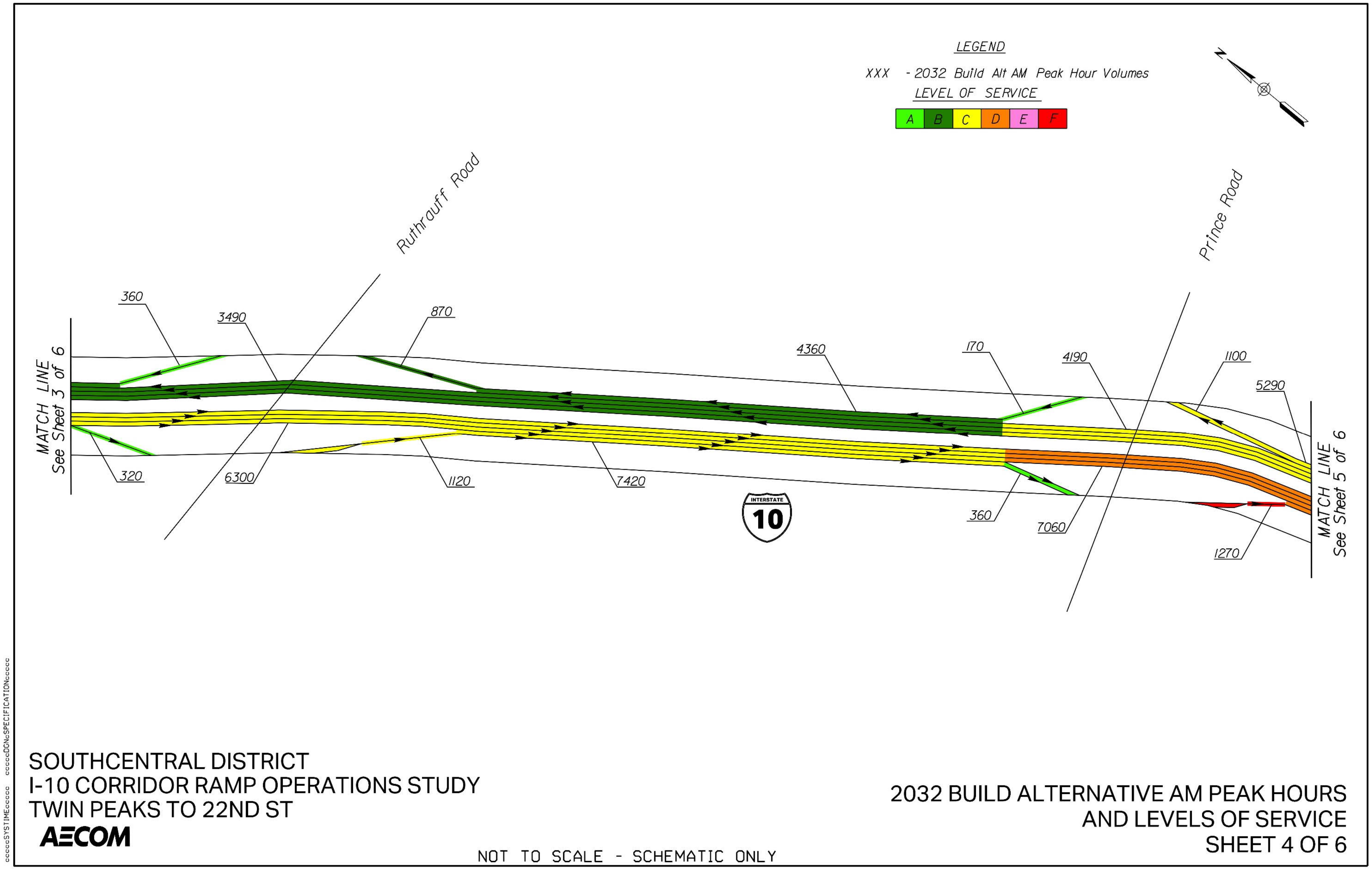


Figure 9 - continued

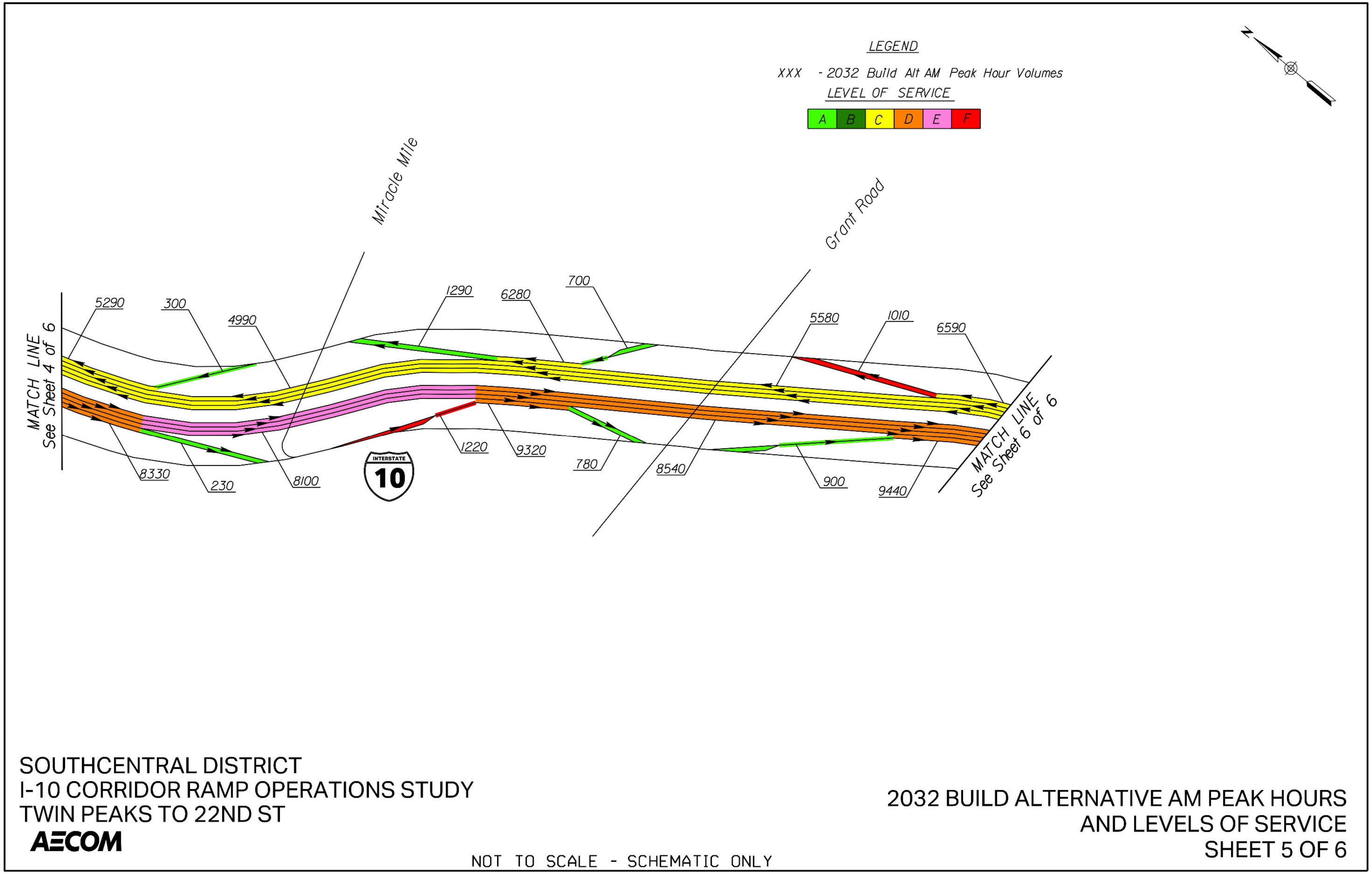


Figure 9 - continued

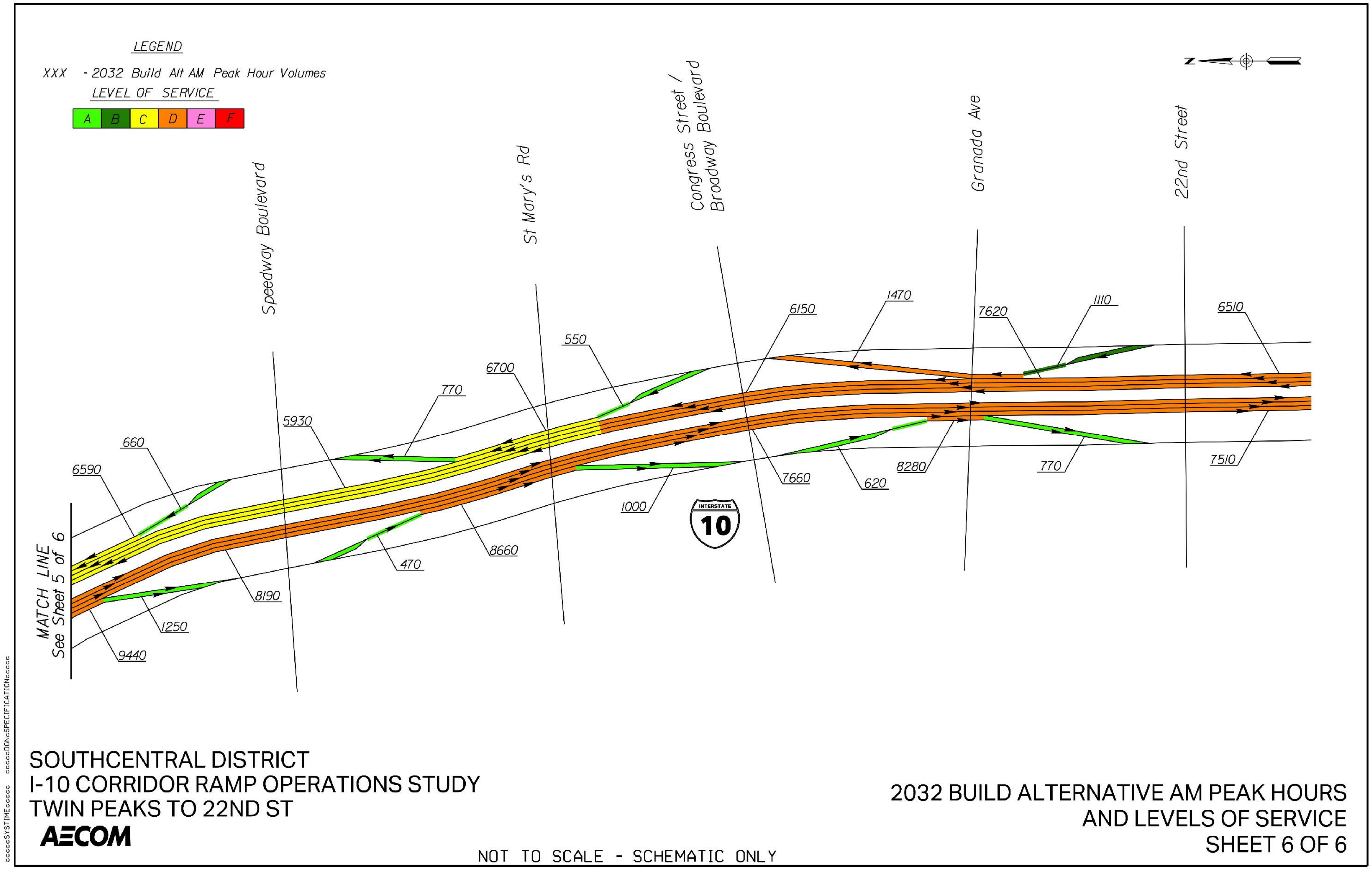
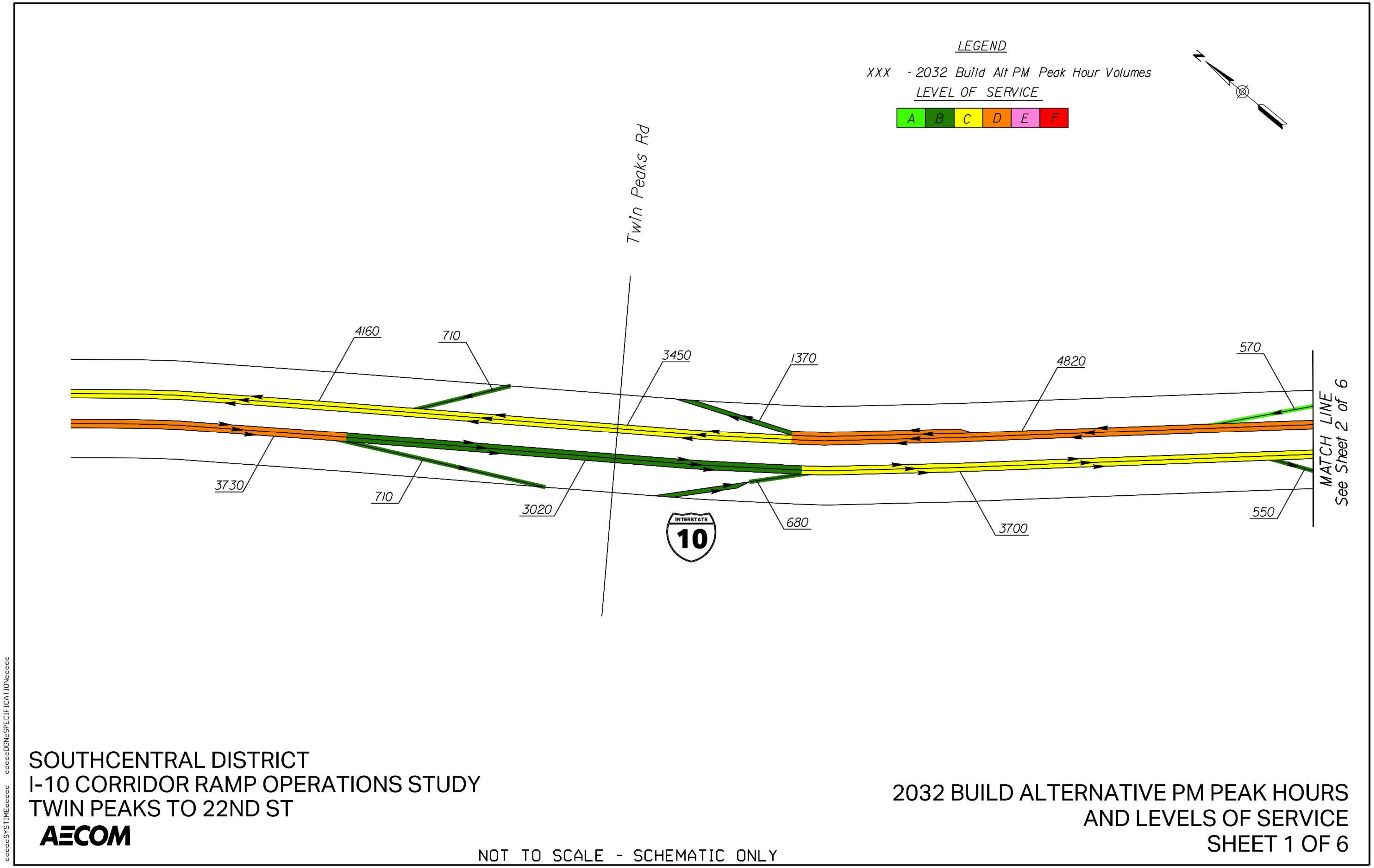


Figure 10: 2032 Build Alternative PM Peak Hour LOS Results



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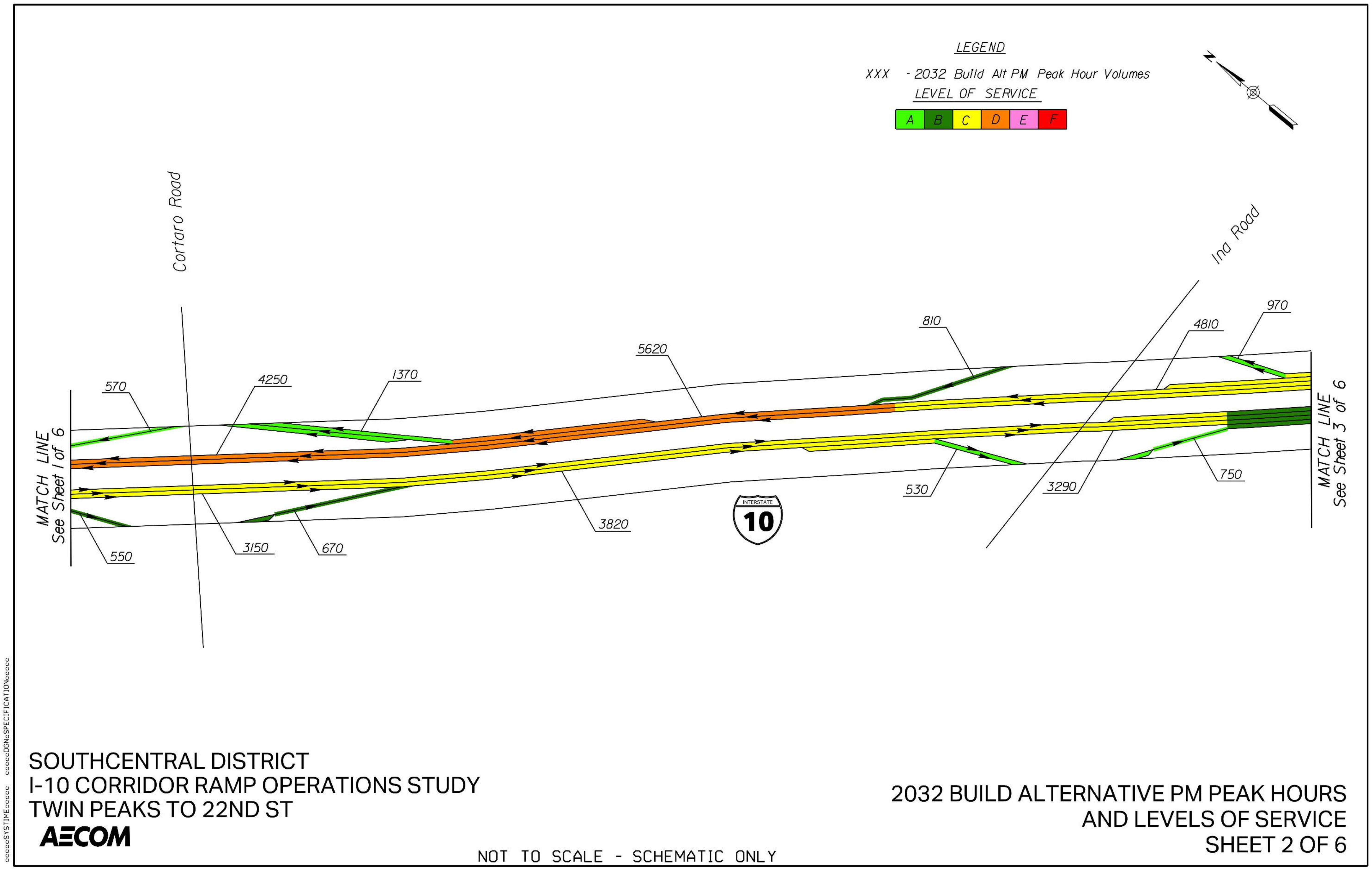

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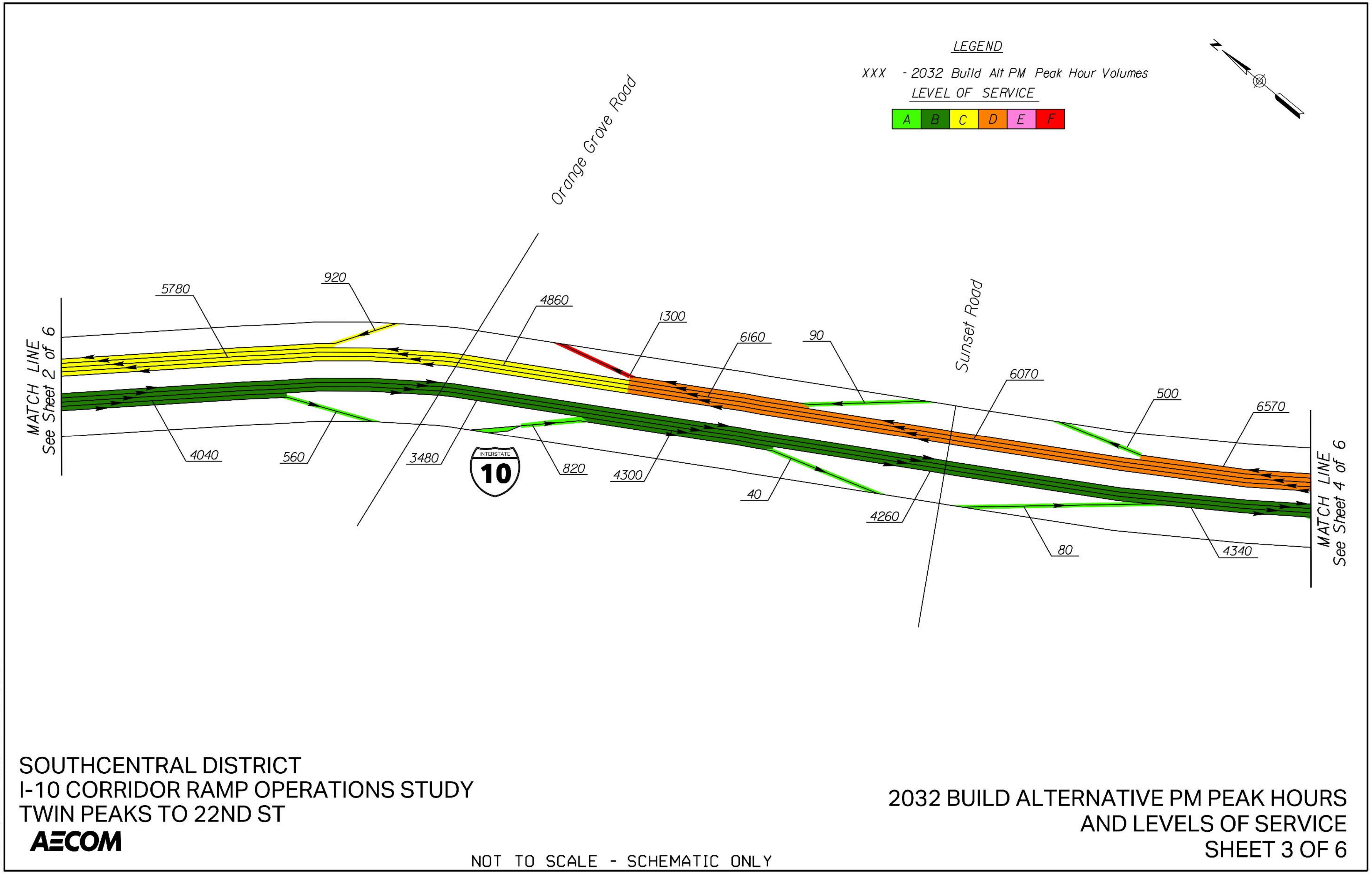

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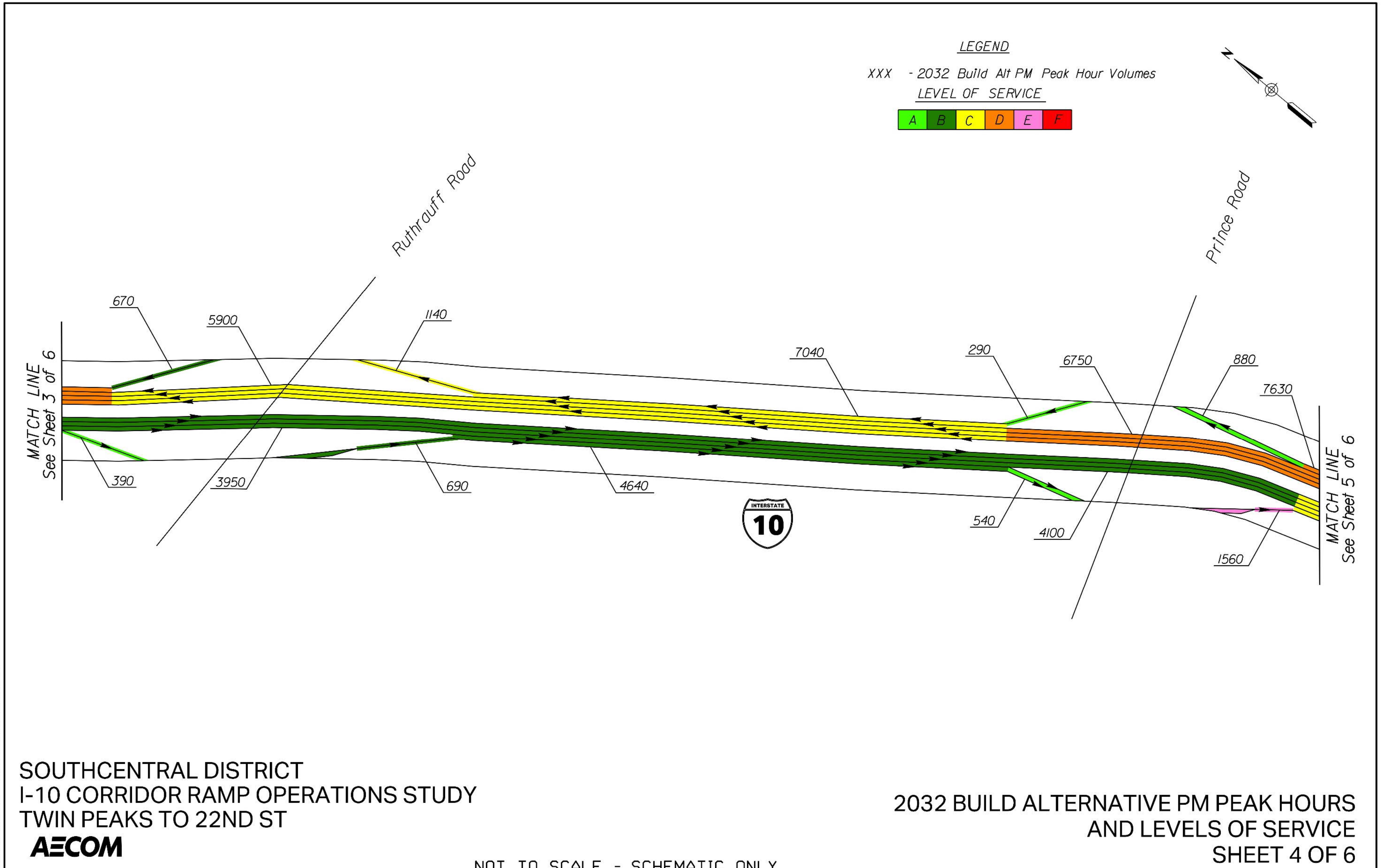

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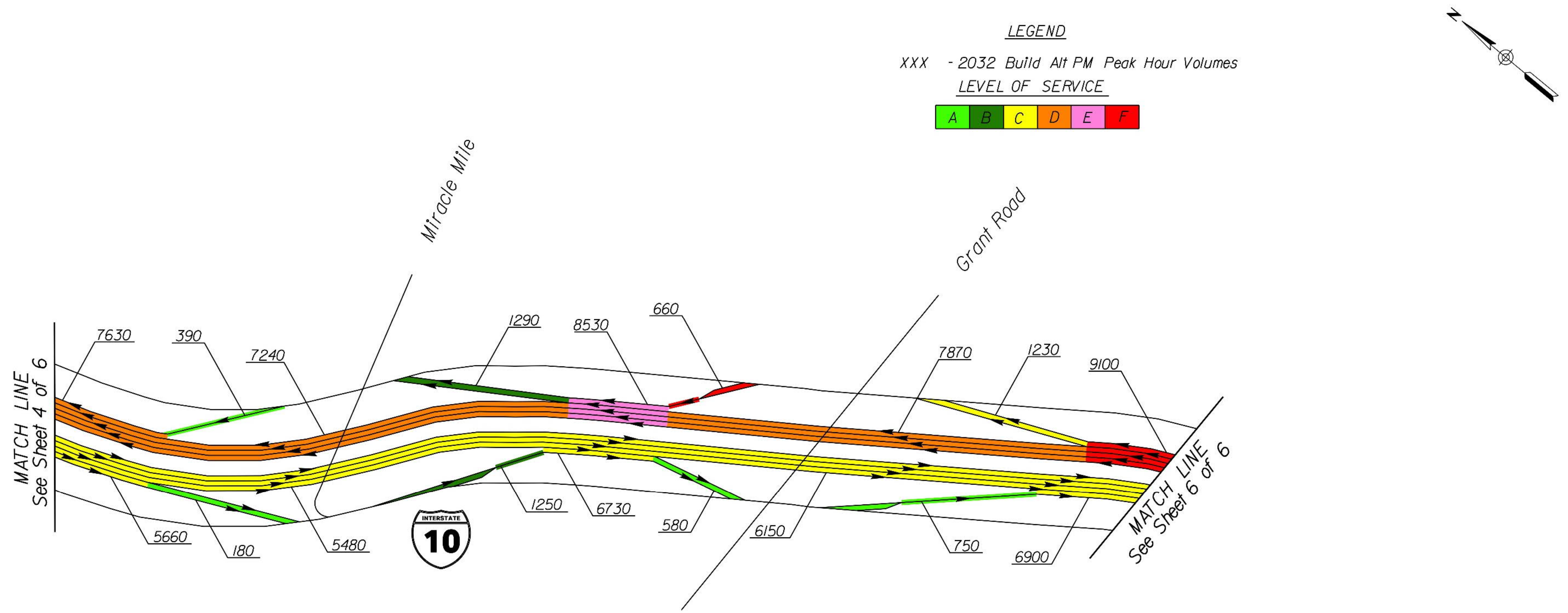


SOUTHCENTRAL DISTRICT
I-10 CORRIDOR RAMP OPERATIONS STUDY
TWIN PEAKS TO 22ND ST
AECOM

NOT TO SCALE - SCHEMATIC ONLY

2032 BUILD ALTERNATIVE PM PEAK HOURS
AND LEVELS OF SERVICE
SHEET 5 OF 6

Figure 10 - continued

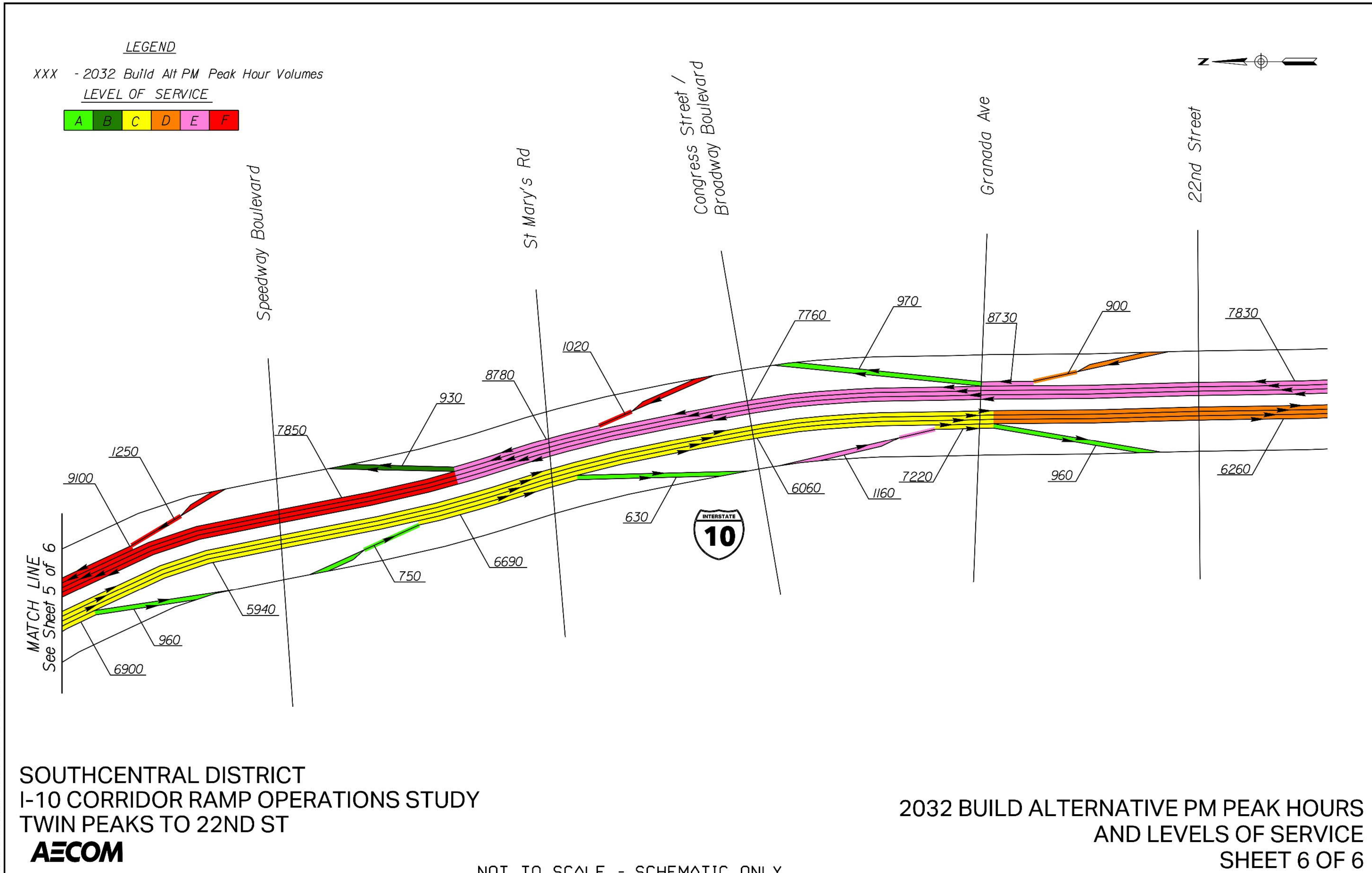
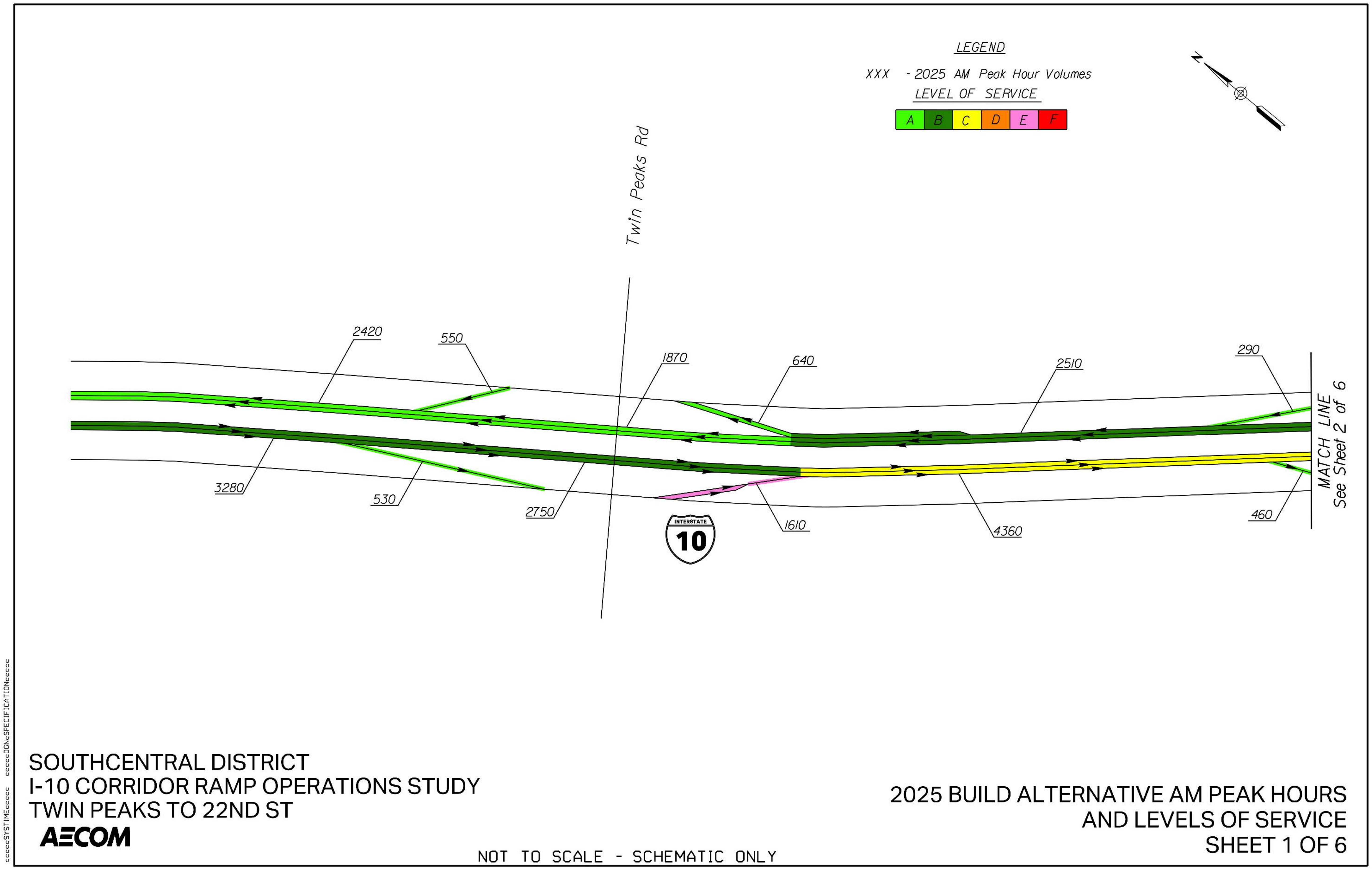


Figure 11: 2025 Build Alternative AM Peak Hour LOS Results



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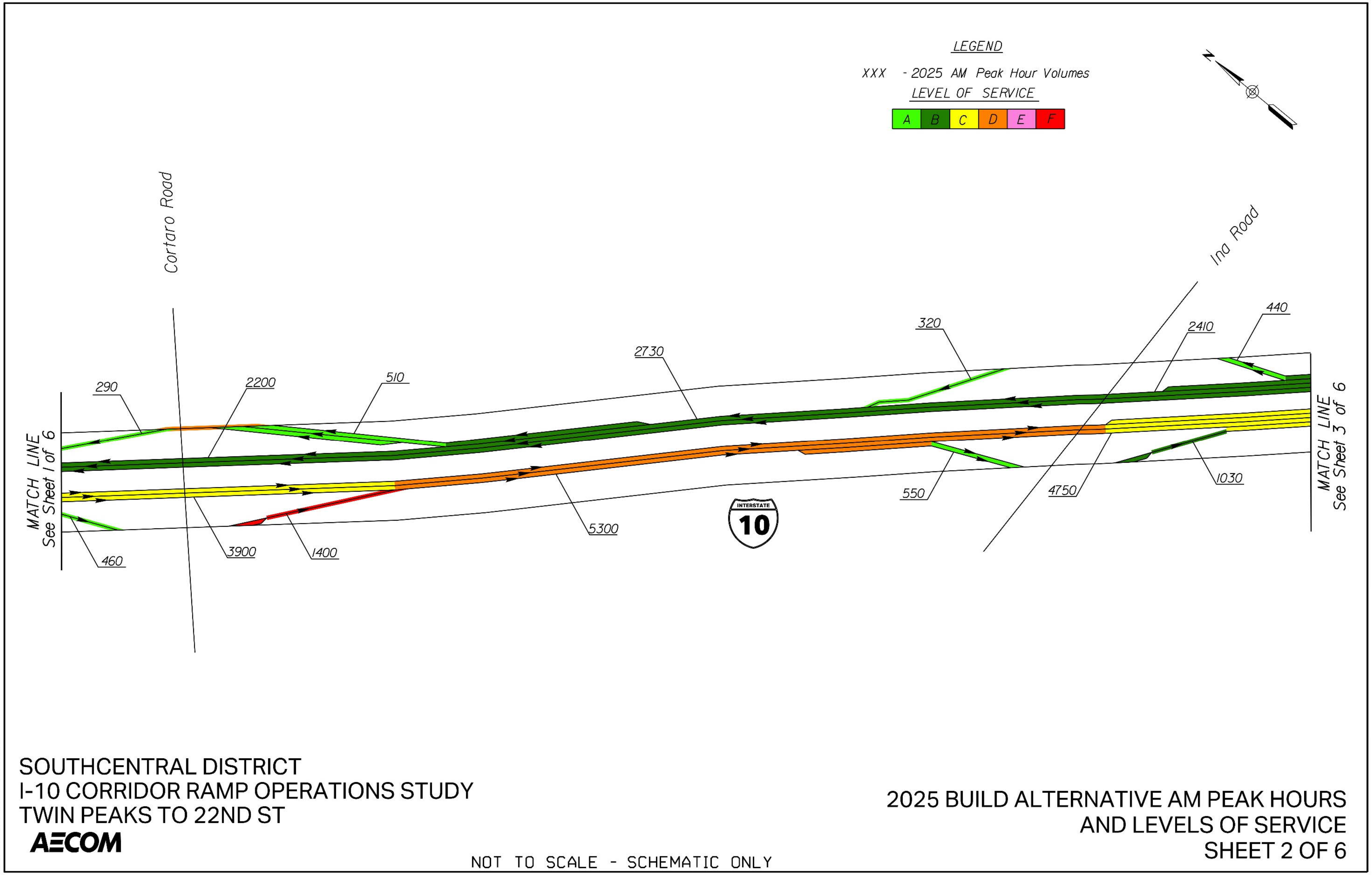

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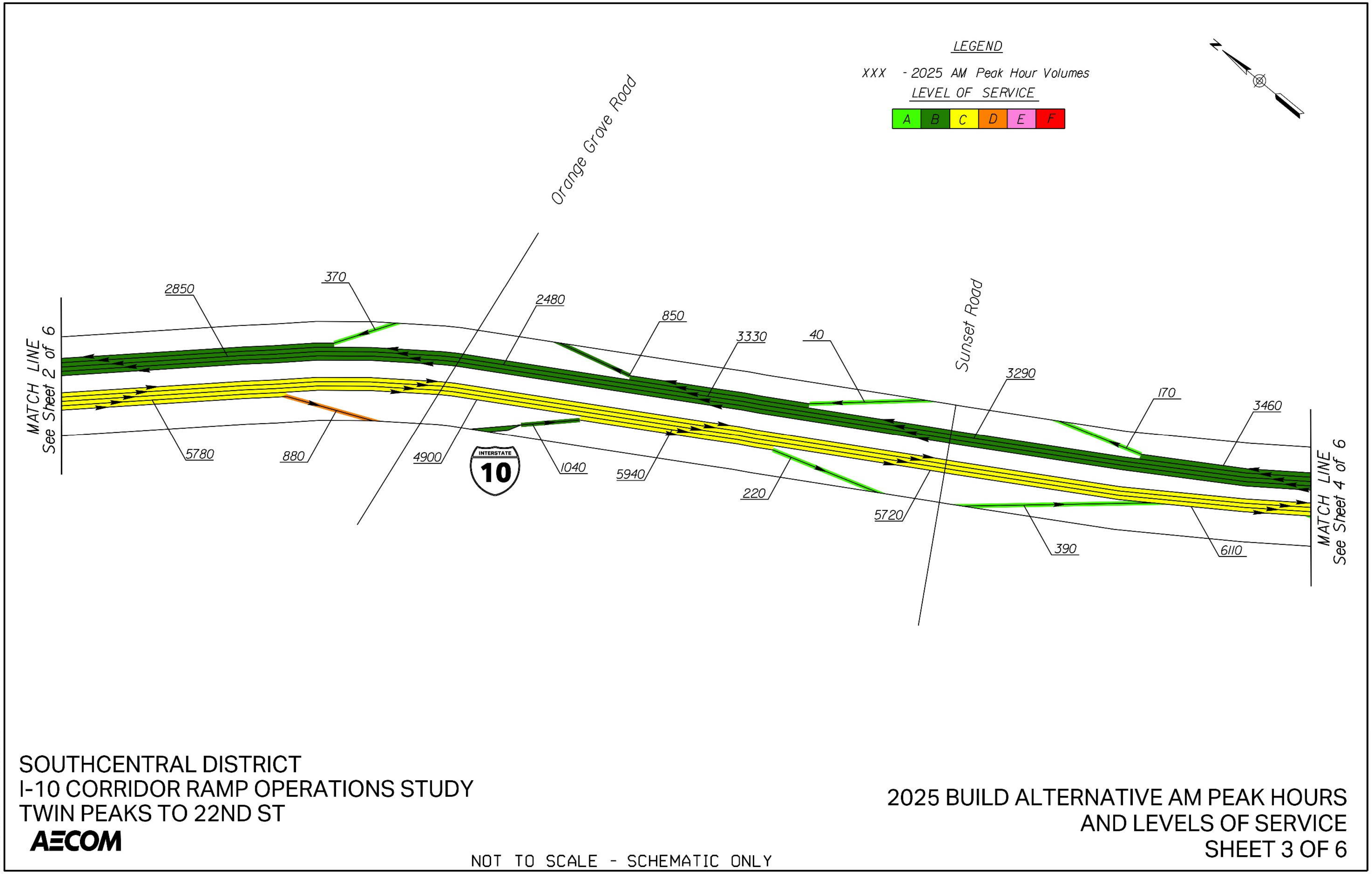

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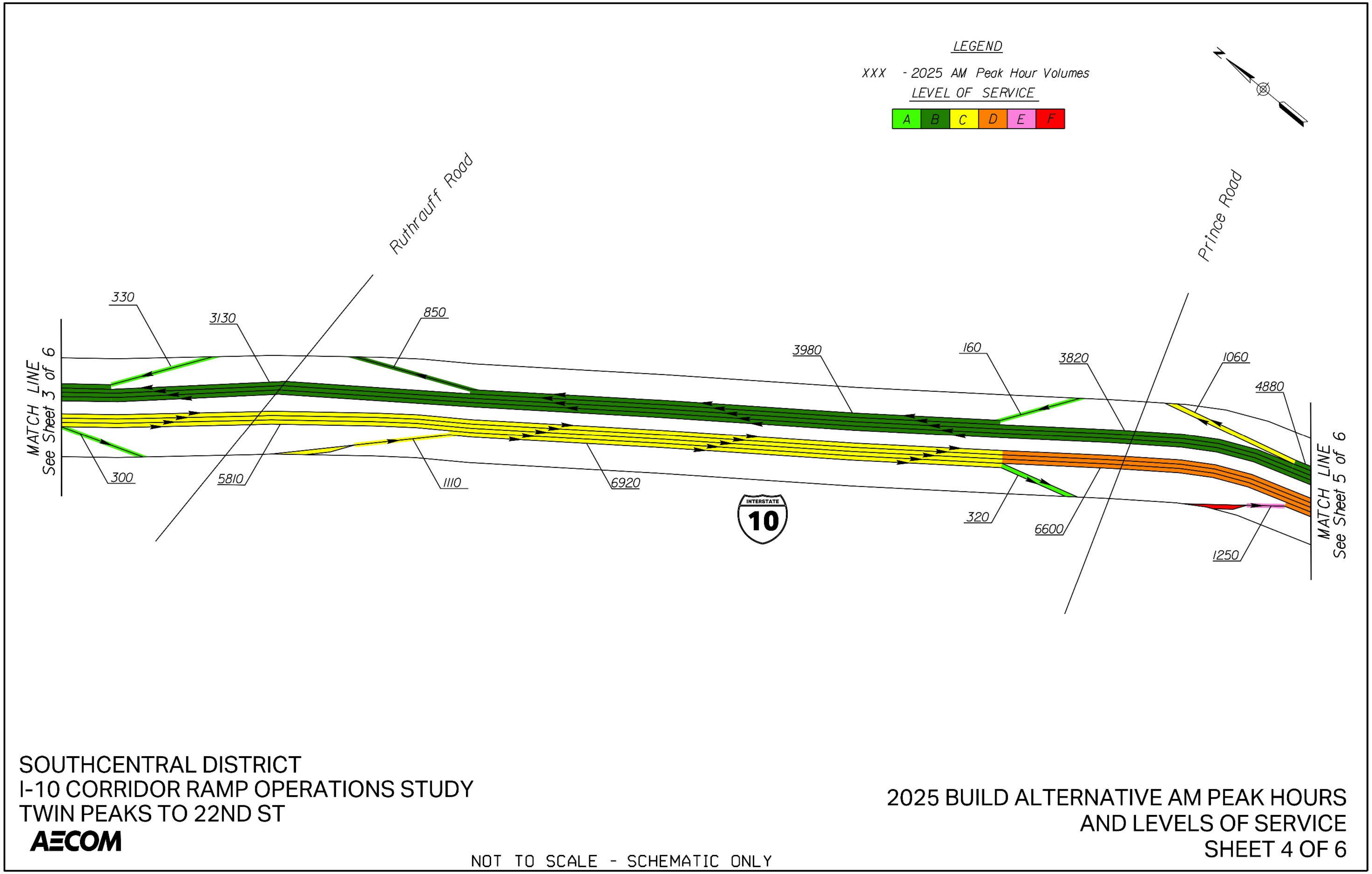

