Interchange Modification Justification Report

I-229 Exit 9 (Benson Road)

I-229 Benson Road Interchange Modification Study

Project # IM2292(98)67N, PCN 04XK

Sioux Falls, South Dakota

January, 2019

City of Sioux Falls
SOUTH DAKOTA

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Abbreviations

AASHTO	American Association of State Highway Transportation Officials
CATEX	Categorical Exclusion
CMF	Crash Modification Factor
CRM	Critical Rate Factor
FHWA	Federal Highway Administration
HCS	Highway Capacity Software
HOT	High Occupancy Transit
HOV	High Occupancy Vehicle
HSM	Highway Safety Manual
IMJR	Interchange Modification Justification Report
LOS	Level of Service
MRM	Mileage Reference Marker
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Area
SDDOT	South Dakota Department of Transportation
STIP	Statewide Transportation Improvement Program
TAZ	Traffic Analysis Zone
TIP	Transportation Improvement Program

1.0 Executive Summary

This Interchange Modification Justification Report (IMJR) provides technical analysis related to proposed changes to the existing Benson Road interchange (Exit 9) on Interstate 229 (I-229) in Sioux Falls, SD.

The proposed action is a reconfiguration of the existing Benson Road Interchange on I- 229 in Sioux Falls, SD. The action is proposed to bring the existing interchange up to current design standards and provide appropriate operational capacity for future traffic demand. No adverse impacts to the Interstate highway system are forecast due to the proposed change.

The Federal policy considerations and requirements have been addressed in the Recommendations section of this report and summary responses to the requirements associated with the Policy on Access to the Interstate System, dated May 22, 2017 are provided below.

The proposed change is a reconfiguration of an existing interchange and improvements to the existing crossroad facility (Benson Road). The changes will address current and future capacity needs of the Benson Road Interchange and along the Benson Road Corridor, as well as improve accessibility for non-automobile transportation modes along Benson Road. The proposed change does not result in any new access points on the Interstate Highway System.

The concept alternatives involve changes to the geometric design of an existing diamond interchange and changes to the crossroad arterial street (Benson Road) to meet the transportation needs in the study area. Mass transit reaches a limited market in South Dakota and HOV facilities are currently not in use because they have not been shown to be economically feasible. Neither mass transit nor HOV facilities will provide sufficient relief to future travel demand within the study planning horizon.

The operation and safety analysis contained in this study shows that the proposed build alternatives are not expected to adversely affect the safety or efficiency of the Interstate system. The build alternatives are also expected to improve access management on the crossroad in the vicinity of the interchange.

Conceptual signing plans were prepared for each interchange alternative and for the Benson Road arterial corridor on each side of I-229.

The proposed access is a reconfiguration of an existing interchange with full access to an arterial city street and includes all movements. The conceptual drawings have been prepared using current standards and further design using current standards is anticipated and will receive additional reviews throughout the next steps of the design.

This proposal is the result of land use and transportation plans prepared within the MPO process, including the Sioux Falls MPO Long Range Transportation Plan, the SDDOT 2010 Decennial Interstate Corridor Study, the I-229 Major Investment Corridor Study, and the I-229 Exit 9 Crossroad Corridor Study. The Benson Road Interchange project PE is programmed in the Statewide Transportation Improvement Program (STIP) for 2022 with construction in the 2023-2025 timeframe.

Analysis techniques included an evaluation of operational capacity using Highway Capacity Manual 2010 techniques via HCS 2010. Highway Safety Manual techniques were used to the extent possible in this report. Other techniques and reference materials are detailed in a Methods and Assumptions document prepared for this study and signed by the South Dakota Department of Transportation and Federal Highway Administration participants in February 2018 and modified as necessary throughout the study. The Methods and Assumptions document is included in **Appendix 2**.

2.0 Introduction

2.1 Background and Project Need

The I-229 Exit 9 interchange (Benson Road) is located in northeast Sioux Falls, SD and serves as one of the primary access points to the Sioux Falls Regional Airport and one of the region's largest industrial areas. The interchange currently experiences high peak-hour demand as drivers commute to and from industrial-area jobs. This high peak-hour use and continued job growth around the interchange have driven demands for interchange improvements.

The South Dakota Department of Transportation (SDDOT), the City of Sioux Falls, the Sioux Falls MPO, and the Federal Highway Administration (FHWA) conducted a Major Investment Study for the I-229 corridor which was finished in 2017. That study, which included a sub-study component for Exit 9, recommended improvements at the Exit 9 interchange and identified two alternatives for further consideration:

- A modified diamond interchange with a northbound-to-westbound loop in the northeast quadrant
- A diverging diamond interchange

The Major Investment Study identified several specific issues/needs for Exit 9:

- Congestion at the Benson Road/I-229 interchange
- Future growth along Benson Road east of I-229
- Need for improved pedestrian connectivity
- Need for a possible connection to the Veterans Parkway corridor

This Interchange Modification Justification Report seeks to provide the necessary analysis for approval of the interchange modification action. A companion environmental document will provide environmental analysis and determine a recommended alternative.

The primary need of this project is to improve traffic operations and safety and to enhance mobility for other modes of transportation at the Benson Road Interchange and along the Benson Road Corridor. The Purpose and Need statement is included in **Appendix 1**.

The 2017 Benson Road Corridor Study concluded that improvements were necessary along Benson Road and at the Benson Road Interchange to address existing congestion issues and to accommodate planned growth which are expected to worsen traffic operations at the interchange along Benson Road.

The study continues the previous planning work and provides the necessary analysis for consideration by SDDOT and FHWA.

2.2 Study Area

The study area is shown in **Figure 1**. It includes I-229 from Rice Street (Exit 7) to Interstate 90 (Exit 10), including the interchanges at Exit 7, Exit 9 and Exit 10. The crossing arterial street at Exit 9, Benson Road, is included from its intersection with Cliff Avenue on the west to its intersection with Sycamore Avenue on the east. The crossing arterial street at Exit 7, Rice Street, is included from its intersection with Cliff Avenue on the west to its intersection with Bahnson Avenue on the east.

The following arterial street intersections were included in the study analysis:

- Benson Road/Cliff Avenue
- Benson Road/Lewis Avenue

- Benson Road/Potsdam Avenue
- Benson Road/I-229 southbound
- Benson Road/I-229 northbound
- Benson Road/Hall Avenue
- Rice Street/Cliff Avenue
- Rice Street/Wayland Avenue
- Rice Street/I-229 southbound
- Rice Street/I-229 northbound
- Rice Street/Bahnson Avenue