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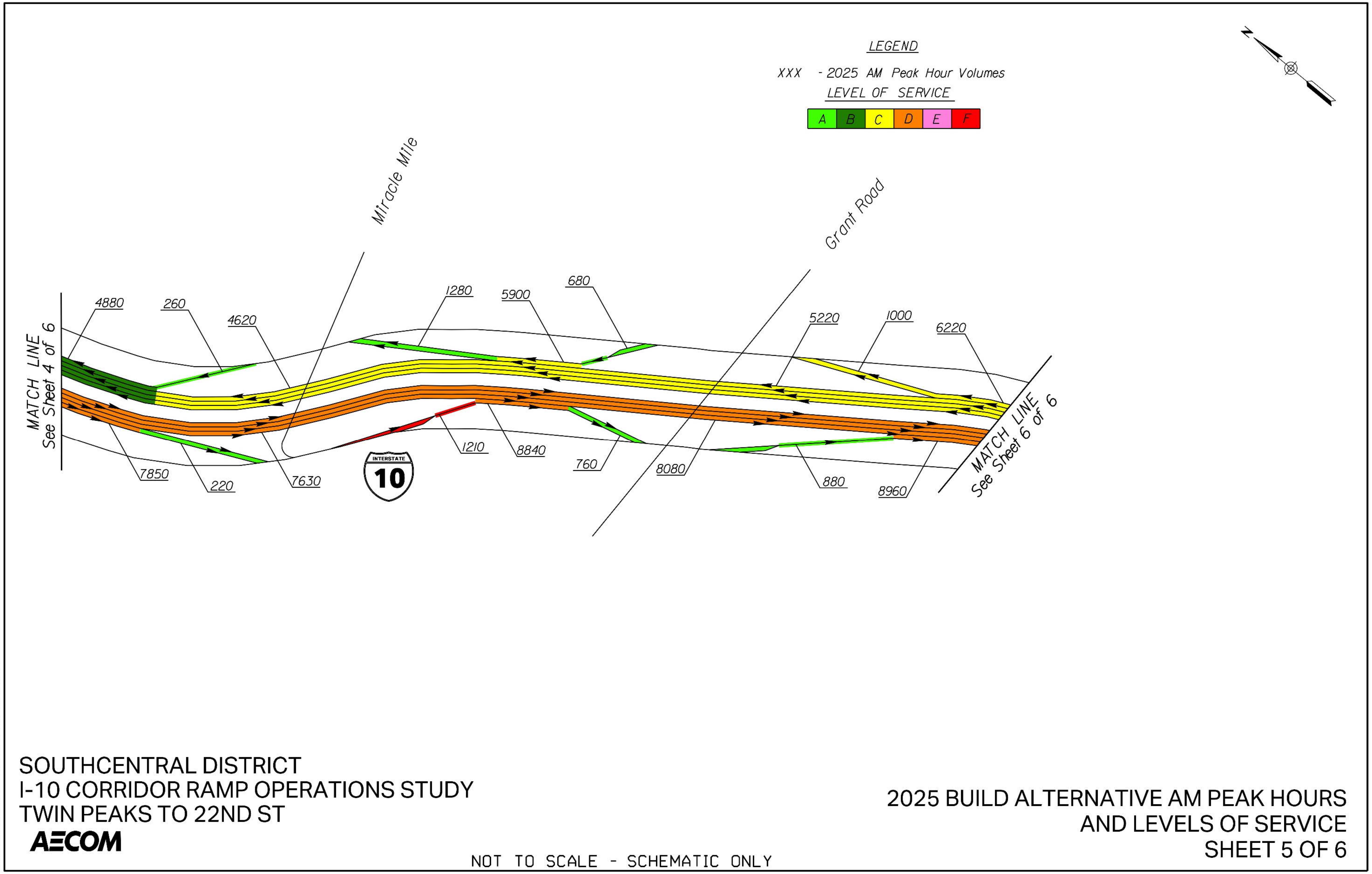

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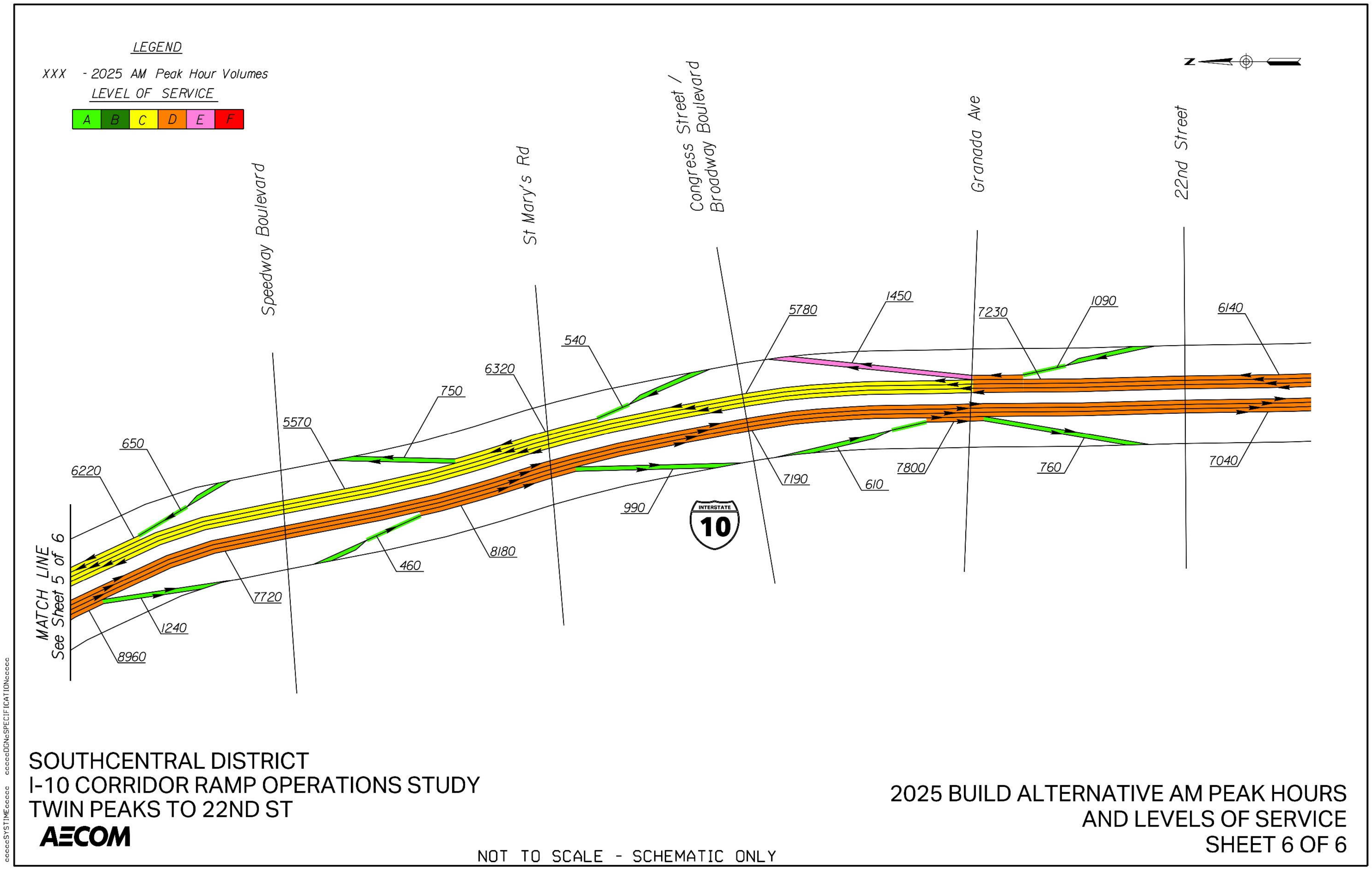
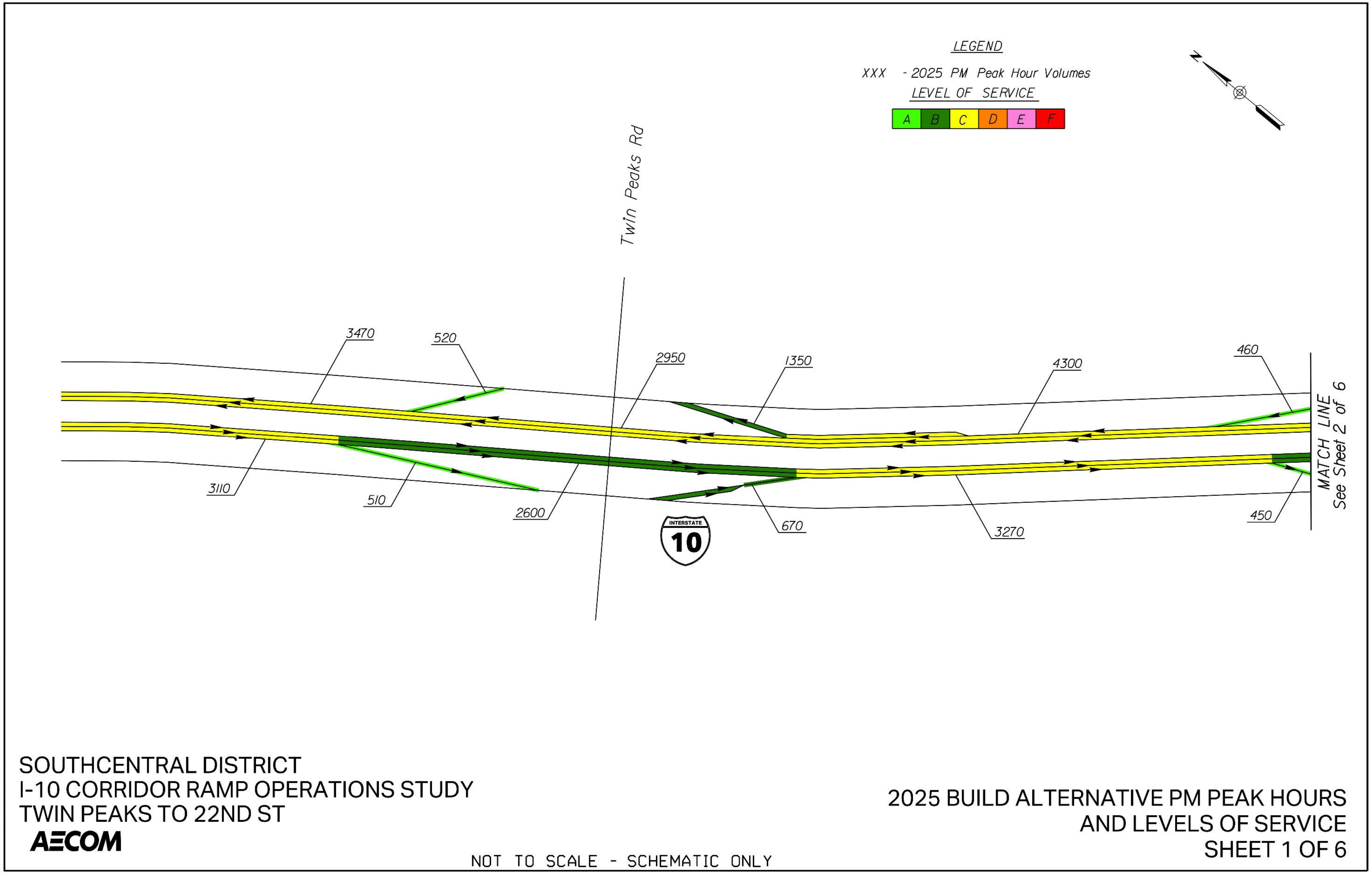


Figure 12: 2025 Build Alternative PM Peak Hour LOS Results



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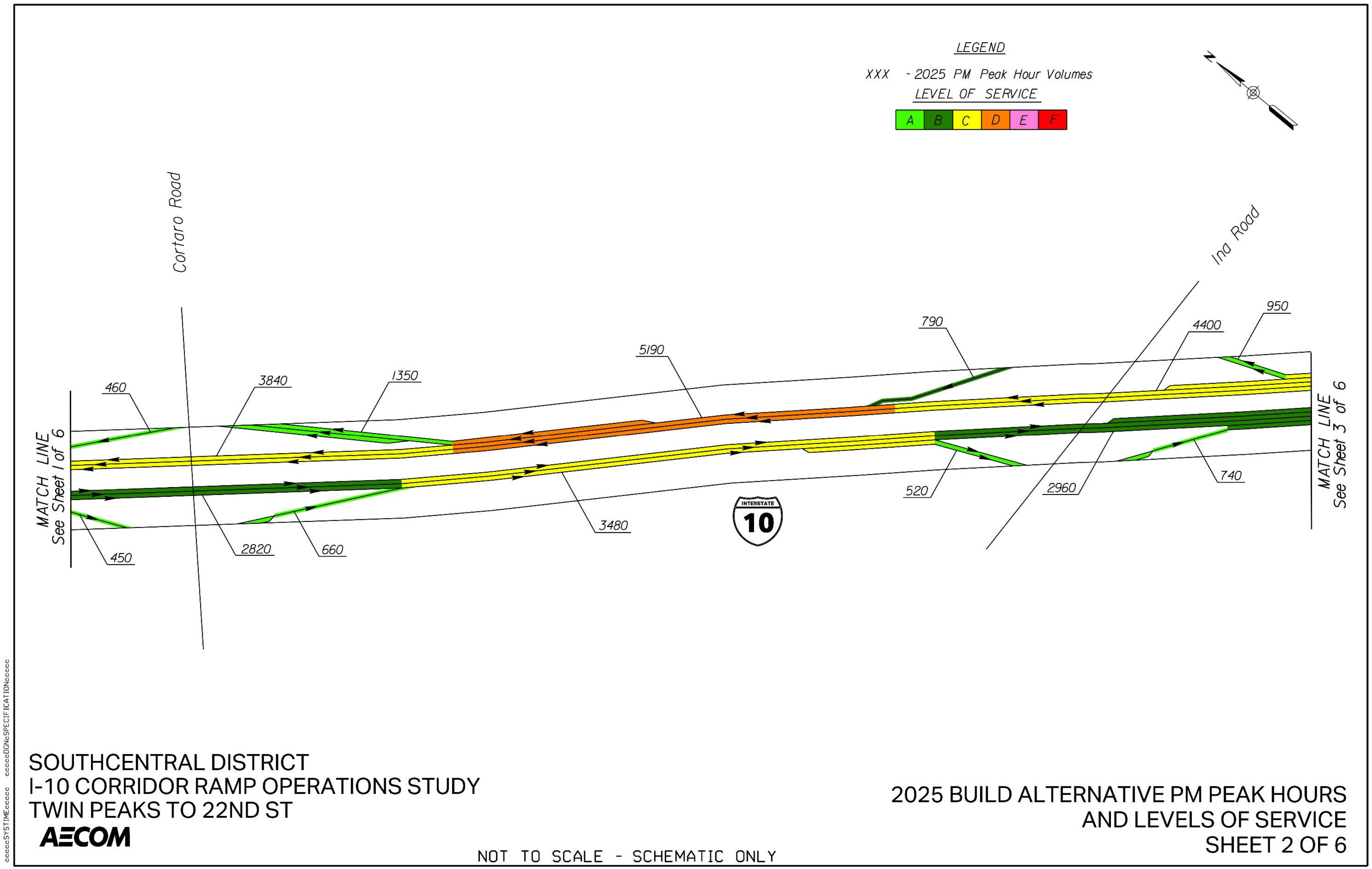

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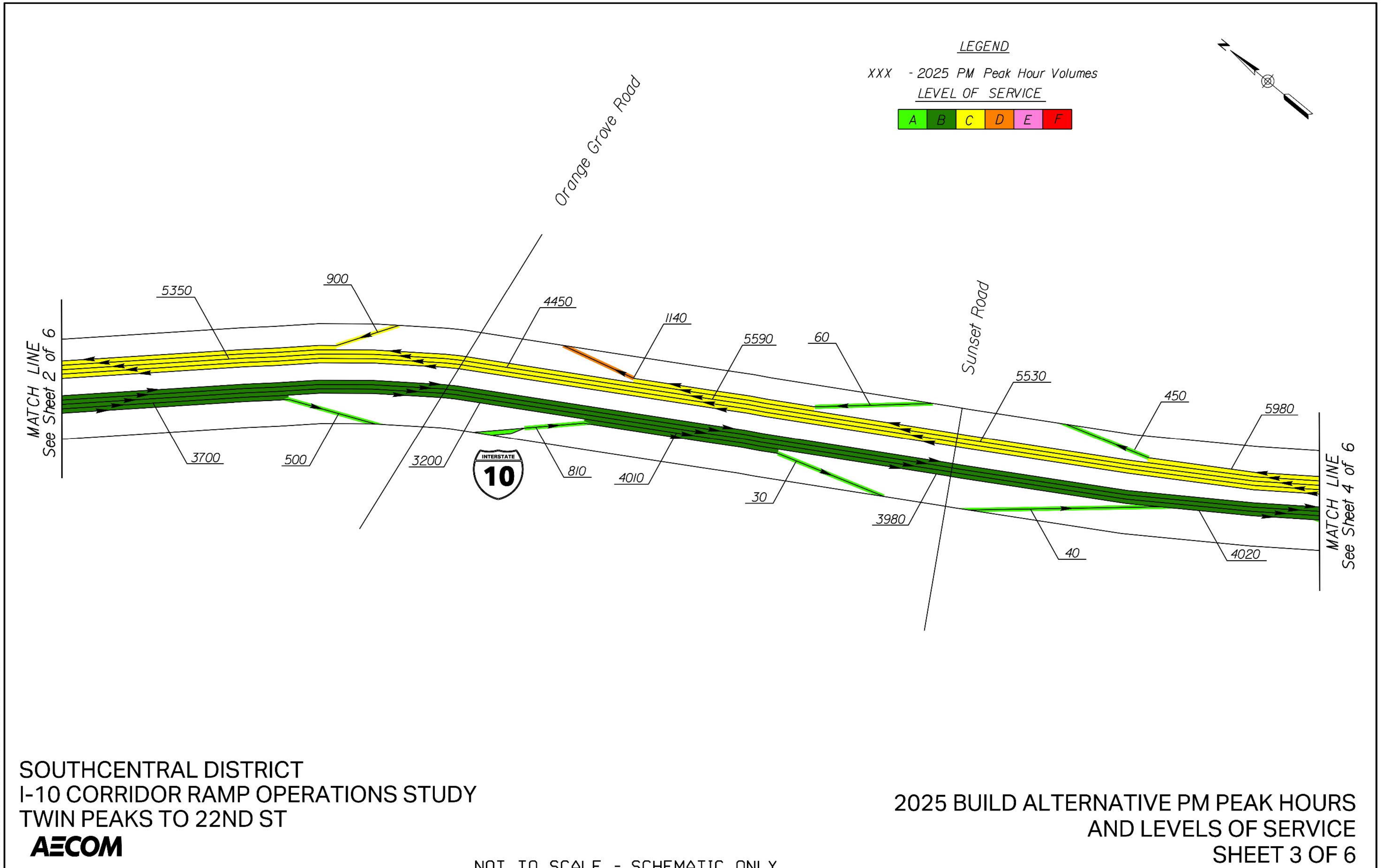

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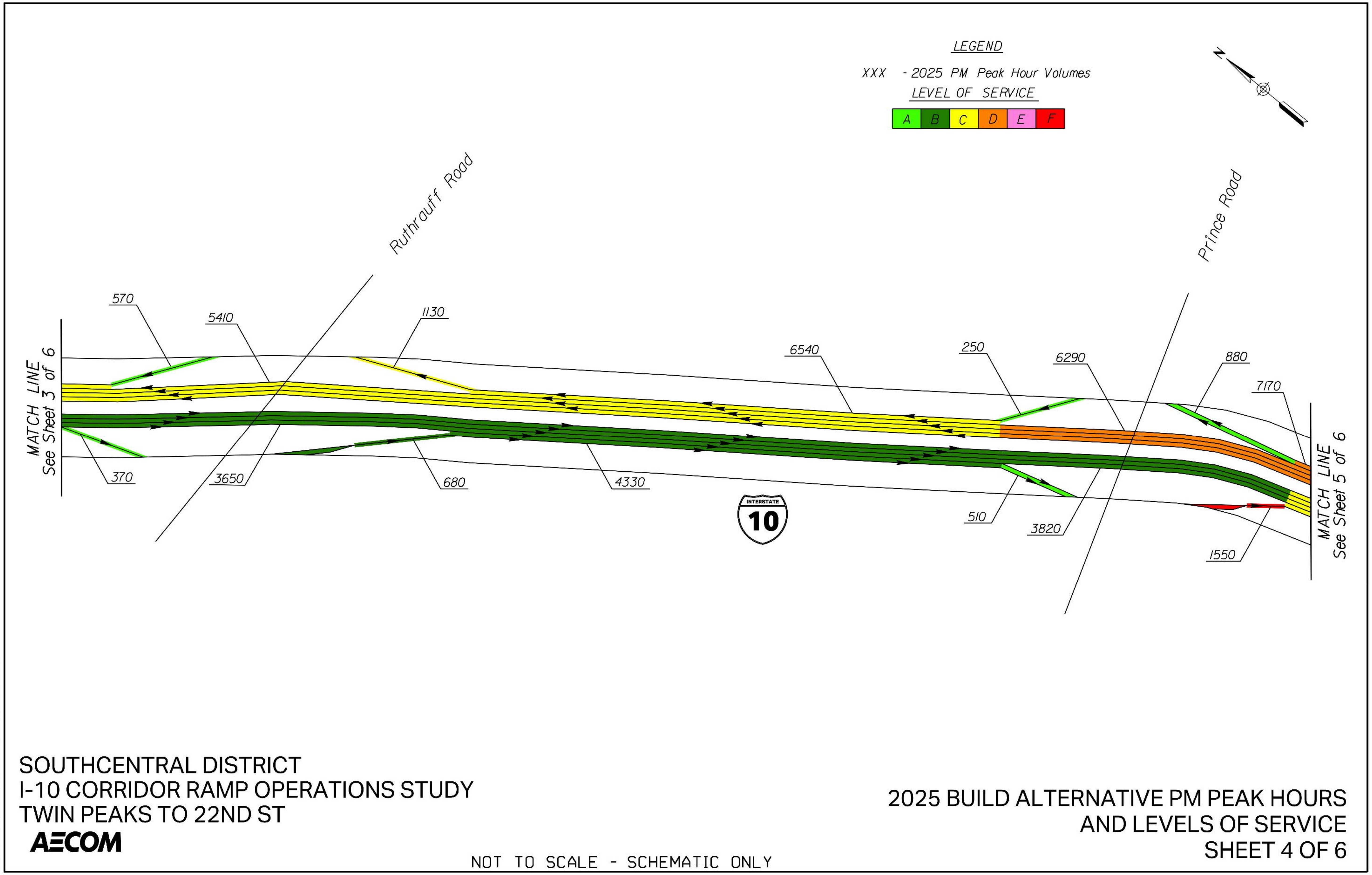

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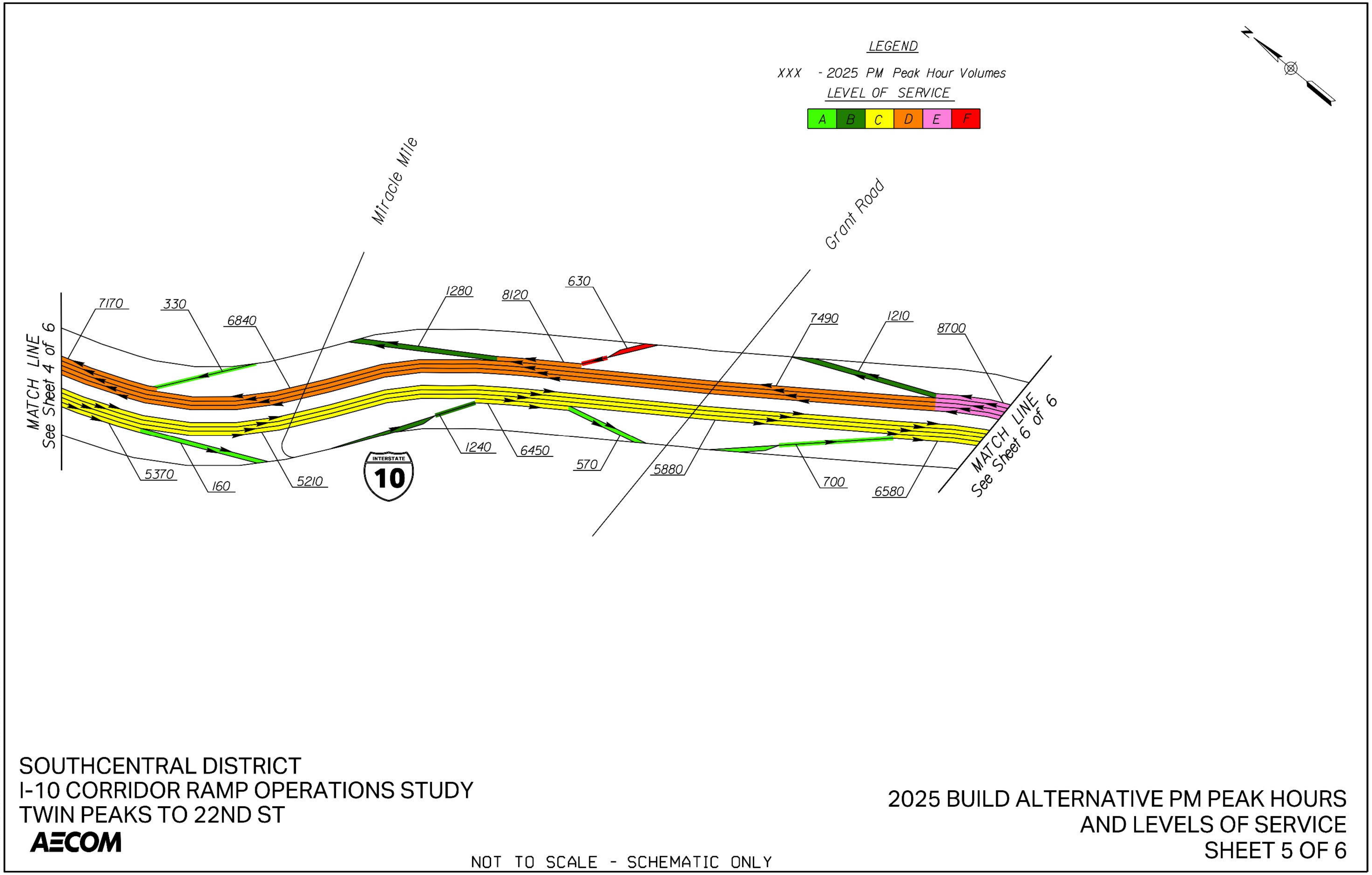

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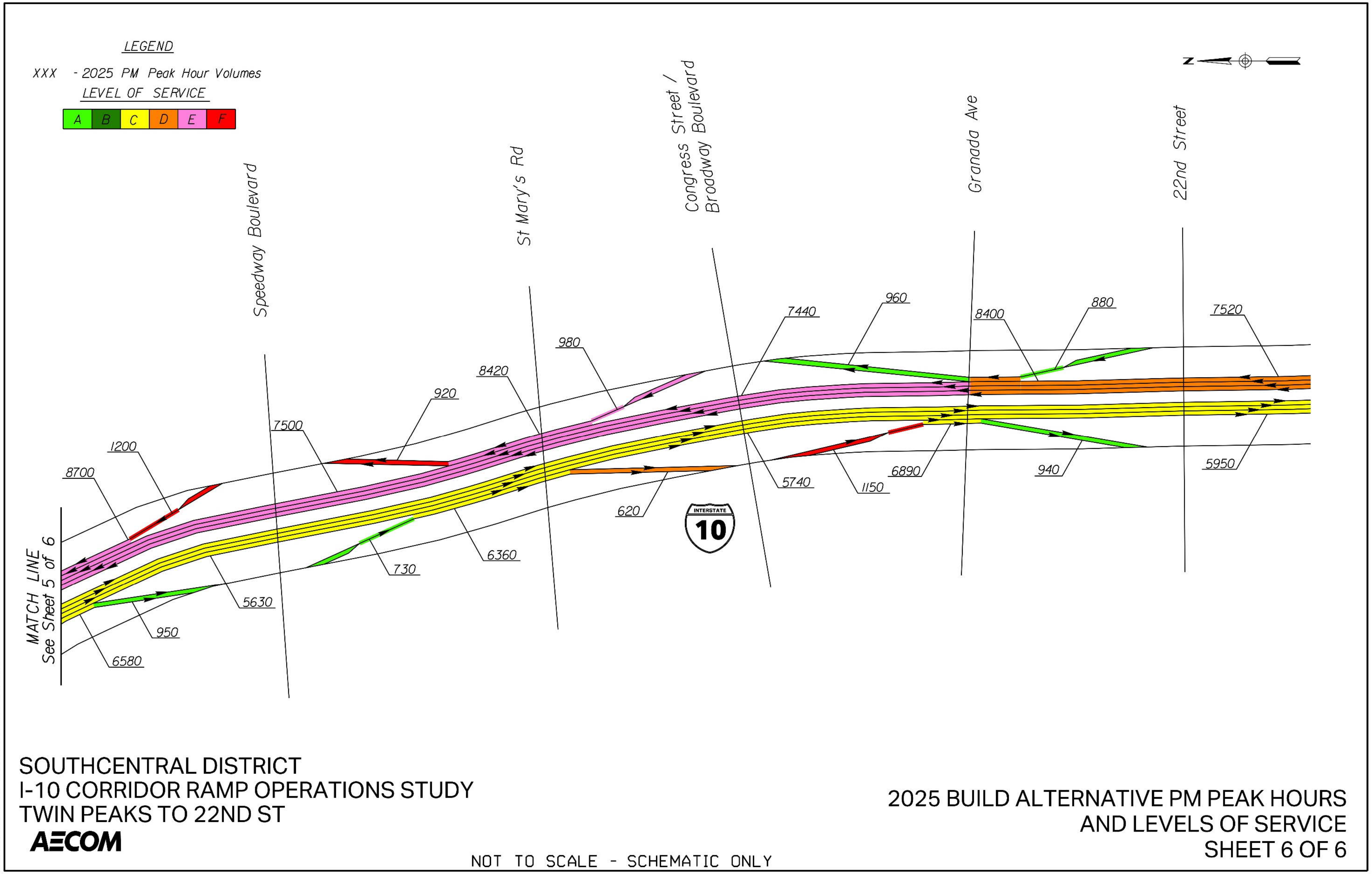


4.4 Benefit- Cost Analysis

In a benefit-cost analysis (BCA), the benefits and costs of a project are estimated and compared to each other to determine if the benefits exceed the costs. This is accomplished by quantifying the benefits in dollars and using a ratio (benefits divided by costs) to make the comparison. If the resulting ratio is greater than 1.0, then the benefits are greater than the costs. The higher the ratio is above 1.0, the more the benefits exceed the costs. The BCA computes agency costs and user benefits over time and presents the results in a common measure, the present value in dollars.

A BCA estimates the anticipated benefits that are expected from a project over a specified time period and compares them to the costs to implement and maintain the asset during the same time period. The benefits may include travel time reduction, crash reduction, vehicle emission reduction, residual value of the asset, etc.

After accounting for effects of inflation to express costs and benefits in real dollars, a second, distinct adjustment is made to account for the time value of money. This concept reflects the principle that benefits and costs that occur sooner in time are more highly valued than those that occur in the more distant future, and that there is a cost associated with diverting the resources needed for an investment from other productive uses. This process, known as discounting, will result in future streams of benefits and costs being expressed in the same present value terms. This factor is called the "discount rate" and accounts for the inflation rate and the time value of money.

The *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (USDOT, 2018) suggests the use of a 7% discount rate. The analysis for this study used discount rates of 3% and 7%. Projects hoping to receive federal grants must show a 7% discount rate, and a 3% rate is shown for comparison as a representation of the economic climate of recent years.

The previous sections identified the locations that would warrant the installation of ramp meters by 2025 and 2032. The scoping, design, and construction phases typically take at least 2- 3 years and the installation of ramp meters along I-10 is not currently funded for design or construction. In addition, the scoping phase would typically address a future horizon year. Therefore, the BCA assumes that all ramp meters would be installed in 2025.

Benefit-Cost Analysis tools are available for purchase (ITS Deployment Analysis System (IDAS), for example) or for free (Tool for Operations Benefit Cost Analysis (TOPS-BC), for example). Since this study has collected project specific travel time and crash data, the BCA was based on guidance from the USDOT, typical ADOT costs, and benefits derived specific to this corridor.

4.4.1 Cost Analysis

Planning-level cost estimates were developed for the implementation of ramp metering along the I-10 corridor. These estimates include the ramp meter infrastructure such as poles, signal heads, foundations, pull boxes, conduit, conductors, signal controller and cabinet (and associated hardware), and loop detectors. In addition, the cost estimates include roadway improvements at three ramps (eastbound Prince Road and Miracle Mile, and westbound Speedway Boulevard) to provide additional storage. Since this study does not include conceptual design, it was assumed that approximately 500' of ramp length would be widened along each of the three ramps.

Based on discussion with ADOT TSMO staff, it is our understanding that fiber optic trunk lines currently exist along the I-10 corridor as well as the infrastructure to communicate with the ADOT Traffic Operations Center in Phoenix. Therefore, the cost estimates only include the infrastructure associated with the ramp meters and do not include the fiber optic backbone for FMS.

Table 23 shows a summary of the cost estimates. Additional information is provided in **Appendix D**.

Table 23: Cost Estimate Summary

Entrance Ramp	Direction	Cost Estimate
Prince Rd	EB	$550,000
Miracle Mile	EB	$650,000
Congress St	EB	$180,000
Ruthrauff Rd	WB	$160,000
Grant Rd	WB	$160,000
Speedway Blvd	WB	$550,000
Congress St	WB	$160,000
22nd St	WB	$160,000
Total		$2,570,000

4.4.2 Benefit Analysis

While the financial benefits may be derived from a few sources, the analysis for this study focused on crash reductions and travel time reductions.

4.4.2.1 Crash Reduction

The installation of ramp meters is anticipated to enhance traffic operations on the mainline in both the AM and PM peak periods. In the AM peak period, it is anticipated that traffic operations would improve in the eastbound direction of travel between Price Road and Grant Road. In the PM peak period, it is anticipated that traffic operations would improve in the westbound direction of travel between 22nd Street and Miracle Mile. As discussed in Section 2.2.2, ADOT provided crash data for the 5-year period from November 2012 through November 2017. **Table 24** shows the average annual severity of mainline crashes in these locations which were used to estimate the benefits associated with a reduction in crashes.

Table 24: Annual Average Mainline Crash Severity by Location

Location	No Injury	Possible Injury	Suspected Minor Injury	Suspected Serious Injury	Fatal	Total
Eastbound I-10 (AM peak period crashes between Prince Road and Grant Road)	22.2	1.6	2.4	0.4	0.2	26.8
	82.8%	6.0%	9.0%	1.5%	0.7%	
Westbound I-10 (PM peak period crashes between 22nd St and Miracle Mile)	67	10.2	6.4	1.0	0.4	85.0
	78.8%	12.0%	7.5%	1.2%	0.5%	

In accordance with the *Highway Safety Manual* (AASHTO, 2010), a crash modification factor (CMF) is used to compute the expected number of crashes after implementing a given countermeasure at a specific site. The Crash Modification Factor Clearinghouse is funded by the USDOT and includes all of the CMF's listed in the *Highway Safety Manual* as well as other research-based CMF's. The Crash Modification Factor Clearinghouse provides a CMF of 0.64 for the installation of ramp meters. This CMF is based on *Ramp Metering Influence on Freeway Operational Safety near On-ramp Exits* (International Journal of Transportation Science and Technology, 2013). This CMF was applied to the locations described above to estimate the benefit of crash reduction along I-10. Since the ramp meters would only be activated during the AM and PM peak periods, the calculation of the reduction in crashes accounted for the percentage of average daily crashes that occurred during these time periods.

Conversely, the installation of ramp meters could increase the frequency of crashes on the entrance ramps, especially rear-end crashes. **Table 25** shows the average annual severity of ramp crashes on the entrance ramps being considered in this analysis.

Table 25: Annual Average Entrance Ramp Crash Severity by Location

Entrance Ramp	Annual Average Crashes					
	No Injury	Possible Injury	Suspected Minor Injury	Suspected Serious Injury	Fatal	Total
Prince Rd Eastbound	0.6	0	0	0	0	0.6
Miracle Mile Eastbound	1.8	0	0	0	0	1.8
Congress Rd Eastbound	0.4	0	0	0	0	0.4
Ruthrauff Rd Westbound	0.4	0	0	0	0	0.4
Grant Rd Westbound	0.4	0	0	0	0	0.4
Speedway Blvd Westbound	0.8	0.2	0	0	0	1.0
Congress Rd Westbound	0	0.2	0	0	0	0.2
22nd St Westbound	0.2	0	0	0	0	0.2
Total	4.6	0.4	0	0	0	5.0
% of Total	92%	8%	0%	0%	0%	

The Crash Modification Factor Clearinghouse provides various CMF's for the installation of a traffic signal, with none being specific to the installation of a ramp meter. With the assumption that crashes would increase (many of the CMF's do show crash reductions for various types of crashes), the Crash Modification Factor Clearinghouse provides a CMF of 1.58 specific to rear-end crashes at a newly installed traffic signal. As shown in Table 23, 92% of the crashes on the ramps were classified as No Injury, which have a value of $3,200 in the benefit analysis. Therefore, given the very low frequency of crashes, and the severity of the crashes (nearly all are "no injury" crashes), this potential minor increase in crashes was not included in the analysis.

4.4.2.2 Travel Time Reduction

The VISSIM models were used to estimate changes in travel time along the I-10 corridor. The Build models only included network changes related to the installation of ramp meters, so it is assumed that a majority of the changes in travel times are related to the ramp meters. VISSIM is a microsimulation software which allows each individual driver to make "decisions" about car following distance, gap acceptance, etc., therefore mimicking real world travel conditions. However, this microsimulation depends upon a random process, so that each driver can be slightly different. Therefore, some stochasticity is to be expected in the results. To account for this, the travel time/speed changes in the Build models were only considered in the peak direction of travel which would have the ramp meters active. Therefore, travel time/speed changes were only quantified in the eastbound direction during the AM peak period and travel time/speed changes were only quantified in the westbound direction during the PM peak hour. **Table 26** summarizes the locations with a travel time increase/reduction in the 2032 AM peak period and **Table 27** summaries the locations with a travel time increase/reduction in the 2032 PM peak period. These travel time/speed changes were used to estimate the benefit of travel time reduction along I-10

Table 26: 2032 AM Peak Period Travel Times

Location	2032 No-Build travel time (minutes)	2032 Build travel time (minutes)	2032 travel time change (minutes)
EB I-10 Mainline Prince Off Ramp to Prince On Ramp	0.82	0.76	-0.06
EB I-10 Mainline Prince On Ramp to Miracle Mile Off Ramp	0.47	0.27	-0.20
EB I-10 Mainline Miracle Mile Off Ramp to Miracle Mile On Ramp	0.98	0.54	-0.44
EB I-10 Mainline Miracle Mile On Ramp to Grant Off Ramp	0.15	0.12	-0.03
EB Prince Rd On Ramp	0.31	2.59	+2.28
EB Miracle Mile On Ramp	0.17	2.97	+2.80

Table 27: 2032 PM Peak Period Travel Times

Location	2032 No-Build travel time (minutes)	2032 Build travel time (minutes)	2032 travel time change (minutes)
WB I-10 Mainline Project Begin to 22nd On Ramp	0.83	0.77	-0.06
WB I-10 Mainline 22nd On Ramp to Congress Off Ramp	0.18	0.15	-0.03
WB I-10 Mainline Congress Off Ramp to Congress On Ramp	1.20	0.97	-0.23
WB I-10 Mainline Congress On Ramp to Speedway Off Ramp	0.16	0.14	-0.02
WB I-10 Mainline Speedway Off Ramp to Speedway On Ramp	1.62	1.32	-0.30
WB 22nd St On Ramp	0.22	0.62	+0.40
WB Congress St On Ramp	0.19	0.76	+0.57
WB Speedway Blvd On Ramp	0.23	3.05	+2.82

4.4.3 BCA Results

The BCA was generally based on *guidance* provided in *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (USDOT, 2018). A number of assumptions were used in the analysis, including:

- Analysis period is 2025 to 2044, or 20 full years of operation
- Construction takes place in 2025
- All values are in 2018 dollars
- Approximately $9.6 million for fatality, $459,000 for incapacitating injury, $125,000 for non-incapacitating injury, $64,000 for possible injury, and $3,200 for non-injury crashes, based on USDOT guidance (in 2017 dollars)(these values were adjusted for future years)
- Value of time is $28.60 per hour (in 2017) for trucks and $14.80 per hour (in 2017) for autos, based on USDOT guidance (these values were adjusted for future years)
- Auto occupancy rate of 1.39 people (USDOT guidance)
- The net present value of future costs will be discounted at 3% and 7%
- Trucks are 100% business use and autos are 100% personal use
- O&M costs are 1% (per year) of initial capital costs starting in 2025
- Due to the nature of the asset (ramp meters), a residual value was not included
- The safety and travel time benefits were annualized over 270 days per year to account only for weekdays

The costs and benefits were annualized over the 20 year analysis period and converted to present dollars using both a 3% discount rate and a 7% discount rate. The results of this analysis are shown in **Table 28.** Additional information is provided in **Appendix E.**

Table 28: Benefit Cost Analysis Summary

	2018 Dollars (millions)	
	3% Discount Rate	**7% Discount Rate**
Costs		
Capital Costs	$ 2.09	$ 1.60
O&M Costs	$ 0.32	$ 0.18
Total Costs	***$ 2.41***	***$ 1.78***
Benefits		
Safety Savings	$ 11.06	$ 6.03
Travel Time Savings	$ 0.01	$ 0.00
Total Benefits	***$ 11.07***	***$ 6.03***
BC Ratio	**4.59**	**3.39**

The results of the BCA show that the monetized benefits exceed the costs. Based on the results of the VISSIM models, the I-10 mainline would experience a travel time savings within the vicinity of the ramp meters. However, the travel time increase on the ramps, or at other downstream locations on the mainline, results in a negligible net benefit in terms of travel time. A majority of the benefit is derived from the crash reduction on the mainline.

4.5 Implementation Plan

The warrant analysis shown in section 4.1 demonstrated that several entrance ramps south of Ruthrauff Road would warrant ramp meters by the year 2025 and none of the entrance ramps north of Ruthrauff Road would warrant the installation of ramp meters by the year 2032. Therefore, it is recommended that the first phase of implementation would occur on the south end of the corridor. Based on the results of this initial implementation (and future traffic demand), a future phase could implement ramp meters on the north end of the corridor.

Based on feedback from the Southcentral District and Southern Regional Traffic Engineering, they would prefer to install the ramps meters on successive/adjacent entrance ramps rather than having gaps without meters. Therefore, the recommended implementation plan is shown in **Table 29**.

Table 29: Ramp Meter Implementation Plan

Entrance Ramp	Implement Prior to 2025
Twin Peaks Rd	No
Cortaro Rd	No
Ina Rd	No
Orange Grove Rd	No
Sunset Rd	No
Ruthrauff Rd	**Yes**
Prince Rd	**Yes**
Miracle Mile	**Yes**
Grant Rd	**Yes**
Speedway Blvd	**Yes**
Congress St	**Yes**
22nd St	**Yes**

5.0 FRONTAGE ROAD-EXIT RAMP INTERFACE

As part of a separate on-going study, ADOT is developing guidelines for traffic control at the interface between a frontage road and an exit ramp. *Draft Working Paper #2, Frontage Road Traffic Control Guidelines* (ADOT) (see Appendix F) were used to evaluate the traffic control at the exit ramps within the study area. The following is a description of the preliminary guidelines from the above referenced document:

1. A STOP (R1-1) sign should not be recommended on multi-lane frontage roads.
2. If the weaving distance (distance between tip of striped gore to the beginning of the solid white stripe at the arterial street intersection) is less than 300 feet, consider restriping the striped gore, where physically possible, to provide a weaving distance of 300 feet or more.
3. For single lane frontage roads with a weaving distance of less than 300 feet, and after confirmation of STEP 2, a STOP sign shall be installed.
4. For two lane frontage roads with a weaving distance of less than 300 feet, and after confirmation of STEP 2, a traffic volume analysis shall be completed to determine if the two lanes should be merged into one lane based on the following criteria, then, install a STOP sign.
   - Number of lanes and traffic volumes upstream and downstream of the striped gore where frontage road merges with the exit ramp,
   - Signal timing at the arterial street intersection to determine if any existing traffic volume backups can/cannot be mitigated by adjusting the signal timing,
   - Crashes associated with weaving vehicles between the physical gore and arterial street intersection,
   - Presence of driveways between the physical gore and the arterial street intersection ensure that there are no driveway conflicts,
   - Sight visibility is adequate etc.
5. If the weaving distance for a two-lane frontage road cannot be increased/expanded to 300 feet per STEP 2, and if the traffic analysis determines that the two-lane frontage roads cannot be merged into one lane, then a YIELD (R1-2) sign shall be installed.
6. If the weaving distance is between 300 feet and 700 feet for both one lane and two-lane frontage roads, install YIELD signs.
7. If the weaving distance is between 700 feet (750 feet per document referenced above but changed to match step 6 above) and 1,000 feet and there are no sight restrictions for both one lane and two-lane frontage roads, further crash analysis shall be performed to determine if a YIELD sign is warranted or if no traffic control sign shall be recommended.
8. If the weaving distance is greater than 1,000 feet for both one lane and two-lane frontage roads, no traffic control sign is recommended.

Based on these preliminary guidelines (subject to change), a summary of the recommendations is provided below with specific exit ramps shown in **Table 30**.

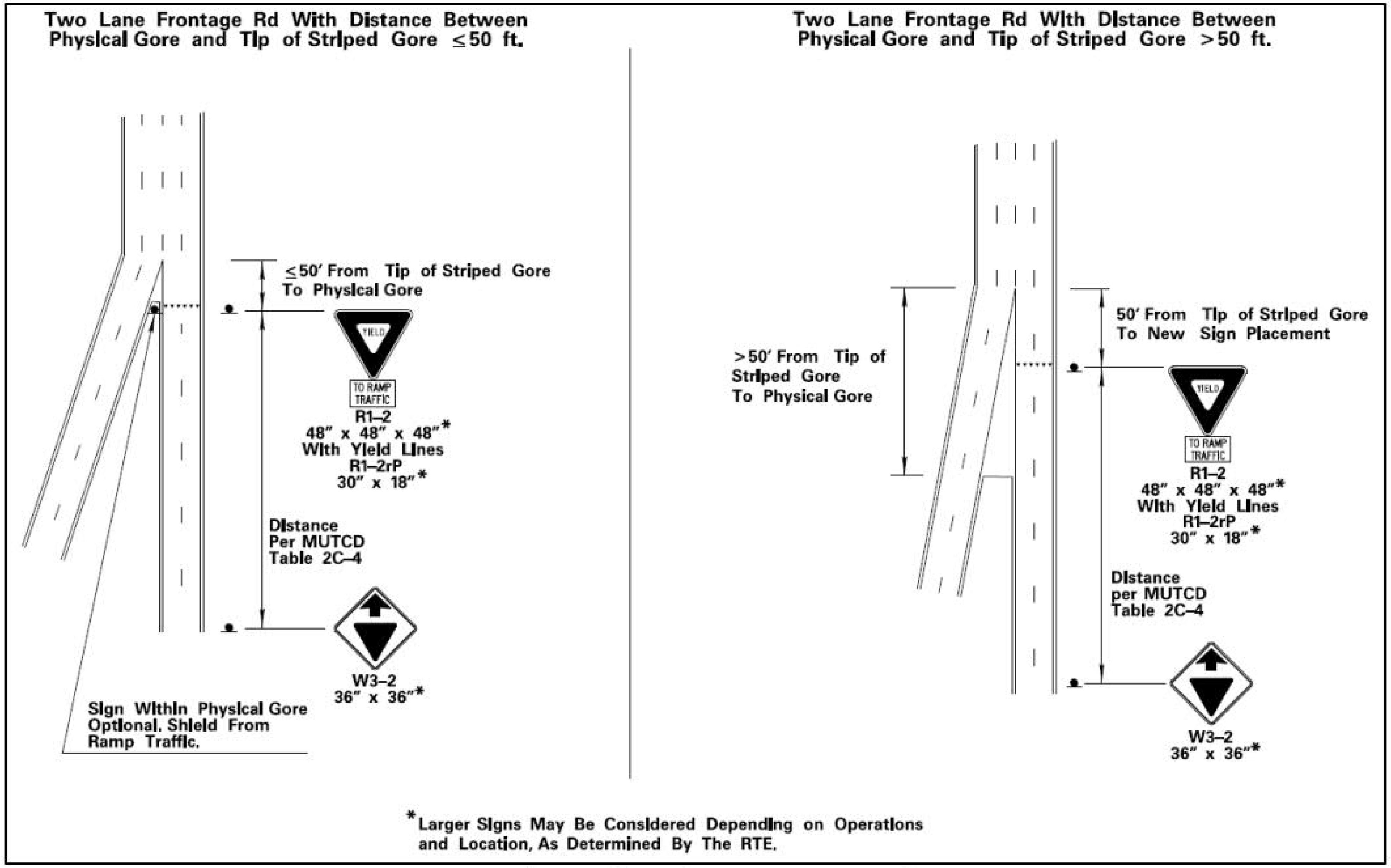
- Restripe gore at 9 locations
- Restripe gore and possibly reduce storage length at 1 location
- Consider reduction to 1 lane at the EB Miracle Mile exit; based on the traffic volumes available from ADOT that were used for this study, this location has a weaving area < 300' and may have traffic volumes low enough to consider 1 lane with a stop sign
- Keep the yield control at all other locations
- Update the pavement marking per the new guidelines (see Figure 13)
- Relocate/update the signing per the new guidelines (see Figure 13)

Table 30: Frontage Road/Exit Ramp Recommendations

Location	Weave length (ft)	Striped Gore Length (ft)	# Frt Rd lanes	Recommended Control	Striped Gore
Eastbound					
Twin Peaks Rd	570	210	2	Yield	No changes
Cortaro Rd	570	460	2	Yield	**Restripe gore**
Ina Rd	Currently under construction				
Orange Grove Rd	420	280	2	Yield	**Restripe gore**
Sunset Rd	360	280	2	Yield	**Restripe gore**
Ruthrauff Rd	300	350	2	Yield	**Restripe gore**
Prince Rd	350	360	2	Yield	**Restripe gore**
Miracle Mile	180	350	2	**Consider reduce to 1 lane and add Stop sign**	**Restripe gore**
Grant Rd	250	180	2	Yield	No changes -gore already tapered
Speedway Blvd	320	410	2	Yield	**Restripe gore**
Congress Rd	100	150	2	Yield	No changes - gore already tapered
22nd St	240	160	2	Yield	No changes - gore already tapered
Westbound					
22nd St	N/A				
Congress Rd	250	310	2	Yield	**Restripe gore**
Speedway Blvd	250	270	2	Yield	No changes - gore already tapered
Grant Rd	470	270	2	Yield	No changes - gore already tapered
Miracle Mile	190	130	2	Yield	**Consider reduction to storage length and restriping gore**
Prince Rd	490	200	2	Yield	No changes
Ruthrauff Rd	700	430	2	Yield	No changes
Sunset Rd	800	370	2	Yield	No changes
Orange Grove Rd	860	250	2	Yield	No changes
Ina Rd	Currently under construction				
Cortaro Rd	510	350	1	Yield	No changes
Twin Peaks Rd	320	450	2	Yield	**Restripe gore**

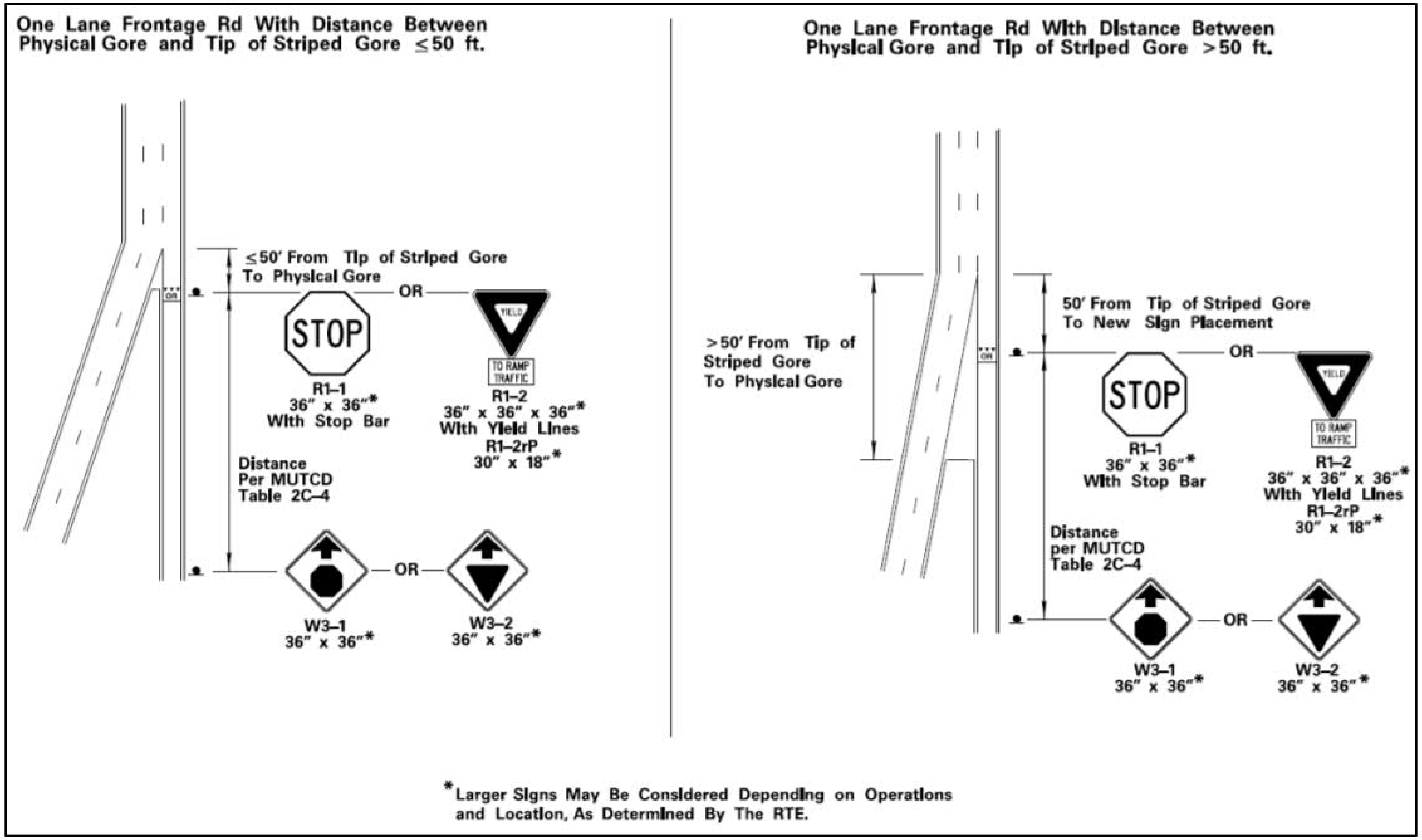
Figure 13 shows the preliminary signing and pavement marking guidelines from Draft Working Paper #2 (subject to change).

Figure 13: Frontage Road/Exit Ramp Signing



Source: Central District Frontage Road Traffic Control Study; Draft Working Paper #2, Frontage Road Traffic Control Guidelines (ADOT)

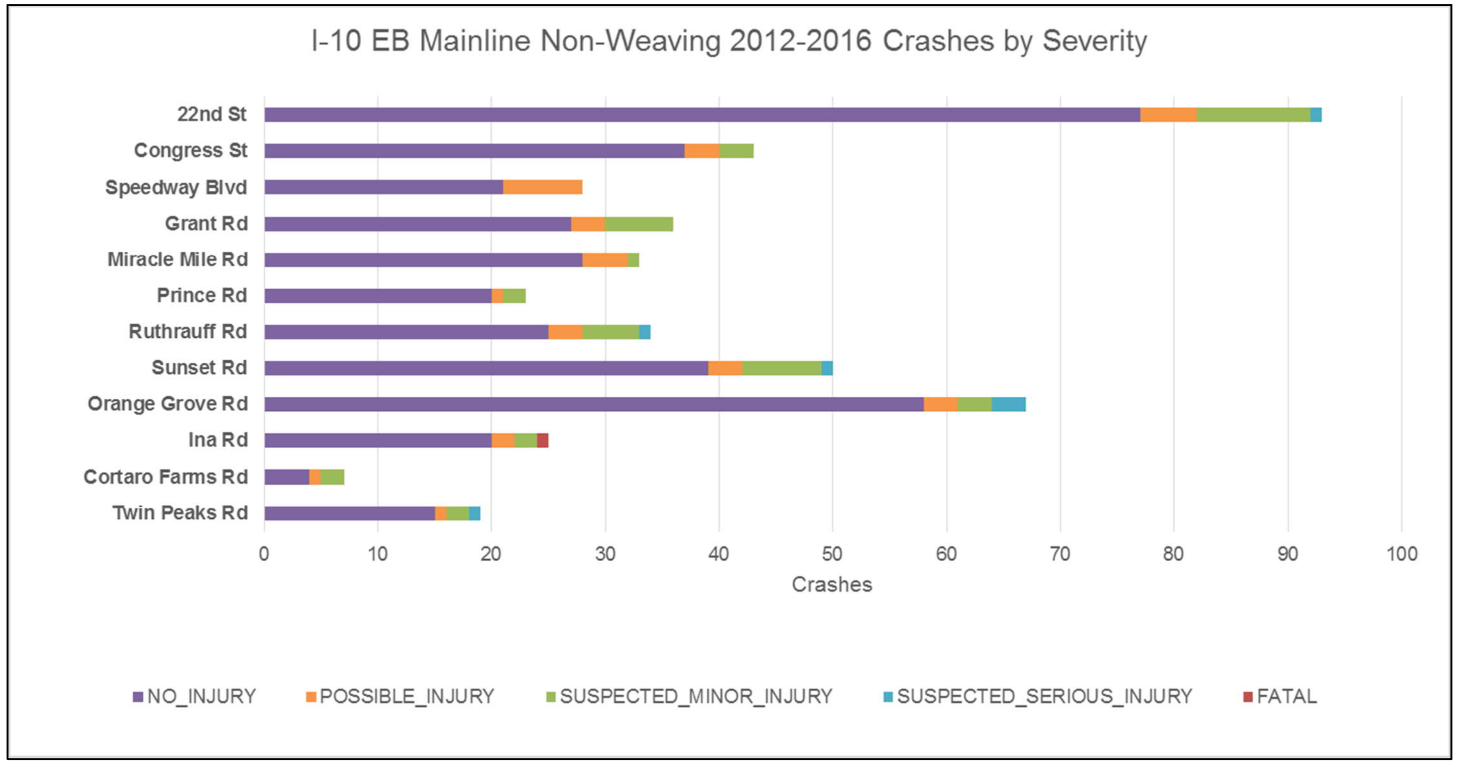
Figure 13: Frontage Road/Exit Ramp Signing - continued

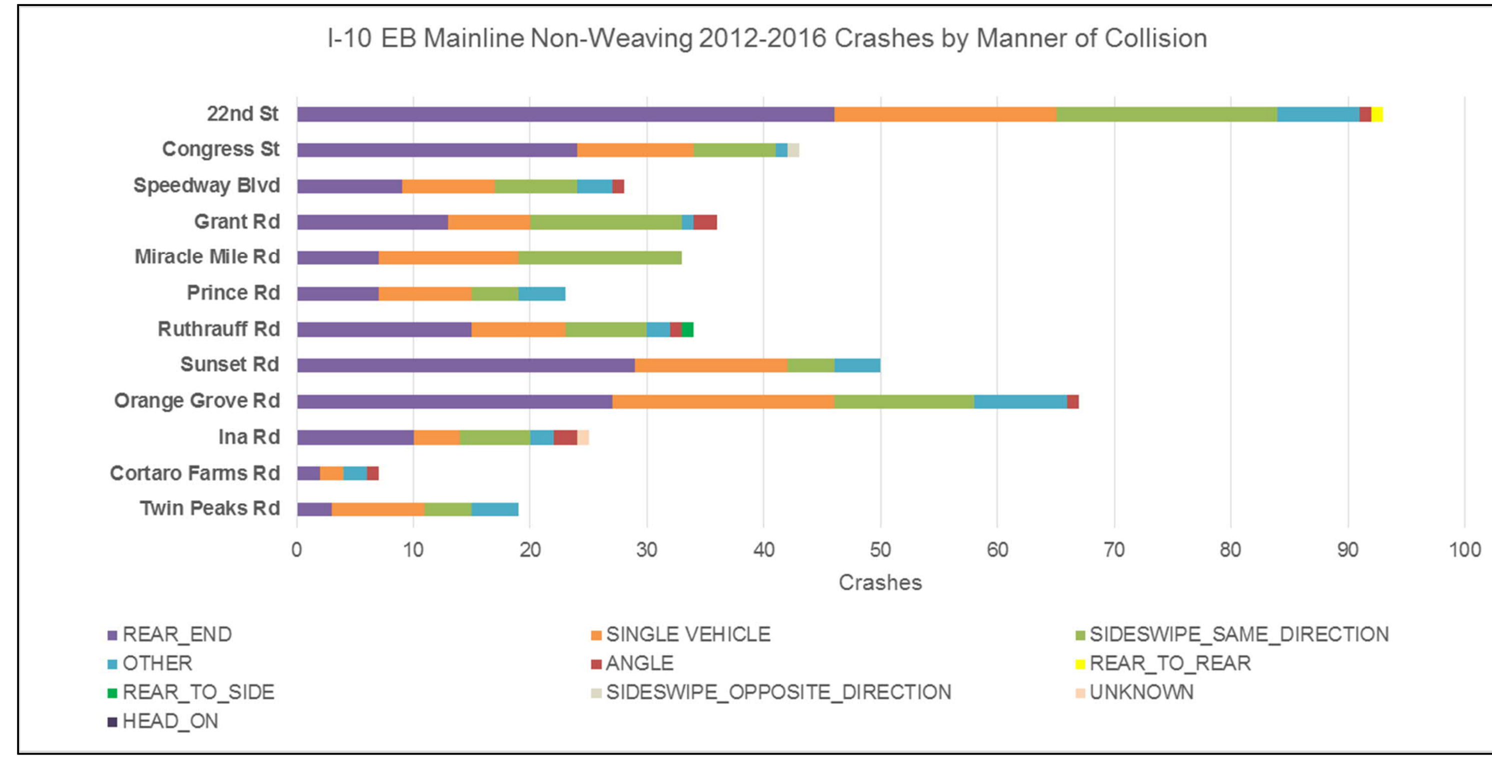


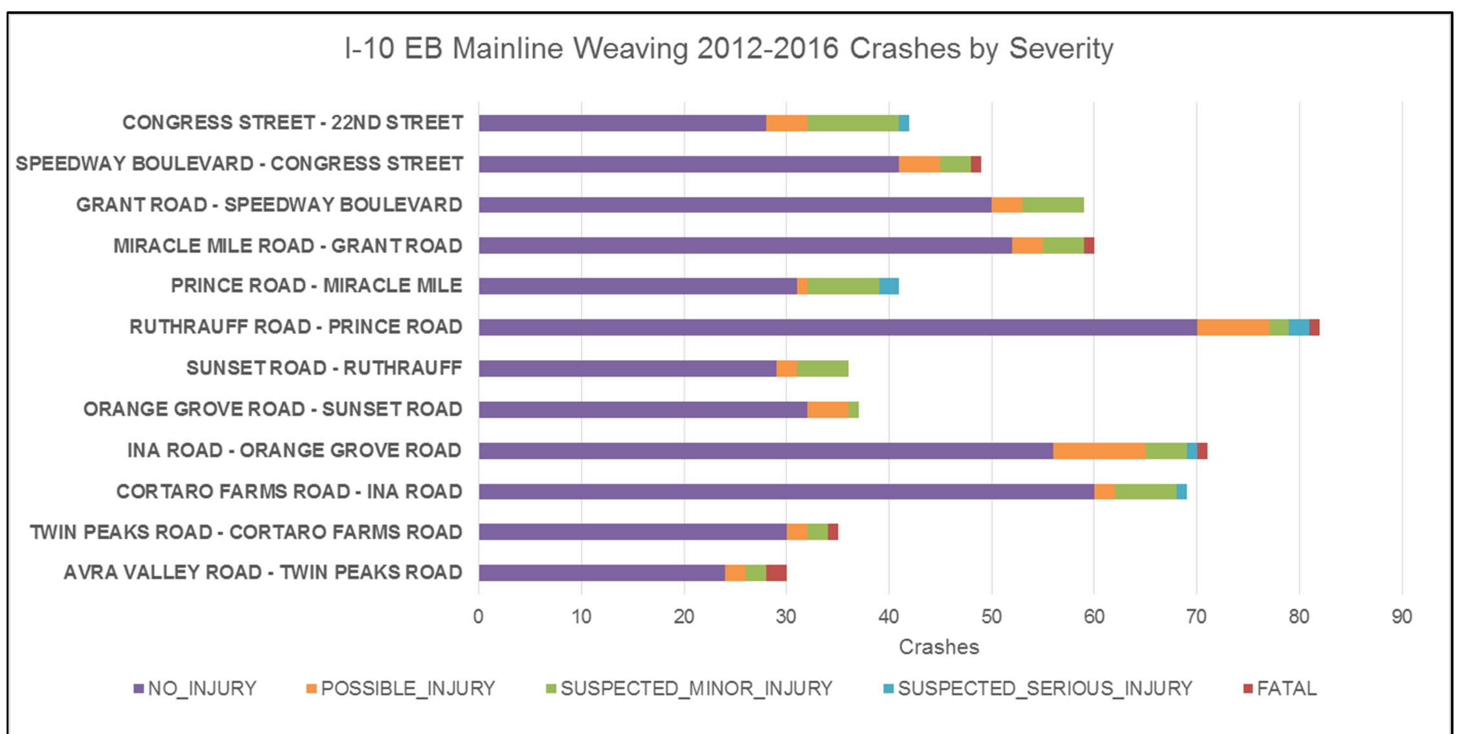
Source: Central District Frontage Road Traffic Control Study; Draft Working Paper #2, Frontage Road Traffic Control Guidelines (ADOT)

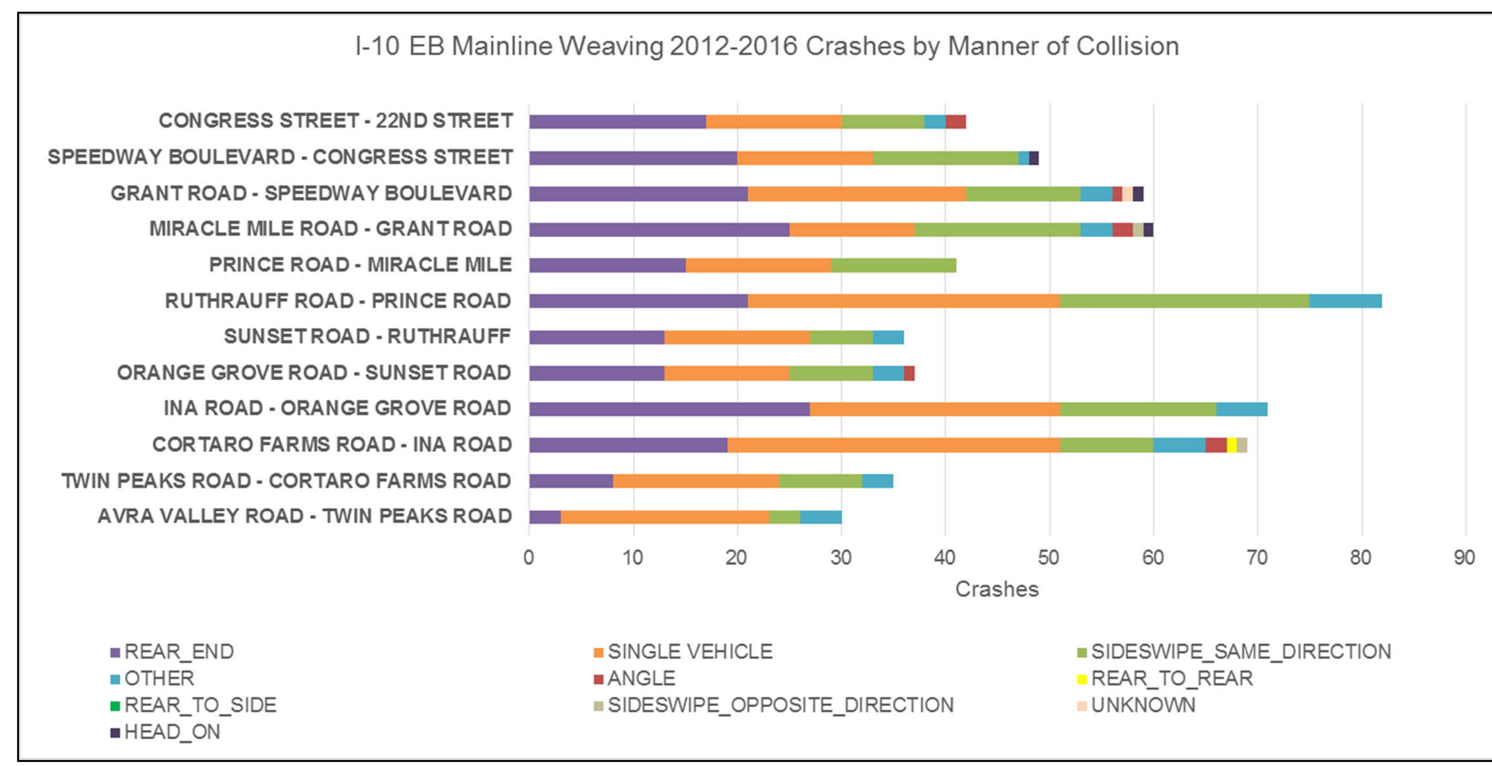
APPENDIX A – CRASH FREQUENCIES ALONG THE MAINLINE

Eastbound I-10

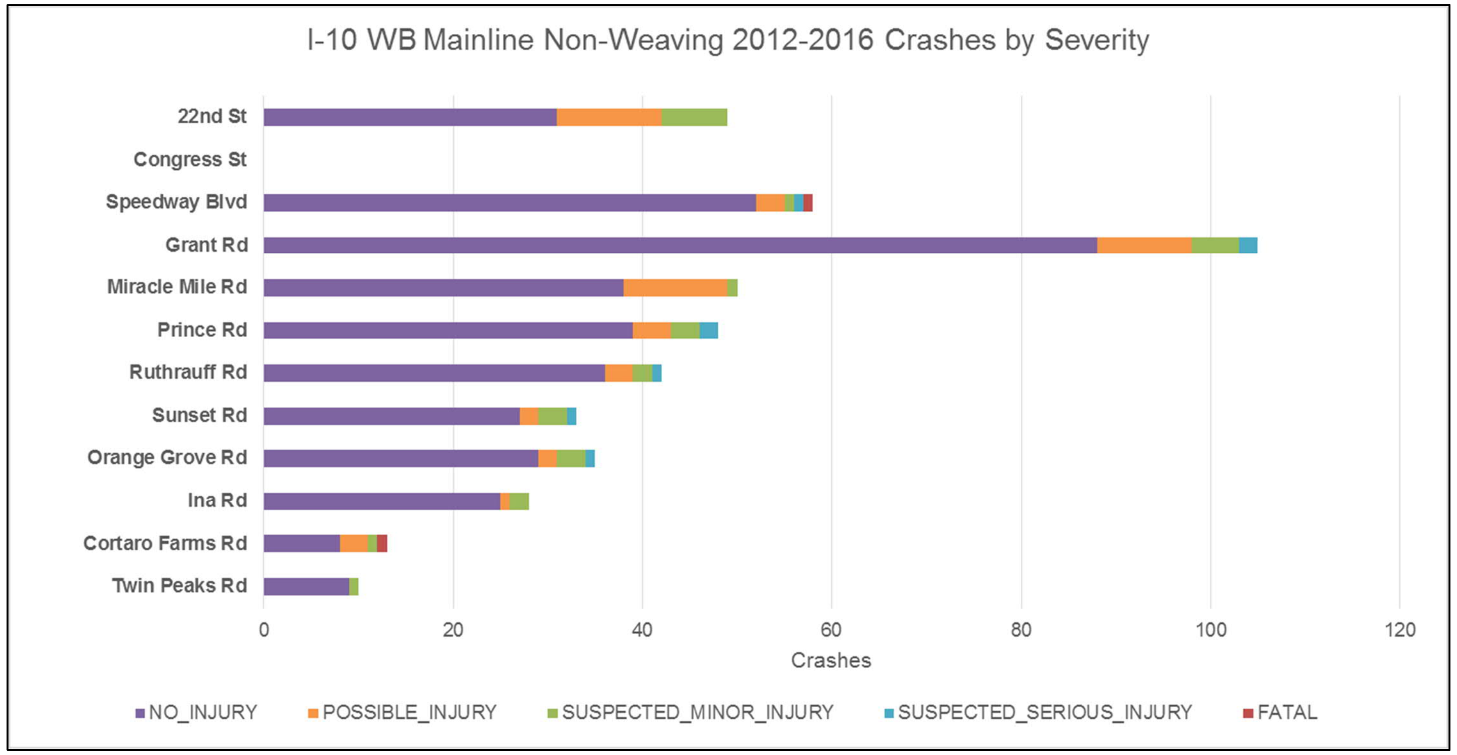


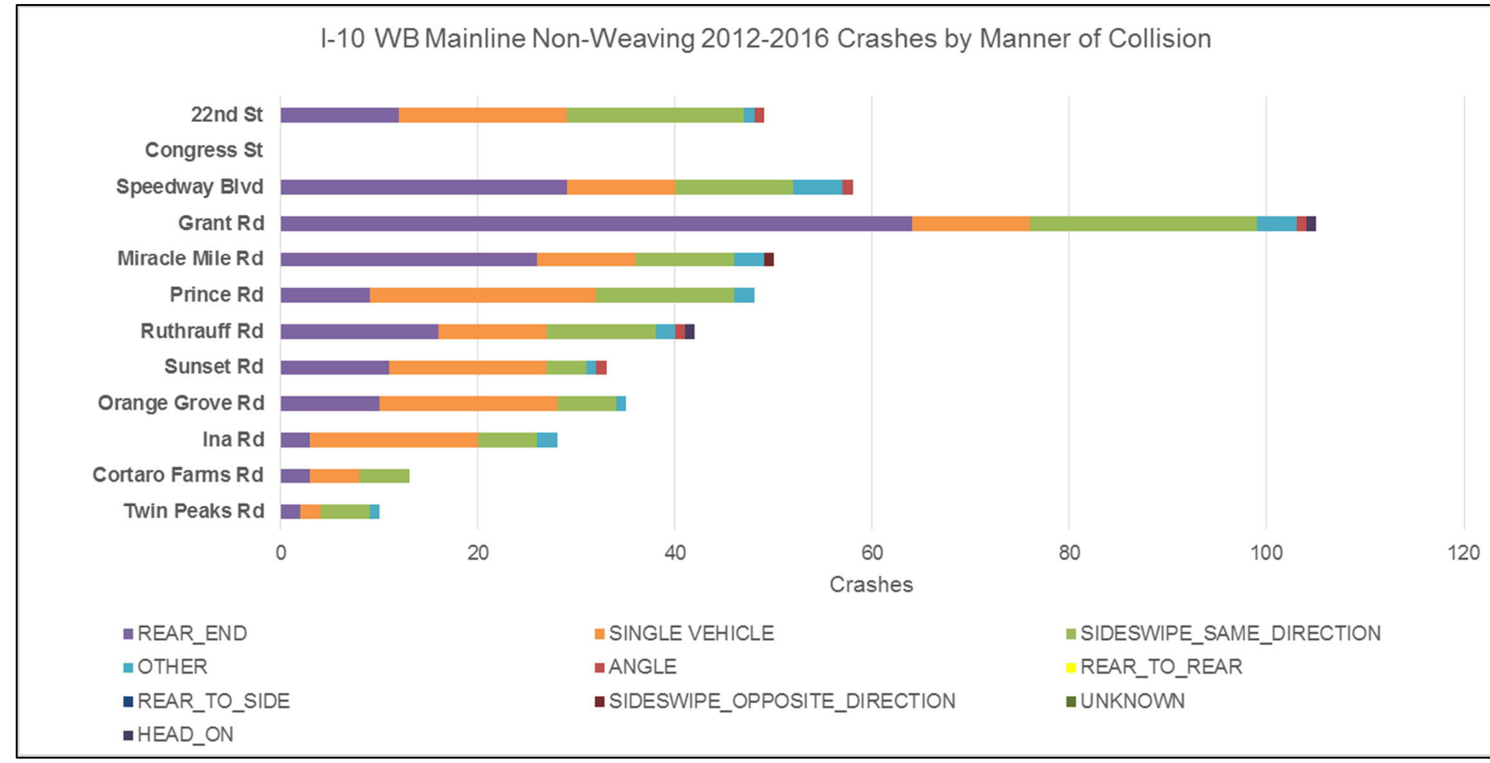


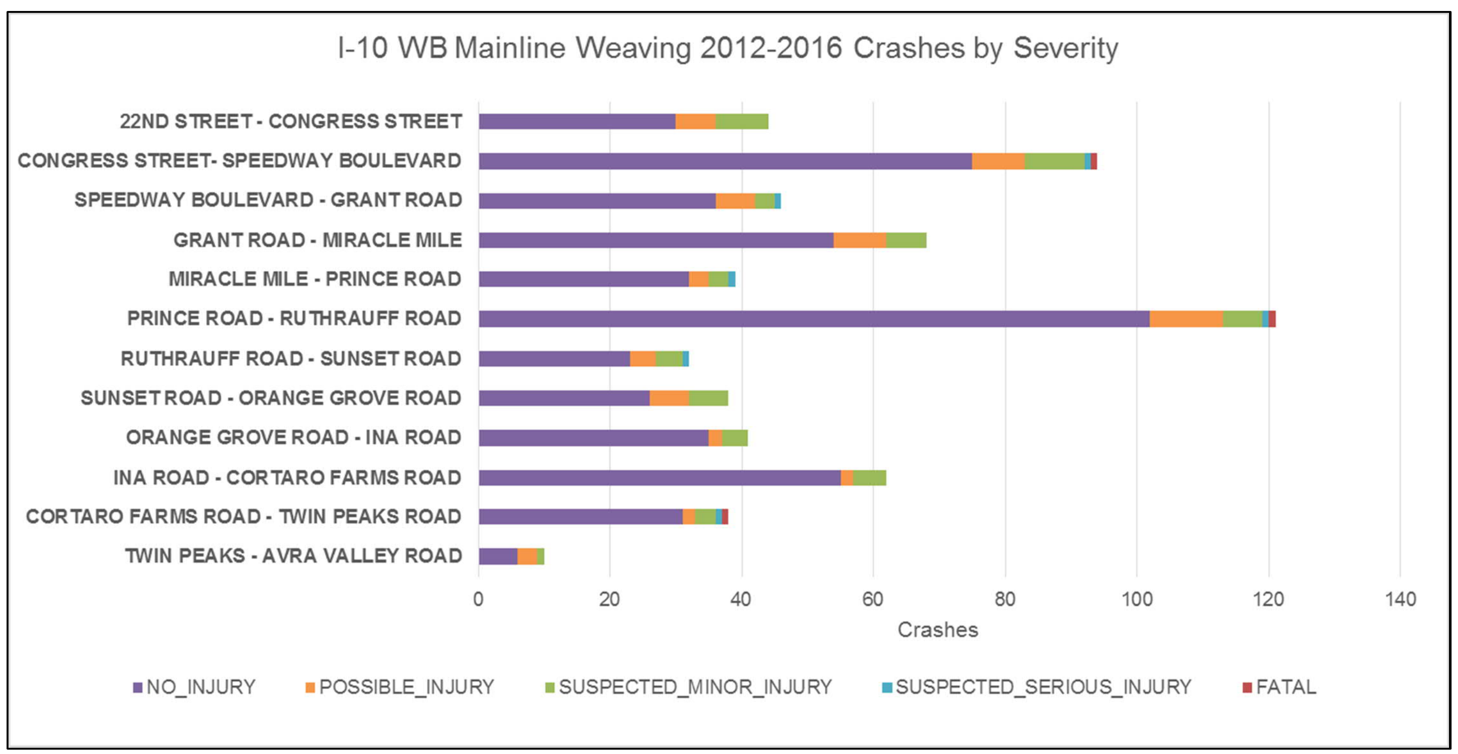


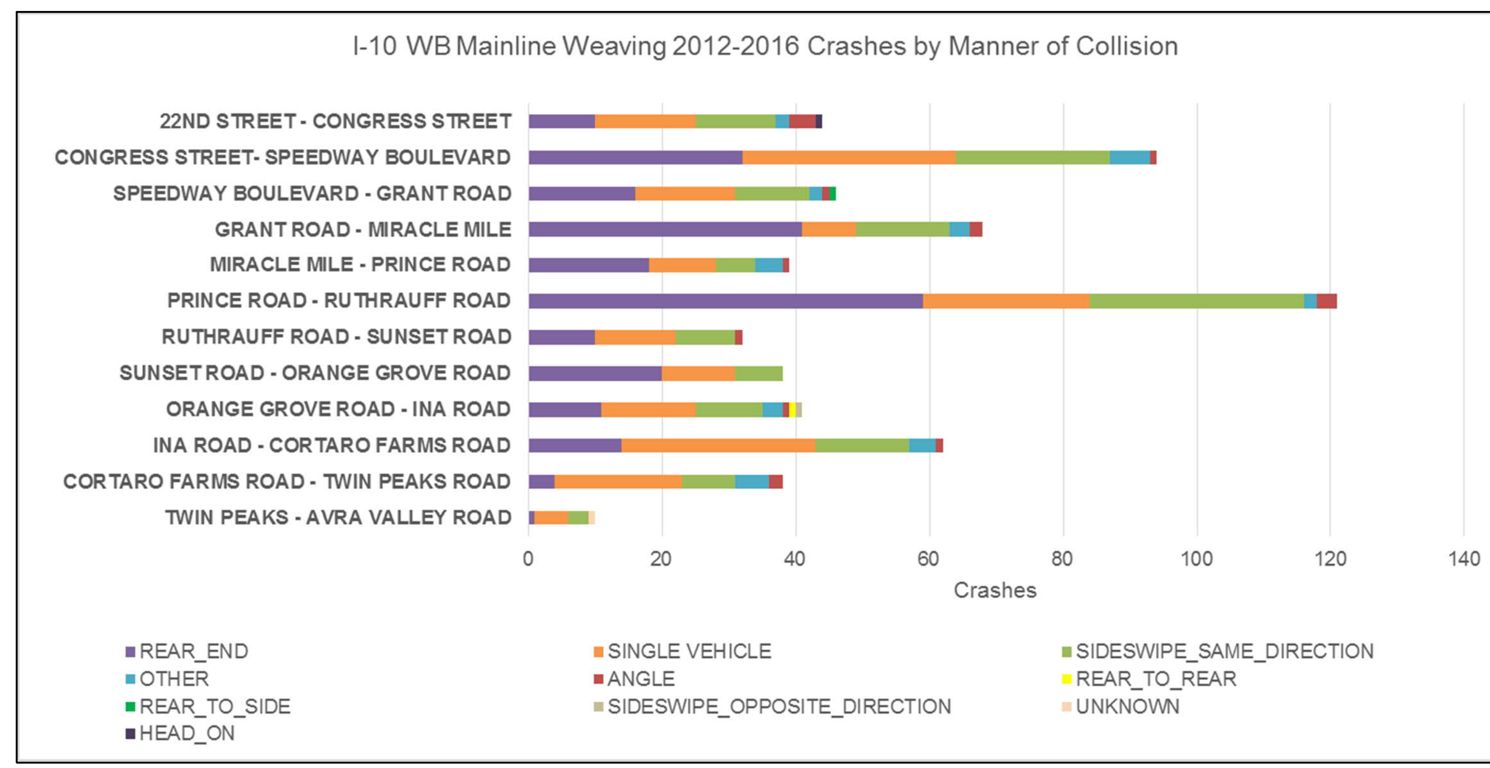


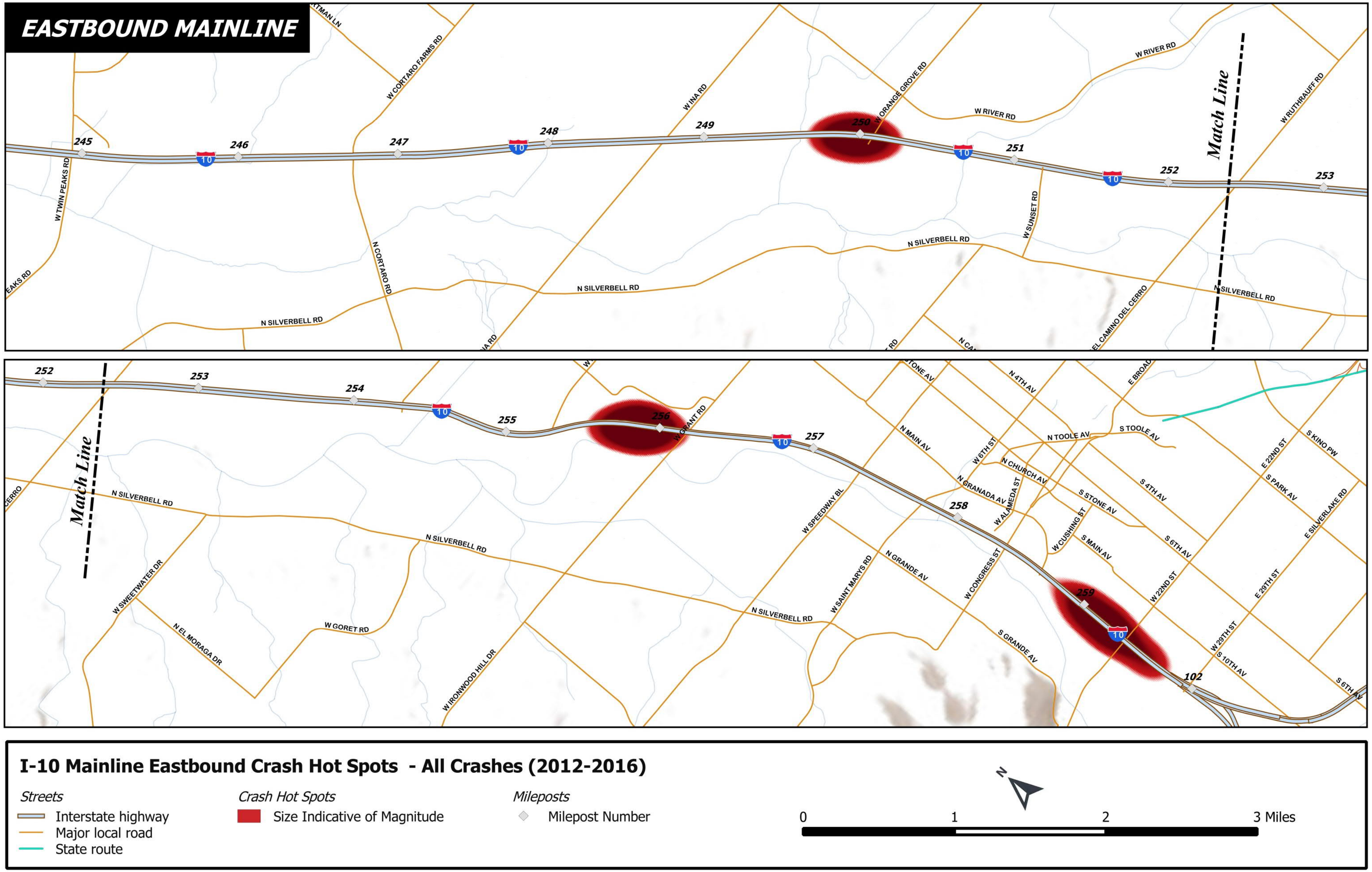
Westbound I-10

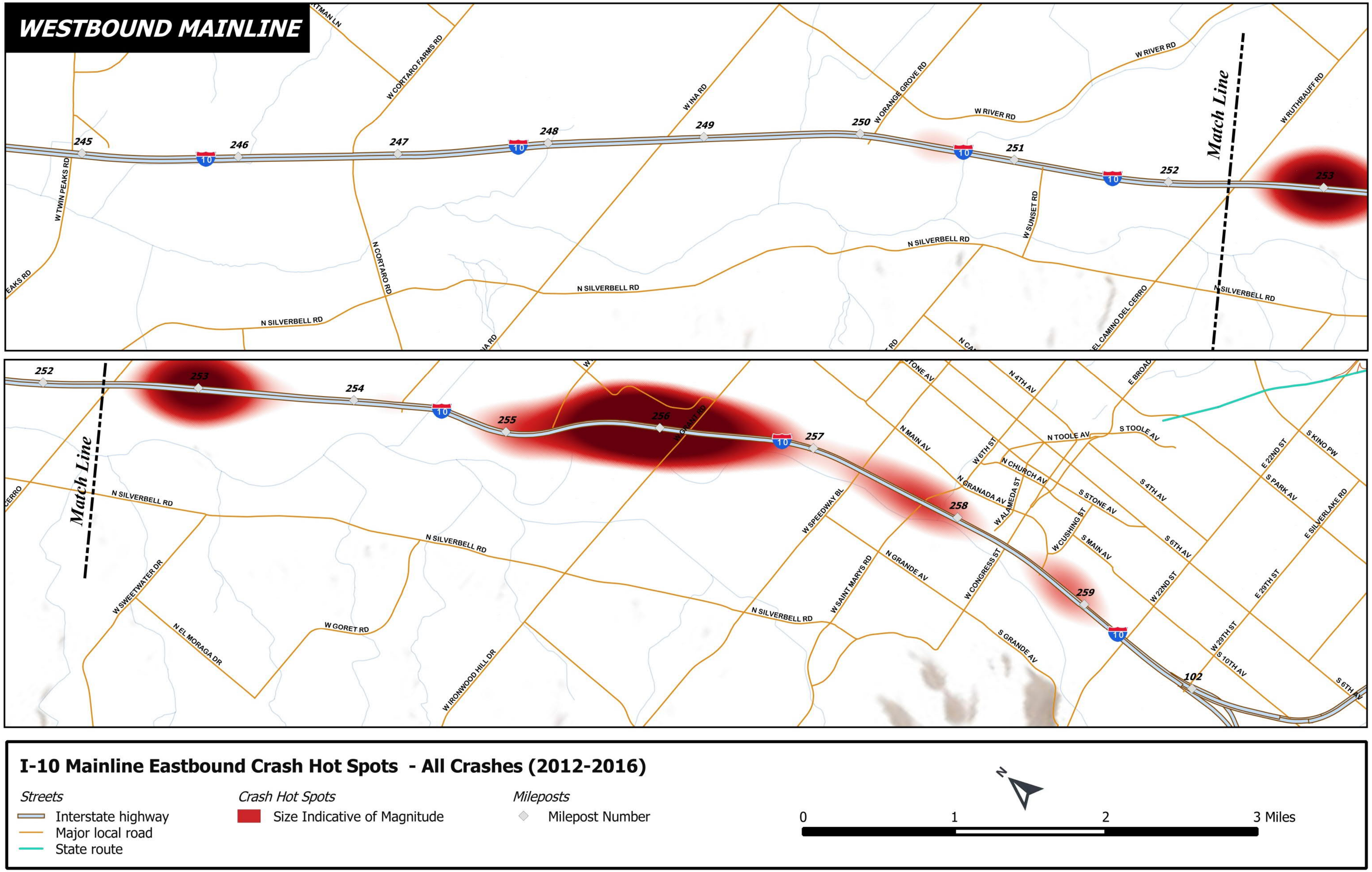






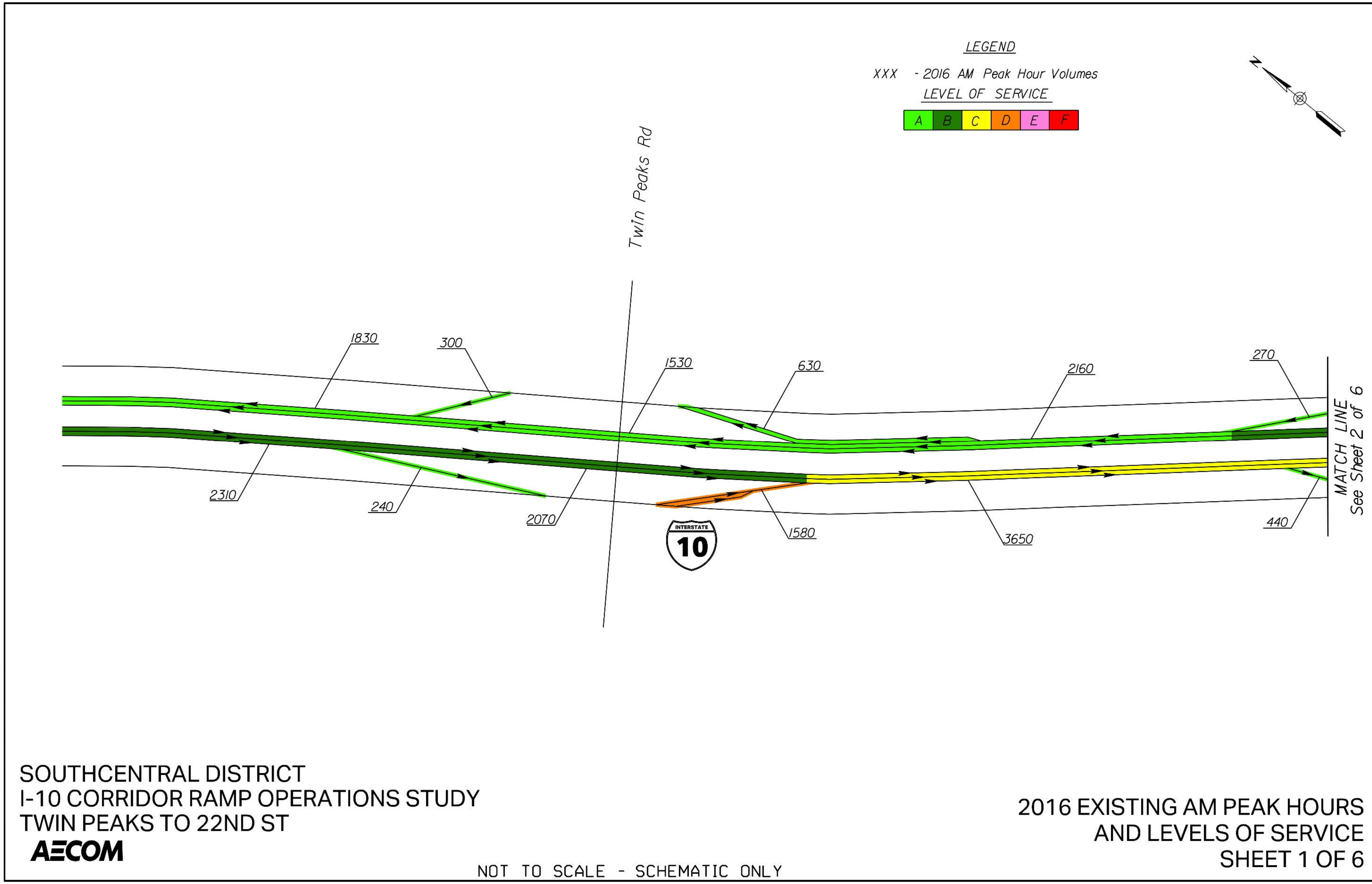



EASTBOUND MAINLINE
Match Line
I-10 Mainline Eastbound Crash Hot Spots - All Crashes (2012-2016)
Streets
Interstate highway
Major local road
State route
Crash Hot Spots
Size Indicative of Magnitude
Mileposts
Milepost Number
0
1
2
3 Miles
N