2.3 Methods and Assumptions

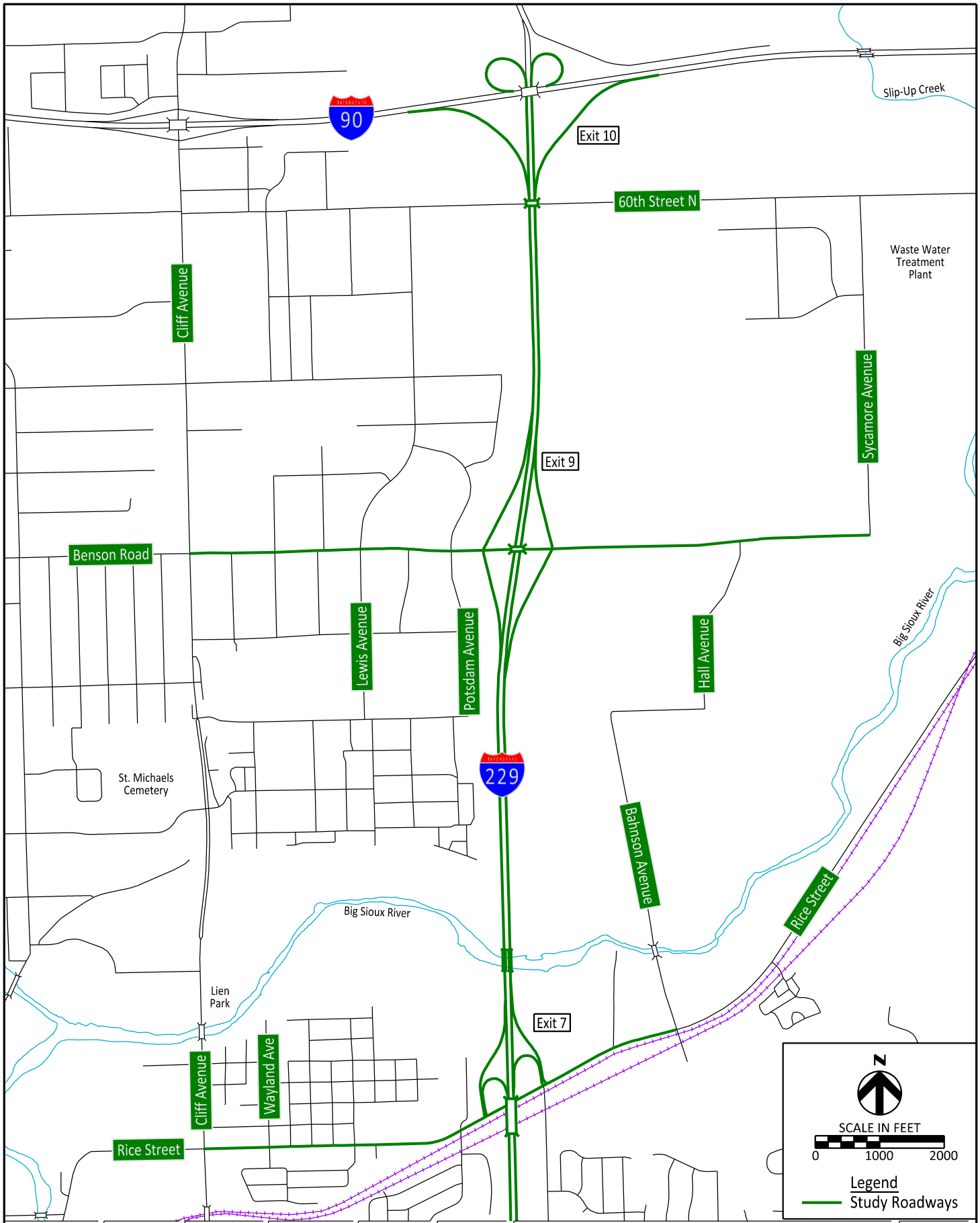
Preparation of this report included the following work tasks:

- Data Gathering
- Review previous Interstate studies and coordinate with preparation of the environmental studies, including feasible alternatives and the recommended alternative.
- Determine existing and future operational characteristics of Interstate and local street facilities.
- Prepare a deliverable report.

Traffic forecasts were prepared using output from the regional travel demand model maintained by the City of Sioux Falls and the Sioux Falls MPO. Traffic operations were analyzed using the Highway Capacity Manual techniques using HCS 2010 software modules and Highway Safety Manual techniques.

This IMJR Document is organized in accordance with FHWA's Policy on Access to the Interstate System – May 22, 2017.

The analysis methods and assumptions used in this study are documented in a separate Methods and Assumptions document that was negotiated between the supervising agencies and the consultant. A copy of the Methods and Assumptions document is provided in **Appendix 2**.



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Date: 1/30/2018
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Date: 1/30/2018
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Study Area

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 1

3.0 Operational and Safety Analysis

3.1 Existing Conditions Analysis

Demographics

The Sioux Falls metropolitan area enjoys a robust economy and sustained population growth. During the period 1980 – 2000 the population grew at a steady rate of 2% - 3% per year. Even in the face of the recent recession, the population continued to grow at an annual rate of 1%-2% per year and the 2010 Census shows the city with a population of 153,888, while the Metropolitan Statistical Area (MSA) had a population of 228,261 and the market area had a population of 1,043,450 (market area is a term used in economics and human geography describing the area surrounding a central place, from which people are attracted to use the place's goods or services).

Generally, employment for the Sioux Falls area has grown at approximately the same rate as the population and unemployment is currently near 2% in Sioux Falls, compared with a statewide rate of 2.7%, regional rate of 3.0%, and a national unemployment rate of 5.0%.

Existing Land Use

Land use around the Exit 9 interchange and along Benson Road is a mix of agriculture, industrial, office, and commercial development. The study area Traffic Analysis Zones (TAZ's) currently reflect the existing population and employment inputs. The area is in transition, in particular east of I-229 which has been designated as a growth area. The future year TAZ's show infill of uses similar to those currently existing in the study area.

The future land use plan for Sioux Falls shows continued development of light industrial land uses for this portion of the urban area.

Existing Roadway Network

As previously identified, the existing major corridors within the study area include:

- I-229 – from Interstate 90 to Exit 7 (Rice Street)
- Benson Road – from Cliff Avenue to Bahnson Avenue/Hall Avenue
- Rice Street – from Cliff Avenue to Bahnson Avenue

The following major intersections were analyzed:

- Benson Road/Cliff Avenue
- Benson Road/Lewis Avenue
- Benson Road/Potsdam Avenue
- Benson Road/I-229 SB Ramp Terminal
- Benson Road/I-229 NB Ramp Terminal
- Benson Road/Hall Avenue
- Rice Street/Cliff Avenue
- Rice Street/Wayland Place
- Rice Street/I-229 SB Ramp Terminal
- Rice Street/I-229 NB Ramp Terminal
- Rice Street/Bahnson Avenue

Alternative Travel Modes

Travel within the study area is primarily by automobile. The 2017 Benson Road Corridor Study recommended building sidewalks along Benson Road to provide pedestrian access for the planned growth along the corridor. Multimodal level of service (LOS) analysis was completed for the build alternatives for pedestrian, bicycle and transit modes along Benson Road and discussed in the report.

Interchanges

Interchanges in the study area include:

- I-90/I-229 Interchange (I-90 Exit 400) – Partial Cloverleaf Interchange
- I-229/Benson Road (Exit 9) – Diamond Interchange with signalized control at NB ramp terminal.
- I-229/Rice Street (Exit 7) – Folded Diamond Interchange with signalized control at both ramp termini.

Existing Data

Traffic counts on the Interstate roadway segments were gathered by SDDOT in 2017. Traffic counts on the arterial street system were obtained from the City of Sioux Falls and HDR counts from 2015 and 2017. Count data were assembled and balanced to produce a representation of peak hour traffic flows through the study area. Peak hour traffic volumes are shown in **Figures 2, 3** and **6**.

Operational Performance

Operational performance of highways is evaluated in terms of the quality of service, which describes how well a transportation facility operates from the traveler's perspective. Quality of service is usually measured with "Level of Service", a letter grade similar to those used in school. Level of service "A" refers to uncongested traffic conditions, with level of service "B" through "E" describing increasingly more congested conditions and level of service "F" describing the highest congestion or saturation. Level of service is determined in different ways for different roadway facilities, with Interstate highway facilities evaluated in terms of vehicle density, urban intersections evaluated in terms of vehicle delay, and other facilities evaluated using other measures of roadway dynamics. All quality of service is determined using techniques developed for the Highway Capacity Manual (HCM), published by the Transportation Research Board.

The existing study area roadways were evaluated using the HCM methodologies for Interstate highways and urban streets. SDDOT has established a minimum level of service standard of "C" for interstate facilities, including ramp terminal intersections. The City of Sioux Falls has established minimum level of service standard of "D" for arterial signalized intersections.