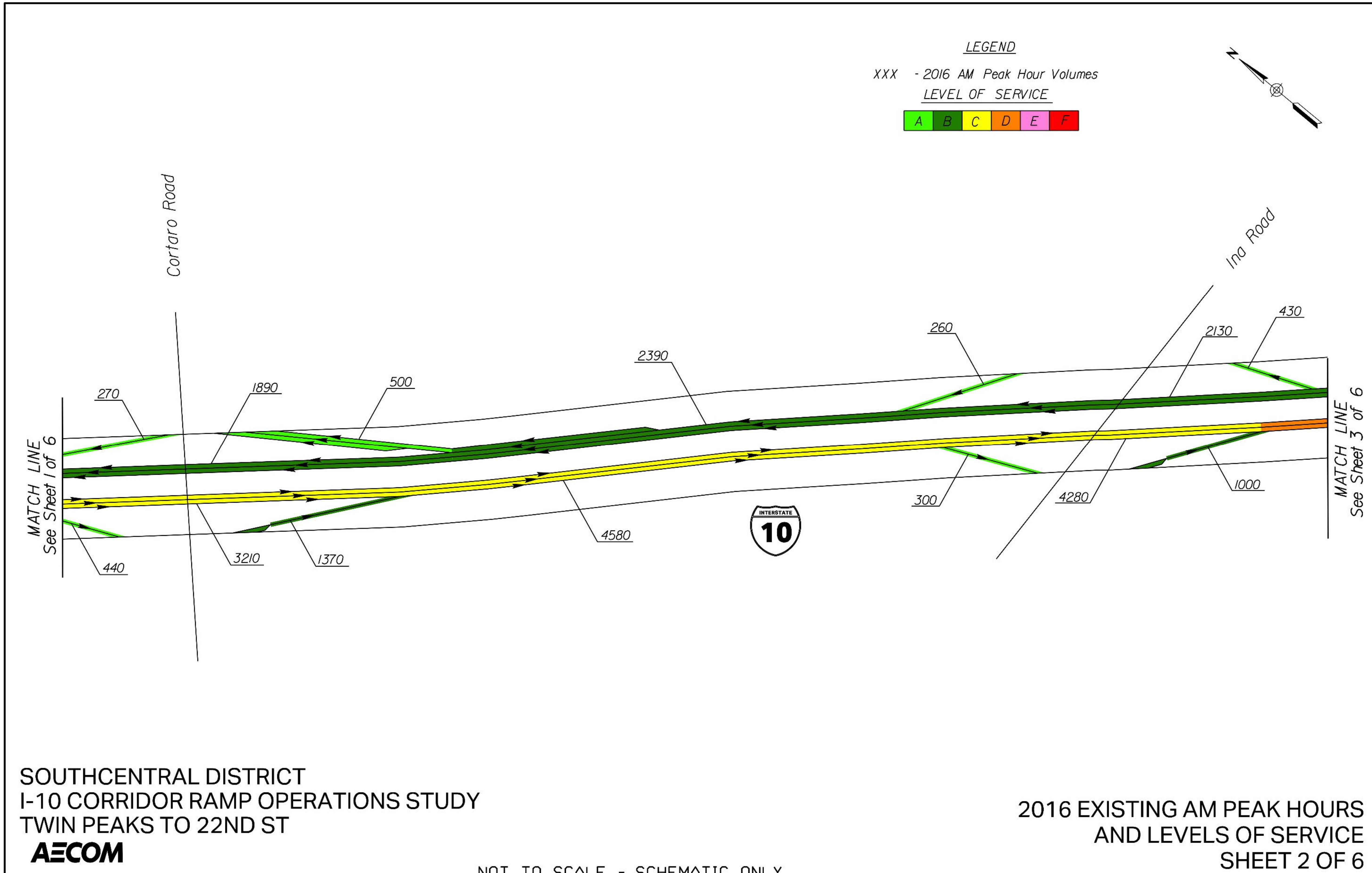

WESTBOUND MAINLINE
Match Line
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
102
W TWIN PEAKS RD
W CORTARO FARMS RD
N CORTARO RD
W INA RD
W ORANGE GROVE RD
W RIVER RD
W SUNSET RD
N SILVERBELL RD
EL CAMINO DEL CERRO
W RUTHRAUFF RD
W SWEETWATER DR
N EL MORAGA DR
W GORET RD
W IRONWOOD HILL DR
W SPEEDWAY BL
W SAINT MARYS RD
N GRANDE AV
S GRANDE AV
W CONGRESS ST
N MAIN AV
W 6TH ST
N GRANADA AV
W ALAMEDA ST
N CHURCH AV
N TOOLE AV
S TOOLE AV
N 4TH AV
E BROADWAY
S STONE AV
W CUSHING ST
S MAIN AV
S 4TH AV
S 6TH AV
W 22ND ST
W 29TH ST
S 10TH AV
E 22ND ST
S PARK AV
S KINO PW
E 29TH ST
E SILVERLAKE RD
I-10 Mainline Eastbound Crash Hot Spots - All Crashes (2012-2016)
Streets
Interstate highway
Major local road
State route
Crash Hot Spots
Size Indicative of Magnitude
Mileposts
Milepost Number
0
1
2
3 Miles
N

APPENDIX B – EXISTING AND FUTURE NO-BUILD LOS RESULTS

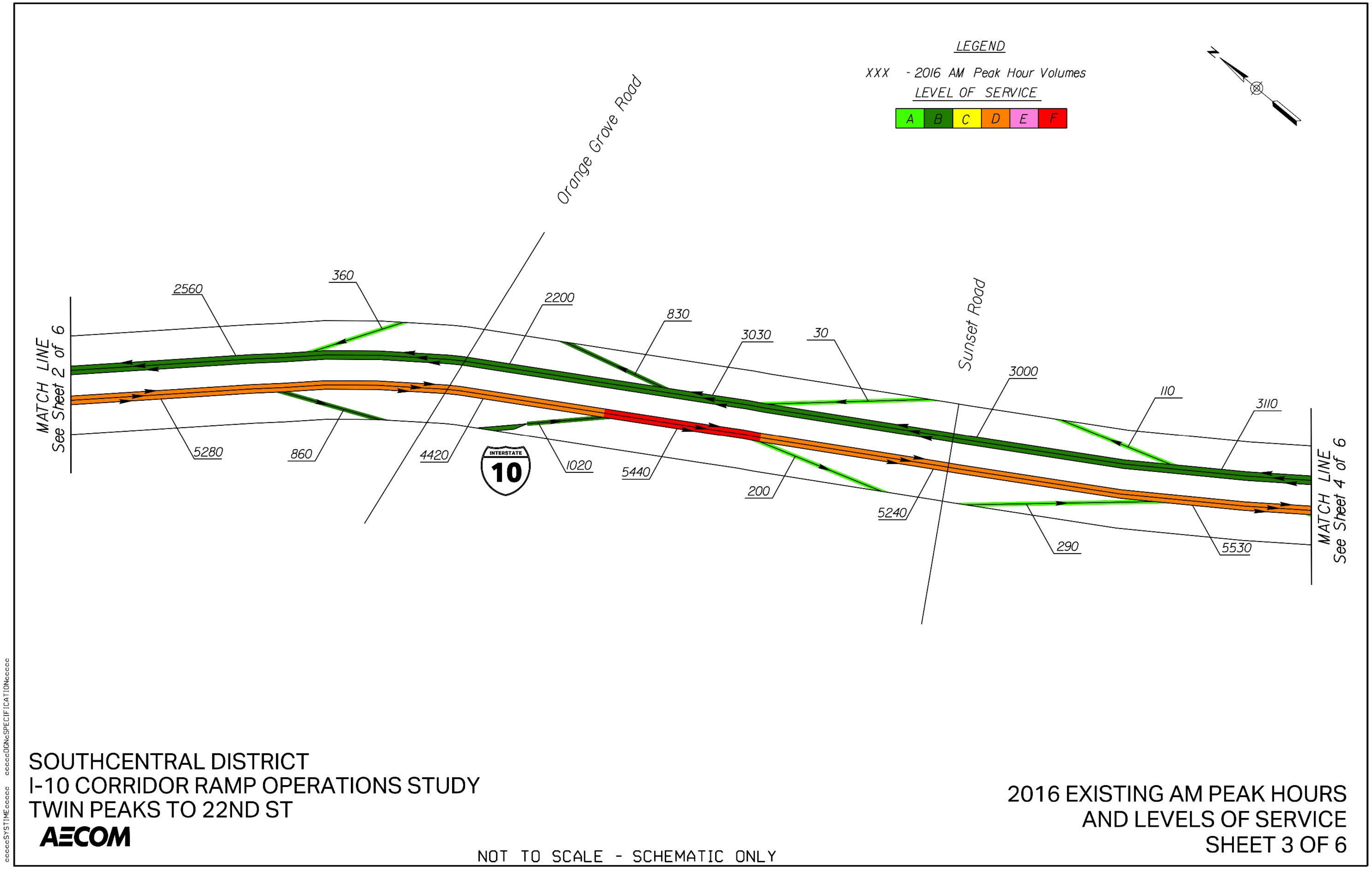
2016 AM Peak Hour LOS Results



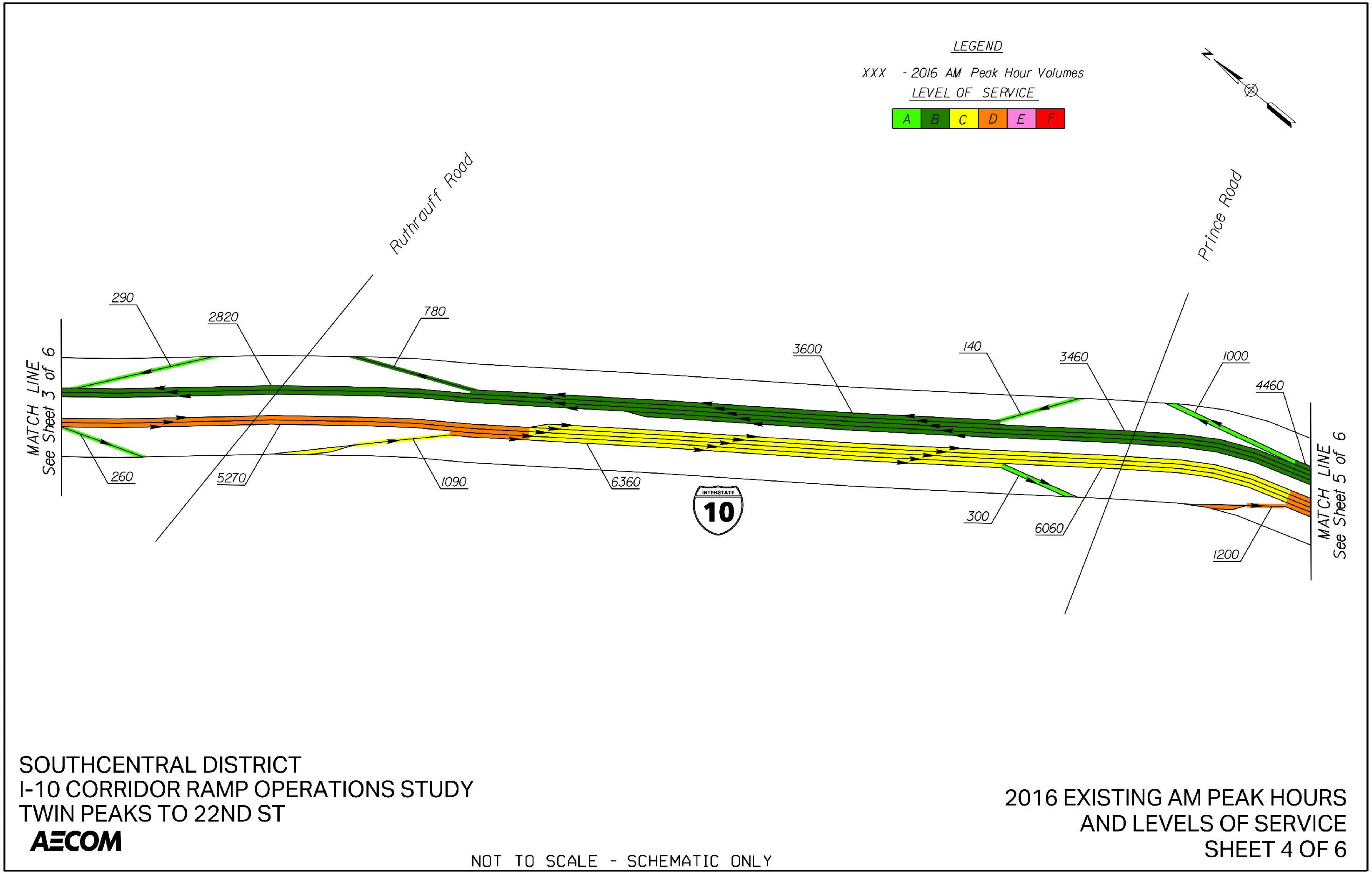
2016 AM Peak Hour LOS Results (continued)

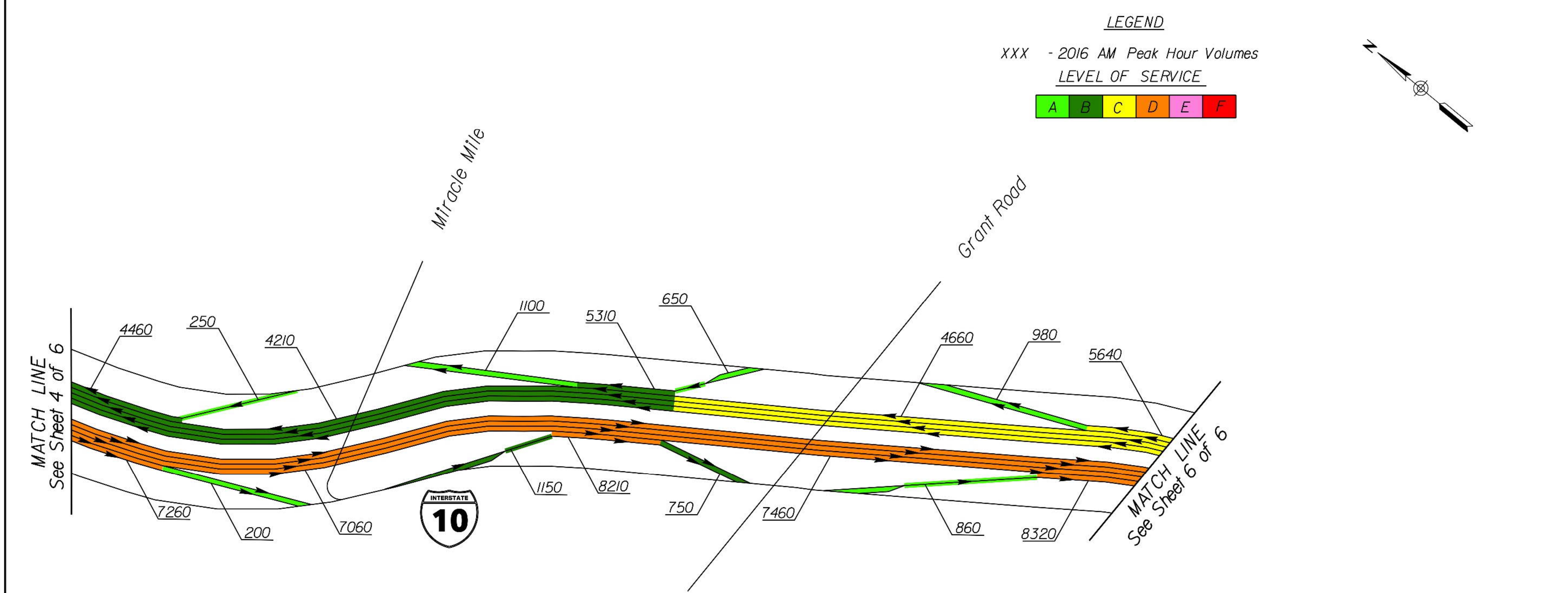


2016 AM Peak Hour LOS Results (continued)



2016 AM Peak Hour LOS Results (continued)





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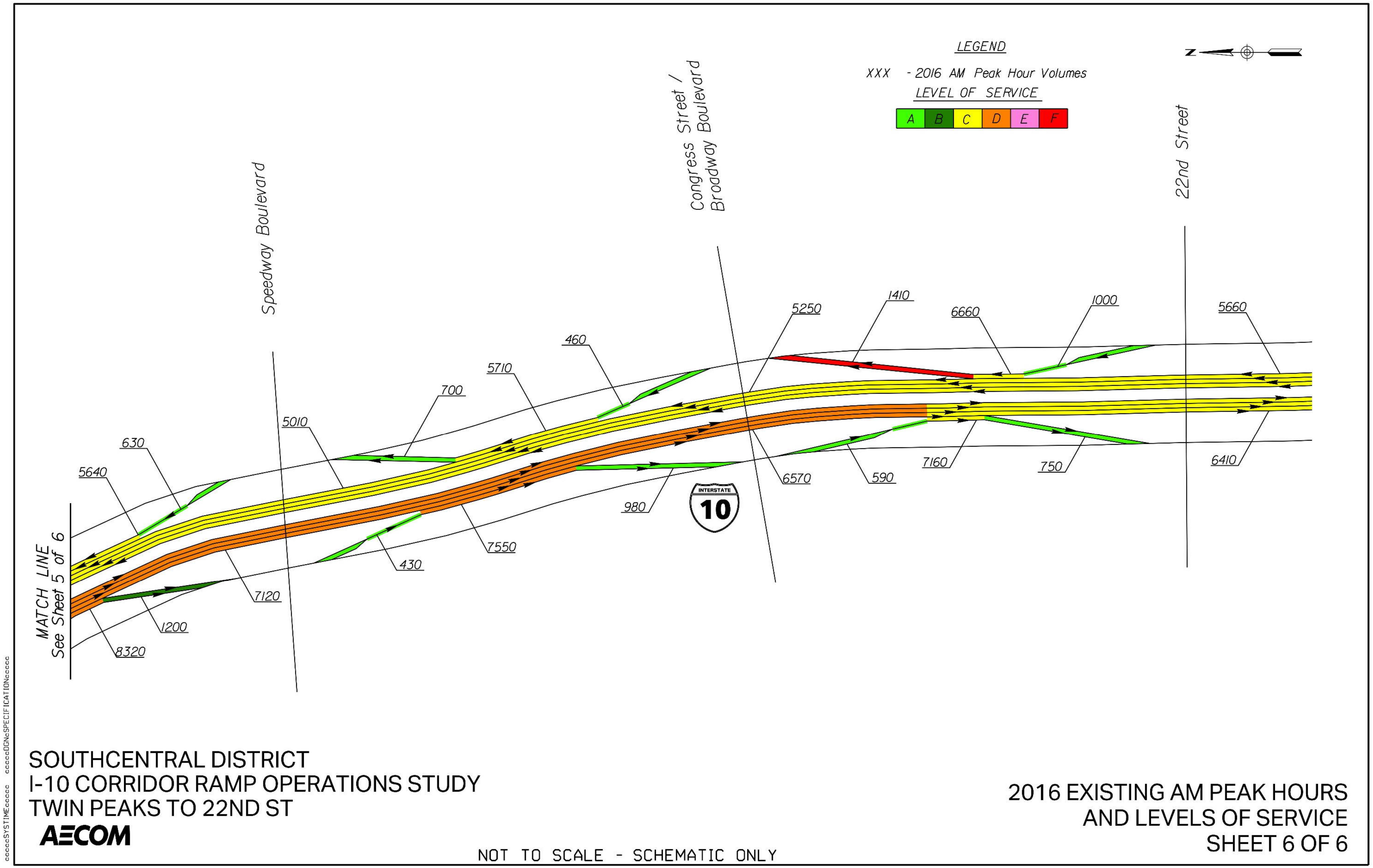
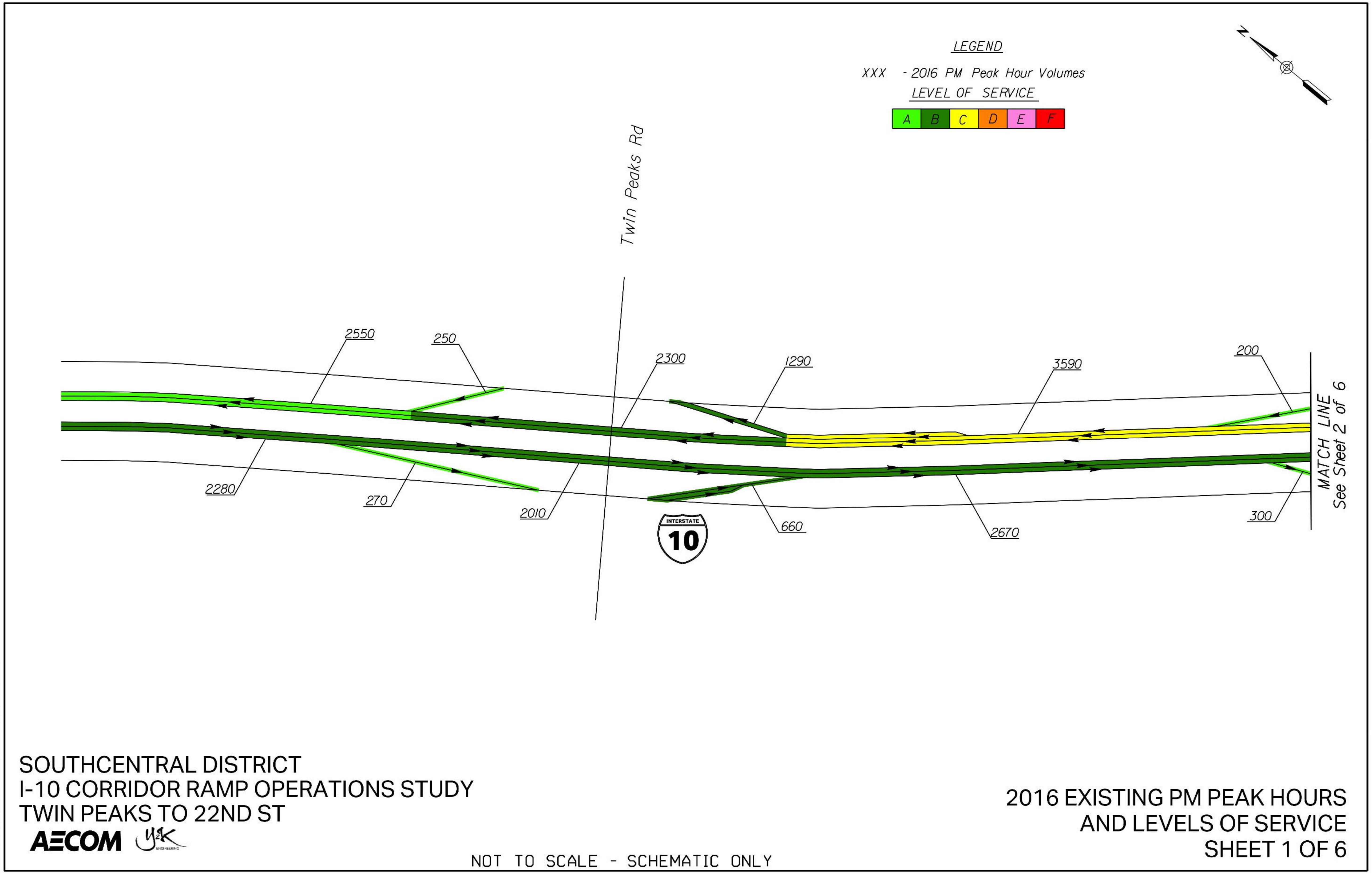
ccccSYSTIMEcccc ccccDGNcSPECIFICATIONcccc

2016 AM Peak Hour LOS Results (continued)



2016 PM Peak Hour LOS Results



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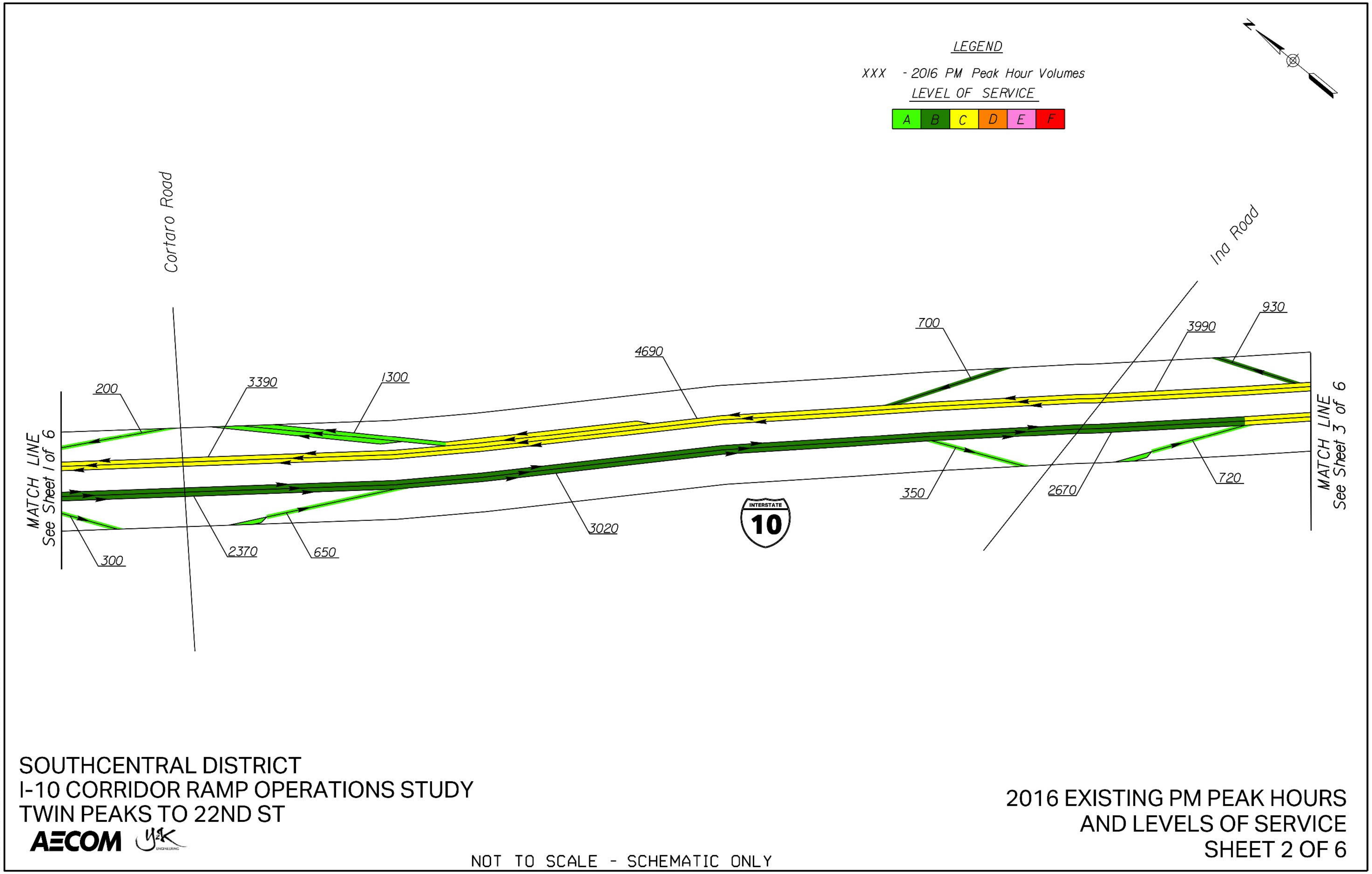
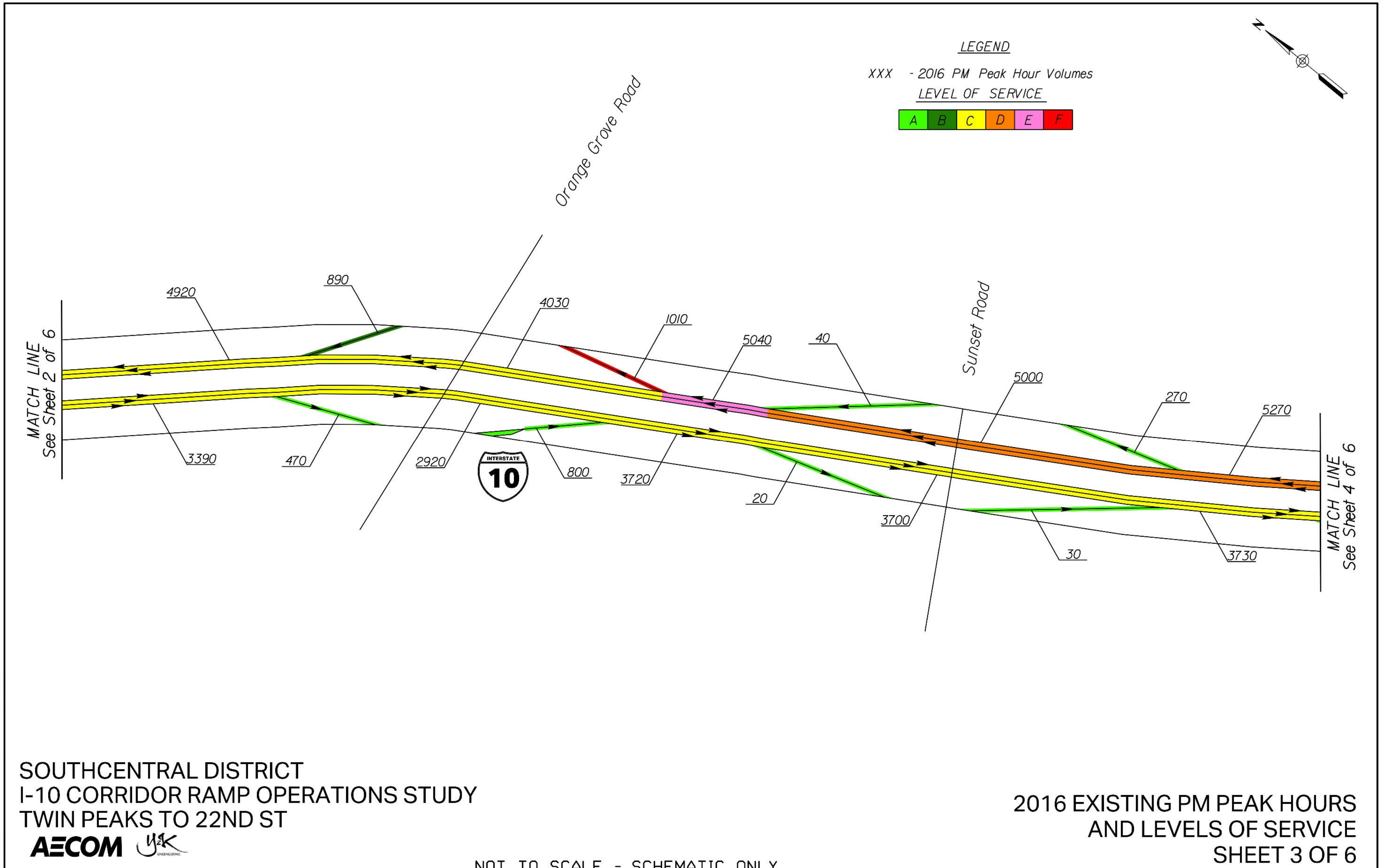
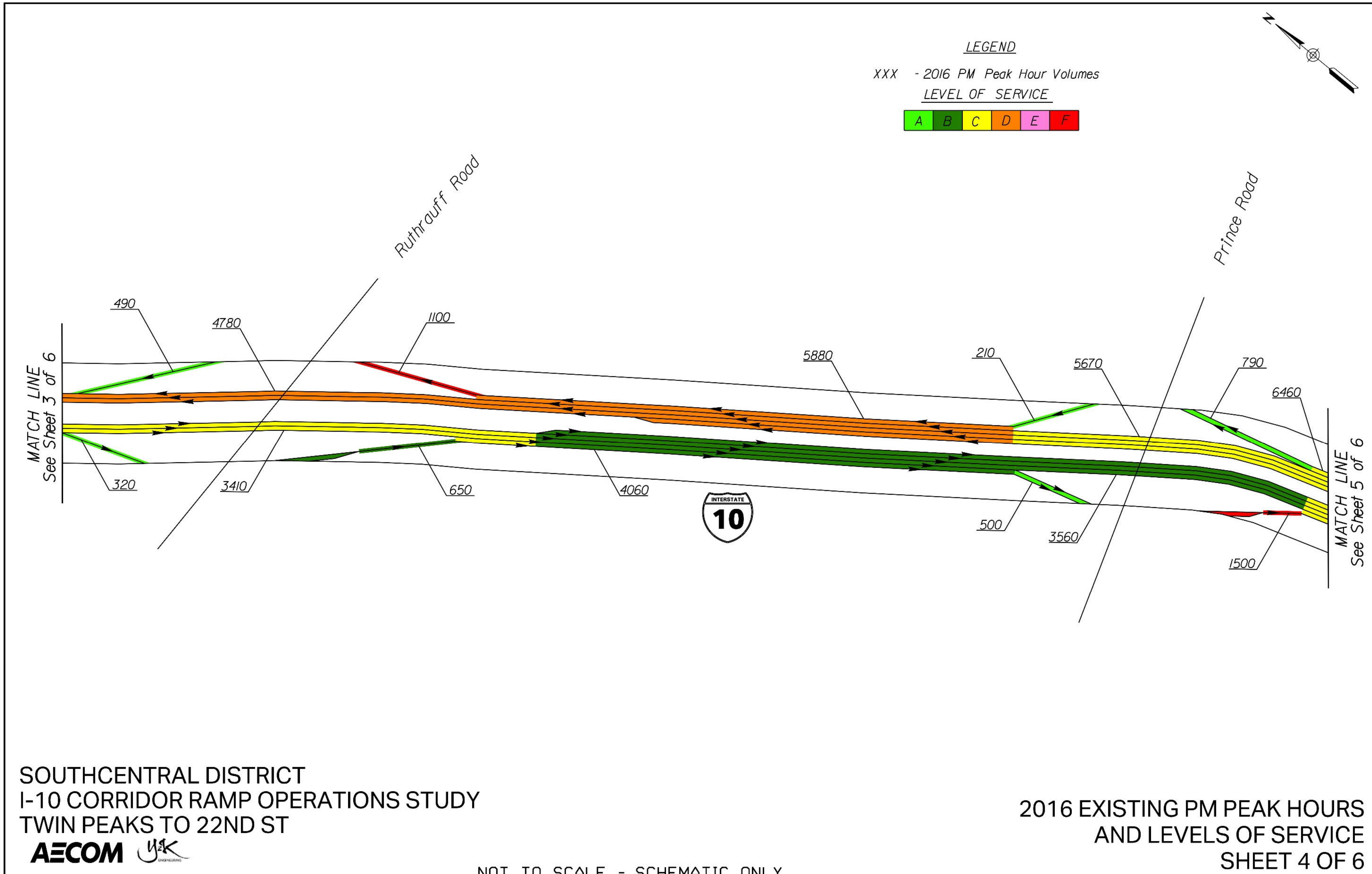


2016 PM Peak Hour LOS Results (continued)



2016 PM Peak Hour LOS Results (continued)



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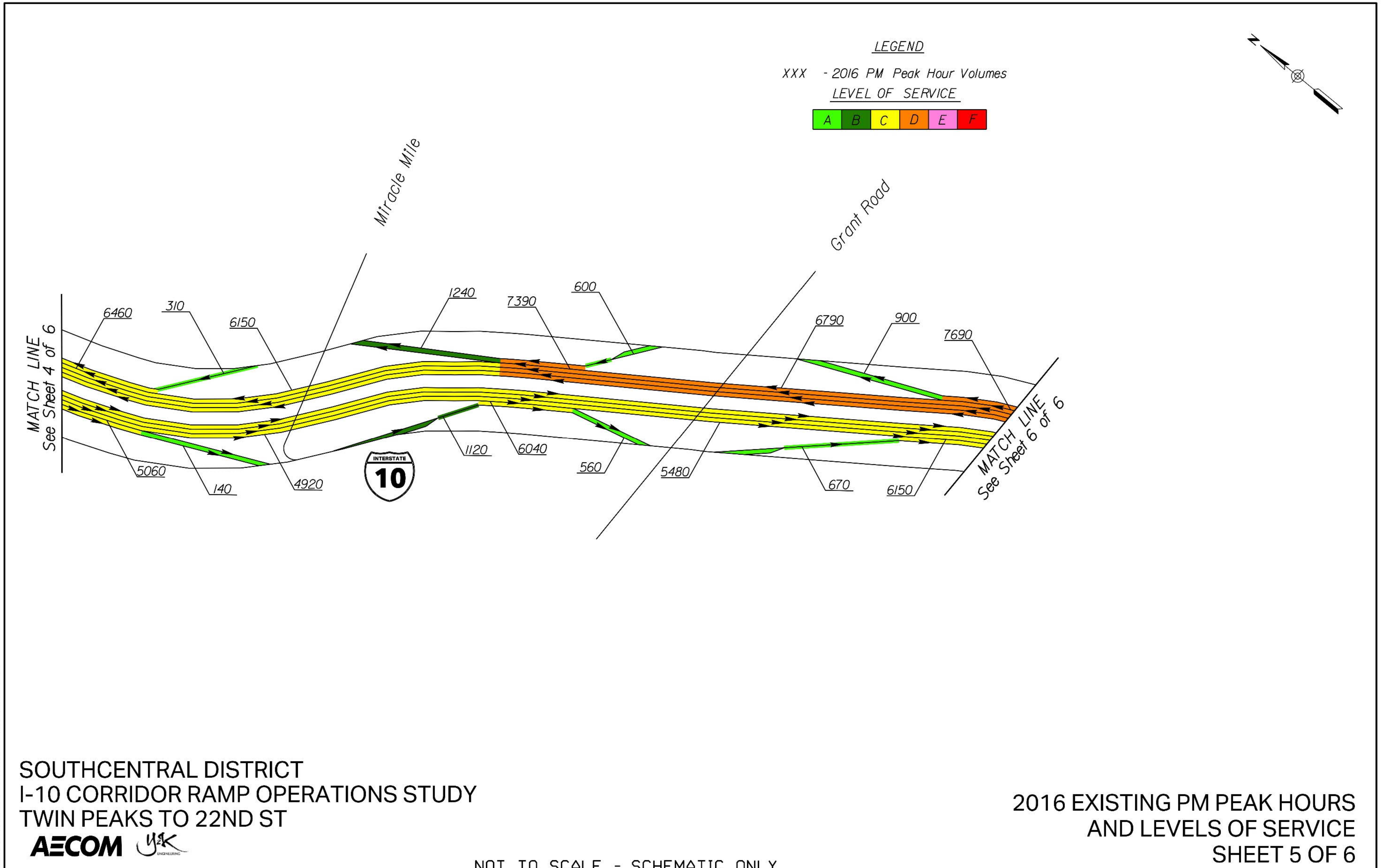
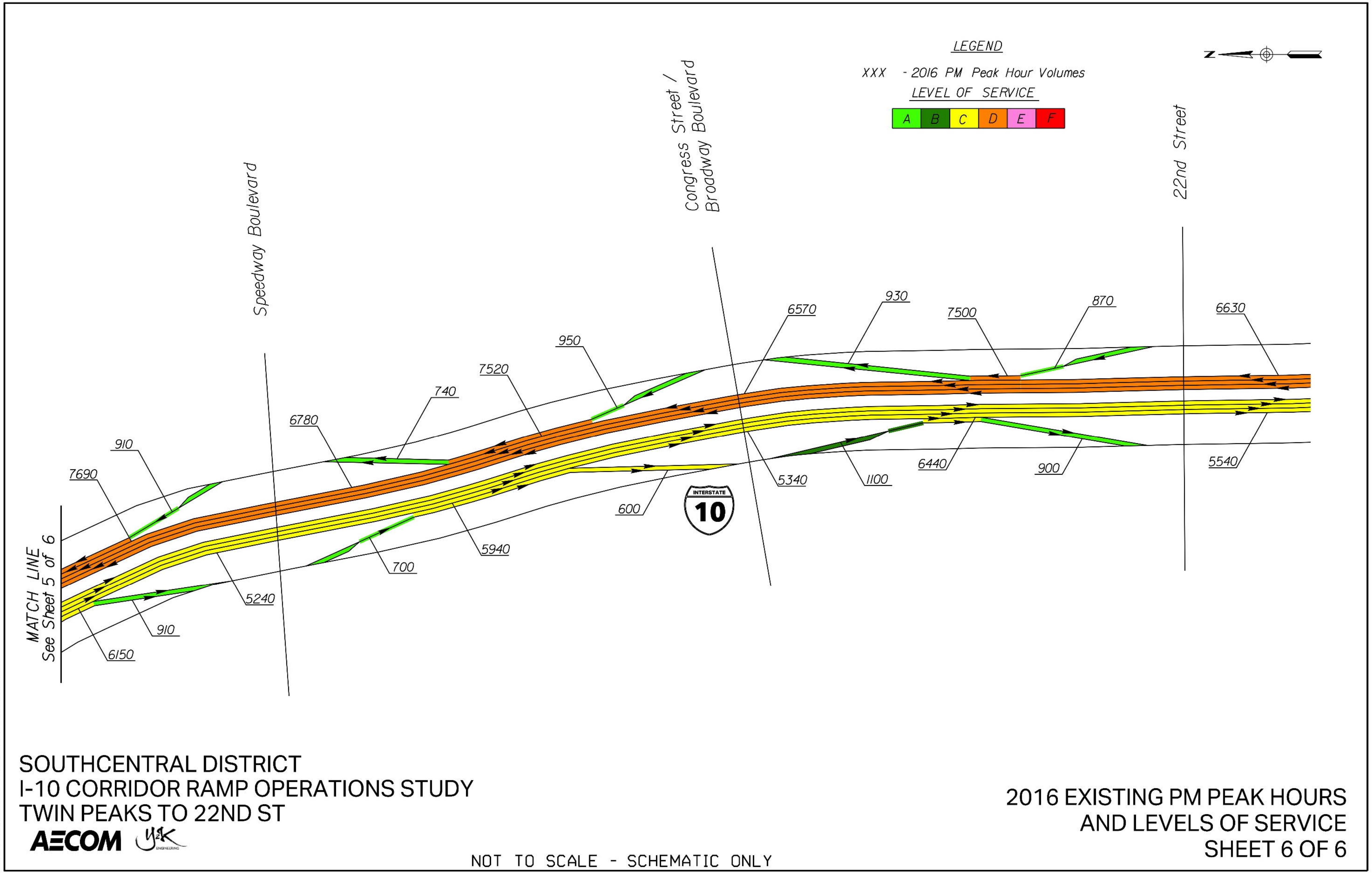
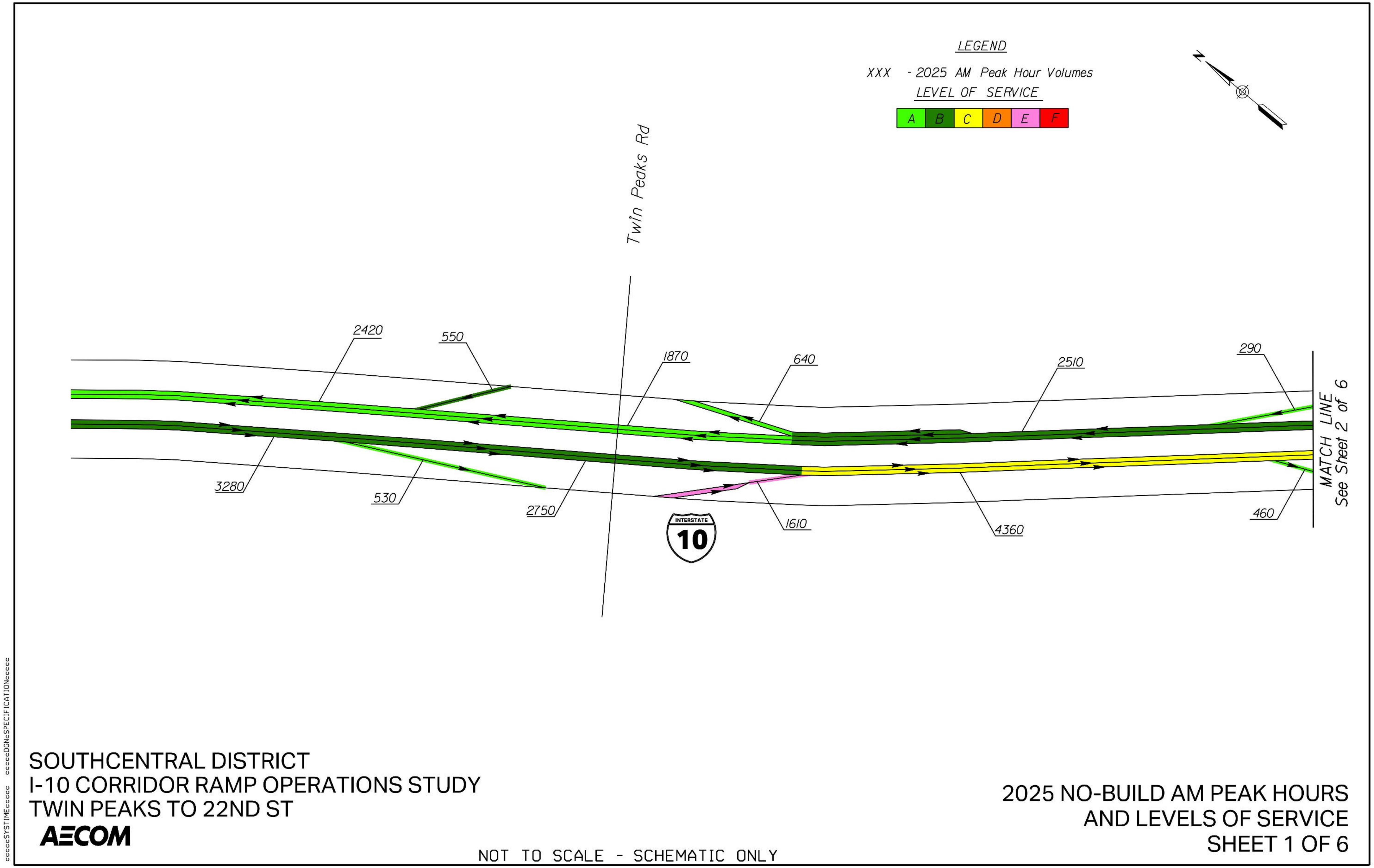


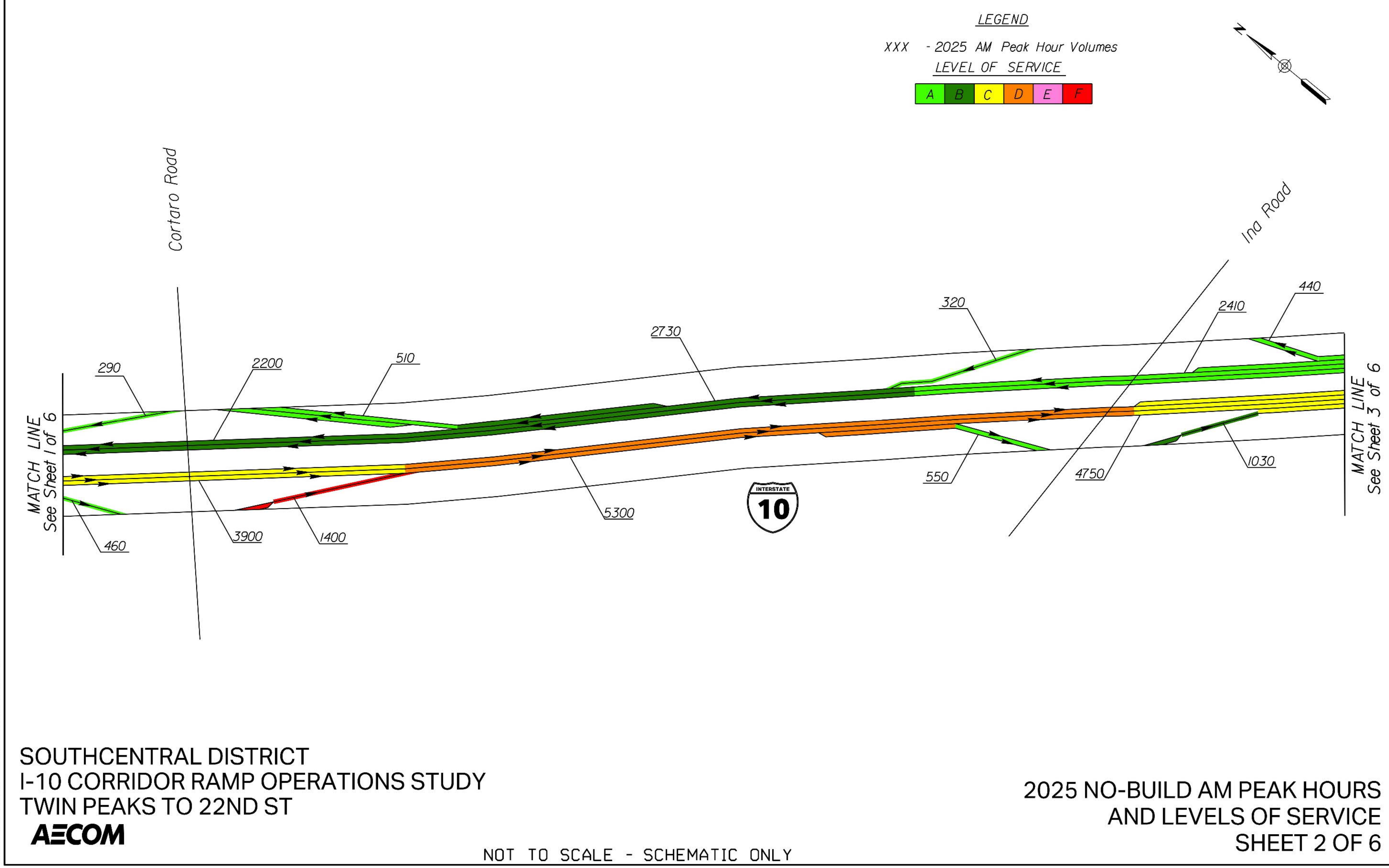
2016 PM Peak Hour LOS Results (continued)



2025 No-Build AM Peak Hour LOS Results



2025 No-Build AM Peak Hour LOS Results (continued)



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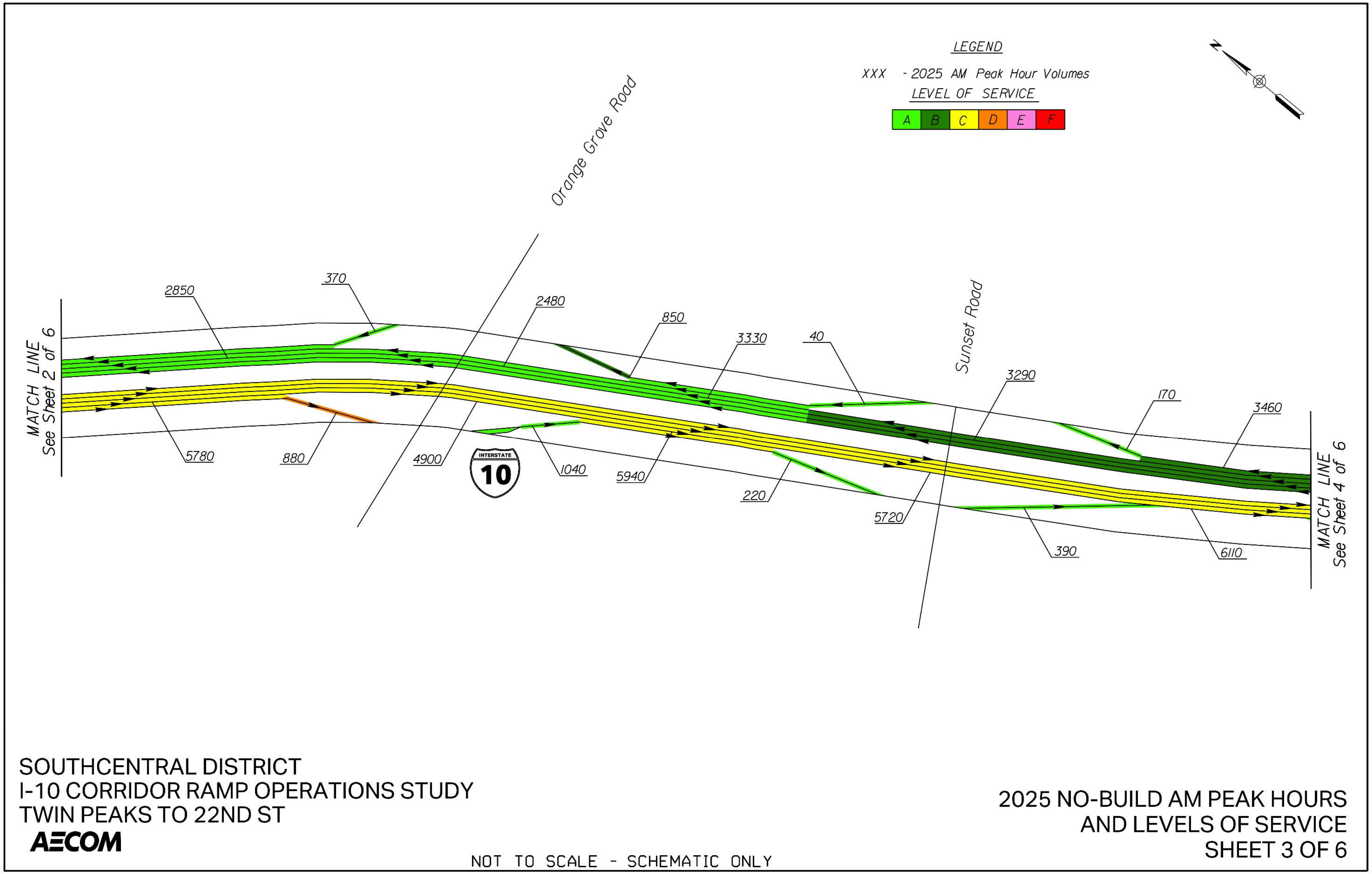
2025 No-Build AM Peak Hour LOS Results (continued)



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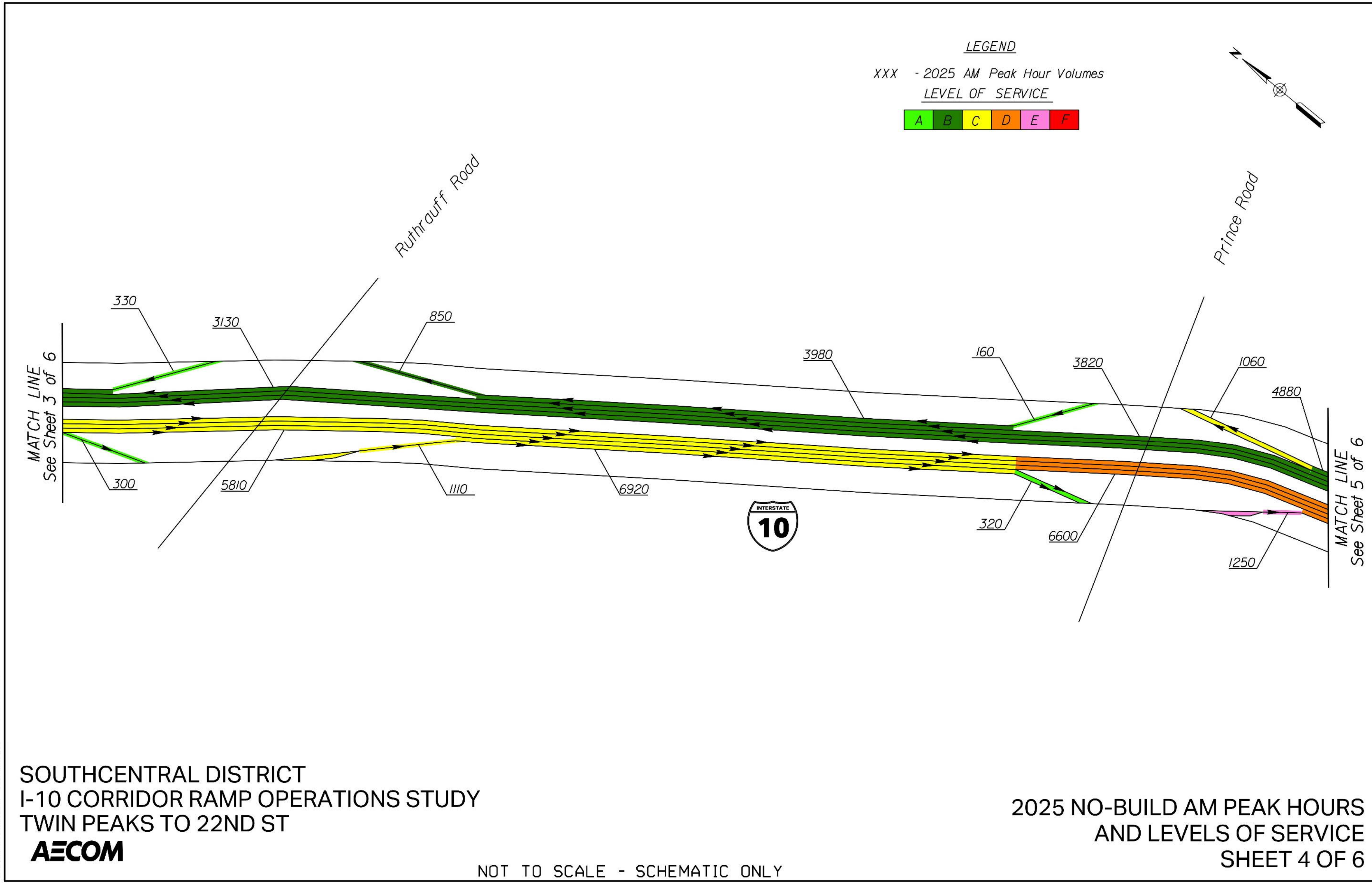

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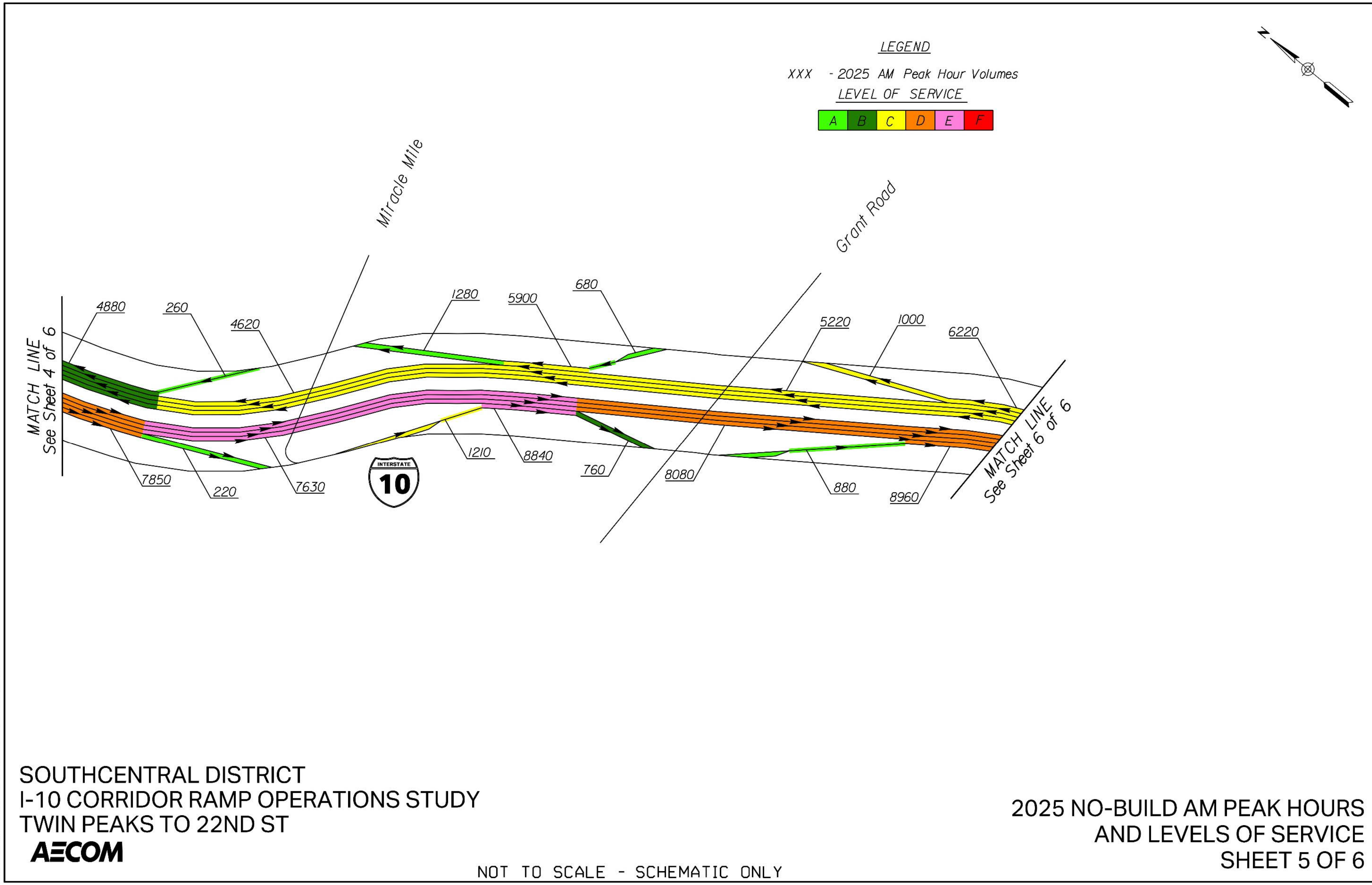

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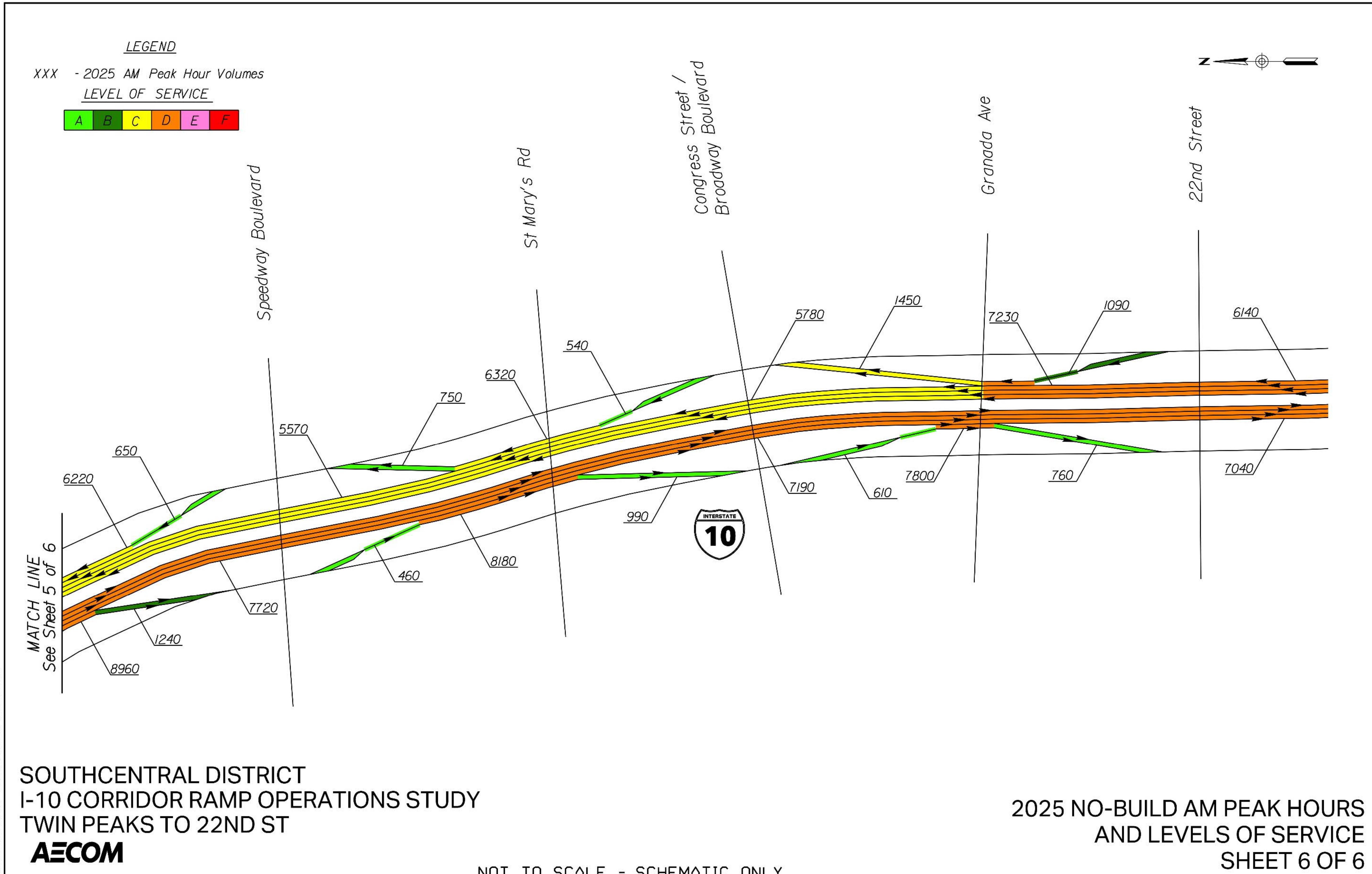
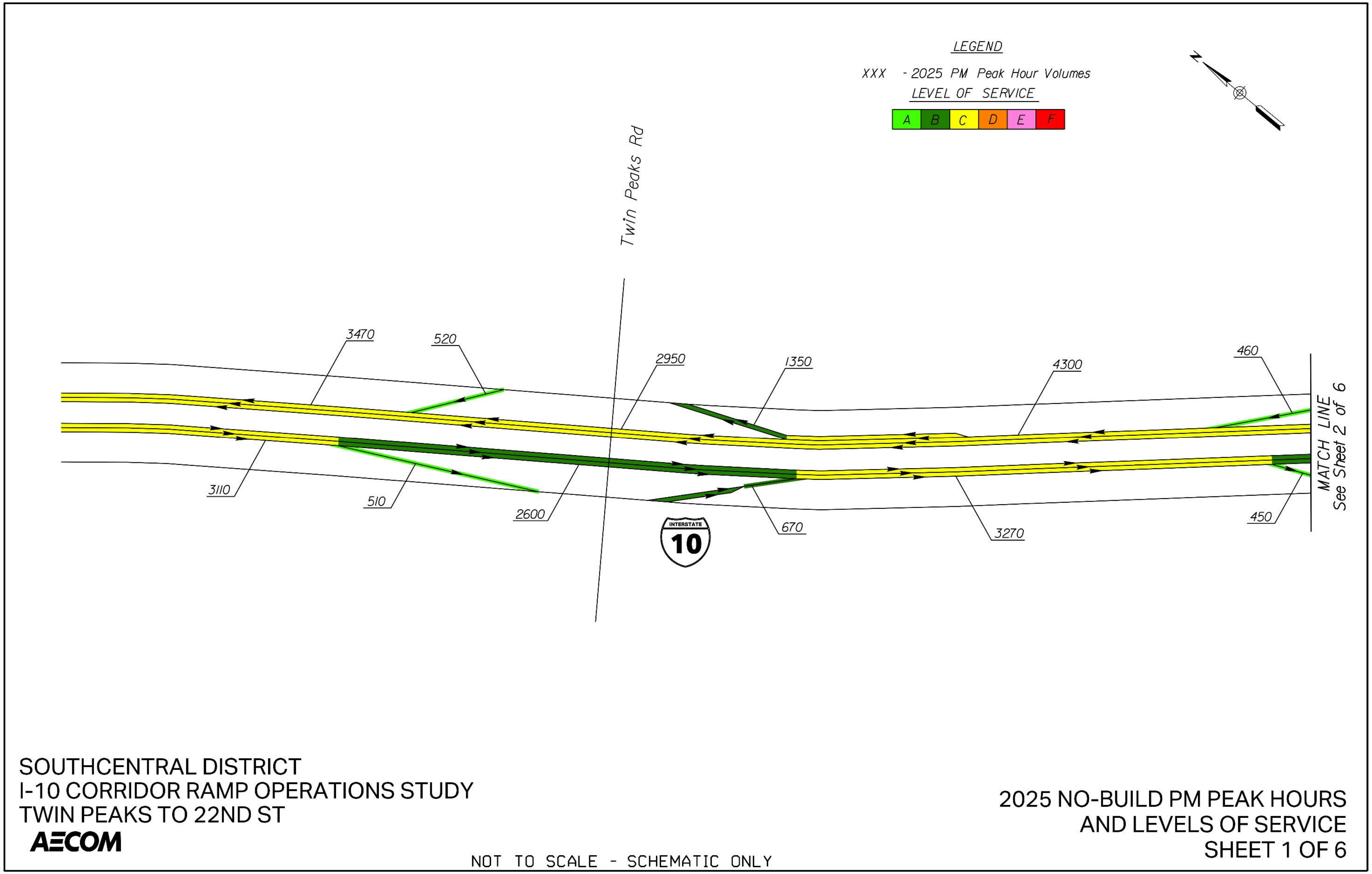


2025 No-Build PM Peak Hour LOS Results



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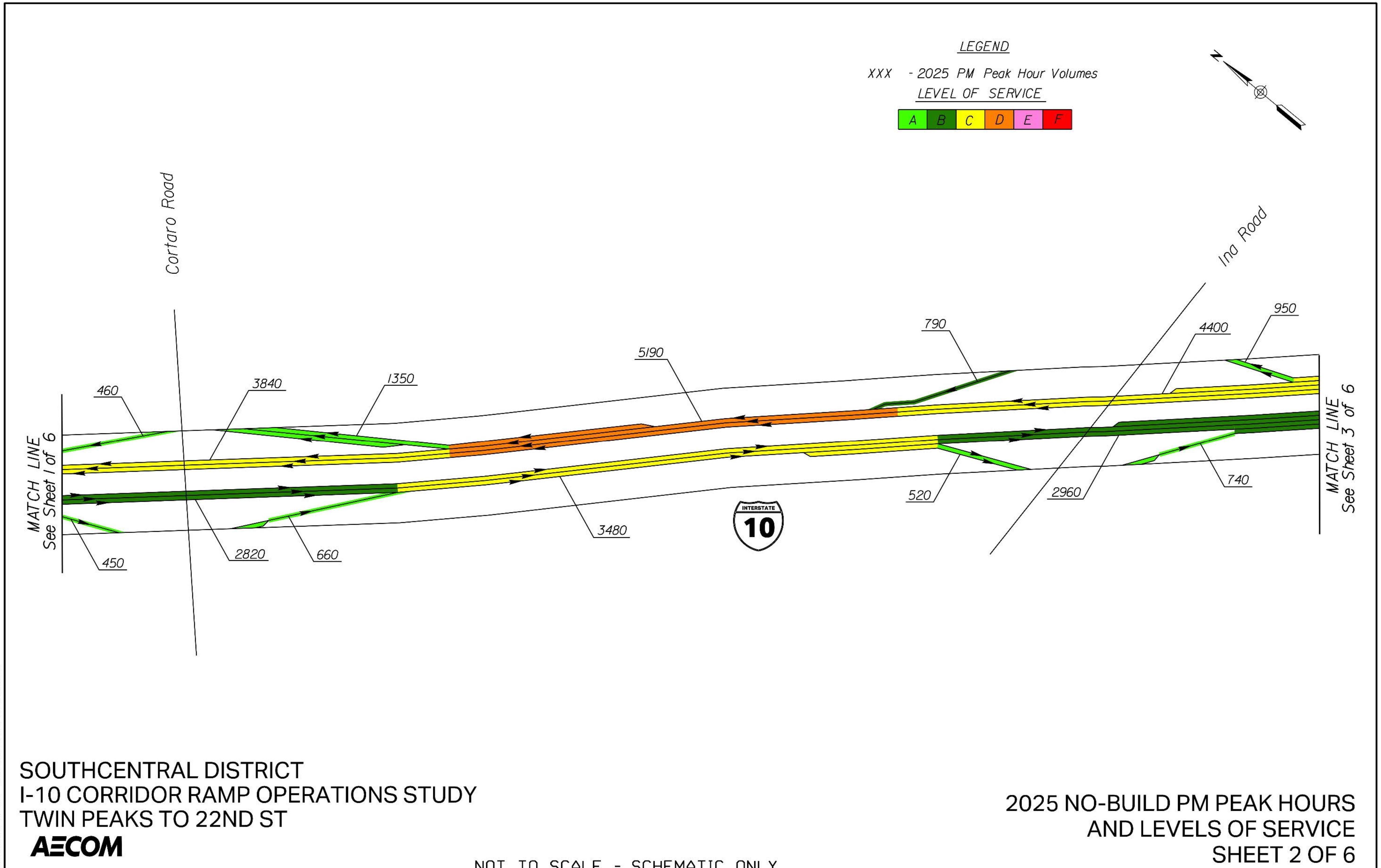

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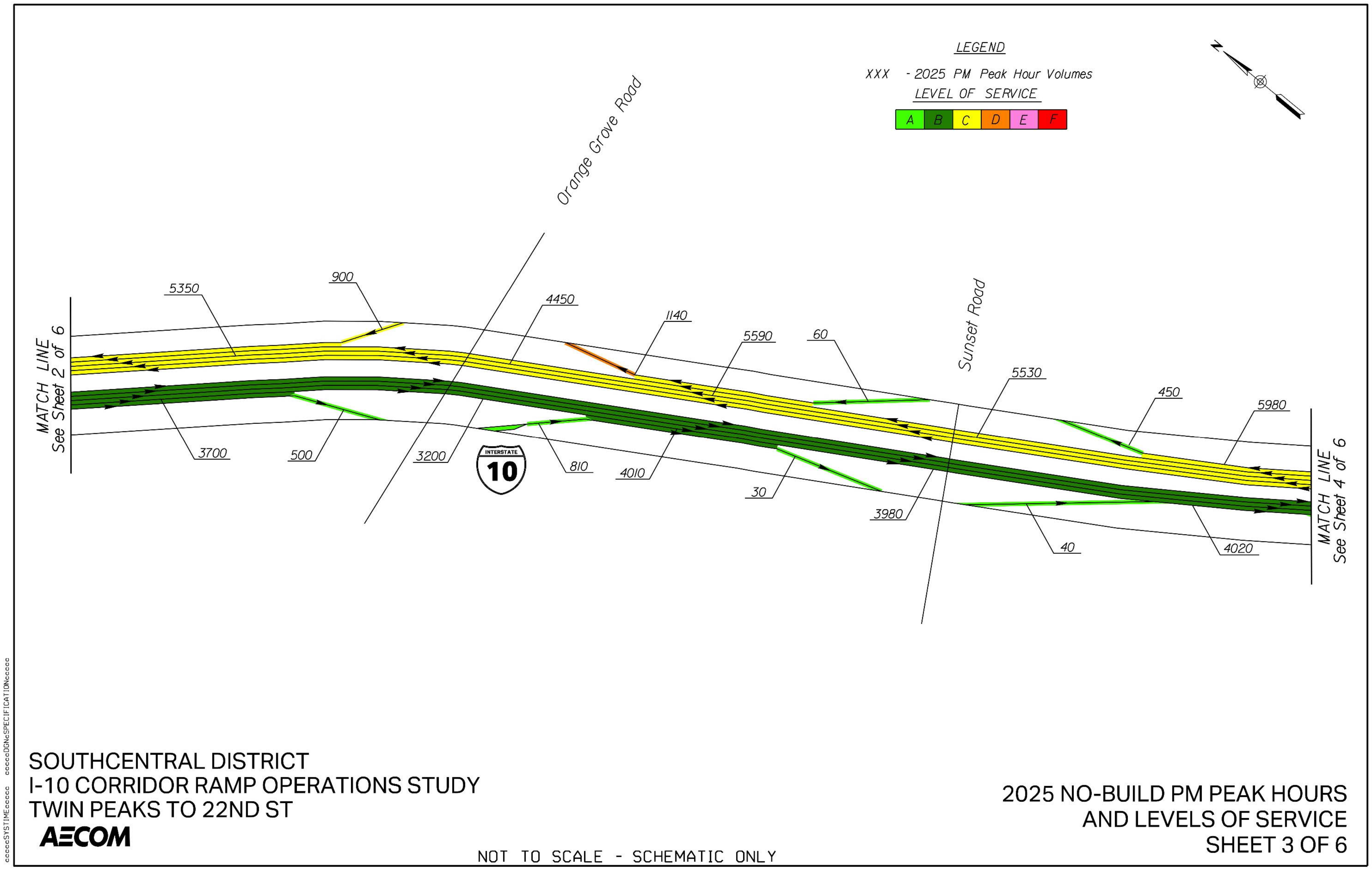
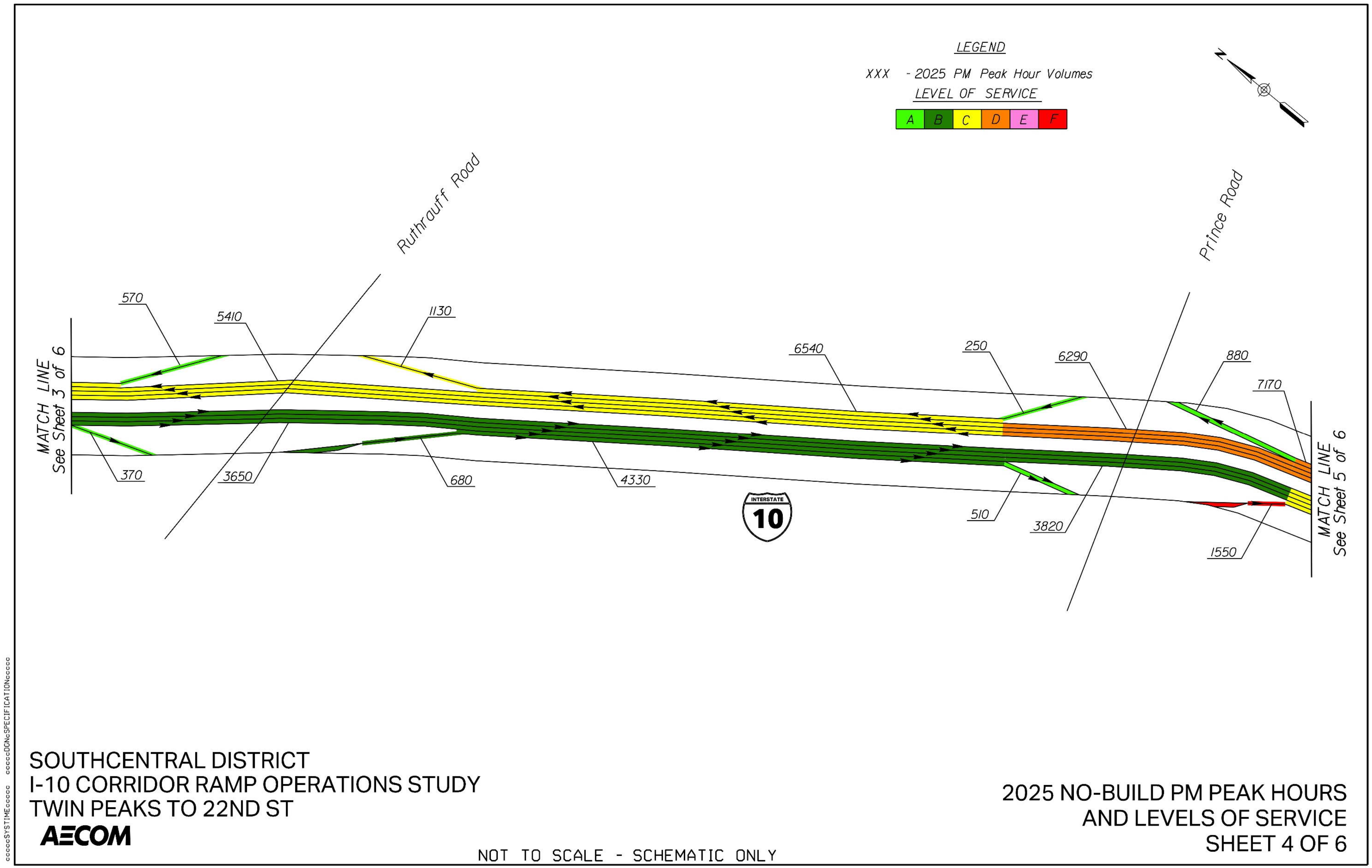


2025 No-Build PM Peak Hour LOS Results (continued)



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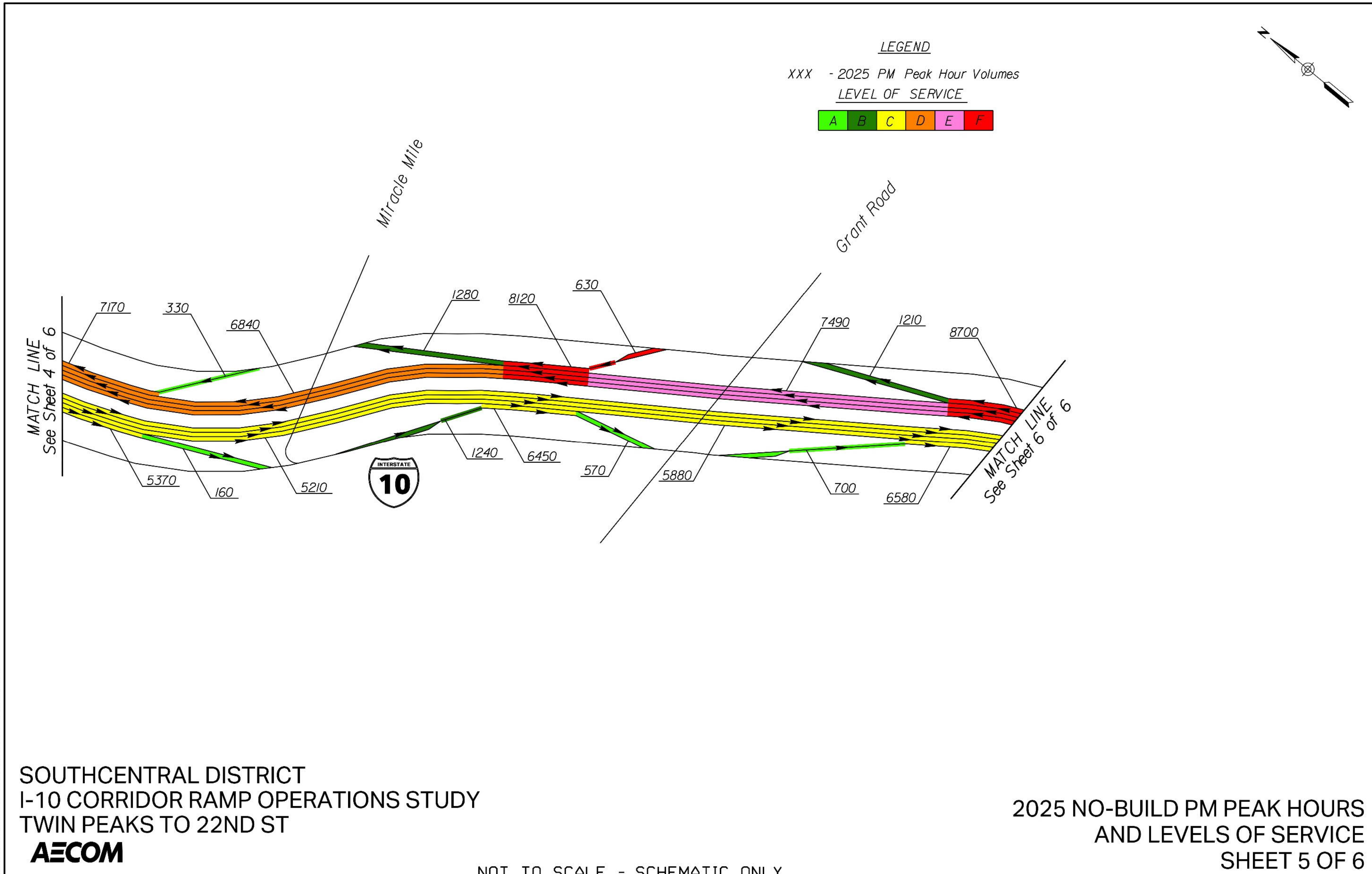

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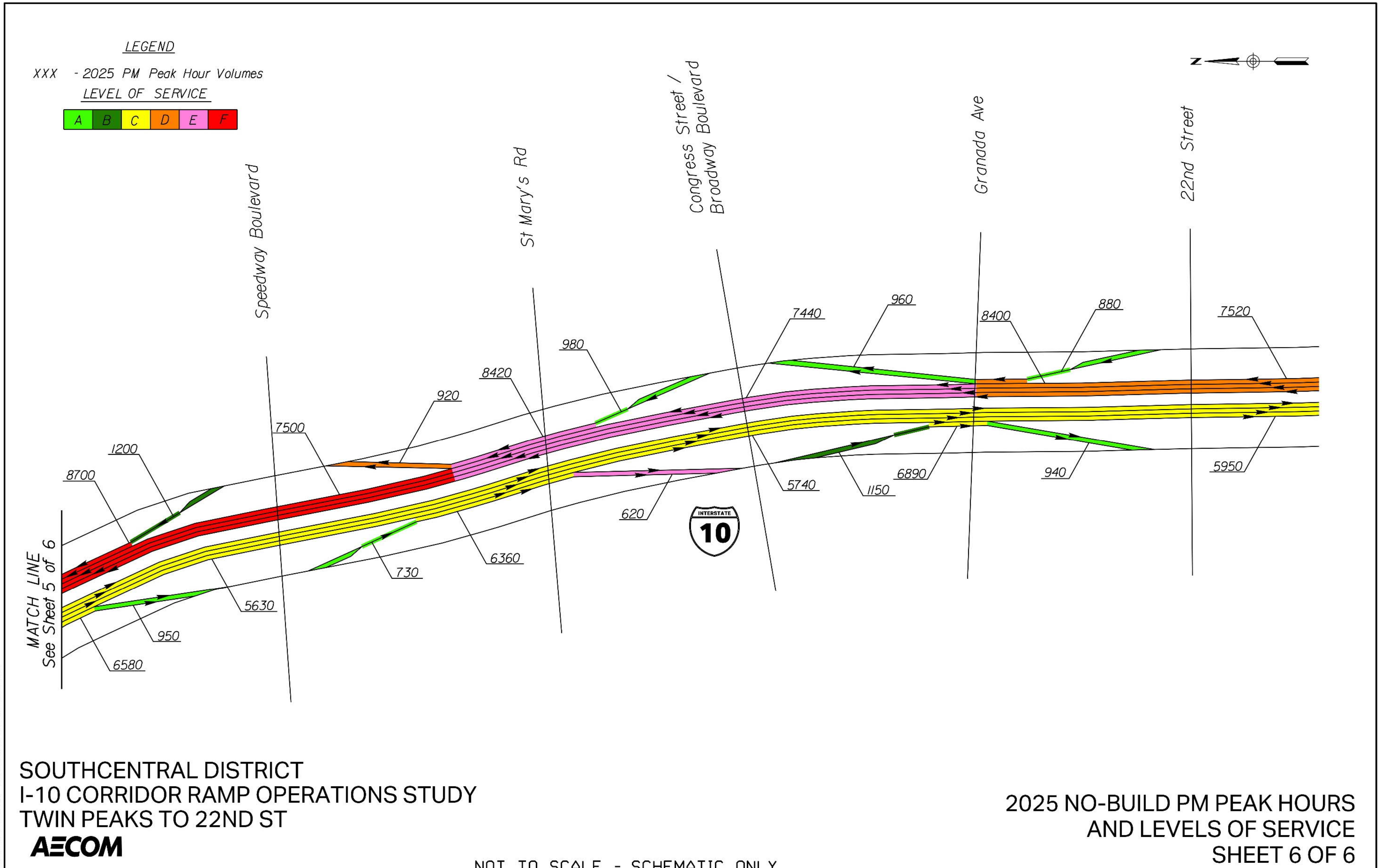
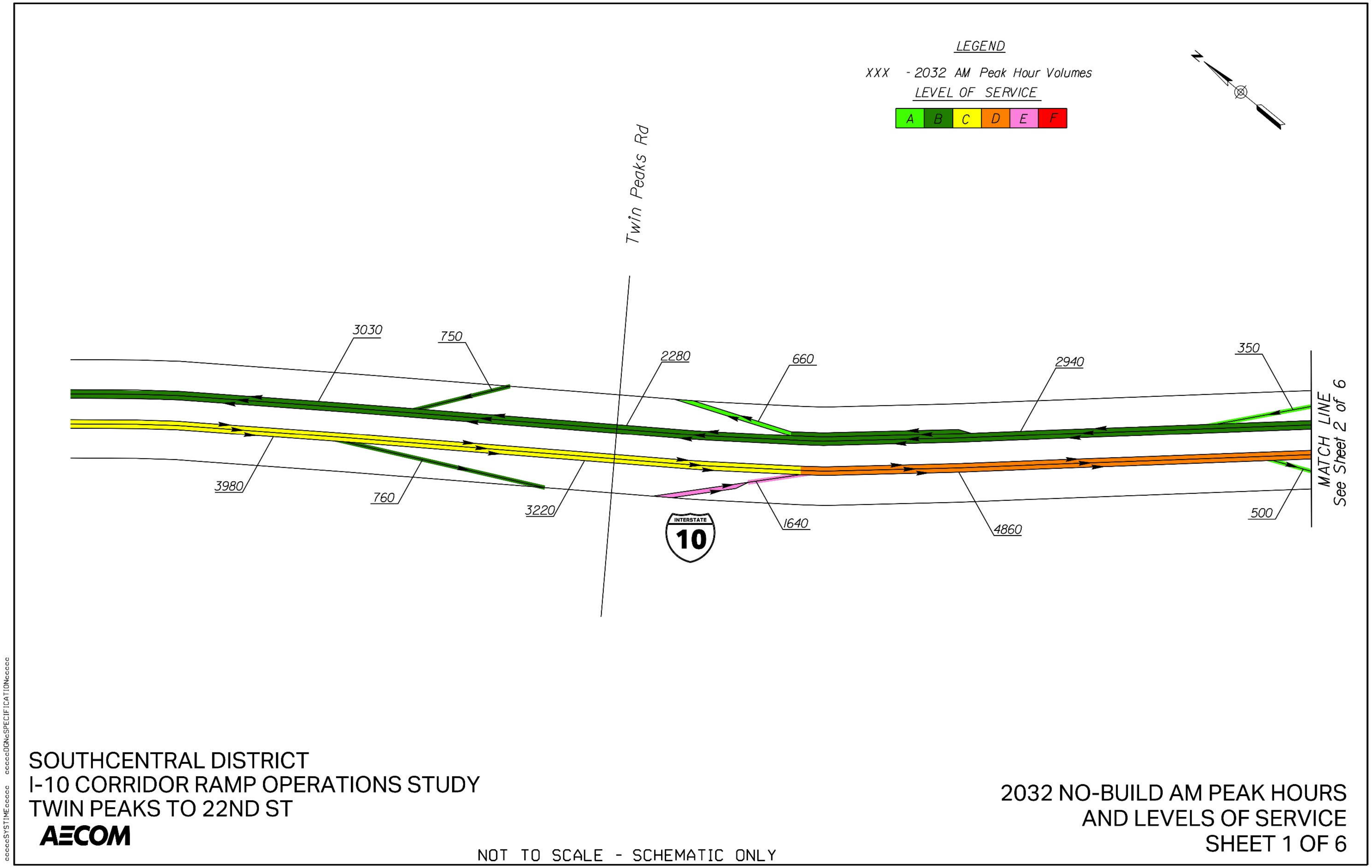


2032 No-Build AM Peak Hour LOS Results



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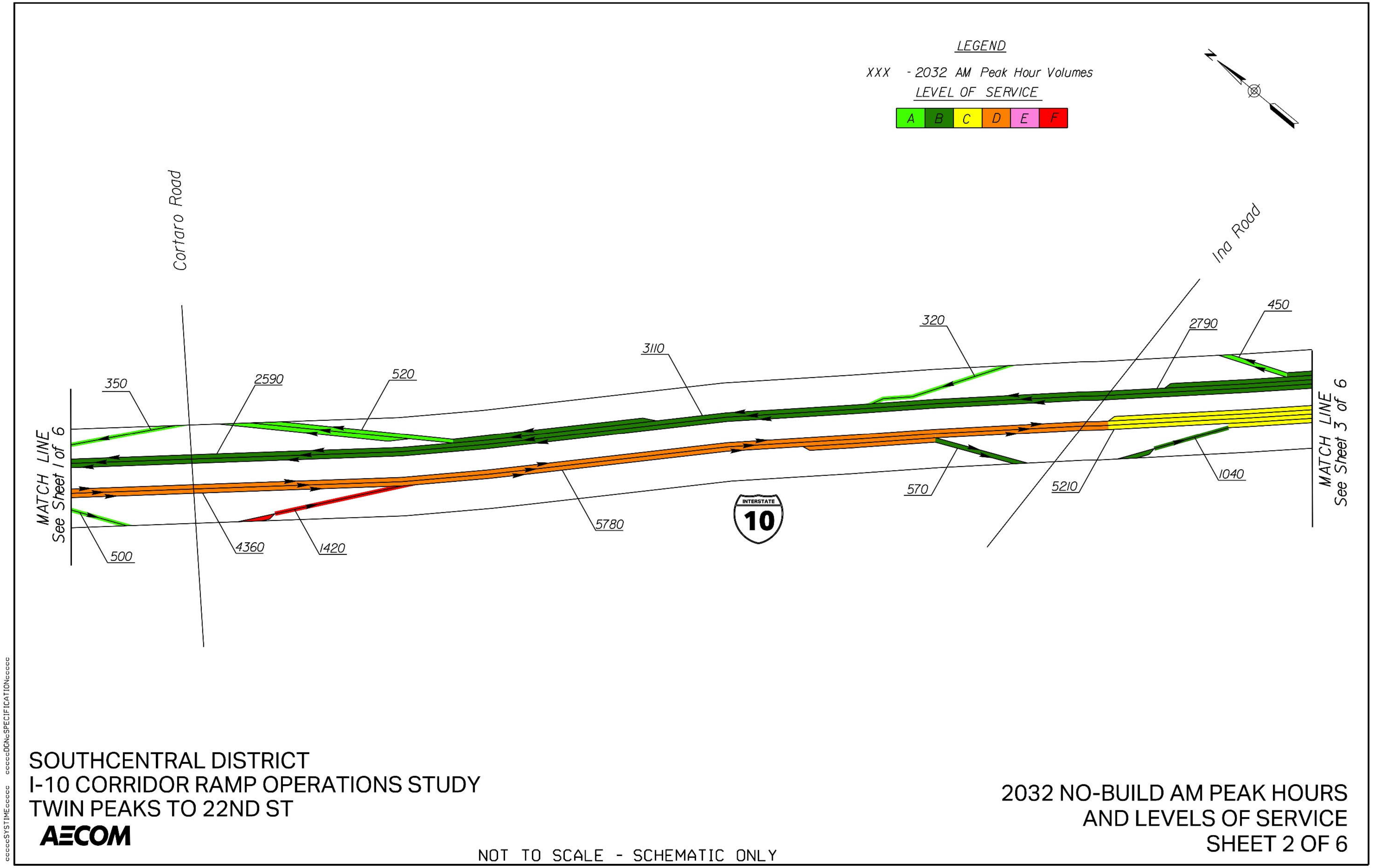