Level of service on I-229 was calculated for mainline, ramp merge-diverge, and weave areas for peak hours under 2017 conditions. The level of service results are shown in **Figure 6**. Note that several Interstate mainline segments were analyzed both as regular mainline segments and weaving segments. If it was determined that the segment satisfied the conditions for weaving, the weaving level of service was reported and indicated by an asterisk (*) next to the level of service result.

The Interstate system operates at acceptable levels of service within the study area.

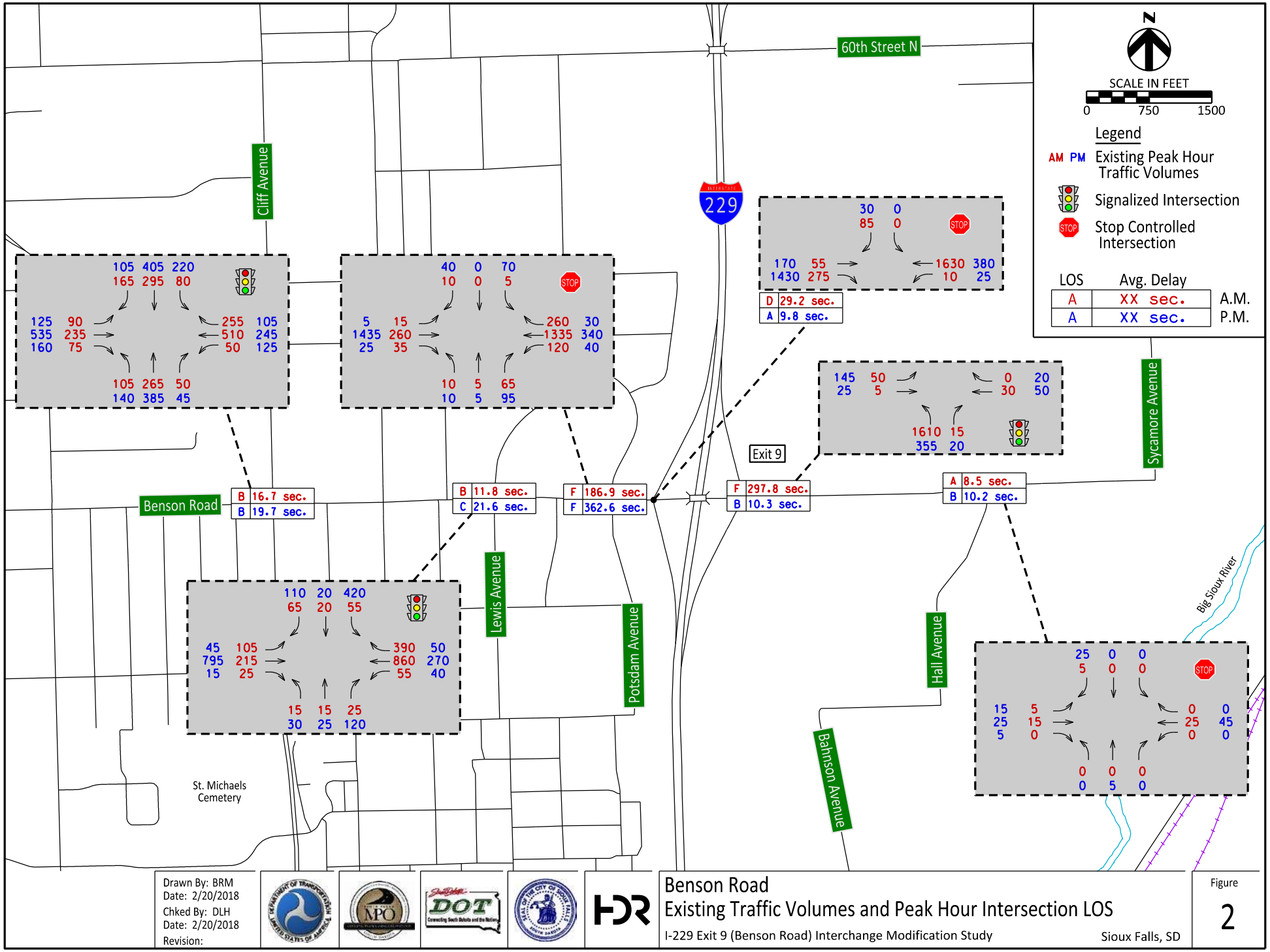
Intersection turning volumes and level of service for peak hours under 2018 conditions are shown in **Figures 2** and **3** for the Benson Road and Rice Street arterial corridors. Multimodal levels of service for the Benson Road and Rice Street arterial corridors are shown in **Figures 4** and **5**. The Existing Conditions Traffic Memo is included for reference in **Appendix 3**.

The arterial street system experiences peak hour congestion at the following locations:

- Benson Road/Potsdam Avenue
- Benson Road/I-229 Southbound Ramp Terminal
- Benson Road/I-229 Northbound Ramp Terminal
- Rice Street/I-229 Southbound Ramp Terminal
- Rice Street/I-229 Northbound Ramp Terminal

Certain movements experienced low levels of service or queues that exceeded the length of the available storage during particular peak hours. The southbound left turn at Rice Street/Cliff Avenue is an example of this characteristic, with the left turn queue extending through the Bennett Street/Cliff Avenue intersection at times.

Multi-modal level of service varies widely throughout the Benson Road and Rice Street corridors. The lowest levels of service are related to locations with the absence of specific facilities for pedestrians and bicyclists in these corridors.