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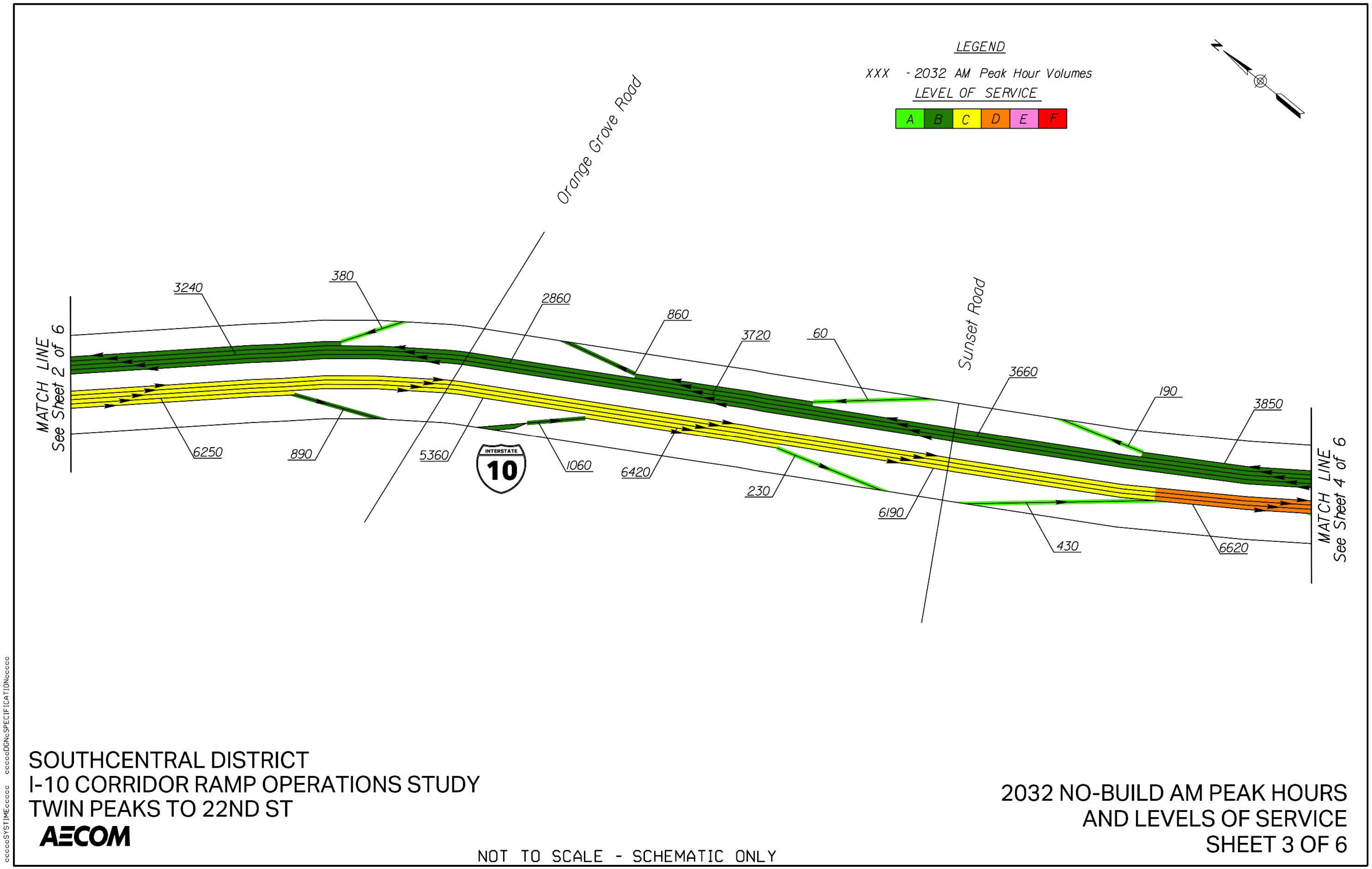

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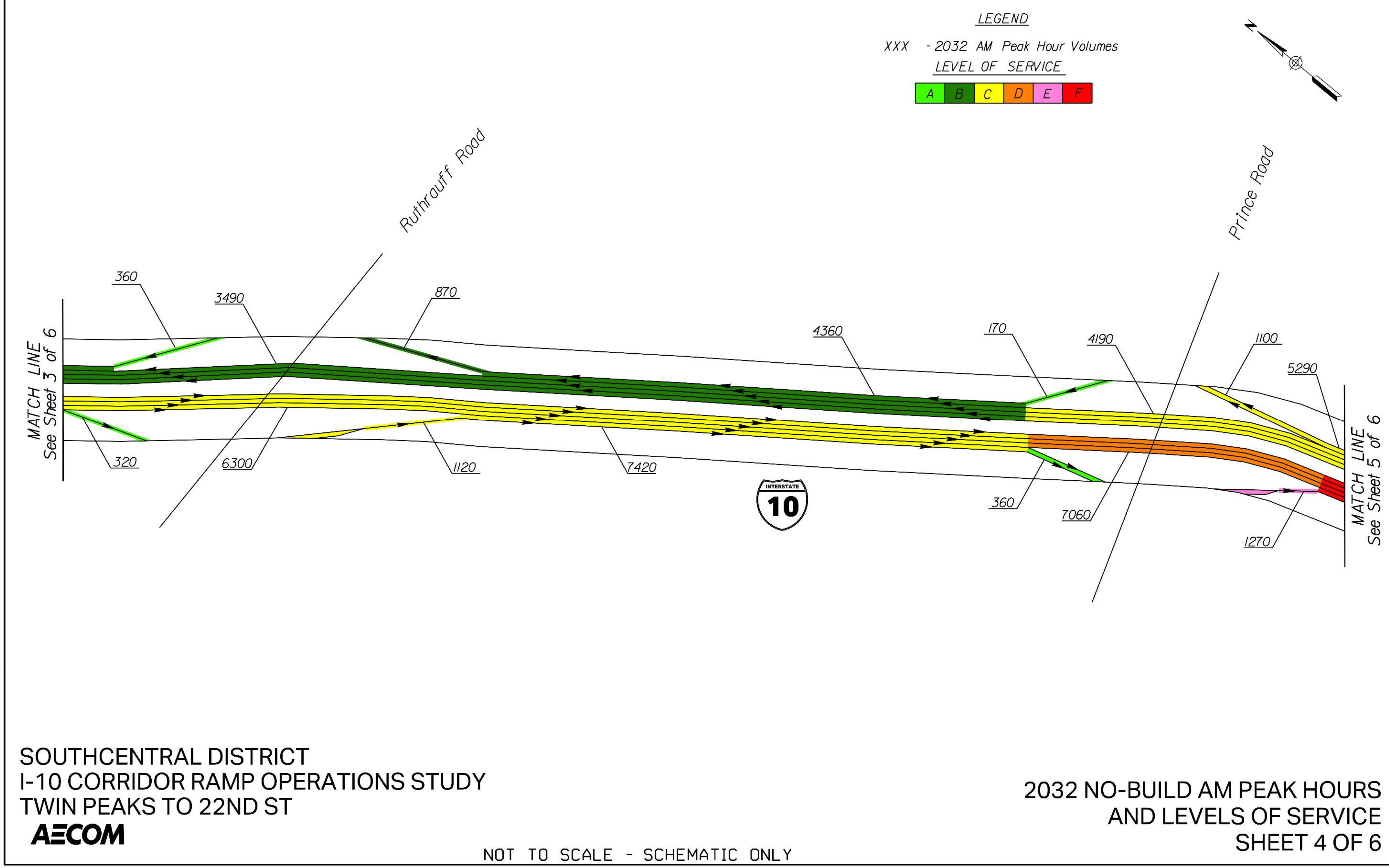

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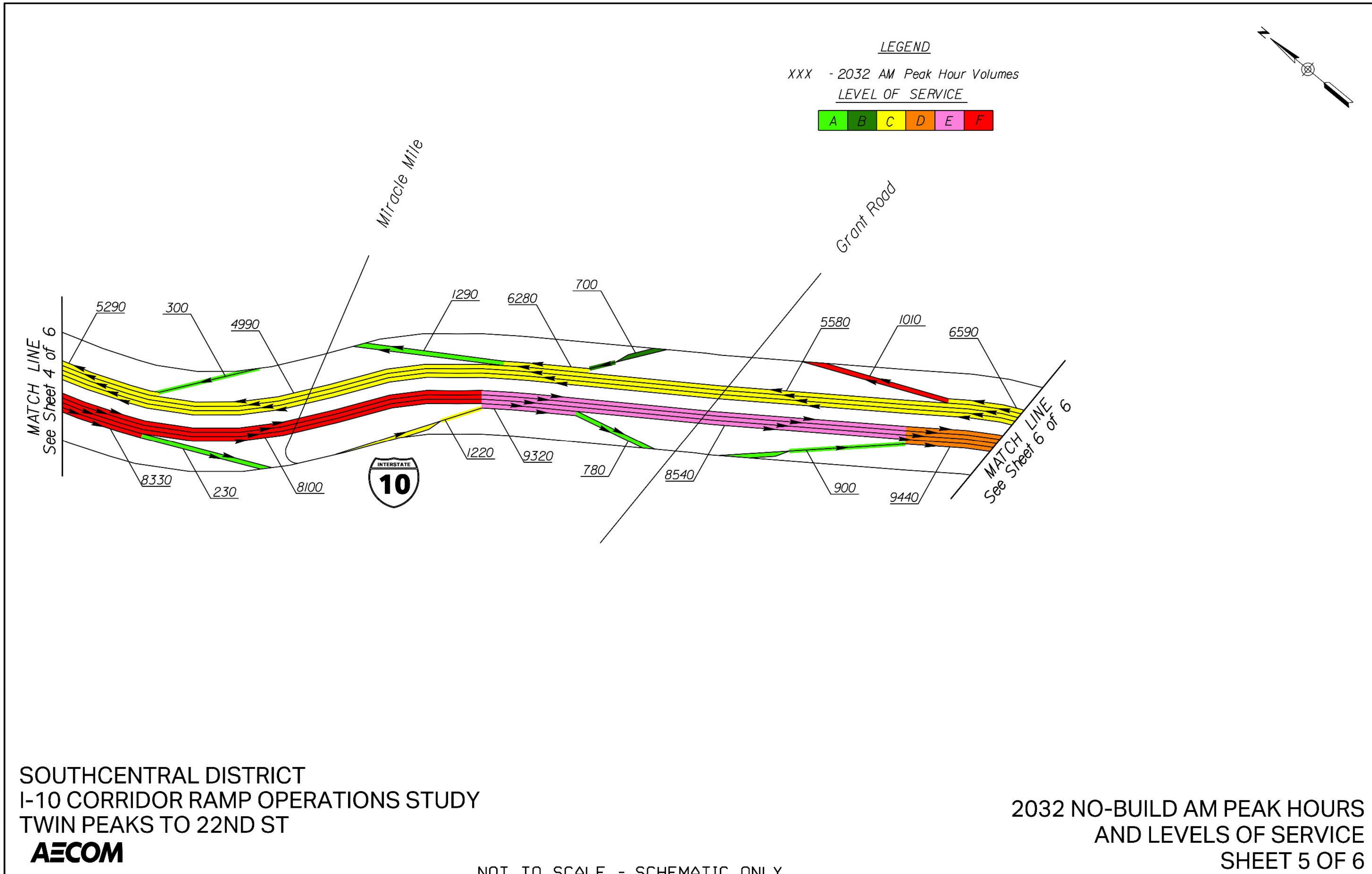
2032 No-Build AM Peak Hour LOS Results (continued)



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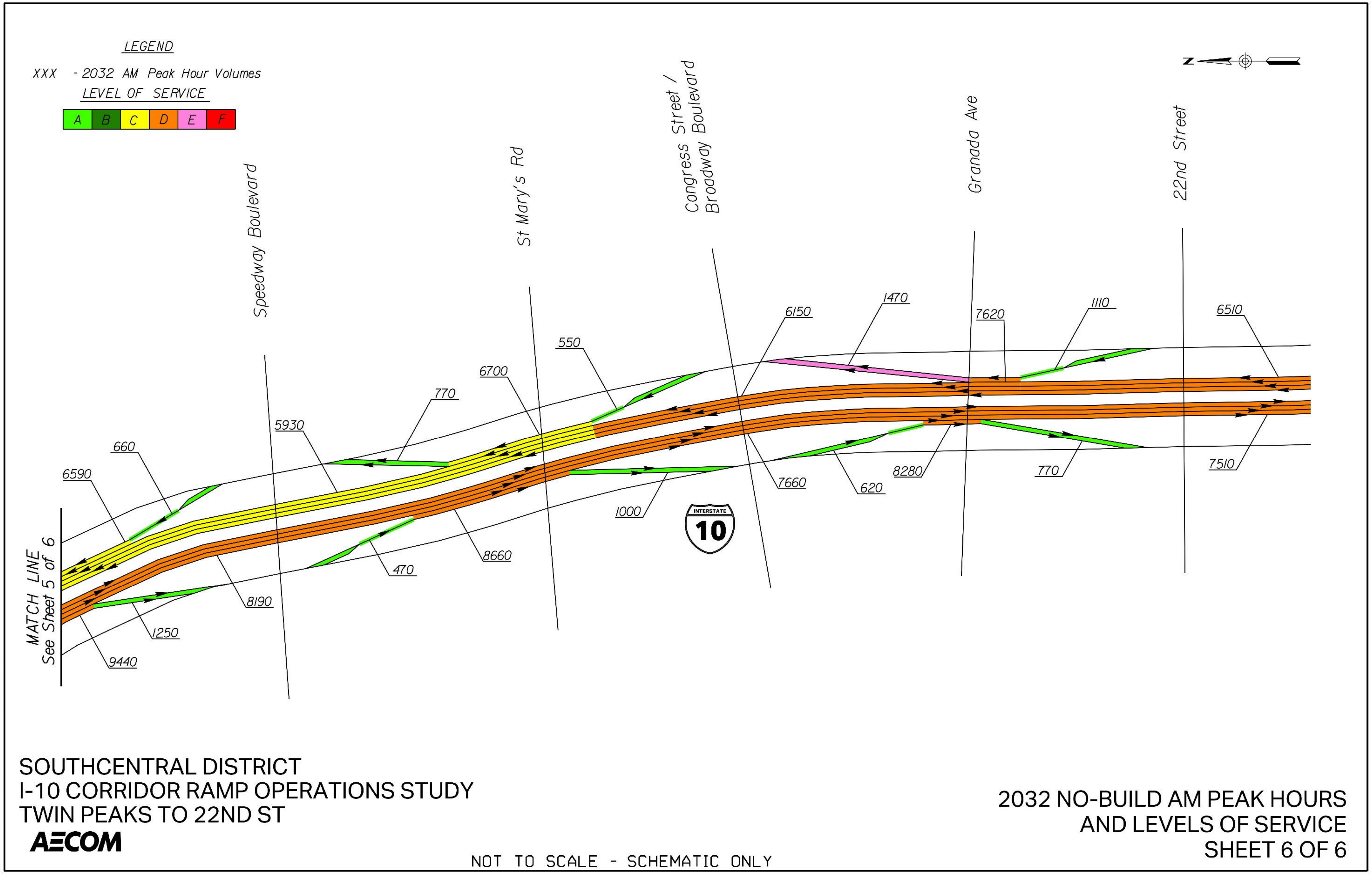
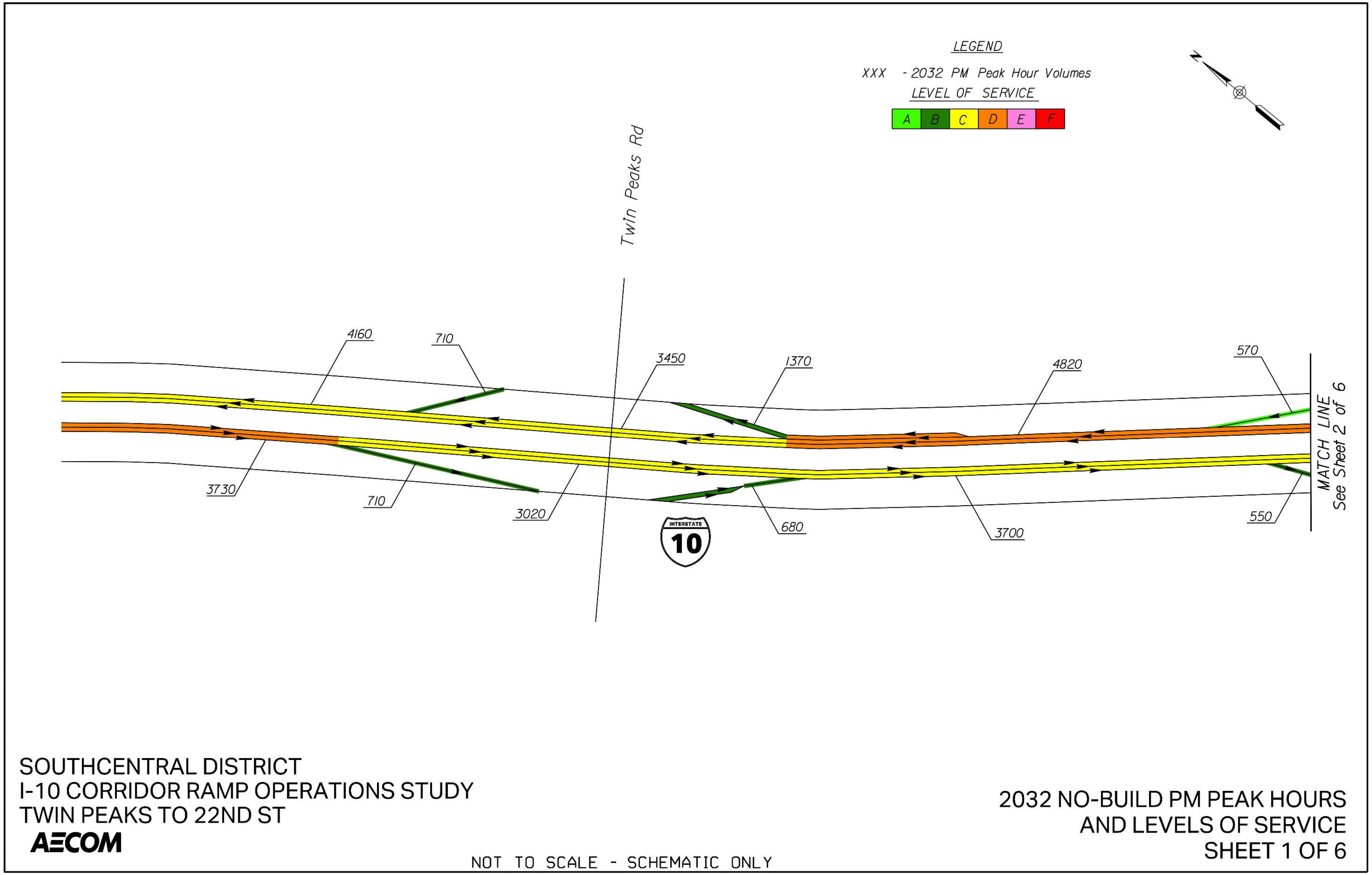
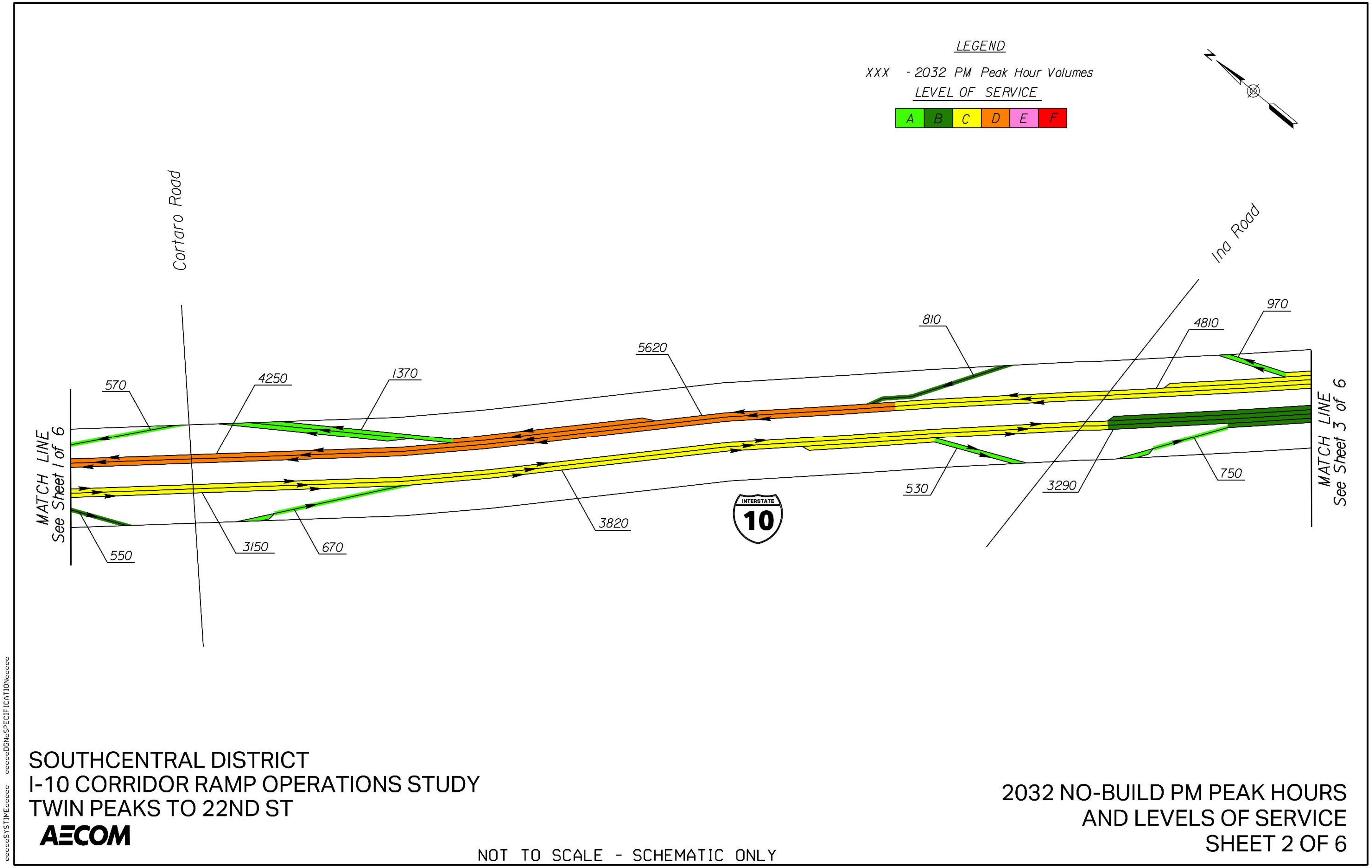


2032 No-Build PM Peak Hour LOS Results

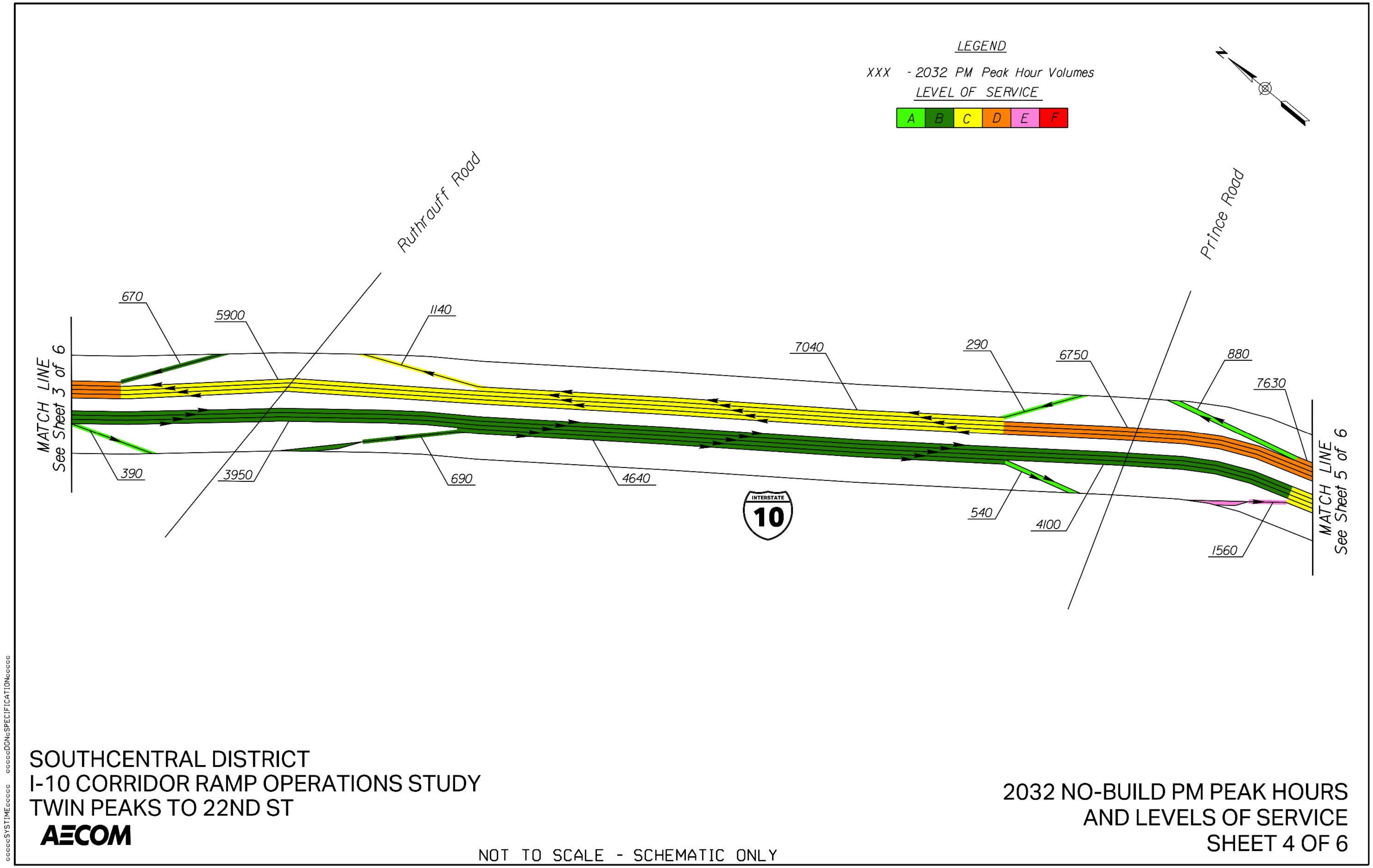


2032 No-Build PM Peak Hour LOS Results (continued)

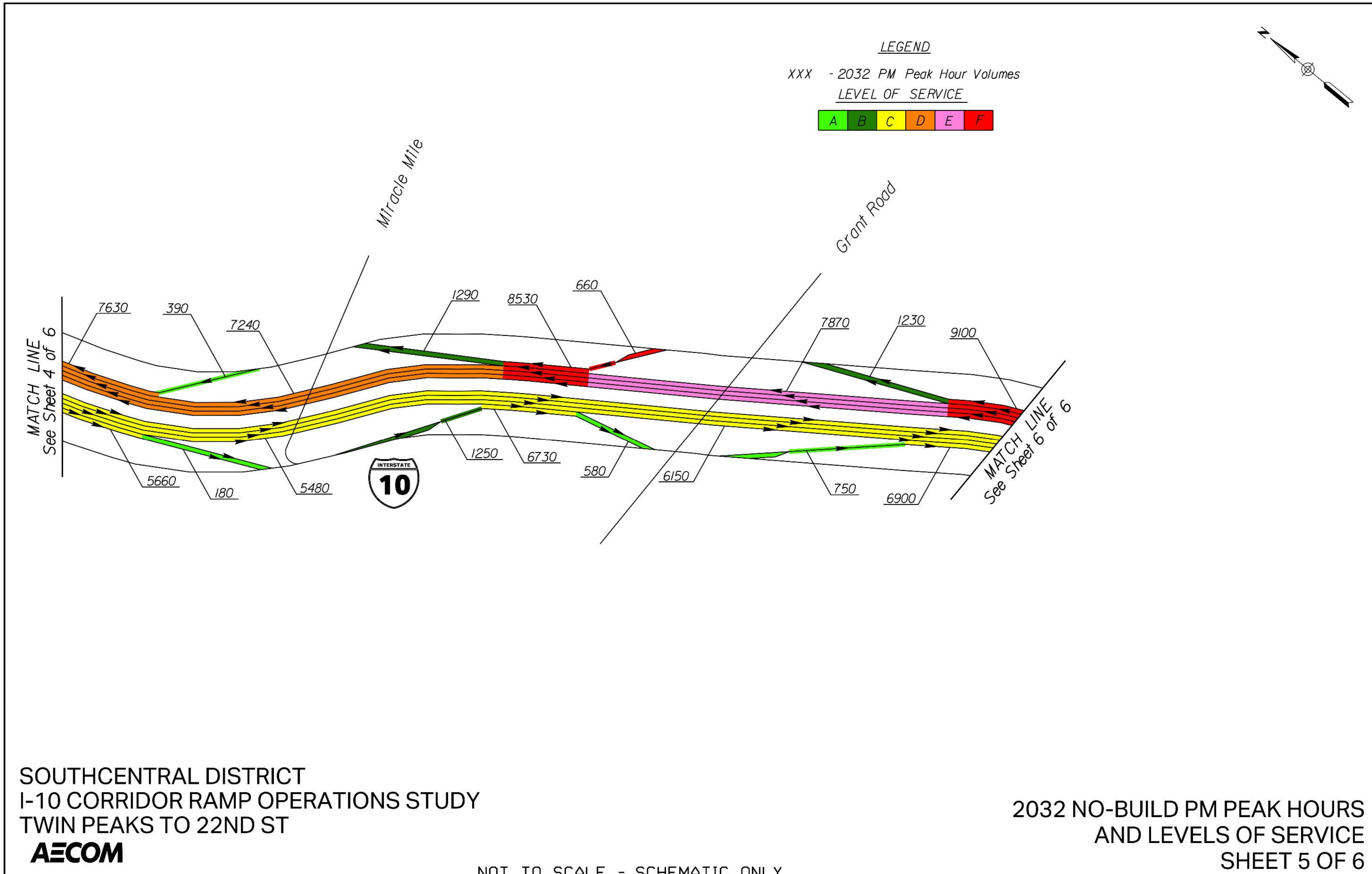


2032 No-Build PM Peak Hour LOS Results (continued)

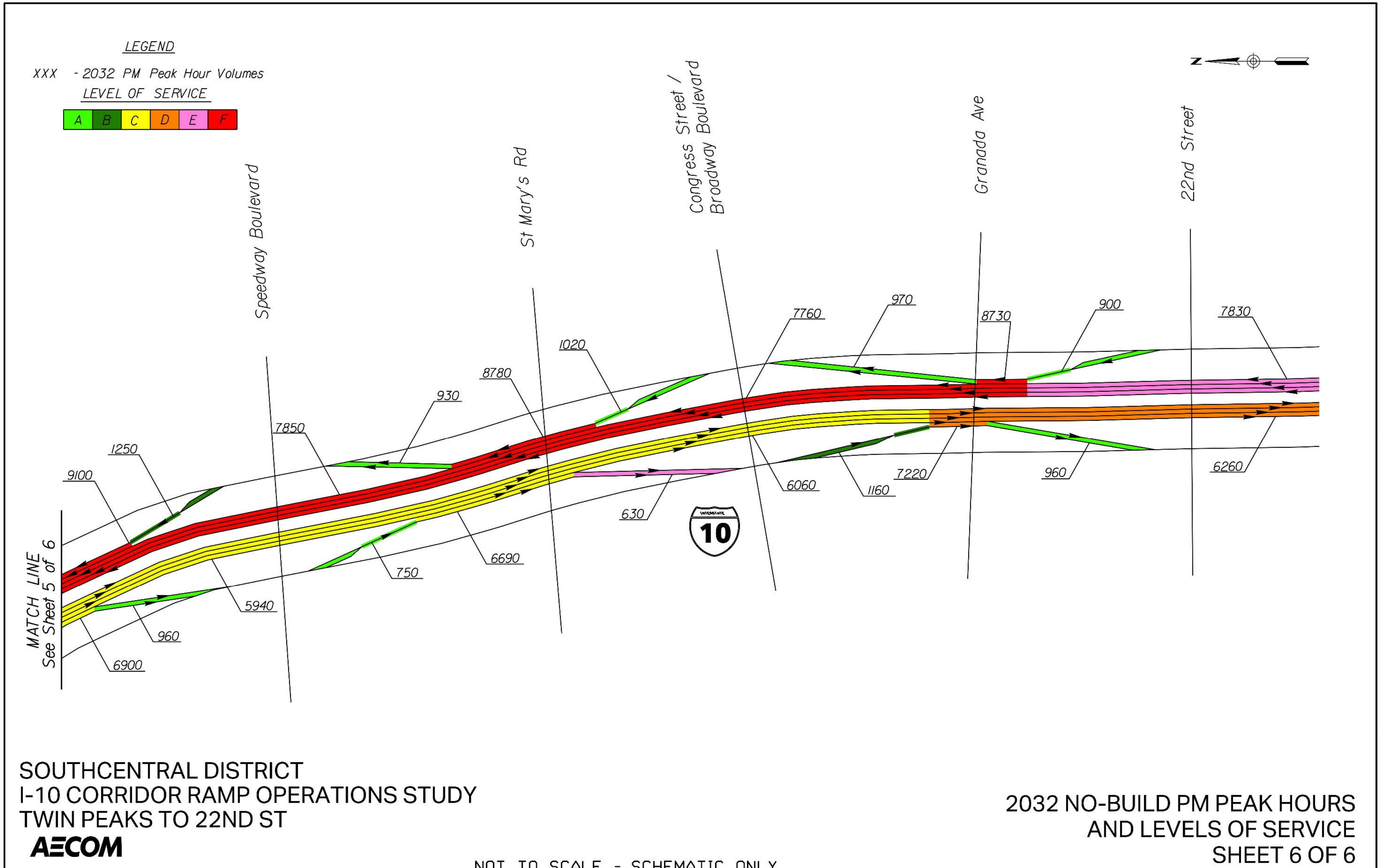
2032 No-Build PM Peak Hour LOS Results (continued)



2032 No-Build PM Peak Hour LOS Results (continued)



2032 No-Build PM Peak Hour LOS Results (continued)



APPENDIX C – RAMP METERING

Source: Ramp Metering: A Proven, Cost-Effective Operational Strategy—A Primer, Feb. 1st, 2017
Available at: https://ops.fhwa.dot.gov/publications/fhwahop14020/sec1.htm

When agencies implement effective ramp metering programs using strategies suitable to the region, they often realize significant, long-term benefits. While the magnitude of the benefits may vary depending on the level of congestion and configuration, common benefits persist across many regions. The widespread benefits of ramp metering, relative to its costs, make it one of the most cost-effective freeway management strategies.

	Mpls. / St. Paul	Portland	Denver	Seattle
Traffic Speed	+15%	+170%	+55%	+10%
Travel Time	-20%	-160%	-35%	-50%
Collisions	-25%	-40%	-50%	-35%
Emissions	-60%	--	-20%	--

Three primary types of ramp meter control strategies are available:

1. Local fixed time strategy – Simplest approach; no traffic detection or communication with TMC
2. Local traffic responsive control strategy – Will adjust metering rates based on traffic conditions at the ramp and adjacent mainline location. Cannot factor in adjacent ramp meter conditions. Often a fallback strategy to system-wide control
3. System-wide traffic responsive control strategy – Considers traffic conditions upstream and downstream from an individual ramp along a specific freeway segment or along an entire corridor; metering rates can be adjusted for multiple ramps. Multiple types of algorithms in different metro areas:
    a. Fuzzy Logic (Seattle, Miami) – Controls multiple ramps, uses comprehensive mainline and ramp inputs, and uses different heuristics that allows for the most flexibility on determining metering rates for changing local conditions.
    b. Stratified Zone Metering (SZM) (Mpls. / St. Paul) - Operates on density measurements of traffic in zones and requires detection upstream of the ramp merge, at mainline exit ramps, and on the mainline. Attempts to rebalance the increase in mainline density by making other meter rates in the active zone more restrictive. Ramp queue wait times are managed by a separate algorithm function.
    c. System-Wide Adaptive Ramp Metering (SWARM) (Portland, Orange County, CA) - Metering rates calculated based on current density, required density, and number of vehicles that should be removed or added to a freeway zone between each ramp. Additional upstream ramps are called to action when a single ramp has exceeded its capacity to balance the zone density.
    d. Corridor Adaptive Ramp Metering Algorithm (CARMA) (Kansas City) - Metering rates determined based on mainline speeds and prevailing local controller conditions. Concept is based on assumption that a ramp can allow maximum vehicles when the speed is high, and minimum vehicles when the speed is near optimal.

Ramp Metering Challenges

- Geometry of Existing Infrastructure - Not all ramps will have adequate acceleration length, some ramps may be too closely spaced ramps, and/or have limited sight distances
- Costs and Funding - Monetary costs for deploying and maintaining ramp metering systems
- Public Opposition – Can be rooted in misconceptions about ramp metering and effectiveness
- Heavy Ramp Volume – Long ramp meter vehicle queues could spill onto arterials resulting in inefficient arterial operations
- Local Agency Opposition – Can be concerns that the ramp metering strategies will negatively impact traffic operations in local jurisdictions
- Lack of Agency Support – Can result from lack of understanding benefits of ramp meters and from concern over long term maintenance and operations costs

Fuzzy Logic Approach Summary

Source: https://www.wsdot.wa.gov/research/reports/fullreports/481.1.pdf

Fuzzy logic control (FLC) uses rule-based logic to incorporate traffic operator expertise about a network system of highways, and allows an easier control over how ramp meters operate over time.

There are three general steps in the process of setting up Fuzzy Logic:

1. Data from detectors is input into a Fuzzy Logic Controller (FLC) which categorizes and pre-processes the inputs into "fuzzy" groups or classes.
2. A set of rules (i.e. if-then statements) is defined around operational objectives regarding mainline congestion, ramp queue lengths, and other objectives that can be measured through quantitative inputs from traffic detectors. Each rule is also assigned a percentage weight to signify its importance to traffic and ramp meter operations.
3. Ramp metering rates and timings are then designed for each possible outcome and implemented by the Fuzzy Logic Controller at the ramp meter.

The fuzzy logic approach has been validated by the Washington State DOT in the Seattle metro region through both simulation testing (multiple corridors) and through field testing (two field corridors) as being more effective, or just as effective as, other local algorithms relying on quantitative inputs and "yes/no" logic (i.e. Seattle Bottleneck Algorithm).

In short, the "pros" Fuzzy Logic Control (FLC) for ramp metering are the following:

1. Details of logic are readily available and can be applicable to multiple metro areas
2. It can balance conflicting objectives, given that different weights of importance can be applied to different objectives (reducing mainline congestion, reducing ramp queues, etc…). This can allow for some cities that implement a Fuzzy Logic method to be responsive to localized concerns about ramp meter wait times by assigning a higher weight of importance to reducing wait times over mainline congestion in certain areas.
3. It does not require extensive system modeling, since it is more generic in its application of ramp metering timings based on the "if-then" rules defined in the FLC.
4. Easier to understand by traffic operators and to modify over time, because the percentage weights can be changed in the controllers and the groupings can be adjusted as needed based on local conditions.

In short, the "cons" of Fuzzy Logic Control for ramp metering are the following:

1. The logic generalizes inputs from detector data into general classes, thus the timing strategies could be more efficient at accomplishing certain objectives
2. There could be an extensive "trial-and-error" period where traffic operators adjust the percentage weights for each rule and then have to monitor ramp meter and mainline operations to verify that the appropriate balance of ramp metering objectives has been obtained

Stratified Zone Metering Approach Summary

Source: https://www.dot.state.mn.us/trafficeng/modeling/dataextraction/Stratified%20Zone%20Metering.pdf

The objective of stratified zone metering is to regulate zones through ramp metering so that the total volume of traffic exiting a zone exceeds the volume entering that zone. The algorithm was designed in 2001 to address the growing public concern of long wait times on ramps. Thus, one of the top priorities for the new algorithm was to ensure that the wait time on a metered ramp was less than approximately four minutes. In order to keep wait times below this threshold, a unique “minimum release rate” is applied to each metered ramp. A minimum release rate is designed so that even if vehicles are backed up to (but not over) the queue detector at the top of the ramp, the last vehicle on that ramp will not have to wait longer than four minutes.

As the name implies, there are also multiple zones layered on top of one another throughout the metro area, the lengths of which are defined by the locations of traffic detection stations along the roadway. The smallest zone is a half-mile in length, while the longest zone is up to 3 miles in length. Within each zone, the objective is to keep the number of vehicles entering that zone less than the number leaving that zone. There are three variables by which vehicles can enter a zone (i.e. Inputs) and three variables by which they may leave (i.e. Outputs):

3 Inputs:

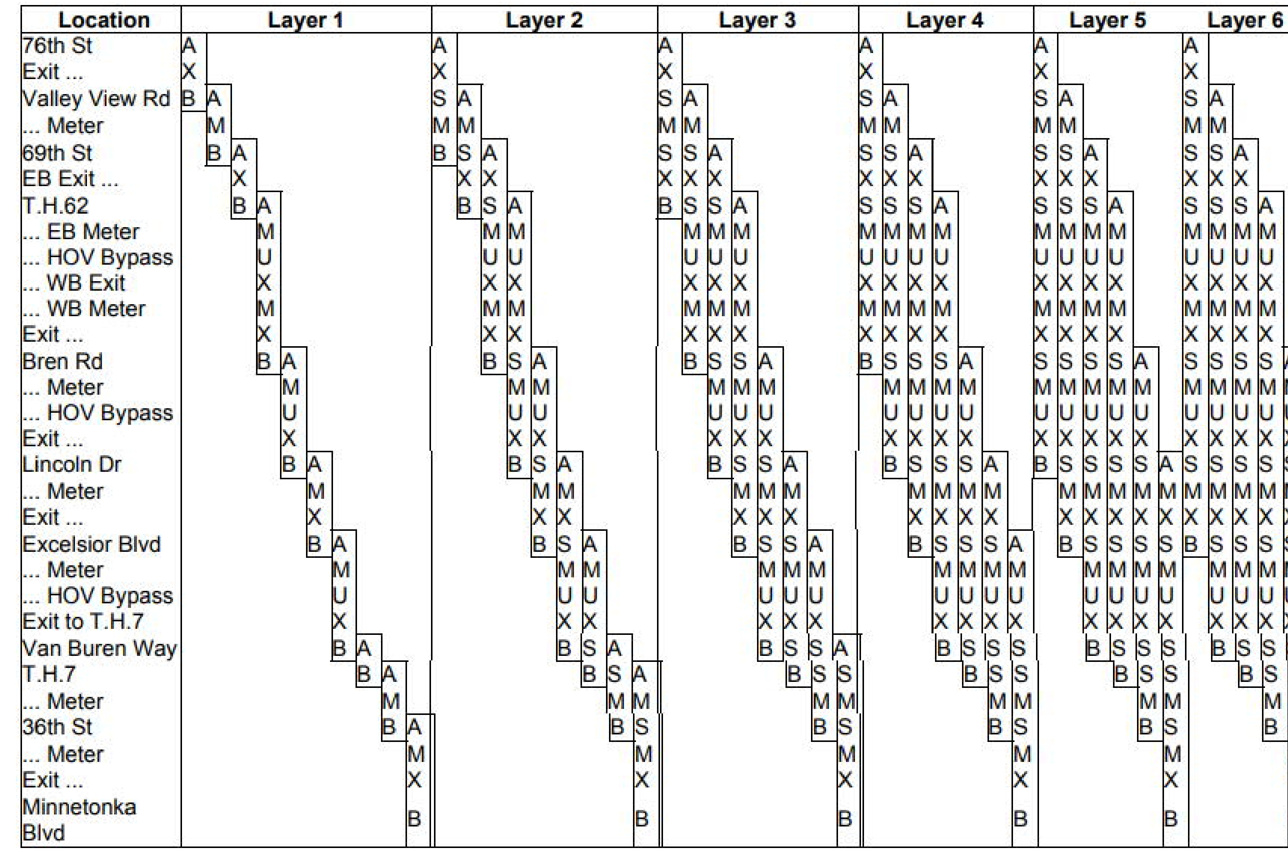
- (M) Metered Entrances: Entrance ramps onto any given freeway that are metered.
- (A) Upstream Mainline Volume: Total number of vehicles entering a zone through the station at the beginning of the zone. (See Appendix; HOV and Auxiliary Lanes)
- (U) Unmetered Entrances: Entrance ramps onto any given freeway that are not metered.

3 Outputs:

- (X) Exits: all exit ramps off any given freeway.
- (B) Downstream Mainline Volume: Total number of vehicles leaving a zone through the station at the end of the zone. Regardless of actual station volume, the value for the B station is set to the approximate capacity of that station: Right lane 1800, all other lanes 2100 veh/hr. A (B) station value based on anything other than capacity would often result in an unreasonable volume. (See Appendix; HOV and Auxiliary Lanes)
- (S) Spare Capacity: If a zone is free-flowing with little traffic, there is said to be “spare capacity” on the mainline, and meters will not need to be as restrictive. For this reason, the spare capacity is regarded as an output. This variable is calculated using average freeway densities for free-flowing traffic compared to current freeway densities (see Appendix; Spare Capacity)

A graphical overview of the zones and the inputs / outputs is presented on the following page.

Table 7: Stratified Zone Metering Example (Hwy 169 NB)



In short, the “pros” of this method for ramp metering are the following:

1. Method can be more responsive to changes in traffic conditions as measured by traffic detection stations along the roadway
2. Management of queue lengths on ramps is designed to minimize concerns of lengthy wait times on ramp meter approaches, and is set to about 4 minutes at most.

In short, the “cons” of this method for ramp metering are the following:

1. Algorithm was custom designed by MnDOT and requires a detailed understanding of the methods and underlying formulas behind the algorithms
2. Requires a consistent deployment of traffic detection stations at evenly spaced intervals throughout a metro area to be effective at achieving the zone objectives across a long corridor or metro area

System-Wide Adaptive Ramp Metering (SWARM) Metering Approach Summary

Source: https://secure.engr.oregonstate.edu/wiki/transportation/uploads/OSU-Startup/Evaluating%20Benefits%20of%20A%20System-wide%20Adaptive%20Ramp-Metering%20Strategy%20in%20PortlandOregon.pdf

Under a SWARM approach, a freeway network is divided into contiguous segments that are defined by the locations of existing traffic loop detectors. Each segment contains multiple on-ramps and off-ramps in between them, and for each segment, there are two "competing" modes of SWARM operations:

1. Global Mode, which operates on an entire system based on forecasted densities at each detection location
2. Local Mode, which operates with respect to real-time local traffic conditions near each ramp

Two metering rates are computed from the global and local modes, and the more restrictive rate of the two is deployed in the field.

In short, the "pros" of this method for ramp metering are the following:
1. Approaches have been field-tested against pre-timed and local traffic-responsive strategies and been found to be more effective at increasing mainline speeds and reducing vehicle travel times
2. Method can be more responsive to changes in traffic conditions as measured by traffic detection stations along the roadway.

In short, the "cons" of this method for ramp metering are the following:

1. Any communication failures between loop detector stations and the traffic management center could lead to an inaccurate application of either the global or local mode in the field. The performance of SWARM largely depends on the availability of accurate data.
2. In order to compute metering rates in response to the real-time traffic conditions, the SWARM algorithm requires large amount of data from multiple freeway locations and on-ramps. A large amount of (simultaneous) data streams can cause communication failures and loss of data if the communication network is not established to accommodate them.

Current ADOT Ramp Metering System

- ADOT uses two ramp metering methods:
  - FIXED RATE METERING:
    - Used at majority of ramp meter locations in Phoenix metro area
    - All ramp meters operating in this mode are planned to be upgraded in the near future
  - LOCAL TRAFFIC RESPONSIVE RAMP METERING:
    - Used on SR 51
    - Adjusts based on real-time traffic data from vehicle detectors
    - One of six metering levels selected based on average speed of right-most mainline lane

CURRENT LOCAL TRAFFIC RESPONSIVE METERING RATES:

Metering Level	Freeway Speed	Metering Rate (for 2 lanes)
	(Miles/Hour)	(Vehicles/Hour)
1	>65	1,440
2	65 to 56	1,320
3	55 to 46	1,200
4	45 to 36	1,080
5	35 to 11	960
6	10 to 0	840

- Current Ramp Metering Time of day
  - Monday –Friday,
    - 6:00 am- 9:00am
    - 3:00pm- 7:00pm
- ADOT uses dual-indication signal heads with red and green indications
  - Desirable setup is two signal heads per lane
  - Warning flasher beacons with "RAMP METERED WHEN FLASHING" sign are installed on entrance ramps in advance of all ramp meters
- Vehicle Detection:
  - All ramp meters use an arrangement of loop detectors consisting of queue detectors, demand detectors, and passage detectors
- Recommendation for Implementation:
  - Ramp metering starts before & after (to the nearest 30-minute increment) historically-recurring freeway congestion adjacent or within 2 miles downstream from the ramp meter.
  - Ramp meters are turned off at locations where traffic at the meter is greater than 2,000 vph, and at taper-type freeway entrances which provide less than 350 feet of acceleration distance

2016 Warrant Analysis

Entrance Ramp	Peak Hour	Right-most Freeway Lane Volume (vph)	Ramp Volume (vph)	Combined Volume (vph)	Warrant Volume	Lowest Freeway Speed (mph)	Warrant Speed (mph)	Ramp Warrants Satisfied
Twin Peaks Rd (EB)	A.M.	760	1760	2520	2050	58	50	No
	P.M.	760	880	1640	2050	59	50	
Cortaro Rd (EB)	A.M.	1160	1680	2840	2050	57	50	No
	P.M.	840	800	1640	2050	59	50	
Ina Rd (EB)	A.M.	1480	1080	2560	2050	54	50	No
	P.M.	1000	840	1840	2050	58	50	
Orange Grove Rd (EB)	A.M.	1640	1160	2800	2050	27	50	Yes
	P.M.	1040	1040	2080	2050	57	50	
Sunset Rd (EB)	A.M.	1920	320	2240	2050	51	50	No
	P.M.	1280	40	1320	2050	57	50	
Ruthrauff Rd (EB)	A.M.	1880	1200	3080	2050	57	50	No
	P.M.	1200	720	1920	2050	58	50	
Prince Rd (EB)	A.M.	1640	1520	3160	2050	54	50	No
	P.M.	960	1760	2720	2050	57	50	
Miracle Mile (EB)	A.M.	1880	1400	3280	2050	47	50	Yes
	P.M.	1240	1720	2960	2050	57	50	
Speedway Blvd (EB)	A.M.	1840	480	2320	2050	57	50	No
	P.M.	1320	800	2120	2050	57	50	
Congress St (EB)	A.M.	1720	800	2520	2050	56	50	No
	P.M.	1360	1200	2560	2050	51	50	
Grant Rd (EB)	A.M.	2000	1520	3520	2050	56	50	No
	P.M.	1400	760	2160	2050	58	50	
Twin Peaks Rd (WB)	A.M.	560	360	920	2050	59	50	No
	P.M.	800	280	1080	2050	59	50	
Cortaro Rd (WB)	A.M.	720	680	1400	2050	59	50	No
	P.M.	1200	320	1520	2050	58	50	
Ina Rd (WB)	A.M.	840	400	1240	2050	59	50	No
	P.M.	1400	760	2160	2050	58	50	

Entrance Ramp	Peak Hour	Right-most Freeway Lane Volume (vph)	Ramp Volume (vph)	Combined Volume (vph)	Warrant Volume	Lowest Freeway Speed (mph)	Warrant Speed (mph)	Ramp Warrants Satisfied
Orange Grove Rd (WB)	A.M.	840	560	1400	2050	59	50	No
	P.M.	1520	920	2440	2050	56	50	
Sunset Rd (WB)	A.M.	1040	80	1120	2050	58	50	No
	P.M.	1760	80	1840	2050	43	50	
Ruthruaff Rd (WB)	A.M.	1080	400	1480	2050	59	50	No
	P.M.	1640	600	2240	2050	56	50	
Prince Rd (WB)	A.M.	920	160	1080	2050	59	50	No
	P.M.	1480	240	1720	2050	42	50	
Miracle Mile (WB)	A.M.	1120	280	1400	2050	59	50	No
	P.M.	1640	360	2000	2050	57	50	
Speedway Blvd (WB)	A.M.	1360	800	2160	2050	58	50	No
	P.M.	1800	920	2720	2050	52	50	
Congress St (WB)	A.M.	1360	480	1840	2050	57	50	No
	P.M.	1760	1000	2760	2050	53	50	
Grant Rd (WB)	A.M.	1280	680	1960	2050	58	50	No
	P.M.	1800	640	2440	2050	54	50	
22nd St (WB)	A.M.	1560	1040	2600	2050	56	50	No
	P.M.	1760	960	2720	2050	54	50	

2025 Warrant Analysis

Entrance Ramp	Peak Hour	Right-most Freeway Lane Volume (vph)	Ramp Volume (vph)	Combined Volume (vph)	Warrant Volume	Lowest Freeway Speed (mph)	Warrant Speed (mph)	Ramp Warrants Satisfied
Twin Peaks Rd (EB)	A.M.	1000	1800	2800	2050	58	50	No
	P.M.	1000	880	1880	2050	58	50	
Cortaro Rd (EB)	A.M.	1400	1720	3120	2050	57	50	No
	P.M.	1040	800	1840	2050	58	50	
Ina Rd (EB)	A.M.	1240	1080	2320	2050	57	50	No
	P.M.	840	880	1720	2050	59	50	
Orange Grove Rd (EB)	A.M.	1360	1200	2560	2050	53	50	No
	P.M.	840	1040	1880	2050	59	50	
Sunset Rd (EB)	A.M.	1560	440	2000	2050	54	50	No
	P.M.	1040	40	1080	2050	58	50	
Ruthrauff Rd (EB)	A.M.	1560	1200	2760	2050	58	50	No
	P.M.	960	760	1720	2050	59	50	
Prince Rd (EB)	A.M.	1800	1560	3360	2050	49	50	Yes
	P.M.	1040	1800	2840	2050	57	50	
Miracle Mile (EB)	A.M.	2040	1480	3520	2050	40	50	Yes
	P.M.	1320	1920	3240	2050	57	50	
Speedway Blvd (EB)	A.M.	2000	520	2520	2050	57	50	No
	P.M.	1440	840	2280	2050	57	50	
Congress St (EB)	A.M.	1880	840	2720	2050	55	50	No
	P.M.	1440	1240	2680	2050	50	50	
Grant Rd (EB)	A.M.	2160	1560	3720	2050	56	50	No
	P.M.	1480	800	2280	2050	58	50	
Twin Peaks Rd (WB)	A.M.	720	640	1360	2050	55	50	No
	P.M.	1040	560	1600	2050	55	50	
Cortaro Rd (WB)	A.M.	840	720	1560	2050	59	50	No
	P.M.	1360	720	2080	2050	57	50	
Ina Rd (WB)	A.M.	960	520	1480	2050	58	50	No
	P.M.	1560	880	2440	2050	57	50	
Orange Grove Rd (WB)	A.M.	720	560	1280	2050	59	50	No
	P.M.	1280	960	2240	2050	58	50	
Sunset Rd (WB)	A.M.	880	80	960	2050	59	50	No
	P.M.	1480	120	1600	2050	56	50	
Ruthruaff Rd (WB)	A.M.	920	440	1360	2050	58	50	No
	P.M.	1400	680	2080	2050	51	50	
Prince Rd (WB)	A.M.	1040	160	1200	2050	59	50	No
	P.M.	1640	280	1920	2050	58	50	
Miracle Mile (WB)	A.M.	1240	280	1520	2050	58	50	No
	P.M.	1800	400	2200	2050	56	50	
Speedway Blvd (WB)	A.M.	1480	840	2320	2050	57	50	Yes
	P.M.	1960	1240	3200	2050	28	50	
Congress St (WB)	A.M.	1520	560	2080	2050	57	50	Yes
	P.M.	1960	1040	3000	2050	42	50	
Grant Rd (WB)	A.M.	1440	720	2160	2050	57	50	Yes
	P.M.	1960	680	2640	2050	49	50	
22nd St (WB)	A.M.	1680	1120	2800	2050	43	50	Yes
	P.M.	1960	1000	2960	2050	51	50	

APPENDIX D – COST ESTIMATES

Ruthrauff Road Westbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	0	$110.00	$0.00
	CURB AND GUTTER	L.FT.	0	$50.00	$0.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$1,500.00	$1,500.00
	CATCH BASIN	EACH	0	$5,000.00	$0.00
	EARTHWORK	L.SUM	0	$20,000.00	$0.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		$87,200.00
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		7,000.00	7,000
	Dust and Water Palliative (0.75%)	COST		1,000.00	1,000
	Quality Control (0.75%)	COST		1,000.00	1,000
	Construction Surveying (1.5%)	COST		2,000.00	2,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		10,500.00	10,500
			PROJECT WIDE SUBTOTAL		22,500
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		22,000.00	22,000
			PROJECT WIDE TOTAL		44,500
OTHER COST					
	Construction Engineering (9%)	COST		12,000.00	12,000
	Construction Contingencies (5%)	COST		7,000.00	7,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		11,000.00	11,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		3,000.00	3,000
			OTHER COST TOTAL		33,000
	SUMMARY				
		ITEM TOTAL			87,200
		PROJECT WIDE			22,500
		OTHER COST TOTAL			33,000
		SUBTOTAL PROJECT COST			142,700
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			15,000
		TOTAL PROJECT COST			157,700
		TOTAL PROJECT COST (ROUNDUP $10K)			160,000

Miracle Mile Eastbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	1,067	$110.00	$117,400.00
	CURB AND GUTTER	L.FT.	800	$50.00	$40,000.00
	CONCRETE BARRIER	L.FT.	800	$120.00	$96,000.00
	STRIPING	L.SUM	1	$2,500.00	$2,500.00
	CATCH BASIN	EACH	1	$5,000.00	$5,000.00
	EARTHWORK	L.SUM	1	$20,000.00	$20,000.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		$366,600.00
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		30,000.00	30,000
	Dust and Water Palliative (0.75%)	COST		3,000.00	3,000
	Quality Control (0.75%)	COST		3,000.00	3,000
	Construction Surveying (1.5%)	COST		6,000.00	6,000
	Erosion Control (0.3%)	COST		2,000.00	2,000
	Mobilization (8% of all construction items)	COST		43,600.00	43,600
			PROJECT WIDE SUBTOTAL		87,600
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		91,000.00	91,000
			PROJECT WIDE TOTAL		178,600
OTHER COST					
	Construction Engineering (9%)	COST		50,000.00	50,000
	Construction Contingencies (5%)	COST		28,000.00	28,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		44,000.00	44,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		11,000.00	11,000
			OTHER COST TOTAL		133,000
	SUMMARY				
		ITEM TOTAL			366,600
		PROJECT WIDE			87,600
		OTHER COST TOTAL			133,000
		SUBTOTAL PROJECT COST			587,200
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			60,000
		TOTAL PROJECT COST			647,200
		TOTAL PROJECT COST (ROUNDUP $10K)			650,000

Congress St Eastbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	0	$110.00	$0.00
	CURB AND GUTTER	L.FT.	0	$50.00	$0.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$1,500.00	$1,500.00
	CATCH BASIN	EACH	0	$5,000.00	$0.00
	EARTHWORK	L.SUM	0	$20,000.00	$0.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	2,100	$10.00	$21,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,800	$5.00	$9,000.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		$94,700.00
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		8,000.00	8,000
	Dust and Water Palliative (0.75%)	COST		1,000.00	1,000
	Quality Control (0.75%)	COST		1,000.00	1,000
	Construction Surveying (1.5%)	COST		2,000.00	2,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		11,500.00	11,500
			PROJECT WIDE SUBTOTAL		24,500
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		24,000.00	24,000
			PROJECT WIDE TOTAL		48,500
OTHER COST					
	Construction Engineering (9%)	COST		13,000.00	13,000
	Construction Contingencies (5%)	COST		8,000.00	8,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		12,000.00	12,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		3,000.00	3,000
			OTHER COST TOTAL		36,000
	SUMMARY				
		ITEM TOTAL			94,700
		PROJECT WIDE			24,500
		OTHER COST TOTAL			36,000
		SUBTOTAL PROJECT COST			155,200
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			16,000
		TOTAL PROJECT COST			171,200
		TOTAL PROJECT COST (ROUNDUP $10K)			180,000

Prince Rd Eastbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	1,267	$110.00	$139,400.00
	CURB AND GUTTER	L.FT.	950	$50.00	$47,500.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$2,500.00	$2,500.00
	CATCH BASIN	EACH	3	$5,000.00	$15,000.00
	EARTHWORK	L.SUM	1	$20,000.00	$20,000.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	14	$750.00	$10,500.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		$308,600.00
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		25,000.00	25,000
	Dust and Water Palliative (0.75%)	COST		3,000.00	3,000
	Quality Control (0.75%)	COST		3,000.00	3,000
	Construction Surveying (1.5%)	COST		5,000.00	5,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		36,800.00	36,800
			PROJECT WIDE SUBTOTAL		73,800
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		77,000.00	77,000
			PROJECT WIDE TOTAL		150,800
OTHER COST					
	Construction Engineering (9%)	COST		42,000.00	42,000
	Construction Contingencies (5%)	COST		23,000.00	23,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		37,000.00	37,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		10,000.00	10,000
			OTHER COST TOTAL		112,000
	SUMMARY				
		ITEM TOTAL			308,600
		PROJECT WIDE			73,800
		OTHER COST TOTAL			112,000
		SUBTOTAL PROJECT COST			494,400
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			51,000
		TOTAL PROJECT COST			545,400
		TOTAL PROJECT COST (ROUNDUP $10K)			550,000

Grant Rd Westbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	0	$110.00	$0.00
	CURB AND GUTTER	L.FT.	0	$50.00	$0.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$1,500.00	$1,500.00
	CATCH BASIN	EACH	0	$5,000.00	$0.00
	EARTHWORK	L.SUM	0	$20,000.00	$0.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		$87,200.00
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		7,000.00	7,000
	Dust and Water Palliative (0.75%)	COST		1,000.00	1,000
	Quality Control (0.75%)	COST		1,000.00	1,000
	Construction Surveying (1.5%)	COST		2,000.00	2,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		10,500.00	10,500
			PROJECT WIDE SUBTOTAL		22,500
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		22,000.00	22,000
			PROJECT WIDE TOTAL		44,500
OTHER COST					
	Construction Engineering (9%)	COST		12,000.00	12,000
	Construction Contingencies (5%)	COST		7,000.00	7,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		11,000.00	11,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		3,000.00	3,000
			OTHER COST TOTAL		33,000
	SUMMARY				
		ITEM TOTAL			87,200
		PROJECT WIDE			22,500
		OTHER COST TOTAL			33,000
		SUBTOTAL PROJECT COST			142,700
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			15,000
		TOTAL PROJECT COST			157,700
		TOTAL PROJECT COST (ROUNDUP $10K)			160,000

Speedway Blvd Westbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	1,067	$110.00	$117,400.00
	CURB AND GUTTER	L.FT.	1,600	$50.00	$80,000.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$2,500.00	$2,500.00
	CATCH BASIN	EACH	1	$5,000.00	$5,000.00
	EARTHWORK	L.SUM	1	$20,000.00	$20,000.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		$310,600.00
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		25,000.00	25,000
	Dust and Water Palliative (0.75%)	COST		3,000.00	3,000
	Quality Control (0.75%)	COST		3,000.00	3,000
	Construction Surveying (1.5%)	COST		5,000.00	5,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		36,900.00	36,900
			PROJECT WIDE SUBTOTAL		73,900
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		77,000.00	77,000
			PROJECT WIDE TOTAL		150,900
OTHER COST					
	Construction Engineering (9%)	COST		42,000.00	42,000
	Construction Contingencies (5%)	COST		24,000.00	24,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		37,000.00	37,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		10,000.00	10,000
			OTHER COST TOTAL		113,000
	SUMMARY				
		ITEM TOTAL			310,600
		PROJECT WIDE			73,900
		OTHER COST TOTAL			113,000
		SUBTOTAL PROJECT COST			497,500
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			51,000
		TOTAL PROJECT COST			548,500
		TOTAL PROJECT COST (ROUNDUP $10K)			550,000

Congress St Westbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	0	$110.00	$0.00
	CURB AND GUTTER	L.FT.	0	$50.00	$0.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$1,500.00	$1,500.00
	CATCH BASIN	EACH	0	$5,000.00	$0.00
	EARTHWORK	L.SUM	0	$20,000.00	$0.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		**$87,200.00**
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		7,000.00	7,000
	Dust and Water Palliative (0.75%)	COST		1,000.00	1,000
	Quality Control (0.75%)	COST		1,000.00	1,000
	Construction Surveying (1.5%)	COST		2,000.00	2,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		10,500.00	10,500
			PROJECT WIDE SUBTOTAL		**22,500**
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		22,000.00	22,000
			PROJECT WIDE TOTAL		**44,500**
OTHER COST					
	Construction Engineering (9%)	COST		12,000.00	12,000
	Construction Contingencies (5%)	COST		7,000.00	7,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		11,000.00	11,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		3,000.00	3,000
			OTHER COST TOTAL		**33,000**
	SUMMARY				
		ITEM TOTAL			**87,200**
		PROJECT WIDE			**22,500**
		OTHER COST TOTAL			**33,000**
		SUBTOTAL PROJECT COST			**142,700**
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			**15,000**
		TOTAL PROJECT COST			**157,700**
		TOTAL PROJECT COST (ROUNDUP $10K)			**160,000**

22nd St Westbound

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	ASPHALTIC CONCRETE PAVEMENT	SY	0	$110.00	$0.00
	CURB AND GUTTER	L.FT.	0	$50.00	$0.00
	CONCRETE BARRIER	L.FT.	0	$120.00	$0.00
	STRIPING	L.SUM	1	$1,500.00	$1,500.00
	CATCH BASIN	EACH	0	$5,000.00	$0.00
	EARTHWORK	L.SUM	0	$20,000.00	$0.00
	TRAFFIC SIGNAL FACE (TYPE D)	EACH	2	$500.00	$1,000.00
	TRAFFIC SIGNAL MOUNTING ASSEMBLY (TYPE III)	EACH	2	$250.00	$500.00
	POLE (TYPE A) (10')	EACH	2	$700.00	$1,400.00
	POLE FOUNDATION (TYPE A)	EACH	2	$700.00	$1,400.00
	CABINET FOUNDATION	EACH	1	$1,200.00	$1,200.00
	WARNING, MARKER, OR REGULATORY SIGN PANEL	SQ.FT.	30	$25.00	$800.00
	PULL BOX (NO. 7)	EACH	5	$600.00	$3,000.00
	PULL BOX (NO. 9)	EACH	1	$3,000.00	$3,000.00
	CONTROLLER CABINET	EACH	1	$15,000.00	$15,000.00
	RAMP METER SIGNAL AND SUPPORT ASSEMBLY	EACH	2	$3,000.00	$6,000.00
	LOOP DETECTOR AMPLIFIERS FOR RAMP METERING	EACH	2	$200.00	$400.00
	LOOP DETECTOR FOR TRAFFIC SIGNALS (6' X 6')	EACH	16	$750.00	$12,000.00
	ELECTRICAL CONDUIT (3") (PVC)	L.FT.	1,600	$10.00	$16,000.00
	ELECTRICAL CONDUIT (3") (HDPE)	L.FT.	400	$35.00	$14,000.00
	CONDUCTORS	L.SUM	1	$500.00	$500.00
	SINGLE MODE FIBER OPTIC CABLE (12 FIBERS)	L.FT.	1,300	$5.00	$6,500.00
	FIBER OPTIC SPLICE CLOSURE (FMS)	EACH	1	$3,000.00	$3,000.00
			ITEM TOTAL		**$87,200.00**
PROJECT WIDE					
	Maintenance and Protection of Traffic (8%)	COST		7,000.00	7,000
	Dust and Water Palliative (0.75%)	COST		1,000.00	1,000
	Quality Control (0.75%)	COST		1,000.00	1,000
	Construction Surveying (1.5%)	COST		2,000.00	2,000
	Erosion Control (0.3%)	COST		1,000.00	1,000
	Mobilization (8% of all construction items)	COST		10,500.00	10,500
			PROJECT WIDE SUBTOTAL		**22,500**
	Unidentified Items (20% of Item Total and Project Wide Subtotal)	COST		22,000.00	22,000
			PROJECT WIDE TOTAL		**44,500**
OTHER COST					
	Construction Engineering (9%)	COST		12,000.00	12,000
	Construction Contingencies (5%)	COST		7,000.00	7,000
	Environmental Mitigation (Unknown at this time)	COST		-	-
	PCCP Quality Incentive	SQ.YD.	0	1.50	-
	AR-ACFC Smoothness Incentive	L.MILE	0	11,000.00	-
	Engineering Design (Includes Surveying and Geotechnical) (8% of all items)	COST		11,000.00	11,000
	Right-of-Way	COST		-	-
	Utilities (Miscellaneous Relocation) (2%)	COST		3,000.00	3,000
			OTHER COST TOTAL		**33,000**
	SUMMARY				
		ITEM TOTAL			**87,200**
		PROJECT WIDE			**22,500**
		OTHER COST TOTAL			**33,000**
		SUBTOTAL PROJECT COST			**142,700**
		INDIRECT COST ALLOCATION (ICAP) (10.14%)			**15,000**
		TOTAL PROJECT COST			**157,700**
		TOTAL PROJECT COST (ROUNDUP $10K)			**160,000**

APPENDIX E – BENEFIT COST ANALYSIS

Capital Costs

Discount Rates	3%
	7%
Discount year	2018

Inputs

Cost Category	Ramp Metering
Total Project Costs	$ 2,570,000

Values in $2015

Assumes all Alternatives have the same spending schedule	2025
Assumes the following distribution of costs across the years:	100%

Outputs

Ramp Metering

	2025
Total	$ 2,570,000

Total	$ 2,570,000
Discounted at 3%	$ 2,089,645
Discounted at 7%	$ 1,600,467

Capital Cost Summary	Total ($M)
Total	$ 2.57
Discounted at 3%	$ 2.09
Discounted at 7%	$ 1.60

O&M Costs

Assume O&M is 1% of Capital, per year for 2025-2044. Assume O&M costs start in 2025. Assumes no change over analysis period.

Discount	0.03
	0.07
Discount year	2018

Ramp Metering 1% % of Capital Cost

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Annual O&M Costs (in millions of 2015$)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
O&M Costs	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700
Total	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700	$25,700
Discounted 7%	$16,005	$14,958	$13,979	$13,065	$12,210	$11,411	$10,665	$9,967	$9,315	$8,705	$8,136	$7,604	$7,106	$6,641	$6,207	$5,801	$5,421	$5,067	$4,735	$4,425
Discounted 3%	$20,896	$20,288	$19,697	$19,123	$18,566	$18,025	$17,500	$16,991	$16,496	$16,015	$15,549	$15,096	$14,656	$14,229	$13,815	$13,413	$13,022	$12,643	$12,274	$11,917

	20 year Total (2020-2039)
Millions of 2015$	$0.51
Discounted 7%	$0.18
Discounted 3%	$0.32

Safety Costs Avoided

Value of Accidents Avoided	2017$ Millions
KABCO Level K (Killled)	$ 9.600
KABCO Level A (Incapacitating)	$ 0.459
KABCO Level B (Non-incapacitating)	$ 0.125
KABCO Level C (Possible injury)	$ 0.064
KABCO Level O (No injury)	$ 0.003

2018 Guidance for Discretionary Grant Programs, see https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/284031/benefit-cost-analysis-guidance-2018_0.pdf

Increase VSL by 1.00% per Year 1.00%

$Millions of 2017 dollars

2017	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
KABCO Level K (Killled)	$ 10.395	$ 10.499	$ 10.604	$ 10.710	$ 10.818	$ 10.926	$ 11.035	$ 11.145	$ 11.257	$ 11.369	$ 11.483	$ 11.598	$ 11.714	$ 11.831	$ 11.949	$ 12.069	$ 12.189	$ 12.311	$ 12.434	$ 12.559
KABCO Level A (Incapacitating)	$ 0.497	$ 0.502	$ 0.507	$ 0.512	$ 0.517	$ 0.522	$ 0.528	$ 0.533	$ 0.538	$ 0.544	$ 0.549	$ 0.555	$ 0.560	$ 0.566	$ 0.571	$ 0.577	$ 0.583	$ 0.589	$ 0.595	$ 0.600
KABCO Level B (Non-incapacitating)	$ 0.135	$ 0.137	$ 0.138	$ 0.139	$ 0.141	$ 0.142	$ 0.144	$ 0.145	$ 0.147	$ 0.148	$ 0.150	$ 0.151	$ 0.153	$ 0.154	$ 0.156	$ 0.157	$ 0.159	$ 0.160	$ 0.162	$ 0.164
KABCO Level C (Possible injury)	$ 0.069	$ 0.070	$ 0.071	$ 0.071	$ 0.072	$ 0.073	$ 0.074	$ 0.074	$ 0.075	$ 0.076	$ 0.077	$ 0.077	$ 0.078	$ 0.079	$ 0.080	$ 0.080	$ 0.081	$ 0.082	$ 0.083	$ 0.084
KABCO Level O (No injury)	$ 0.003	$ 0.003	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004	$ 0.004

Discount Rates		Discount Year
0.03	0.07	2017

Ramp Metering

Baseline Safety	2025	Future Safety	2025
Average Annual Fatal	0.60	Average Annual Fatal	0.52
Average Annual Serious	1.40	Average Annual Serious	1.22
Average Annual Minor	8.80	Average Annual Minor	7.62
Average Annual Possible	11.80	Average Annual Possible	10.16
Average Annual No Injury	89.20	Average Annual No Injury	77.15
Note: assume "serious injury" are KABCO A injuries		Note: assume "serious injury" are KABCO A injuries	
Note: assume "minor injury" are KABCO B injuries		Note: assume "minor injury" are KABCO B injuries	
Note: assume "possible injury" are KABCO C injuries		Note: assume "possible injury" are KABCO C injuries	

Annual growth factor for incidents 1%

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Reduced Fatal Accidents	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Reduced Serious Injury Accidents	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15
Reduced Minor Injury Accidents	1.18	1.17	1.16	1.15	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98
Reduced Possible Injury Accidents	1.64	1.62	1.61	1.59	1.58	1.56	1.54	1.53	1.51	1.50	1.48	1.47	1.46	1.44	1.43	1.41	1.40	1.38	1.37	1.36
Reduced No Injury Accidents	12.05	11.93	11.81	11.70	11.58	11.47	11.35	11.24	11.13	11.02	10.91	10.80	10.69	10.59	10.48	10.38	10.28	10.17	10.07	9.97

Annualization factor 270 (accounts for weekdays only)

Cost Savings from Accidents Avoided (2017$ M)	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
KABCO Level K (Killled)	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62	$ 0.62
KABCO Level A (Incapacitating)	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07	$ 0.07
KABCO Level B (Non-incapacitating)	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12	$ 0.12
KABCO Level C (Possible injury)	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08	$ 0.08
KABCO Level O (No injury)	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.03
Total	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91	$ 0.91
Discounted at 3%	$ 0.72	$ 0.70	$ 0.68	$ 0.66	$ 0.64	$ 0.62	$ 0.60	$ 0.59	$ 0.57	$ 0.55	$ 0.54	$ 0.52	$ 0.51	$ 0.49	$ 0.48	$ 0.46	$ 0.45	$ 0.44	$ 0.42	$ 0.41
Discounted at 7%	$ 0.53	$ 0.50	$ 0.46	$ 0.43	$ 0.41	$ 0.38	$ 0.35	$ 0.33	$ 0.31	$ 0.29	$ 0.27	$ 0.25	$ 0.24	$ 0.22	$ 0.21	$ 0.19	$ 0.18	$ 0.17	$ 0.16	$ 0.15

Ramp Metering	Total
Total	$ 18.29
Discounted at 3%	$ 11.06
Discounted at 7%	$ 6.03

Travel Time Savings

Peak users save time due to average speed increases on the segment

% Truck	5.0%
% Auto	95.0%

Trip Purpose	Business	Personal
Truck	100%	0%
Auto	0%	100%

Hourly Rates	$2017 Value of Time
Truck	$ 28.60
Auto	$ 14.80

Benefit-Cost Analysis Guidance for Discretionary Grant Programs (USDOT, 2018)

Value of Time 1.20% Annual Increase

	2017	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Truck	$ 28.60	$ 31.46	$ 31.84	$ 32.22	$ 32.61	$ 33.00	$ 33.40	$ 33.80	$ 34.20	$ 34.61	$ 35.03	$ 35.45	$ 35.88	$ 36.31	$ 36.74	$ 37.18	$ 37.63	$ 38.08	$ 38.54	$ 39.00
Auto	$ 14.80	$ 16.28	$ 16.48	$ 16.68	$ 16.88	$ 17.08	$ 17.28	$ 17.49	$ 17.70	$ 17.91	$ 18.13	$ 18.34	$ 18.56	$ 18.79	$ 19.01	$ 19.24	$ 19.47	$ 19.71	$ 19.94	$ 20.18

Annualization factor	270	
Avg Auto Occ Rate	1.39	Benefit-Cost Analysis Guidance for Discretionary Grant Programs (USDOT, 2018)
Discount rates	3%	
	7%	
Discount Year	2018	

PEAK Traffic	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Ramp Meters																				
Eastbound (AM)	-16.64	-16.70	-16.76	-16.83	-16.89	-16.95	-17.01	-17.07	(17.24)	(17.42)	(17.59)	(17.77)	(17.94)	(18.12)	(18.31)	(18.49)	(18.67)	(18.86)	(19.05)	(19.24)
Westbound (PM)	35.00	35.36	35.72	36.09	36.45	36.81	37.18	37.54	37.92	38.30	38.68	39.07	39.46	39.85	40.25	40.65	41.06	41.47	41.88	42.30
Note: Assume 1% growth rate	1%	annual AADT growth after 2032																		

Ramp Meters	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Truck																				
Eastbound (AM)	$ (26)	$ (27)	$ (27)	$ (27)	$ (28)	$ (28)	$ (29)	$ (29)	$ (30)	$ (31)	$ (31)	$ (32)	$ (33)	$ (33)	$ (34)	$ (35)	$ (36)	$ (36)	$ (37)	$ (38)
Westbound (PM)	$ 55	$ 56	$ 58	$ 59	$ 60	$ 61	$ 63	$ 64	$ 66	$ 67	$ 69	$ 70	$ 72	$ 73	$ 75	$ 76	$ 78	$ 80	$ 82	$ 83
Auto																				
Eastbound (AM)	$ (358)	$ (363)	$ (369)	$ (375)	$ (381)	$ (387)	$ (393)	$ (399)	$ (408)	$ (417)	$ (426)	$ (436)	$ (445)	$ (455)	$ (465)	$ (475)	$ (486)	$ (497)	$ (508)	$ (519)
Westbound (PM)	$ 752	$ 769	$ 787	$ 804	$ 822	$ 840	$ 859	$ 877	$ 897	$ 917	$ 937	$ 958	$ 979	$ 1,001	$ 1,023	$ 1,045	$ 1,068	$ 1,092	$ 1,116	$ 1,141
Total	$ 424	$ 436	$ 448	$ 461	$ 473	$ 487	$ 500	$ 513	$ 525	$ 536	$ 548	$ 560	$ 573	$ 585	$ 598	$ 612	$ 625	$ 639	$ 653	$ 668
Discounted at 3%	$ 344	$ 344	$ 343	$ 343	$ 342	$ 341	$ 340	$ 339	$ 337	$ 334	$ 332	$ 329	$ 327	$ 324	$ 322	$ 319	$ 317	$ 314	$ 312	$ 310
Discounted at 7%	$ 264	$ 254	$ 244	$ 234	$ 225	$ 216	$ 207	$ 199	$ 190	$ 182	$ 174	$ 166	$ 158	$ 151	$ 145	$ 138	$ 132	$ 126	$ 120	$ 115

Climbing Lane	Total
Total, $M	$ 0.01
Discounted at 3%	$ 0.01
Discounted at 7%	$ 0.00

2032 AM Travel Times

		No Build		Build		No-Build	Build						
Eastbound/Southbound	**Type**	Speed	Volume	Speed	Volume	Minutes	Minutes	Change		hrs/veh x VPH			
Project Begin to Twin Peaks Off Ramp	Mainline	43	4061	43	4061	0.215411	0.215411	0.00		0.0000			
Twin Peaks Off Ramp to Twin Peak On Ramp	Mainline	59	3286	59	3286	1.027828	1.027775	0.00		-0.0029			
Twin Peak On Ramp to Cortaro Off Ramp	Mainline	57	4940	58	4940	0.988867	0.987726	0.00		-0.0940			
Cortaro Off Ramp to Cortaro On Ramp	Mainline	58	4408	58	4408	0.765699	0.765227	0.00		-0.0346			
Cortaro On Ramp to Ina Off Ramp	Mainline	57	5399	57	5401	1.115978	1.115492	0.00		-0.0437			
Ina Off Ramp to Ina On Ramp	Mainline	57	4848	57	4848	0.476621	0.475591	0.00		-0.0833			
Ina On Ramp to Orange Grove Off Ramp	Mainline	57	5820	57	5822	0.514222	0.511952	0.00		-0.2202			
Orange Grove Off Ramp to Orange Grove On Ramp	Mainline	58	4980	58	4976	0.773362	0.772832	0.00		-0.0440			
Orange Grove On Ramp to Sunset Off Ramp	Mainline	49	5982	57	5977	0.227234	0.194446	-0.03		-3.2677			
Sunset Off Ramp to Sunset On Ramp	Mainline	57	5769	58	5772	0.870099	0.862379	-0.01		-0.7425			
Sunset On Ramp to Ruthrauff Off Ramp	Mainline	53	6139	53	6115	0.298421	0.296161	0.00		-0.2307			
Ruthrauff Off Ramp to Ruthrauff On Ramp	Mainline	58	5832	58	5805	0.982894	0.983175	0.00		0.0272			
Ruthrauff On Ramp to Prince Off Ramp	Mainline	58	6958	58	6924	0.879185	0.879085	0.00		-0.0116			
Prince Off Ramp to Prince On Ramp	Mainline	53	6618	57	6584	0.820797	0.759813	-0.06		-6.7097			
Prince On Ramp to Miracle Mile Off Ramp	Mainline	32	7777	55	7661	0.473346	0.272386	-0.20		-25.8533			
Miracle Mile Off Ramp to Miracle Mile On Ramp	Mainline	28	7493	50	7482	0.975319	0.5447	-0.43		-53.7379			
Miracle Mile On Ramp to Grant Off Ramp	Mainline	39	8504	49	8448	0.149486	0.119895	-0.03		-4.1803			
Grant Off Ramp to Grant On Ramp	Mainline	56	7942	56	7896	0.64725	0.640388	-0.01		-0.9057			
Grant On Ramp to Speedway Off Ramp	Mainline	56	8738	56	8698	0.391003	0.393332	0.00		0.3384			
Speedway Off Ramp to Speedway On Ramp	Mainline	57	7682	57	7649	0.750572	0.751344	0.00		0.0987			
Speedway On Ramp to Congress Off Ramp	Mainline	57	8050	57	8011	0.308767	0.30906	0.00		0.0393			
Congress Off Ramp to Congress On Ramp	Mainline	58	7152	58	7120	0.779146	0.778875	0.00		-0.0323			
Congress On Ramp to 22nd Off Ramp	Mainline	56	7712	55	7681	0.125219	0.125972	0.00		0.0967			
22nd Off Ramp to End Project	Mainline	57	7059	57	7032	0.596514	0.596831	0.00		0.0373			
Twin Peaks Off Ramp	Off Ramp	52	782	52	782	0.388987	0.38899	0.00		0.0000			
Cortaro Off Ramp	Off Ramp	54	512	54	513	0.221289	0.219968	0.00		-0.0113			
Ina Off Ramp	Off Ramp	21	535	21	535	0.591047	0.586546	0.00		-0.0401			
Orange Grove Off Ramp	Off Ramp	52	834	52	836	0.253476	0.252763	0.00		-0.0099			
Sunset Off Ramp	Off Ramp	52	214	55	49	0.310159	0.297339	-0.01		-0.0281			
Ruthrauff Off Ramp	Off Ramp	53	297	53	297	0.303236	0.303975	0.00		0.0037			
Prince Off Ramp	Off Ramp	54	325	54	323	0.211182	0.210815	0.00		-0.0020			
Miracle Mile Off Ramp	Off Ramp	50	198	51	205	0.229173	0.22356	-0.01		-0.0189			
Grant Off Ramp	Off Ramp	38	639	38	645	0.287194	0.283673	0.00		-0.0377			
Speedway Off Ramp	Off Ramp	53	1054	53	1049	0.291597	0.291854	0.00		0.0045			
Congress Off Ramp	Off Ramp	54	886	54	883	0.252386	0.252659	0.00		0.0040			
22nd Off Ramp	Off Ramp	54	655	54	653	0.325991	0.325503	0.00		-0.0053			
Twin Peak On Ramp	On Ramp	48	1665	48	1663	0.399581	0.399984	0.00		0.0112			
Cortaro On Ramp	On Ramp	4	1036	4	1039	1.645375	1.675566	0.03		0.5221			
Ina On Ramp	On Ramp	35	999	35	998	0.159655	0.15879	0.00		-0.0144			
Orange Grove On Ramp	On Ramp	46	1026	46	1022	0.119453	0.118942	0.00		-0.0087			
Sunset On Ramp	On Ramp	51	383	51	350	0.380349	0.380213	0.00		-0.0008			
Ruthrauff On Ramp	On Ramp	51	1139	51	1129	0.397523	0.397816	0.00		0.0055			
Prince On Ramp	On Ramp	17	1288	4	1139	0.310484	2.59793	2.29		46.2585			
Miracle Mile On Ramp	On Ramp	32	1209	4	1128	0.166419	2.970153	2.80		54.6078			
Grant On Ramp	On Ramp	38	824	38	826	0.131282	0.131535	0.00		0.0035			
Speedway On Ramp	On Ramp	46	389	46	381	0.13414	0.133856	0.00		-0.0018			
Congress On Ramp	On Ramp	48	608	48	606	0.248783	0.249412	0.00		0.0064			
												2032	2025
										5.6912	3	17.07364	16.63954

2032 PM Travel Times

						No-Build	Build						
Northbound/Westbound	**Type**	No Build		Alt 2		Minutes	Minutes	Change		hrs/veh x VPH			
Project Begin to 22nd On Ramp	Mainline	48	7918	52	7931	0.834137	0.766504	-0.07		-8.9324			
22nd On Ramp to Congress Off Ramp	Mainline	39	8651	47	8677	0.182314	0.149417	-0.03		-4.7503			
Congress Off Ramp to Congress On Ramp	Mainline	42	7801	52	7857	1.199119	0.968449	-0.23		-30.0991			
Congress On Ramp to Speedway Off Ramp	Mainline	37	8640	42	8776	0.16294	0.143158	-0.02		-2.8710			
Speedway Off Ramp to Speedway On Ramp	Mainline	30	7768	36	7923	1.616342	1.317844	-0.30		-39.0325			
Speedway On Ramp to Grant Off Ramp	Mainline	29	8764	30	8802	0.245989	0.233584	-0.01		-1.8159			
Grant Off Ramp to Grant On Ramp	Mainline	56	7717	55	7732	0.870426	0.875521	0.01		0.6558			
Grant On Ramp to Miracle Mile Off Ramp	Mainline	36	8153	39	8253	0.145102	0.134173	-0.01		-1.4942			
Miracle Mile Off Ramp to Miracle Mile On Ramp	Mainline	57	7041	57	7140	0.762039	0.764	0.00		0.2318			
Miracle Mile On Ramp to Prince Off Ramp	Mainline	56	7538	55	7634	0.190656	0.194276	0.00		0.4576			
Prince Off Ramp to Prince On Ramp	Mainline	58	6717	58	6802	0.776197	0.777222	0.00		0.1155			
Prince On Ramp to Ruthrauff Off Ramp	Mainline	58	6937	58	7014	0.771856	0.772139	0.00		0.0329			
Ruthrauff Off Ramp to Ruthrauff On Ramp	Mainline	58	5830	58	5898	0.970968	0.971572	0.00		0.0590			
Ruthrauff On Ramp to Sunset Off Ramp	Mainline	41	6487	38	6557	0.18414	0.197932	0.01		1.4991			
Sunset Off Ramp to Sunset On Ramp	Mainline	58	6029	58	6088	0.744195	0.744012	0.00		-0.0185			
Sunset On Ramp to Orange Grove Off Ramp	Mainline	49	6075	48	6133	0.256174	0.266089	0.01		1.0088			
Orange Grove Off Ramp to Orange Grove On Ramp	Mainline	58	4817	58	4864	0.797971	0.798544	0.00		0.0462			
Orange Grove On Ramp to Ina Off Ramp	Mainline	58	5735	58	5787	0.322469	0.322277	0.00		-0.0184			
Ina Off Ramp to Ina On Ramp	Mainline	51	4930	50	4967	0.498468	0.511345	0.01		1.0621			
Ina On Ramp to Cortaro Off Ramp	Mainline	56	5617	56	5650	0.642567	0.644907	0.00		0.2197			
Cortaro Off Ramp to Cortaro On Ramp	Mainline	58	4465	58	4493	1.12428	1.123486	0.00		-0.0592			
Cortaro On Ramp to Twin Peaks Off Ramp	Mainline	57	4992	57	5015	0.331801	0.331503	0.00		-0.0249			
Twin Peaks Off Ramp to Twin Peaks On Ramp	Mainline	58	3699	58	3709	0.936733	0.936533	0.00		-0.0123			
Twin Peaks On Ramp to End Project	Mainline	55	4401	55	4407	0.11755	0.117579	0.00		0.0021			
Congress Off Ramp	Off Ramp	51	870	52	875	0.411254	0.405511	-0.01		-0.0835			
Speedway Off Ramp	Off Ramp	38	809	38	823	0.426856	0.428956	0.00		0.0286			
Grant Off Ramp	Off Ramp	34	1027	30	1050	0.556373	0.633223	0.08		1.3302			
Miracle Mile Off Ramp	Off Ramp	52	1149	52	1156	0.260777	0.264369	0.00		0.0690			
Prince Off Ramp	Off Ramp	54	811	54	821	0.29701	0.297771	0.00		0.0104			
Ruthrauff Off Ramp	Off Ramp	49	1084	51	1096	0.255408	0.245112	-0.01		-0.1870			
Sunset Off Ramp	Off Ramp	49	441	49	446	0.349836	0.353006	0.00		0.0234			
Orange Grove Off Ramp	Off Ramp	28	1257	27	1270	0.473626	0.49814	0.02		0.5162			
Ina Off Ramp	Off Ramp	54	798	54	805	0.176103	0.176455	0.00		0.0047			
Cortaro Off Ramp	Off Ramp	53	1193	53	1201	0.323978	0.323982	0.00		0.0001			
Twin Peaks Off Ramp	Off Ramp	53	1262	53	1266	0.256327	0.256333	0.00		0.0001			
22nd On Ramp	On Ramp	46	834	16	833	0.217302	0.624781	0.41		5.6620			
Congress On Ramp	On Ramp	45	980	11	984	0.186132	0.760142	0.57		9.3953			
Speedway On Ramp	On Ramp	42	1144	4	1041	0.233689	3.050456	2.82		51.2967			
Grant On Ramp	On Ramp	18	540	11	611	0.291895	0.566312	0.27		2.6340			
Miracle Mile On Ramp	On Ramp	48	508	48	510	0.154526	0.154162	0.00		-0.0031			
Prince On Ramp	On Ramp	52	239	52	240	0.239856	0.239985	0.00		0.0005			
Ruthrauff On Ramp	On Ramp	52	670	47	671	0.4624	0.511799	0.05		0.5522			
Sunset On Ramp	On Ramp	51	85	51	85	0.304659	0.303591	0.00		-0.0015			
Orange Grove On Ramp	On Ramp	51	934	51	936	0.222164	0.221944	0.00		-0.0034			
Ina On Ramp	On Ramp	52	795	52	795	0.278572	0.277159	0.00		-0.0187			
Cortaro On Ramp	On Ramp	51	549	51	548	0.531769	0.532058	0.00		0.0026			
Twin Peaks On Ramp	On Ramp	44	721	44	720	0.285412	0.285026	0.00		-0.0046		2032	2025
										-12.5140	3	-37.5419	-34.9996
											HRS/DAY		

APPENDIX F – DRAFT WORKING PAPER #2, FRONTAGE ROAD TRAFFIC CONTROL GUIDELINES (ADOT)

Central District Freeway Frontage Road Traffic Control Study

Working Paper #2: Frontage Road Traffic Control Guidelines

ADOT

Michael Baker INTERNATIONAL

TABLE OF CONTENTS

ATTACHMENTS

CHAPTER 5 RAMP AND FRONTAGE ROAD TRAFFIC CONTROL GUIDELINES

Introduction

With the completion of Working Paper #1: Current and Future Conditions, and the Nationwide Best Practices survey findings, Working Paper #2 presents draft recommended traffic control design guidelines along ADOT's frontage roads in the Central District. Resulting from an extensive inventory and analysis of the existing ramp and frontage road conditions, crash analysis, coordination and deliberation with the TAC and various ADOT staff members, the draft recommended traffic control guidelines are presented below. It is worth noting that an enhanced level of collaboration occurred with a separate ADOT study team on a somewhat similar and ongoing study in the ADOT Southcentral District. This study team was commissioned to partner with the other study team to examine and ensure consistency between the two studies in their respective application of methodologies, assumptions and findings. The findings and recommendations presented below represent the culmination of these various efforts.

Complaints

As described in the ***Need and Purpose of the Study*** section in Working Paper #1, ADOT has received numerous complaints from constituents regarding the use of "Stop" signs at certain locations where the frontage road merged with the exit ramp vs the use of "Yield" signs at other similar locations along the same corridor. These inquiries and/or complaints reflect a general confusion or frustration with differences or variations in traffic control devices employed at different frontage road/main line ramp convergence locations in the ADOT Central District. Often times these driver inquiries/complaints arise from witnessing other drivers' behaviors in these areas, and as a by-product, the evaluation of the variations in traffic control devices employed at different frontage road/ramp convergence areas that may influence driving behavior at these locations.

A complaint log for the entire study area for the years 2016 to 2018 was obtained from ADOT. A summary of the complaints is included in the **Attachments** section of this report.

There were eight (8) complaints regarding the traffic control signs where frontage road merges with the exit ramp from the years 2016 to 2018. The type of complaints included:

- "Yield to Ramp Traffic" signs are currently lacking, request sign installation,
- "YIELD" signs are placed too far prior to the merge point,
- Drivers on the frontage road often do not yield to the exit ramp traffic etc.

It is our understanding based on conversations with ADOT that there is the likelihood of additional complaints than what was currently provided for this study.

Although the impetus for the ***Central District Freeway Frontage Road Traffic Control Study*** largely resulted from driver complaints within the study area, the data from the complaint log obtained from ADOT does not exclusively provide sufficient information and variables to analyze and determine the potential traffic control recommendations. Therefore, the TAC determined that crash data within the study area should be analyzed to determine patterns/similarities in crashes relating to the traffic control signs. This approach represents a subtle departure from initial observations made in the ***Crash Analysis*** section in Working Paper 1.

Crash Analysis

As mentioned above, a detailed crash analysis was performed at various locations within the study area to determine patterns/similarities in crashes relating to the traffic control signs. Crash analysis was conducted to include locations with the following major elements that represent the freeway frontage road/ramp condition of the existing transportation system along the Central District Frontage Roads:

1. One lane and two-lane frontage roads,
2. STOP sign and YIELD sign locations,
3. YIELD sign locations with and without YIELD pavement marking,
4. Weave lengths less than 300 feet and greater than 300 feet,
5. Weave lengths greater than 1,000 feet, and
6. Locations with driveways existing between the physical gore where frontage road merges with exit ramp and the solid intersection striping.

The parameters that were used for the crash analysis are described below:

<u>Crash Data</u>: crash data for the five-year period from January 1, 2012 to December 31, 2016 obtained from the Arizona Department of Transportation (ADOT) Traffic Records Section was used for the analysis. Crashes that occurred between 300 feet upstream of the physical gore where frontage road merges with the exit ramp and the arterial street intersection are used for the analysis. Engineering judgement was used to determine the crashes that are closer to the arterial street intersection that could have been caused due to the weaving/merging maneuver to be used in the analysis.

<u>Segment Crash Rate</u>: segment crash rate is calculated using the following formula:

$$Segment\ Crash\ Rate = \frac{Number\ of\ Crashes\ in\ the\ n\ Year\ Period * 1{,}000{,}000}{AADT * segment\ length * 365 * number\ of\ years}$$

Average annual daily traffic volume (AADT) for the study locations is obtained from the ADOT Transportation Data Management System (TDMS) website. A combined AADT on the exit ramp and on the frontage road approaching the merge point is used for the analysis.

Segment length is the length between the tip of the striped gore to the stop bar at the intersection.

<u>Weave Length</u>: weave length is the distance between the tip of the striped gore and the start of the solid white line approaching the intersection.

<u>Crash Rate (R) Factor</u>: crash rate (R) factor is calculated using the following formula:

$$R = \frac{Segment\ Crash\ Rate * AADT}{Weave\ Length}$$

<u>Ranking of Locations</u>: after calculating the crash rates and R factors at various study locations, the locations are ranked by various factors, i.e., number of crashes (by decreasing number of crashes), crash rate (by decreasing crash rate), weave length (by increasing weave length) and R-factor (by increasing R factor). Ranking of the study locations by various factors is shown in **Table 1**.

Based on the crash analysis shown in **Table 1**, 20 the top 25 highest crash rate locations have a weave length of less than 300 feet and 23 of the top 25 highest crash rate locations have YIELD signs. In contrast to the top 25 highest crash rates, only 8 of the bottom 25 crash rate locations have a weave length of less than 300 feet and only 12 of the bottom 25 crash rate intersections have YIELD signs. This summary shows a distinct correlation between the weave length, traffic control and the crash rates.