60th Street N
Cliff Avenue
Benson Road
Lewis Avenue
Potsdam Avenue
Exit 9
Sycamore Avenue
Hall Avenue
Bahnson Avenue
Big Sioux River
St. Michaels Cemetery
105 405 220
165 295 80
125 90
535 235
160 75
255 105
510 245
50 125
105 265 50
140 385 45
40 0 70
10 0 5
5 15
1435 260
25 35
260 30
1335 340
120 40
10 5 65
10 5 95
30 0
85 0
170 55
1430 275
1630 380
10 25
D 29.2 sec.
A 9.8 sec.
145 50
25 5
0 20
30 50
1610 15
355 20
110 20 420
65 20 55
45 105
795 215
15 25
390 50
860 270
55 40
15 15 25
30 25 120
25 0 0
5 0 0
15 5
25 15
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0 45
0 0
0 0 0
0 5 0
B 16.7 sec.
B 19.7 sec.
B 11.8 sec.
C 21.6 sec.
F 186.9 sec.
F 362.6 sec.
F 297.8 sec.
B 10.3 sec.
A 8.5 sec.
B 10.2 sec.
N
SCALE IN FEET
0 750 1500
Legend
AM PM Existing Peak Hour Traffic Volumes
Signalized Intersection
Stop Controlled Intersection
LOS Avg. Delay
A XX sec. A.M.
A XX sec. P.M.
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Benson Road
Existing Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD
Figure 2
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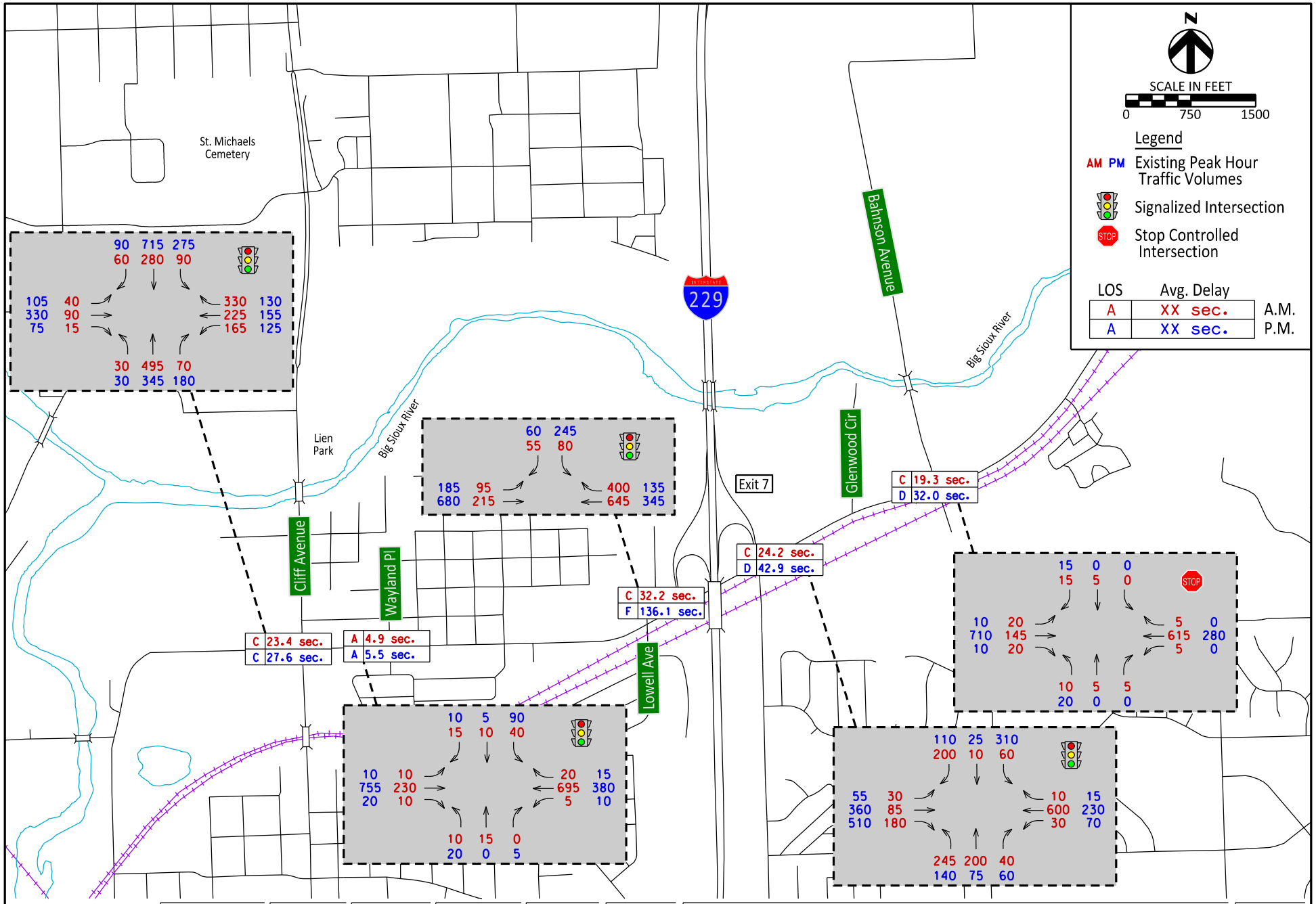

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Rice Street
Existing Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 3

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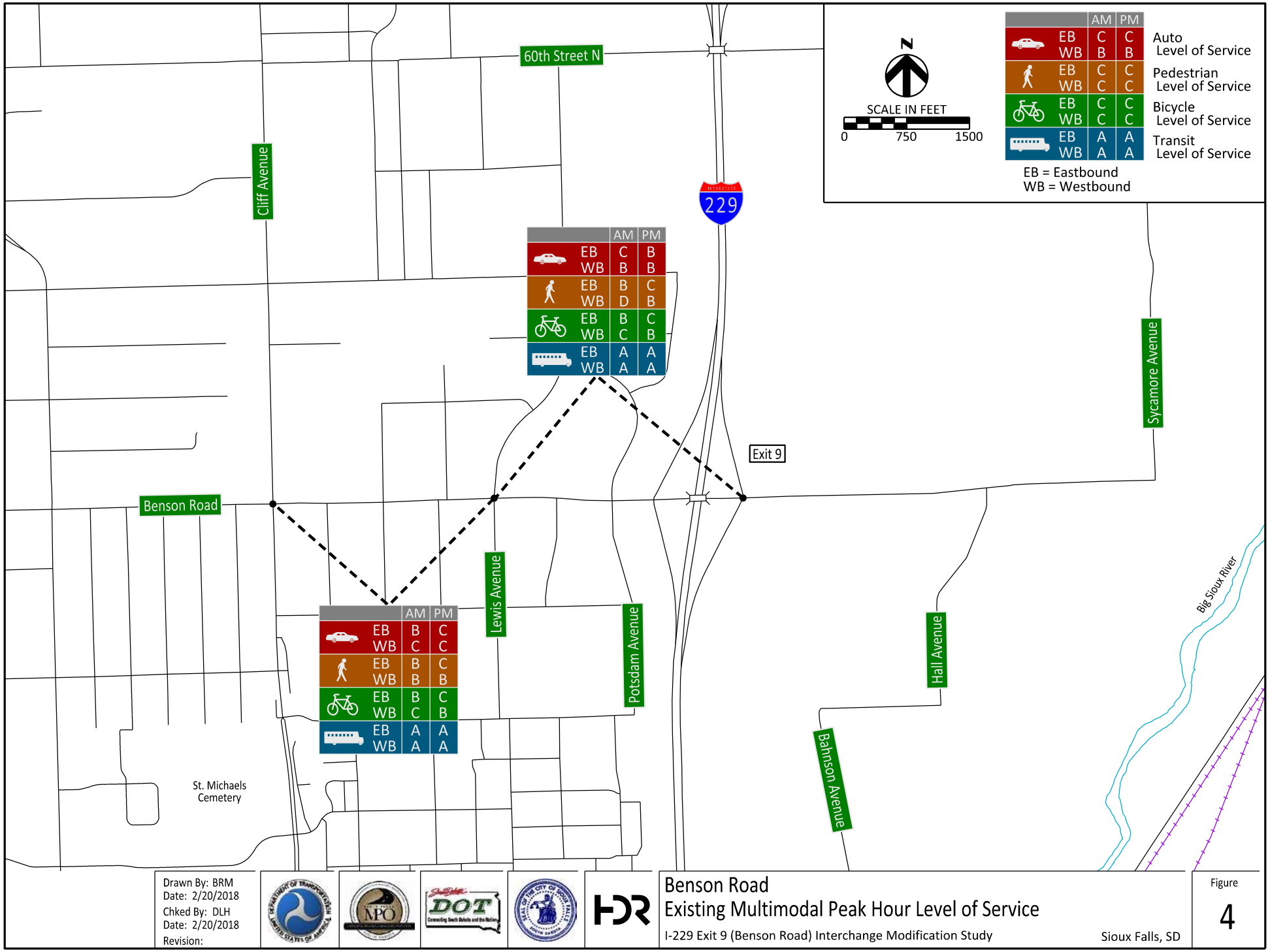

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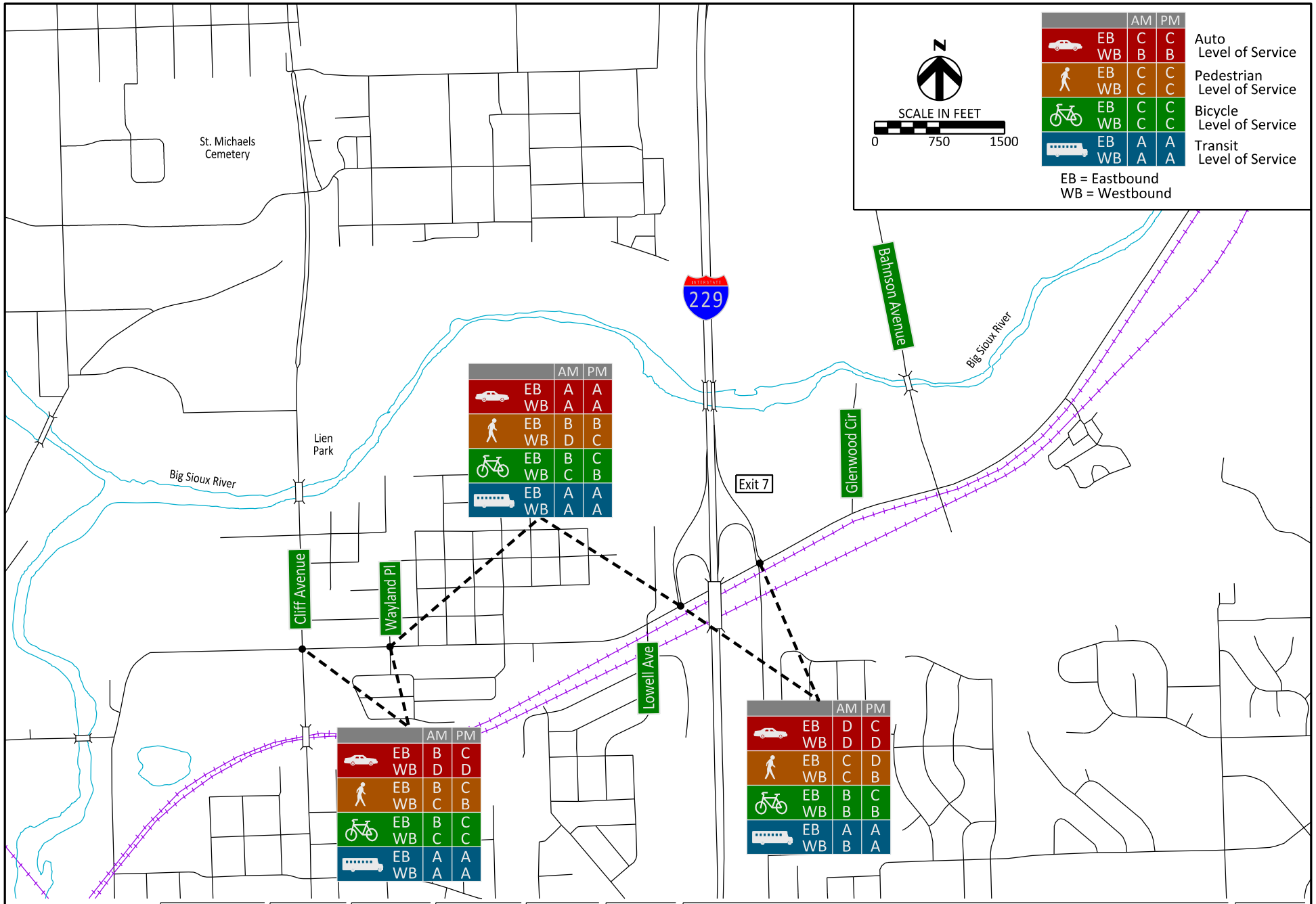
Benson Road
Existing Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 4



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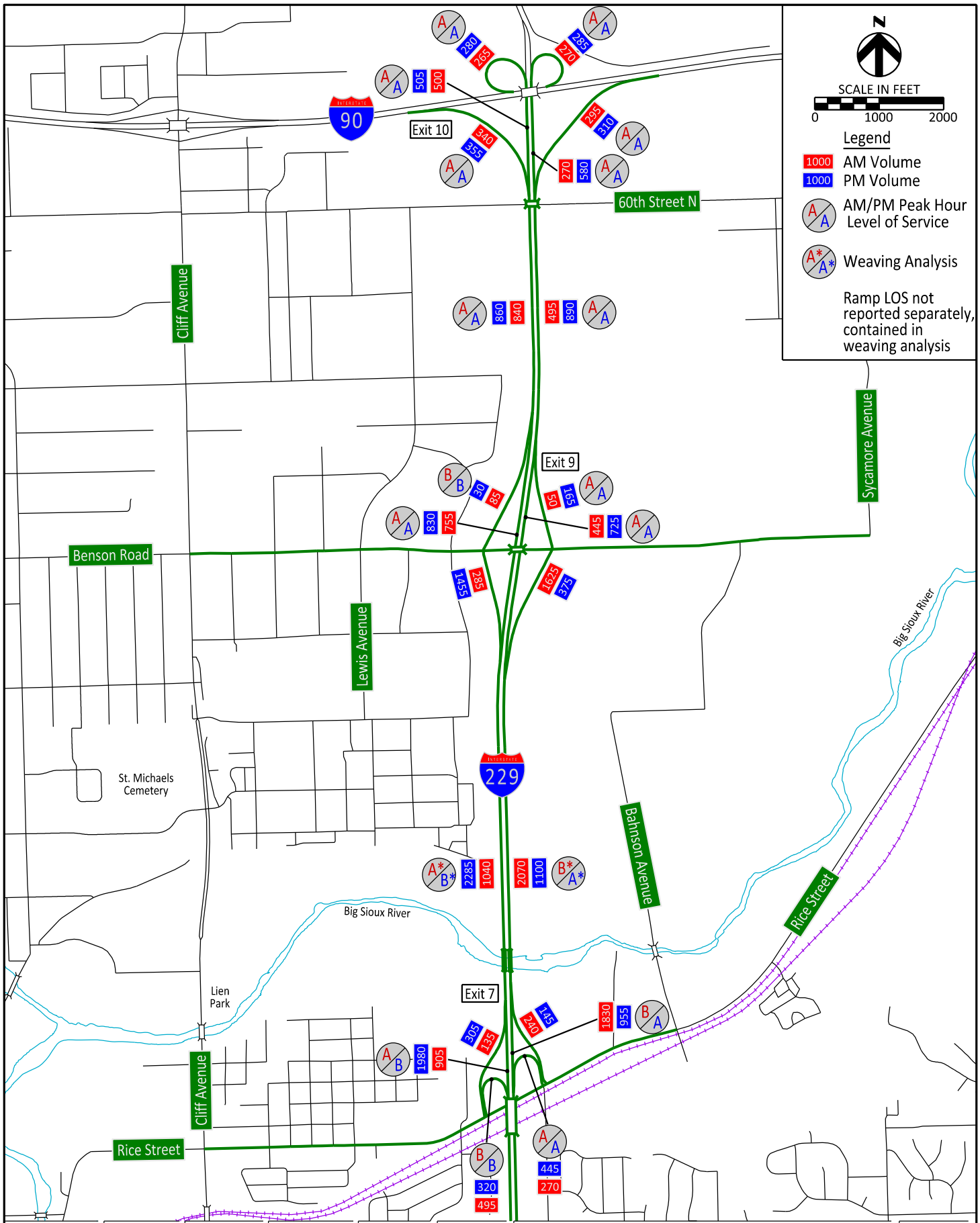
Rice Street
Existing Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 5



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Existing Peak Hour Balanced Traffic Volumes and Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 6

Existing Safety Conditions

An analysis of existing safety conditions was conducted based on crash records provided by SDDOT. The analysis was conducted using the Critical Rate Method, as described in the Highway Safety Manual (HSM), published by the American Association of State Highway and Transportation Officials (AASHTO).

Highway Safety Manual definition:

- *Critical Rate Method (CRM): a method in which the observed crash rate at each site is compared to a calculated critical crash rate that is unique to each site.*

Crash data for the years 2013 through 2017 were provided by SDDOT and reviewed to identify any existing crash concentrations/crash trends and develop potential crash mitigation measures. Analysis were conducted for the following roadway facilities:

- Arterial street intersections
- Arterial street segments
- Interstate mainline segments
- Interstate ramp segments

Critical crash rates were calculated for each segment, ramp, or intersection and used to identify portions of the study area that displayed crash rates higher than the critical rate. Each of the above-critical locations is discussed in subsequent sections of this report.