Weighted Average: A further analysis was performed to determine the ranking of each location by comparing each individual ranking criteria, termed as "Weighted Average". A point system was created for each ranking criterion, i.e., number of crashes, crash rates, weave length and R-factor. A total of eight points were allotted to each criterion, one for number of crashes, three for crash rate and two each for weave length and R-Factor. Weighted Average for each location is calculated as follows:

$$Weighted\ Average = \frac{(\#\ of\ crashes * C) + (Crash\ Rate * CR) + (Weave\ Length * WL) + (R\ Factor * R)}{Total\ Number\ of\ Points}$$

Where,

C = Points allotted to number of crashes, 1,
CR = Points allotted to crash rate, 3,
WL = Points allotted to weave length, 2,
R = Points allotted to R-Factor, 2, and
Total Number of Points = 8.

Table 2 shows the summary of the overall ranking of all study area locations by weighted average.

Table 1: Ranking of Locations by Various Categories

Ranking by # of Crashes							
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor
1	L101 & Broadway	SB	YIELD	46	11.32052	290	936.5583
2	L101 & Boadway Road	SB	YIELD	36	8.859537	290	732.9587
3	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863
4	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664
5	L101 & 27th	EB	YIELD	13	4.758321	330	253.2725
5	L101 & Broadway	NB	YIELD	13	5.387247	130	803.653
7	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178
7	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382
9	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906
9	L101 & Ray Rd	SB	YIELD	9	2.753485	280	189.7839
11	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446
11	L101 & 67th	EB	YIELD	7	4.984925	150	321.4612
11	L101 & Guadalupe	SB	YIELD	7	2.761784	220	191.7808
14	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079
14	L101 & Elliot	NB	YIELD	6	3.643927	230	184.0817
16	L101 & 51st	EB	YIELD	5	3.26703	330	84.29926
16	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353
18	I-17 & Thomas Rd	NB	None	4	0.49203	1,270	5.841209
18	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485
18	L101 & 59th	EB	YIELD	4	2.218589	180	146.1187
18	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565
18	L101 & Ray Rd	NB	YIELD	4	2.088902	250	105.2055
18	L101 & Warner	NB	YIELD	4	2.35707	250	107.6521
18	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133
25	I-17 and Indian School Road	SB	None	3	0.940	340	47.274
25	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494
25	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869
25	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	1.972603
29	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095
29	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	57.86301
29	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215
29	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591
33	I-17 & Northern Avenue	NB	None	1	0.296915	570	6.953018
33	I-17 and Glendale Avenue	SB	None	1	0.361	490	9.841
33	I-17 & 7th St	WB	STOP	1	0.62991	100	93.32744
33	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317
33	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912
33	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1,120	2.018102
33	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765
33	L101 & 19th Ave	WB	YIELD	1	0.550014	350	16.20813
33	L101 & 7th Ave	EB	YIELD	1	0.506111	300	17.85895
42	I-10 and 99th Avenue	WB	None	0	0	160	0
42	I-17 & Buckeye Road	NB	None	0	0	720	0
42	I-17 & Dunlap Rd	NB	None	0	0	680	0
42	I-17 & Northern Avenue	SB	None	0	0	910	0
42	I-17 and Bethany Home Road	NB	None	0	0	550	0
42	I-17 and Bethany Home Road	SB	None	0	0	410	0
42	I-17 and Glendale Avenue	NB	None	0	0	450	0
42	I-17 and Indian School Road	NB	None	0	0	340	0
42	I-17 and McDowell Road	SB	None	0	0	670	0
42	I-17 & 16th St	EB	STOP	0	0	180	0
42	I-17 & 7th Ave	EB	STOP	0	0	20	0
42	I-17 & 7th Ave	WB	STOP	0	0	50	0
42	I-17 & 7th St	EB	STOP	0	0	100	0
42	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0
42	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0
42	I-17 & Grant Road	NB	YIELD	0	0	150	0
42	I-17 & Union Hills	NB	YIELD	0	0	350	0
42	I-17 & Utopia	NB	YIELD	0	0	430	0
42	I-17 and Thomas Rd	SB	YIELD	0	0	430	0
42	L101 & 27th Ave	WB	YIELD	0	0	1,240	0
42	L101 & 7th Ave	WB	YIELD	0	0	380	0
42	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0
42	L202 & Broadway Rd	SB	YIELD	0	0	190	0
42	SR 101 and 7th Street	WB	YIELD	0	0	470	0

Ranking by Rate							
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor
1	L101 & Broadway	SB	YIELD	46	11.32052	290	936.5583
2	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863
3	L101 & Boadway Road	SB	YIELD	36	8.859537	290	732.9587
4	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906
5	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382
6	L101 & Broadway	NB	YIELD	13	5.387247	130	803.653
7	L101 & 67th	EB	YIELD	7	4.985	150	321.46
8	L101 & 27th	EB	YIELD	13	4.758321	330	253.2725
9	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178
10	L101 & Elliot	NB	YIELD	6	3.644	230	184.08
11	L101 & 51st	EB	YIELD	5	3.26703	330	84.29926
12	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446
13	L101 & Guadalupe	SB	YIELD	7	2.762	220	191.78
14	L101 & Ray Rd	SB	YIELD	9	2.753485	280	189.7839
15	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353
16	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664
17	L101 & Warner	NB	YIELD	4	2.357	250	107.65
18	L101 & 59th	EB	YIELD	4	2.218589	180	146.1187
19	L101 & Ray Rd	NB	YIELD	4	2.088902	250	105.2055
20	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565
21	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133
22	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095
23	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494
24	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317
25	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869
26	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079
27	I-17 and Indian School Road	SB	None	3	0.940	340	47.27
28	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	57.86301
29	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485
30	I-17 & 7th St	WB	STOP	1	0.62991	100	93.32744
31	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215
32	L101 & 19th Ave	WB	YIELD	1	0.550014	350	16.20813
33	L101 & 7th Ave	EB	YIELD	1	0.506	300	17.86
34	I-17 & Thomas Rd	NB	None	4	0.49203	1,270	5.841209
35	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912
36	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591
37	I-17 and Glendale Avenue	SB	None	1	0.361	490	9.841
38	I-17 & Northern Avenue	NB	None	1	0.296915	570	6.953018
39	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765
40	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2000	1.972603
41	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1,120	2.018102
42	I-10 and 99th Avenue	WB	None	0	0	160	0
42	I-17 & Buckeye Road	NB	None	0	0	720	0
42	I-17 & Dunlap Rd	NB	None	0	0	680	0
42	I-17 & Northern Avenue	SB	None	0	0	910	0
42	I-17 and Bethany Home Road	NB	None	0	0	550	0
42	I-17 and Bethany Home Road	SB	None	0	0	410	0
42	I-17 and Glendale Avenue	NB	None	0	0	450	0
42	I-17 and Indian School Road	NB	None	0	0	340	0
42	I-17 and McDowell Road	SB	None	0	0	670	0
42	I-17 & 16th St	EB	STOP	0	0	180	0
42	I-17 & 7th Ave	EB	STOP	0	0	20	0
42	I-17 & 7th Ave	WB	STOP	0	0	50	0
42	I-17 & 7th St	EB	STOP	0	0	100	0
42	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0
42	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0
42	I-17 & Grant Road	NB	YIELD	0	0	150	0
42	I-17 & Union Hills	NB	YIELD	0	0	350	0
42	I-17 & Utopia	NB	YIELD	0	0	430	0
42	I-17 and Thomas Rd	SB	YIELD	0	0	430	0
42	L101 & 27th Ave	WB	YIELD	0	0	1,240	0
42	L101 & 7th Ave	WB	YIELD	0	0	380	0
42	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0
42	L202 & Broadway Rd	SB	YIELD	0	0	190	0
42	SR 101 and 7th Street	WB	YIELD	0	0	470	0

Table 1: Ranking of Locations by Various Categories (Continued)

Ranking by Weave Length							
Ranking	Location	Direction	Existing Control	Crashes	Rate	*Weave length*	R Factor
1	I-17 & 7th Ave	EB	STOP	0	0	20	0
2	I-17 & 7th Ave	WB	STOP	0	0	50	0
3	I-17 and Jefferson	SB	STOP	1	1.336254	70	258.317
3	I-17 & Grant	SB	YIELD	9	8.48777	70	1487.906
5	I-10 & Jefferson	NB	STOP	2	1.667176	80	249.4095
6	I-17 & 7th St	WB	STOP	1	0.62991	100	93.32744
6	I-17 & 7th St	EB	STOP	0	0	100	0
8	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	276.8565
8	SR 101 and University Drive	NB	YIELD	20	9.346296	110	1696.863
10	L101 & Broadway	NB	YIELD	13	5.387247	130	803.653
11	SR 101 and Warner	SB	YIELD	4	1.740403	140	201.6133
12	I-17 & Grant Road	NB	YIELD	0	0	150	0
12	L101 & 67th	EB	YIELD	7	4.984925	150	321.4612
14	I-10 and 99th Avenue	WB	None	0	0	160	0
15	I-17 & 16th St	EB	STOP	0	0	180	0
15	L101 & 59th	EB	YIELD	4	2.218589	180	146.1187
17	L101 & 59th Ave	WB	YIELD	5	2.664239	190	173.0353
17	L202 & Broadway Rd	SB	YIELD	0	0	190	0
19	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	89.8494
20	L101 & Guadalupe	SB	YIELD	7	2.762	220	191.78
21	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	0
21	I-17 & Thunderbird	SB	YIELD	2	0.557473	230	52.41215
21	L101 & Elliot	NB	YIELD	6	3.643927	230	184.0817
24	L101 & 67th Ave	WB	YIELD	11	3.859078	240	270.6178
25	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	57.86301
25	L101 & Ray Rd	NB	YIELD	4	2.088902	250	105.2055
25	L101 & Warner	NB	YIELD	4	2.35707	250	107.6521
28	L101 & Ray Rd	SB	YIELD	9	2.753485	280	189.7839
29	I-17 & Cactus	SB	YIELD	1	0.403459	290	16.90912
29	L101 & Boadway Road	SB	YIELD	36	8.859537	290	732.9587
29	L101 & Broadway	SB	YIELD	46	11.32052	290	936.5583
32	L101 & 7th Ave	EB	YIELD	1	0.506	300	17.86
32	L101 & Southern Ave	SB	YIELD	11	5.657264	300	235.7382
34	L101 & 27th	EB	YIELD	13	4.758321	330	253.2725
34	L101 & 35th	EB	YIELD	7	3.18002	330	125.2446
34	L101 & 51st	EB	YIELD	5	3.26703	330	84.29926
37	I-17 and Indian School Road	SB	None	3	0.94011	340	47.2737
37	I-17 and Indian School Road	NB	None	0	0	340	0
39	I-17 & Union Hills	NB	YIELD	0	0	350	0
39	L101 & 19th Ave	WB	YIELD	1	0.550014	350	16.20813
41	I-17 and Durango Street	SB	STOP	6	1.184016	380	61.97079
41	L101 & 7th Ave	WB	YIELD	0	0	380	0
41	L101 & 7th St	EB	YIELD	3	1.201381	380	40.7869
44	I-17 and Bethany Home Road	SB	None	0	0	410	0
44	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	8.501765
46	I-17 & Utopia	NB	YIELD	0	0	430	0
46	I-17 and Thomas Rd	SB	YIELD	0	0	430	0
48	I-17 and Glendale Avenue	NB	None	0	0	450	0
49	I-17 and Camelback Road	SB	None	4	0.765782	470	40.36485
49	SR 101 and 7th Street	WB	YIELD	0	0	470	0
51	I-17 and Glendale Avenue	SB	None	1	0.360841	490	9.840649
52	I-17 and Bethany Home Road	NB	None	0	0	550	0
53	I-17 & Northern Avenue	NB	None	1	0.297	570	6.95
54	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	10.11591
55	I-17 and McDowell Road	SB	None	0	0	670	0
56	I-17 & Dunlap Rd	NB	None	0	0	680	0
57	I-17 & Buckeye Road	NB	None	0	0	720	0
58	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	44.01664
59	I-17 & Northern Avenue	SB	None	0	0	910	0
60	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1,120	2.018102
61	L101 & 27th Ave	WB	YIELD	0	0	1,240	0
62	I-17 & Thomas Rd	NB	None	4	0.49203	1,270	5.841209
63	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	1.972603
64	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	0
65	I-10 & 99th Ave	EB	YIELD	0	0	3,230	0

Ranking by R-Factor							
Ranking	Location	Direction	Existing Control	Crashes	Rate	*Weave length*	R Factor
1	SR 101 and University Drive	NB	YIELD	20	9.346296	110	***1696.863***
2	I-17 & Grant	SB	YIELD	9	8.48777	70	***1487.906***
3	L101 & Broadway	SB	YIELD	46	11.32052	290	***936.5583***
4	L101 & Broadway	NB	YIELD	13	5.387247	130	***803.653***
5	L101 & Boadway Road	SB	YIELD	36	8.859537	290	***732.9587***
6	L101 & 67th	EB	YIELD	7	4.984925	150	***321.4612***
7	L101 & Elliot Rd	SB	YIELD	4	2.00146	110	***276.8565***
8	L101 & 67th Ave	WB	YIELD	11	3.859078	240	***270.6178***
9	I-17 and Jefferson	SB	STOP	1	1.336254	70	***258.317***
10	L101 & 27th	EB	YIELD	13	4.758321	330	***253.2725***
11	I-10 & Jefferson	NB	STOP	2	1.667176	80	***249.4095***
12	L101 & Southern Ave	SB	YIELD	11	5.657264	300	***235.7382***
13	SR 101 and Warner	SB	YIELD	4	1.740403	140	***201.6133***
14	L101 & Guadalupe	SB	YIELD	7	2.762	220	***191.78***
15	L101 & Ray Rd	SB	YIELD	9	2.753485	280	***189.7839***
16	L101 & Elliot	NB	YIELD	6	3.643927	230	***184.0817***
17	L101 & 59th Ave	WB	YIELD	5	2.664239	190	***173.0353***
18	L101 & 59th	EB	YIELD	4	2.218589	180	***146.1187***
19	L101 & 35th	EB	YIELD	7	3.180	330	***125.24***
20	L101 & Warner	NB	YIELD	4	2.357	250	***107.65***
21	L101 & Ray Rd	NB	YIELD	4	2.088902	250	***105.2055***
22	I-17 & 7th St	WB	STOP	1	0.62991	100	***93.32744***
23	I-17 & Pinnacle Peak Rd	NB	YIELD	3	1.462211	210	***89.8494***
24	L101 & 51st	EB	YIELD	5	3.26703	330	***84.29926***
25	I-17 and Durango Street	SB	STOP	6	1.184016	380	***61.97079***
26	I-17 and 19th Avenue	WB	STOP	2	0.91054	250	***57.86301***
27	I-17 & Thunderbird	SB	YIELD	2	0.557	230	***52.41***
28	I-17 and Indian School Road	SB	None	3	0.94011	340	***47.2737***
29	I-17 and Peoria Road	SB	YIELD	14	2.39736	860	***44.01664***
30	L101 & 7th St	EB	YIELD	3	1.201381	380	***40.7869***
31	I-17 and Camelback Road	SB	None	4	0.765782	470	***40.36485***
32	L101 & 7th Ave	EB	YIELD	1	0.506111	300	***17.85895***
33	I-17 & Cactus	SB	YIELD	1	0.403	290	***16.91***
34	L101 & 19th Ave	WB	YIELD	1	0.550014	350	***16.20813***
35	L101 & Frank Lloyd Wright	SB	YIELD	2	0.366274	650	***10.11591***
36	I-17 and Glendale Avenue	SB	None	1	0.360841	490	***9.840649***
37	I-17 & Greenway Road	NB	YIELD	1	0.256021	410	***8.50***
38	I-17 & Northern Avenue	NB	None	1	0.297	570	***6.95***
39	I-17 & Thomas Rd	NB	None	4	0.49203	1,270	***5.841209***
40	I-17 & Dunlap Rd	SB	YIELD	1	0.154475	1,120	***2.018102***
41	L101 & Ranitree Dr	SB	YIELD	3	0.175937	2,000	***1.972603***
42	I-10 and 99th Avenue	WB	None	0	0	160	***0***
42	I-17 & Buckeye Road	NB	None	0	0	720	***0***
42	I-17 & Dunlap Rd	NB	None	0	0	680	***0***
42	I-17 & Northern Avenue	SB	None	0	0	910	***0***
42	I-17 and Bethany Home Road	NB	None	0	0	550	***0***
42	I-17 and Bethany Home Road	SB	None	0	0	410	***0***
42	I-17 and Glendale Avenue	NB	None	0	0	450	***0***
42	I-17 and Indian School Road	NB	None	0	0	340	***0***
42	I-17 and McDowell Road	SB	None	0	0	670	***0***
42	I-17 & 16th St	EB	STOP	0	0	180	***0***
42	I-17 & 7th Ave	EB	STOP	0	0	20	***0***
42	I-17 & 7th Ave	WB	STOP	0	0	50	***0***
42	I-17 & 7th St	EB	STOP	0	0	100	***0***
42	I-10 & 99th Ave	EB	YIELD	0	0	3,230	***0***
42	I-17 & Deer Valley Rd	NB	YIELD	0	0	230	***0***
42	I-17 & Grant Road	NB	YIELD	0	0	150	***0***
42	I-17 & Union Hills	NB	YIELD	0	0	350	***0***
42	I-17 & Utopia	NB	YIELD	0	0	430	***0***
42	I-17 and Thomas Rd	SB	YIELD	0	0	430	***0***
42	L101 & 27th Ave	WB	YIELD	0	0	1,240	***0***
42	L101 & 7th Ave	WB	YIELD	0	0	380	***0***
42	L101 & Frank Lloyd Wright	NB	YIELD	0	0	2,420	***0***
42	L202 & Broadway Rd	SB	YIELD	0	0	190	***0***
42	SR 101 and 7th Street	WB	YIELD	0	0	470	***0***

Table 2: Overall Ranking of Locations by Weighted Average

Overall Ranking by Weighted Average								
Ranking	Location	Direction	Existing Control	Crashes	Rate	Weave length	R Factor	*Wt Avg Rank*
1	SR 101 and University Drive	NB	YIELD	3	2	8	1	***3.4***
2	L101 & Broadway	SB	YIELD	1	1	10	3	***3.8***
3	I-17 & Grant	SB	YIELD	9	4	3	2	***3.9***
4	L101 & 67th	EB	YIELD	11	7	12	6	***8.5***
5	L101 & Boadway Road	SB	YIELD	2	3	29	5	***9.9***
6	L101 & Broadway	NB	YIELD	5	6	29	4	***11.1***
7	L101 & 67th Ave	WB	YIELD	7	9	24	8	***12.3***
8	L101 & Elliot Rd	SB	YIELD	18	20	8	7	***13.5***
9	L101 & Southern Ave	SB	YIELD	7	5	32	12	***13.8***
10	L101 & 27th	EB	YIELD	5	8	34	10	***14.6***
11	L101 & Elliot	NB	YIELD	14	10	21	16	***14.8***
11	L101 & Guadalupe	SB	YIELD	11	13	20	14	***14.8***
13	I-10 & Jefferson	NB	STOP	29	22	5	11	***15.9***
14	I-17 and Jefferson	SB	STOP	33	24	3	9	***16.1***
14	L101 & 59th Ave	WB	YIELD	16	15	17	17	***16.1***
14	SR 101 and Warner	SB	YIELD	18	21	11	13	***16.1***
17	L101 & Ray Rd	SB	YIELD	9	14	28	15	***17.1***
18	L101 & 59th	EB	YIELD	18	18	15	18	***17.3***
19	L101 & 35th	EB	YIELD	11	12	34	19	***19.1***
20	L101 & Warner	NB	YIELD	18	17	25	20	***19.9***
21	L101 & 51st	EB	YIELD	16	11	34	24	***20.6***
22	L101 & Ray Rd	NB	YIELD	18	19	25	21	***20.9***
23	I-17 & Pinnacle Peak Rd	NB	YIELD	25	23	19	23	***22.3***
24	I-17 & 7th St	WB	STOP	33	30	6	22	***22.4***
25	I-17 and 19th Avenue	WB	STOP	29	28	25	26	***26.9***
26	I-17 & Thunderbird	SB	YIELD	29	31	21	27	***27.3***
27	I-17 and Durango Street	SB	STOP	14	26	41	25	***28.0***
28	I-17 and Peoria Road	SB	YIELD	4	16	58	29	***28.3***
29	I-17 and Indian School Road	SB	None	25	27	37	28	***29.5***
30	L101 & 7th St	EB	YIELD	25	25	41	30	***30.3***
31	I-17 & 7th Ave	EB	STOP	42	42	1	42	***31.8***
32	I-17 & 7th Ave	WB	STOP	42	42	2	42	***32.0***
33	L101 & 7th Ave	EB	YIELD	33	33	32	32	***32.5***
34	I-17 & Cactus	SB	YIELD	33	35	29	33	***32.8***
35	I-17 & 7th St	EB	STOP	42	42	6	42	***33.0***
36	I-17 and Camelback Road	SB	None	18	29	49	31	***33.1***
37	L101 & 19th Ave	WB	YIELD	33	32	39	34	***34.4***
38	I-17 & Grant Road	NB	YIELD	42	42	12	42	***34.5***
39	I-10 and 99th Avenue	WB	None	42	42	14	42	***35.0***
40	I-17 & 16th St	EB	STOP	42	42	15	42	***35.3***
41	L202 & Broadway Rd	SB	YIELD	42	42	17	42	***35.8***
42	I-17 & Deer Valley Rd	NB	YIELD	42	42	21	42	***36.8***
43	I-17 and Glendale Avenue	SB	None	33	37	48	36	***39.0***
43	I-17 & Greenway Road	NB	YIELD	33	39	44	37	***39.0***
45	L101 & Frank Lloyd Wright	SB	YIELD	29	36	54	35	***39.4***
46	I-17 & Thomas Rd	NB	None	18	34	62	39	***40.3***
47	I-17 and Indian School Road	NB	None	42	42	37	42	***40.8***
48	I-17 & Northern Avenue	NB	None	33	38	53	38	***41.1***
49	I-17 & Union Hills	NB	YIELD	42	42	39	42	***41.3***
50	L101 & 7th Ave	WB	YIELD	42	42	41	42	***41.8***
51	I-17 and Bethany Home Road	NB	None	42	42	44	42	***42.5***
52	I-17 & Utopia	NB	YIELD	42	42	46	42	***43.0***
52	I-17 and Thomas Rd	SB	YIELD	42	42	46	42	***43.0***
54	I-17 & Dunlap Rd	SB	YIELD	33	41	56	40	***43.5***
55	SR 101 and 7th Street	WB	YIELD	42	42	49	42	***43.8***
56	L101 & Ranitree Dr	SB	YIELD	25	40	63	41	***44.1***
57	I-17 and Glendale Avenue	NB	None	42	42	51	42	***44.3***
58	I-17 and Bethany Home Road	SB	None	42	42	52	42	***44.5***
59	I-17 and McDowell Road	SB	None	42	42	55	42	***45.3***
60	I-17 & Buckeye Road	NB	None	42	42	57	42	***45.8***
61	I-17 & Northern Avenue	SB	None	42	42	59	42	***46.3***
62	I-17 & Dunlap Rd	NB	None	42	42	60	42	***46.5***
63	L101 & 27th Ave	WB	YIELD	42	42	61	42	***46.8***
64	L101 & Frank Lloyd Wright	NB	YIELD	42	42	64	42	***47.5***
65	I-10 & 99th Ave	EB	YIELD	42	42	65	42	***47.8***

Summary and Results of the Crash Analysis

Shown below is a brief summary of the crash analysis included in **Table 1** and **Table 2**.

Overall Summary

- A total of 65 locations are included in the analysis,
- Nine of the 65 locations are STOP controlled, 42 are YIELD controlled and 14 have no traffic control signs,
- The average weave length of all the locations analyzed is 462 feet,
- Average weave length of the top 10 locations based on weighted average is 202 feet,
- Average weave length of the bottom 10 locations based on weighted average is 1,273 feet,
- 75th percentile crash rate is 2.377215,
- Average weave length above the 75th percentile crash rate is 272 feet,
- 20 of the top 25 locations based on the crash rate have weave lengths less than 300 feet,
- 23 of the top 25 locations based on the crash rate are YIELD controlled,
- Eight of the bottom 25 locations based on the crash rate have weave lengths less than 300 feet,
- 12 of the bottom 25 locations based on the crash rate are YIELD controlled,
- 22 of the top 25 locations based on the weighted average have weave lengths less than 300 feet,
- 21 of the top 25 locations based on the weighted average are YIELD controlled,
- 14 of the bottom 25 locations based on the weighted average are YIELD controlled, and
- Two of the bottom 25 locations based on the weighted average have weave lengths less than 300 feet.

STOP Controlled Locations Summary

- Average weave length of the STOP controlled locations is 137 feet,
- 75th percentile crash rate at the STOP controlled locations is 1.26, and
- Average weave length above the 75th percentile crash rate at the STOP controlled locations is 75 feet.

YIELD Controlled Locations Summary

- Average weave length of the YIELD controlled locations is 494 feet,
- Average weave length of the top 10 YIELD controlled locations by weighted average is 192 feet,
- Average weave length of the bottom 10 YIELD controlled locations by weighted average is 1,207 feet,
- 75th percentile crash rate of the YIELD controlled locations is 3.361254, and
- Average weave length above the 75th percentile crash rate at the YIELD controlled locations is 214 feet.

NO Traffic Control Locations Summary

- Average weave length of the locations with NO traffic control is 574 feet,
- 75th percentile crash rate of the NO traffic control locations is 0.393638, and
- Average weave length above the 75th percentile crash rate at the NO traffic control locations is 693 feet.

Based on the crash analysis and the summary described above, it can be concluded that the locations with YIELD signs and weave lengths less than 300 feet have the highest ranking. Locations with YIELD signs and weave lengths greater than 1,000 feet ranked the lowest for crash rates.

According to the Manual on Uniform Traffic Control Devices (MUCTD) Table 2C-4 and the American Association of State Highway and Transportation Officials (AASHTO) Policy on Geometric Design, vehicle drivers need approximately 4.5 seconds of time for making vehicle maneuvers in addition to the perception-reaction time, which would include performing weaving maneuvers. Assuming the typical frontage road posted speed limit of 45 mph, this 4.5 second time demand results in a distance of 300 feet required for a driver to perform a weave maneuver. Assuming the perception-reaction time occurs before approaching the striped gore, an additional 300 feet is needed from the tip of the striped gore to the solid white intersection striping for a driver to be able to perform the weaving maneuver. These important factors and assumptions, together with the crash analysis findings, are important in influencing the recommended traffic control.

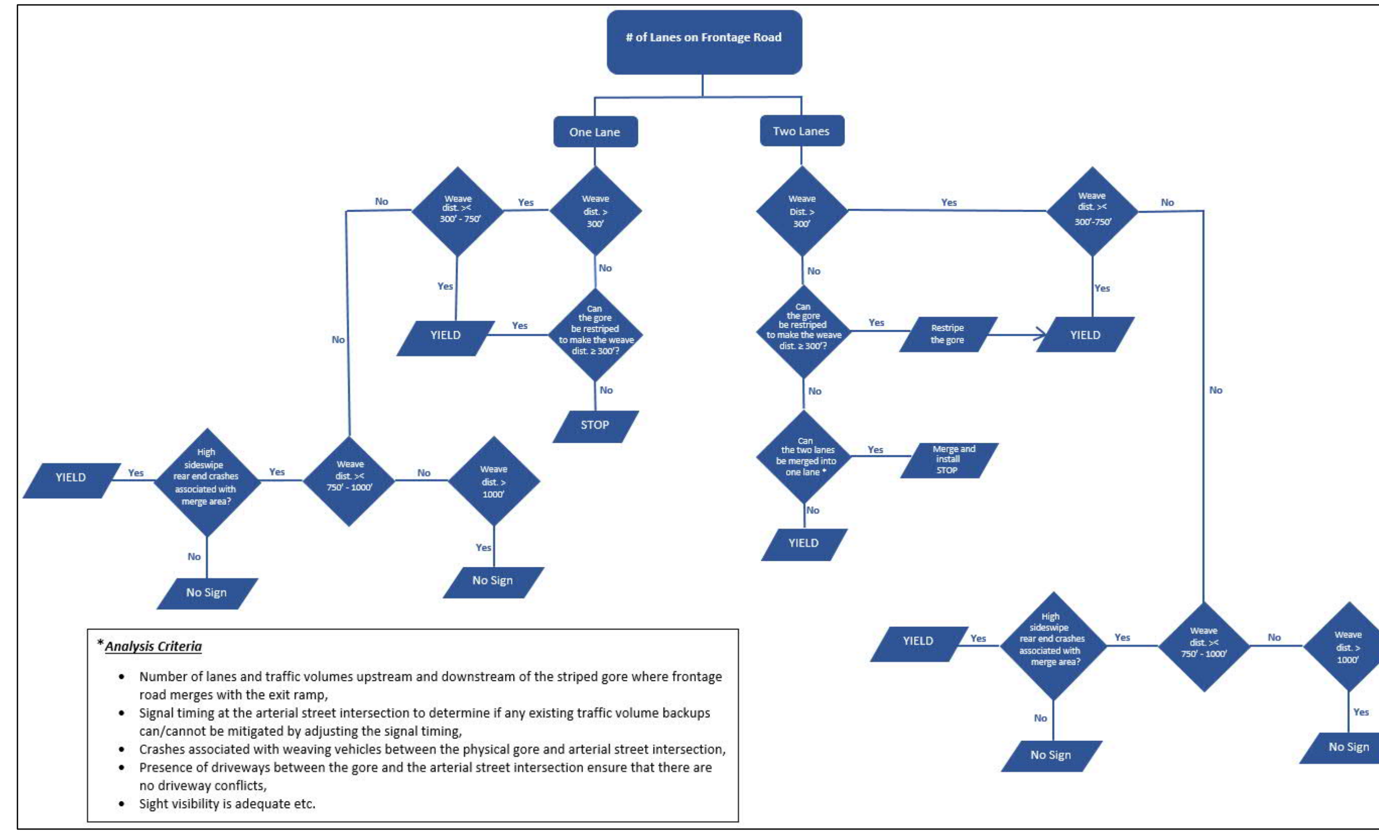
Recommended Traffic Control

Based on the conclusions from the crash analysis and the MUTCD/AASHTO suggestions, the following standards/guidelines are recommended for the frontage road traffic control:

1. A STOP (R1-1) sign should not be recommended on multi-lane frontage roads.
2. If the weaving distance (distance between tip of striped gore to the beginning of the solid white stripe at the arterial street intersection) is less than 300 feet, consider restriping the striped gore, where physically possible, to provide a weaving distance of 300 feet or more.
3. For single lane frontage roads with a weaving distance of less than 300 feet, and after confirmation of STEP 2, a STOP sign shall be installed.
4. For two lane frontage roads with a weaving distance of less than 300 feet, and after confirmation of STEP 2, a traffic volume analysis shall be completed to determine if the two lanes should be merged into one lane based on the following criteria, then, install a STOP sign.
    - Number of lanes and traffic volumes upstream and downstream of the striped gore where frontage road merges with the exit ramp,
    - Signal timing at the arterial street intersection to determine if any existing traffic volume backups can/cannot be mitigated by adjusting the signal timing,
    - Crashes associated with weaving vehicles between the physical gore and arterial street intersection,
    - Presence of driveways between the physical gore and the arterial street intersection ensure that there are no driveway conflicts,
    - Sight visibility is adequate etc.
5. If the weaving distance for a two-lane frontage road cannot be increased/expanded to 300 feet per STEP 2, and if the traffic analysis determines that the two-lane frontage roads cannot be merged into one lane, then a YIELD (R1-2) sign shall be installed.
6. If the weaving distance is between 300 feet and 700 feet for both one lane and two-lane frontage roads, install YIELD signs.
7. If the weaving distance is between 750 feet and 1,000 feet and there are no sight restrictions for both one lane and two-lane frontage roads, further crash analysis shall be performed to determine if a YIELD sign is warranted or if no traffic control sign shall be recommended.

8. If the weaving distance is greater than 1,000 feet for both one lane and two-lane frontage roads, no traffic control sign is recommended.

Figure 1 is a flowchart illustrating the sequencing of steps/considerations in determining the recommended traffic control for one lane and two-lane frontage roads.



Analysis Criteria

- Number of lanes and traffic volumes upstream and downstream of the striped gore where frontage road merges with the exit ramp,
- Signal timing at the arterial street intersection to determine if any existing traffic volume backups can/cannot be mitigated by adjusting the signal timing,
- Crashes associated with weaving vehicles between the physical gore and arterial street intersection,
- Presence of driveways between the gore and the arterial street intersection ensure that there are no driveway conflicts,
- Sight visibility is adequate etc.

Figure 1: Flowchart of the Traffic Control Recommendations Along Frontage Roads

Sign Size Recommendations

Recommended sign sizes along the frontage roads where they merge with the exit ramps within the Central District are as follows:

1. STOP (R1-1) signs shall be 36" x 36" (per MUTCD Section 2B.03)
2. YIELD (R1-2) signs shall be 36" x 36" x 36" for one lane frontage road and 48" x 48" x 48" for two lane frontage roads (per MUTCD Table 2B.1)
3. STOP AHEAD (W3-1) and YIELD AHEAD (W3-2) signs shall be 36" x 36".
4. TO RAMP TRAFFIC (R1-2rP) supplemental plaque shall be 30" x 18" (ADOT Manual of Approved Signs).
5. Larger signs may be considered to bring attention to sign if deemed necessary by the Regional Traffic Engineer (RTE).

Placement of Signs and Pavement Marking Recommendations

Locations of the sign placements along the frontage roads where they merge with the exit ramps within the Central District are as follows:

1. For single lane frontage roads with no sight visibility issues (such as landscaping, noise reduction walls etc.) between the frontage road and exit ramp, a STOP sign or Yield sign (as recommended per the ***Recommended Traffic Control*** section) shall be placed 50 feet from the tip of the striped gore on the right-hand side of the approach. If the distance between physical gore and striped gore is less than 50 feet with no sight visibility issues between the frontage road and exit ramp, STOP sign or YIELD sign (as recommended per the ***Recommended Traffic Control*** section) shall be placed at the physical gore on the right-hand side of the approach.
2. For two-lane frontage roads with no sight visibility issues between the frontage road and exit ramp and the distance between striped gore and physical gore is greater than 50 feet, a YIELD sign shall be placed at 50 feet from the tip of striped gore on the right-hand side of the frontage road approach. YIELD pavement marking shall be installed with the YIELD sign to improve visibility and right-of-way control.
3. For two-lane frontage roads with no sight visibility issues between the frontage road and exit ramp and the distance between the striped gore and physical gore is less than 50 feet, a YIELD sign shall be placed at the physical gore on the right-hand side of the approach. YIELD pavement marking shall be installed with the YIELD sign to improve visibility and right-of-way control. An additional YIELD sign may be installed on the left-hand side of the frontage road if sight visibility is not obstructed. If a YIELD sign is placed on the left-hand side of the frontage road, it should be angled towards the frontage road and shielded from the exit ramp traffic.
4. If there are sight visibility issues between the frontage road and exit ramp, the STOP sign or YIELD sign (as recommended per the ***Recommended Traffic Control*** section) shall be placed at 10 feet from the tip of the striped gore for both one lane and two-lane frontage roads, assuming that there are no more sight visibility restrictions at this location.
5. A "To Ramp Traffic" plaque shall be installed under all YIELD signs as discussed above.
6. "Stop Ahead" and "Yield Ahead" signs shall be installed in accordance with MUTCD Table 2C-4: Placement of Advance Warning Signs.

Figure 2 and **Figure 3** shows a schematic of sign placement and sign sizes along one lane and two-lane frontage roads respectively.

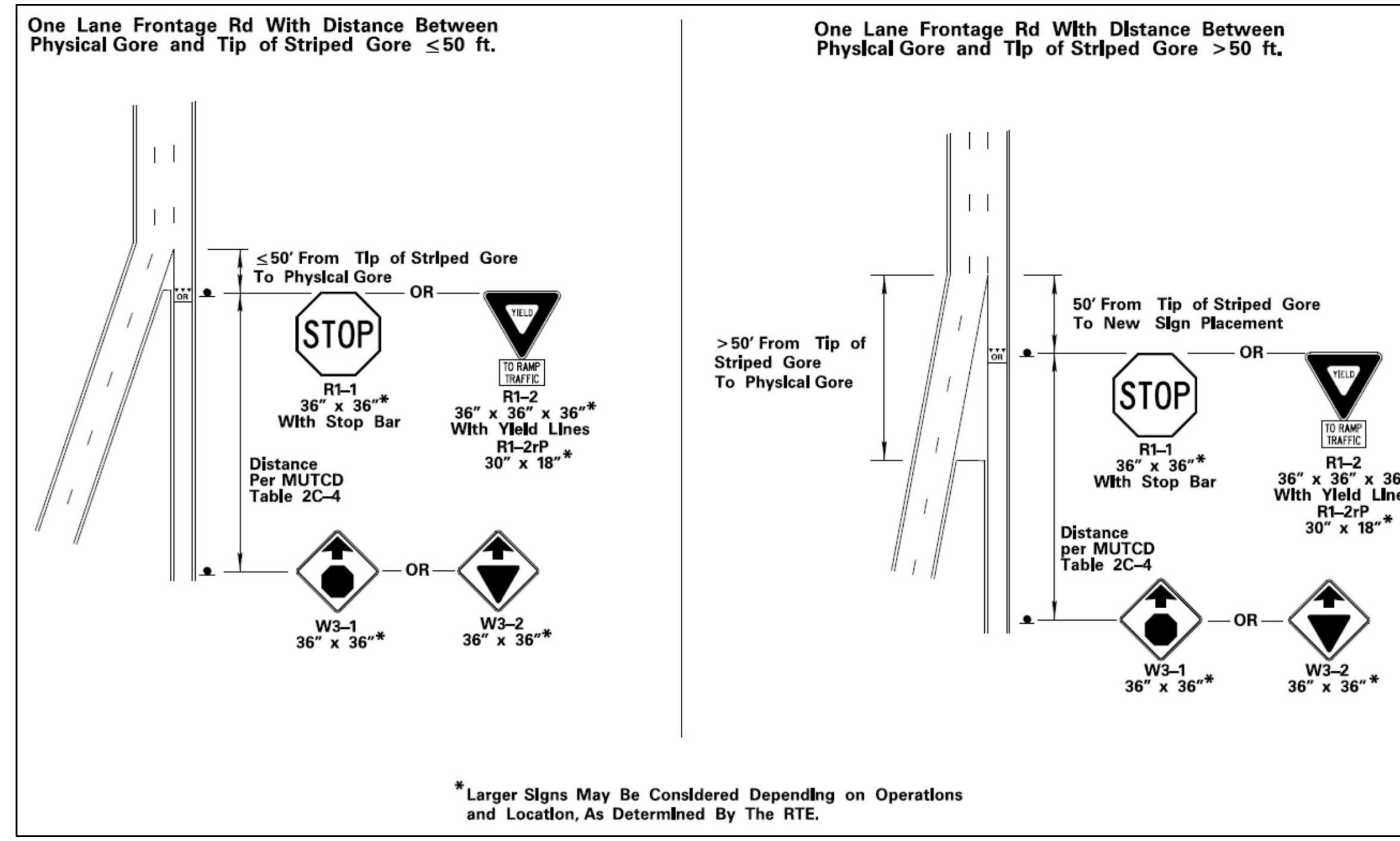


Figure 2: Sign Placement Schematic along One Lane Frontage Roads

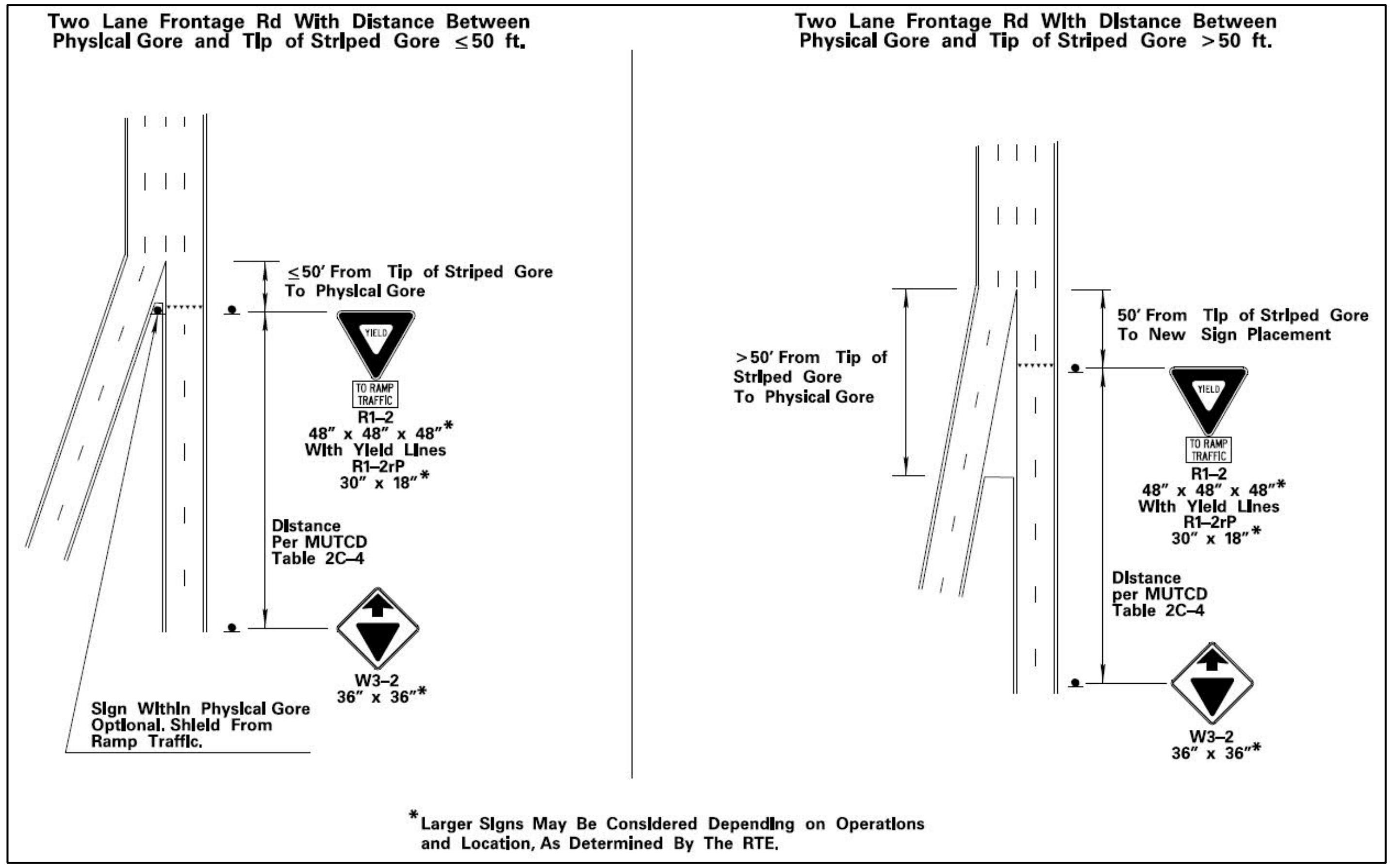


Figure 3: Sign Placement Schematic along Two Lane Frontage Roads

ATTACHMENT A

COMPLAINTS LOG

Date	Complaint #	Freeway	Cross Street	Complaint	Action	Action Result		Applicable to this project
						Disposition	Date	
3/23/2016		SR 101	Broadway Road	DPS and Tempe PD, with neither willing to enforce the “YIELD TO RAMP TRAFFIC” signage - concerned about the merging/gore area of SB Price and SB Loop 101 Frontage Rd at Broadway Rd in Tempe	Provided signing and striping improvements (Go to work order for details)	Completed	6/26/2016	Yes
11/15/2016		SR 101	Pima	As cars come fast down the north 101 off-ramp heading toward the traffic light at the intersection with Pima. Unfortunately, the traffic headng north on the Frontage Road (which crosses into the off-ramp) are often (may be even more often) not yielding until the last section, if at all (maybe because of bad sight lines). to avoid a big accident (if one hasn't happened already), Scottsdale and/or the State needs to do more! Should we be enlarging the yield sign or placing a blinking yellow light to warn the side-road's drivers of the need for caution as they head across/into the off-ramp?	Move the Yield sign close to the tip of the gore. We will also be moving the shark teeth to line up with the new Yield location.	Completed	12/13/2016	Yes
1/12/2017	1701281262	SR 101	Exit 36 - Pima Road NB	Every day I travel along the northbound 101 freeway, sometimes several times in one day, and exit at #36 to head north on Pima Road. As the time of the year gets busier, this exit ramp is so dangerous. The lower traffic is to YIELD to the exiting ramp traffic. THIS NEVER HAPPENS! Its's as if the YIELD sign does not exist. Any chance this is going to become at least a FLASHING yield sign or even a stop sign. We have a newer driver at our home and this intersection is terrifying!				Yes
1/12/2017	1701281262	SR 101	Frank Lloyd Wright NB	The second one in the area that is horrible also is as you are heading south on the 101 and exit Frank Lloyd Wright. If you want to head West on Frank Lloyd Wright, you need to cut over three lanes of traffic, which once again are supposed to YIELD to ramp traffic. Same problem here.				Yes
8/9/2017		SR 101	Warner Road NB	On NB 101 Warner Rd exit, there used to be a 'yield to ramp traffic' sign that was located on the left side of frontage road. Was it damaged and removed? Are there plans to reinstall it? How about merging the frontage road to one lane (similar to SB 202 at Elliott) to help prevent the off ramp traffic from getting backed up and having to cross to lanes of traffic to turn right?				Yes
10/27/2017	1730065877	SR 101	Ray Road SB	I have a concern as a driver. When exiting the 101 Loop South in Chandler, AZ to take Exit 59 at Ray Road, drivers that are approaching Ray Road from Price Road are supposed to yield to drivers taking the ramp off the 101. However, drivers on Price Road rarely do yield properly and often make a dangerous driving situation. I think putting a STOP sign instead of a YIELD sign for those traveling south on Price Road towards Ray Road would make for a better.	https://www.google.com/maps/@33.3221296,-111.8945761,3a,75y,191.31h,84.43t/data=!3m6!1e1!3m4!1svot-GyV8xF5lz1rReueqWg!2e0!7i13312!8i6656			Yes
11/14/2017	1731730208			Sure, that is what you and I would do if we were on the access road, yield to freeway traffic. But that becomes challenging for them too because both access road lanes get backed up from the light by 6-8 cars which is past the merge lines, so when the light turns green they would have to stay stationary in order to let anyone merge. However we have been driving this route for almost a year now, and unfortunately we have found that not many people will actually yield, and what seems to make it more difficult at this location is that the actual merge lines (where the solid white shoulder line changes to white dashed) are only a few short car lengths from the light, so when the access road traffic is full, as it often is around 8:10am, merging when you are almost at the light makes it extra challenging. I'm sure it's been this way forever, I just can't understand why the solid white shoulder line goes on for so long. Probably because it may be hard to see around the Great Wall if it was shorter. Some will even cut through the shoulder to try to ensure they will get over far enough to turn right which only further complicates things for those attempting to merge farther up at the dashed lines. Thanks for listening anyway. Have a good day.				Not sure of the location
11/17/2017	1732132524		Ray Road, Chandler Blvd	Yield Sign at Ray Road / Chandler Blvd is not visible for drivers to convey - heading EAST - and drivers coming from Ray rd are subject to collisions *** “Yield Sign” is NOT visible — It is posted on PASSENGER SIDE OF ROAD & POSTED TOO FAR AFTER THE TURN for vehicles to slow down and yield to oncoming traffic				Not sure of the location
1/19/2018	1801971588	SR 101	59th Avenue EB	The way this exit is designed makes it almost impossible for the freeway traffic to exit south. The gore point funnels all highway traffic into the left turn only lane. It directs traffic from the access road to the 3 right lanes. Many people live just south of the freeway. Tonite, like most evenings, there was a 1/4 mile backup onto the freeway because of this problem. People coming off the access road DO NOT yield. Freeway traffic is forced to drive across the gore point in order to get to any of the right 3 lanes. I see near misses every day. Very poor design, very unsafe. Please look at the design here.				Yes