Segment, Ramp and Intersection Crash Rates

The study area was divided into segments representing:

- Interstate mainline segments (Figure 7, Table 1)
- Interstate ramp segments (Figure 8, Table 2)
- Arterial street intersections (Figures 9 & 10, Table 3)
- Arterial street segments (Figures 11 & 12, Table 4)

Mainline and ramp sections were each analyzed separately to allow calculation of representative crash rates and critical rates for each type of Interstate feature.

The study arterial street intersections and intervening arterial street segments were each grouped for calculation of crash rates and critical rates.

Details of the crash records for each segment and intersection are contained in **Appendix 4**.

Segment and Intersection Critical Crash Rates:

Critical crash rates were calculated based on the statistical populations in each spreadsheet, using the methods shown in the Highway Safety Manual (American Association of State Highway and Transportation Officials (AASHTO), 2010). Those segments and intersections that lay outside the critical rates are shown in red coloration in the last column of each spreadsheet. All the segments and intersections that lay within the critical limits are shown in green. The locations of non-critical or critical crash rates are also illustrated on the figures.

Crash Trends:

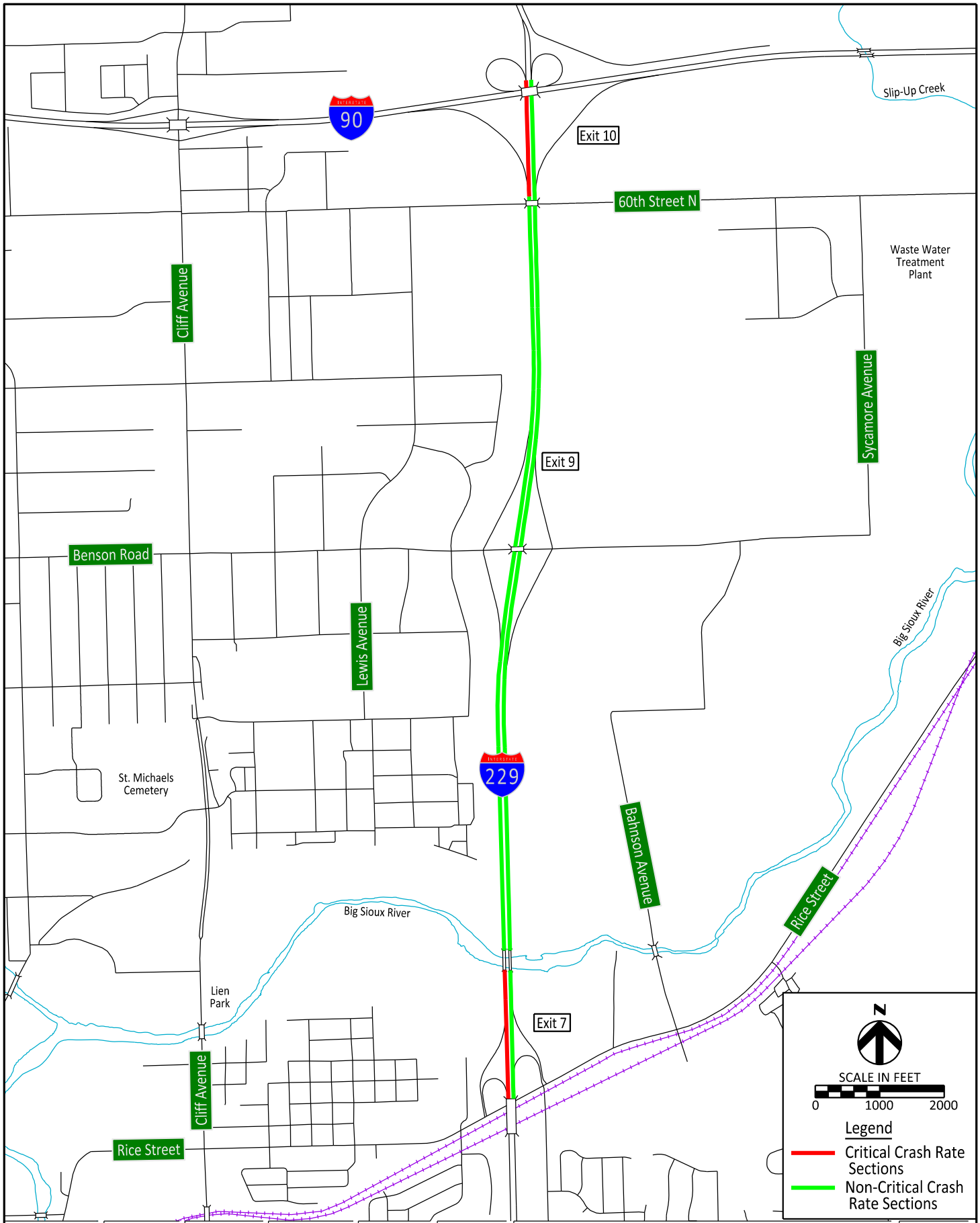
Review of the crash summaries for each Interstate and arterial street section revealed a few crash trends:

- Slightly elevated incidence of single vehicle crashes on southbound I-229 at I-90 during inclement weather events.
- A short-term concentration of crashes on southbound I-229 at Rice Street, likely during construction activities.
- Single-vehicle run-off crashes on the northbound Rice Street off-ramp during inclement weather (only 5 in the 5-year period, but enough to appear outside the critical rate boundary).
- Concentrations of angle crashes at the Benson/Cliff and Rice/Cliff intersections.
- A concentration of crashes involving parked cars on Rice between Wayland and I-229 SB.

Potential Mitigation Measures:

The general crash trends identified above suggest several potential strategies for reducing crash rates with the study area:

- Consider ITS-related means of communicating slippery roadway conditions to drivers and continue aggressive winter maintenance.
- Addition of high-friction surface courses on bridges, curves, and weaving areas may help reduce crashes that occur during inclement weather.
- Consider work zone traffic control that doesn't require drivers to enter high speed traffic from a stop condition.
- Conduct road safety audits of the Benson/Cliff and Rice/Cliff intersections to consider ways to reduce angle crashes.
- Consider a wider edge line to delineate the parking lane along Rice Street.



FILE: ...\Figure 07 (Interstate Crash).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 2/28/2018
Chked By: DLH
Date: 2/28/2018
Revision:

Interstate Segments for Crash Analysis (See Table 1)

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 7

TABLE 1 - INTERSTATE SEGMENT CRASH RATES (2013-2017)

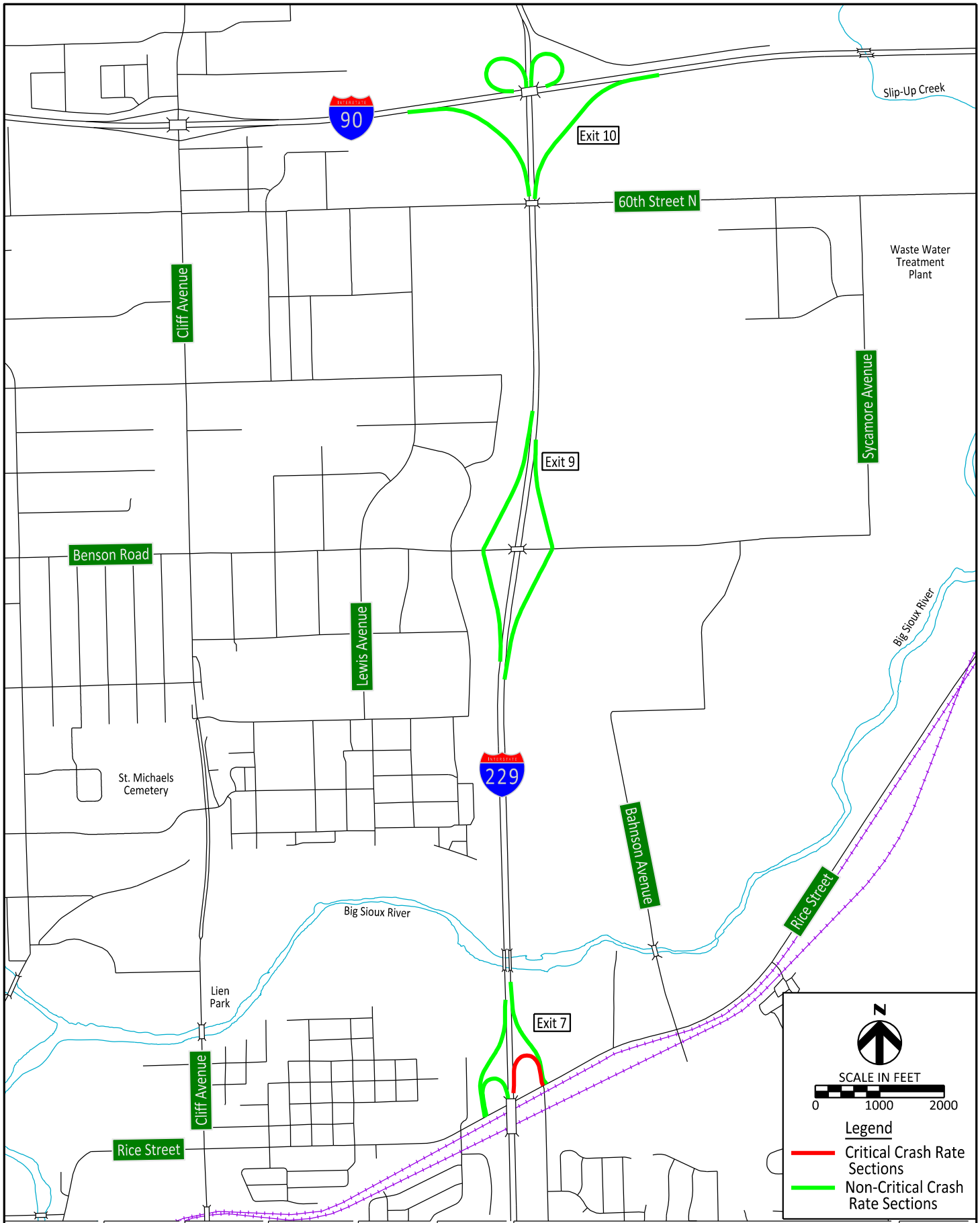
I-229/BENSON INTERSTATE ACCESS STUDY

TRAVEL DIRECTION	SEGMENT	NUMBER CRASHES	SEGMENT LENGTH	DAILY VOLUME	MVMT[1]	CRASH RATE	*TEV*R*[2]	CRITICAL RATE	CRASH/CRITICAL RATIO
SB	I-90 INTERCHANGE AREA	11	0.331	4265	2.58	4.27	18209.66	2.89	1.48
SB	I-90 TO BENSON	16	0.686	7900	9.89	1.62	12780.06	2.14	0.76
SB	BENSON INTERCHANGE AREA	2	0.692	7170	9.05	0.22	1583.66	2.18	0.10
SB	BENSON TO RICE	22	1.080	13775	27.15	0.81	11161.85	1.86	0.44
SB	RICE INTERCHANGE AREA	16	0.205	12270	4.59	3.49	42766.46	2.50	1.40
NB	RICE INTERCHANGE AREA	5	0.189	12190	4.20	1.19	14495.90	2.55	0.47
NB	RICE TO BENSON	35	0.974	13775	24.49	1.43	19690.02	1.88	0.76
NB	BENSON INTERCHANGE AREA	3	0.652	8740	10.40	0.29	2521.22	2.12	0.14
NB	BENSON TO I-90	2	0.771	7900	11.12	0.18	1421.39	2.10	0.09
NB	I-90 INTERCHANGE AREA	7	0.357	4745	3.09	2.26	10744.02	2.75	0.82
	COLUMN TOTAL			92730			135374.24		
	WEIGHTED AVERAGE RATE					1.46			

[1]MVMT = MILLION VEHICLE MILES TRAVELED

[2]TEV*R = TOTAL ENTERING VEHICLES PER DAY, TIMES OBSERVED CRASH RATE

SOURCE: HIGHWAY SAFETY MANUAL, FIRST EDITION, 2010, AASHTO



FILE: ...\Figure 08 (Interstate Ramp Crash).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 2/28/2018
Chked By: DLH
Date: 2/28/2018
Revision:

Interstate Ramps for Crash Analysis (See Table 2)

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 8

TABLE 2 - INTERSTATE RAMP CRASH RATES (2013-2017)

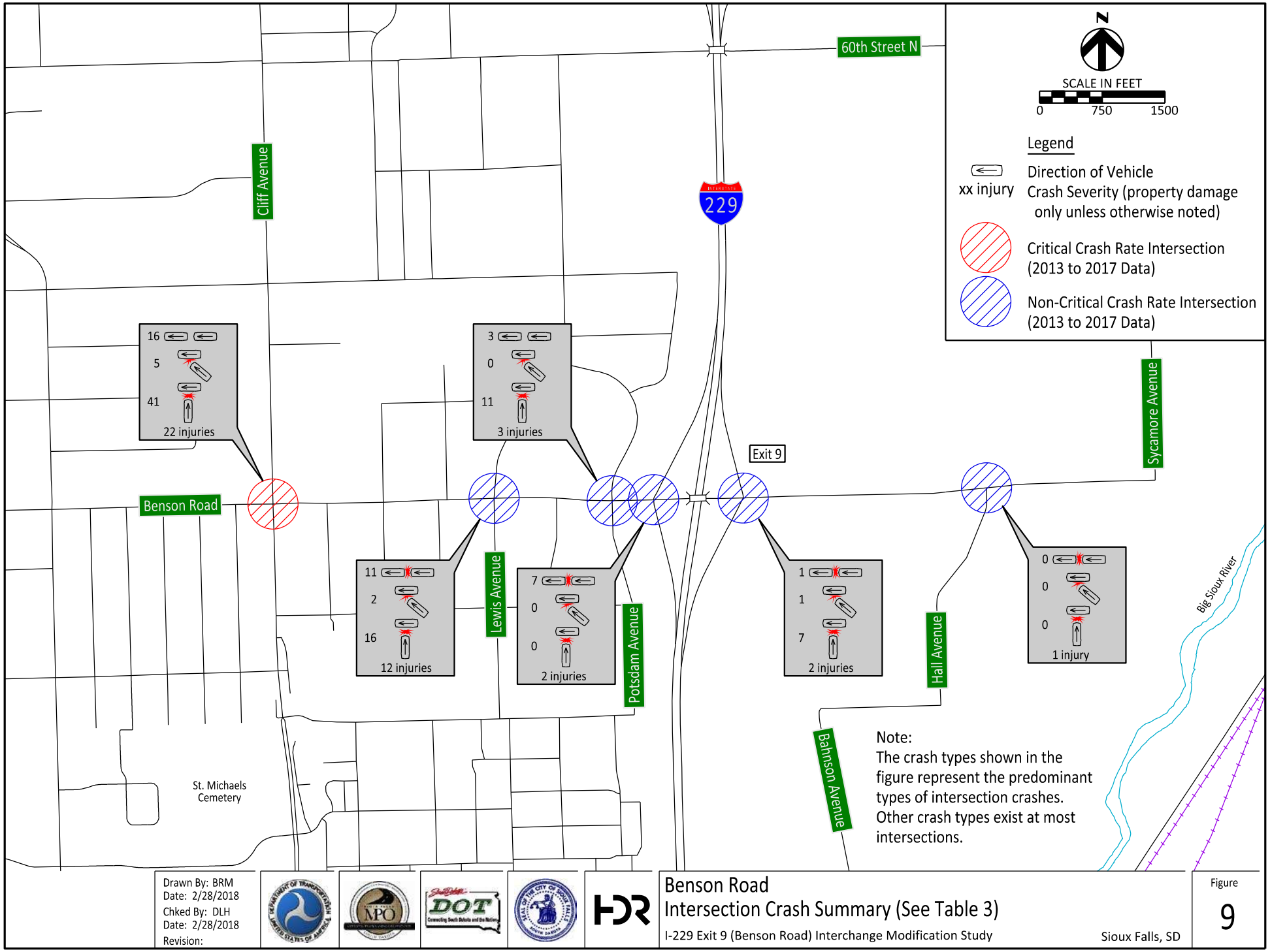
I-229/BENSON INTERSTATE ACCESS STUDY

TRAVEL DIRECTION	SEGMENT	NUMBER CRASHES	SEGMENT LENGTH	DAILY VOLUME	MVMT[1]	CRASH RATE	*TEV*R*[2]	CRITICAL RATE	CRASH/CRITICAL RATIO
SB	I-90 WB ON RAMP	4	0.234	2840	1.21	3.30	9366.58	4.91	0.67
SB	I-90 EB ON RAMP	0	0.367	3635	2.43	0.00	0.00	4.04	0.00
SB	BENSON OFF RAMP	2	0.371	730	0.49	4.05	2953.88	6.78	0.60
SB	BENSON ON RAMP	4	0.283	5140	2.65	1.51	7744.81	3.96	0.38
SB	RICE OFF RAMP	1	0.270	1505	0.74	1.35	2029.43	5.79	0.23
SB	RICE ON RAMP	1	0.173	2735	0.86	1.16	3167.31	5.49	0.21
NB	RICE OFF RAMP	5	0.152	2835	0.79	6.36	18024.51	5.67	1.12
NB	RICE ON RAMP	4	0.235	1585	0.68	5.88	9326.73	5.98	0.98
NB	BENSON OFF RAMP	8	0.360	5035	3.31	2.42	12176.56	3.76	0.64
NB	BENSON ON RAMP	0	0.264	970	0.47	0.00	0.00	6.93	0.00
NB	I-90 EB OFF RAMP	3	0.425	3155	2.45	1.23	3867.85	4.03	0.30
NB	I-90 WB OFF RAMP	2	0.189	2895	1.00	2.00	5798.36	5.22	0.38
	COLUMN TOTAL			33060			74456.03		
	WEIGHTED AVERAGE RATE					2.25			

[1]MVMT = MILLION VEHICLE MILES TRAVELED

[2]TEV*R = TOTAL ENTERING VEHICLES TIMES CRASH RATE

SOURCE: HIGHWAY SAFETY MANUAL, FIRST EDITION, 2010, AASHTO



FILE: ...\Figure 09 (Benson Crash).dgn
PLOTTING DATE: 10-09-2018

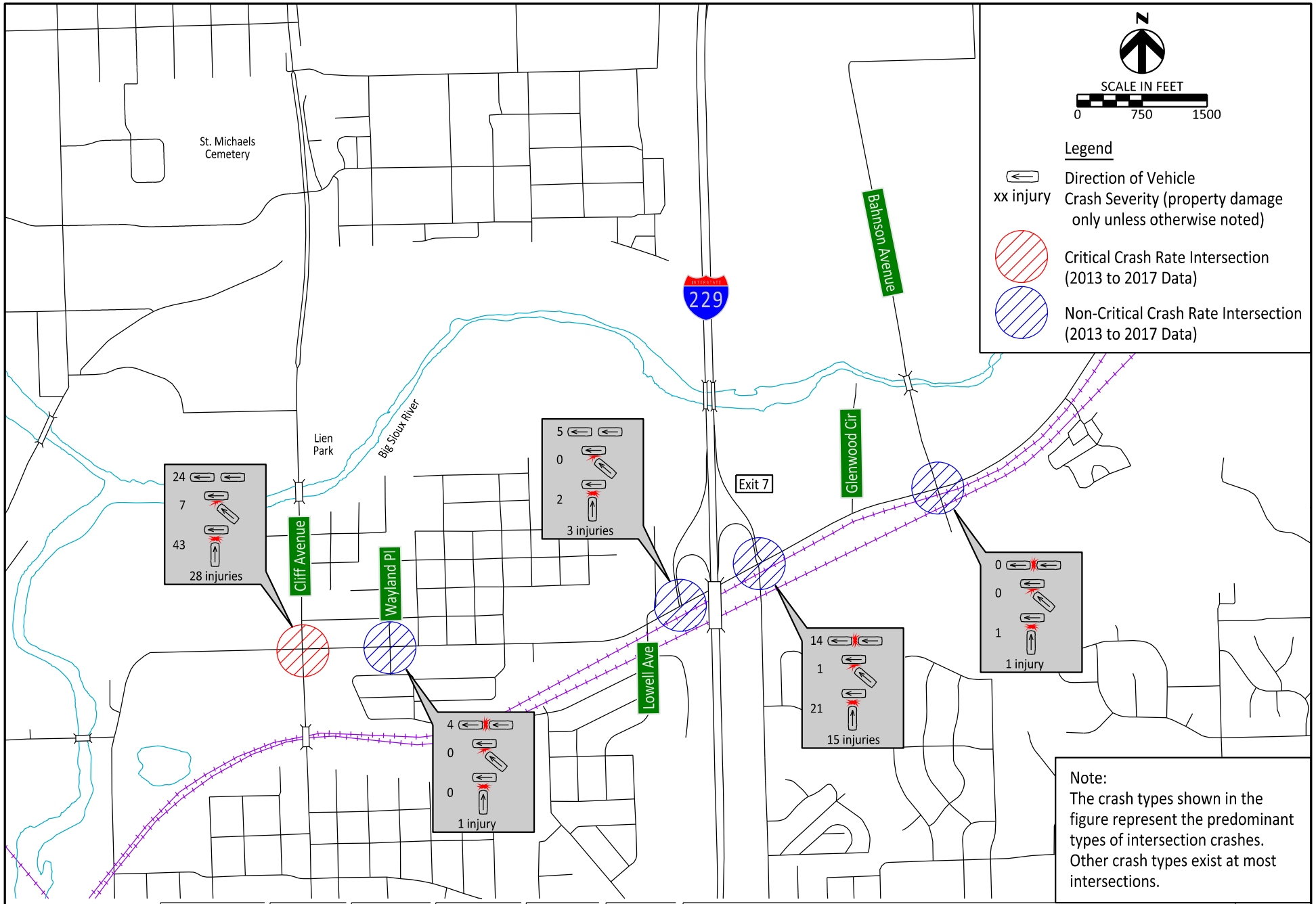
Drawn By: BRM
Date: 2/28/2018
Chked By: DLH
Date: 2/28/2018
Revision:

Benson Road
Intersection Crash Summary (See Table 3)

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 9



Drawn By: BRM
Date: 2/28/2018
Chked By: DLH
Date: 2/28/2018
Revision:

Rice Street
Intersection Crash Summary (See Table 3)
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure
10

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PLOTTING DATE: 10-09-2018

TABLE 3 - INTERSECTION CRASH RATES (2013-2017)

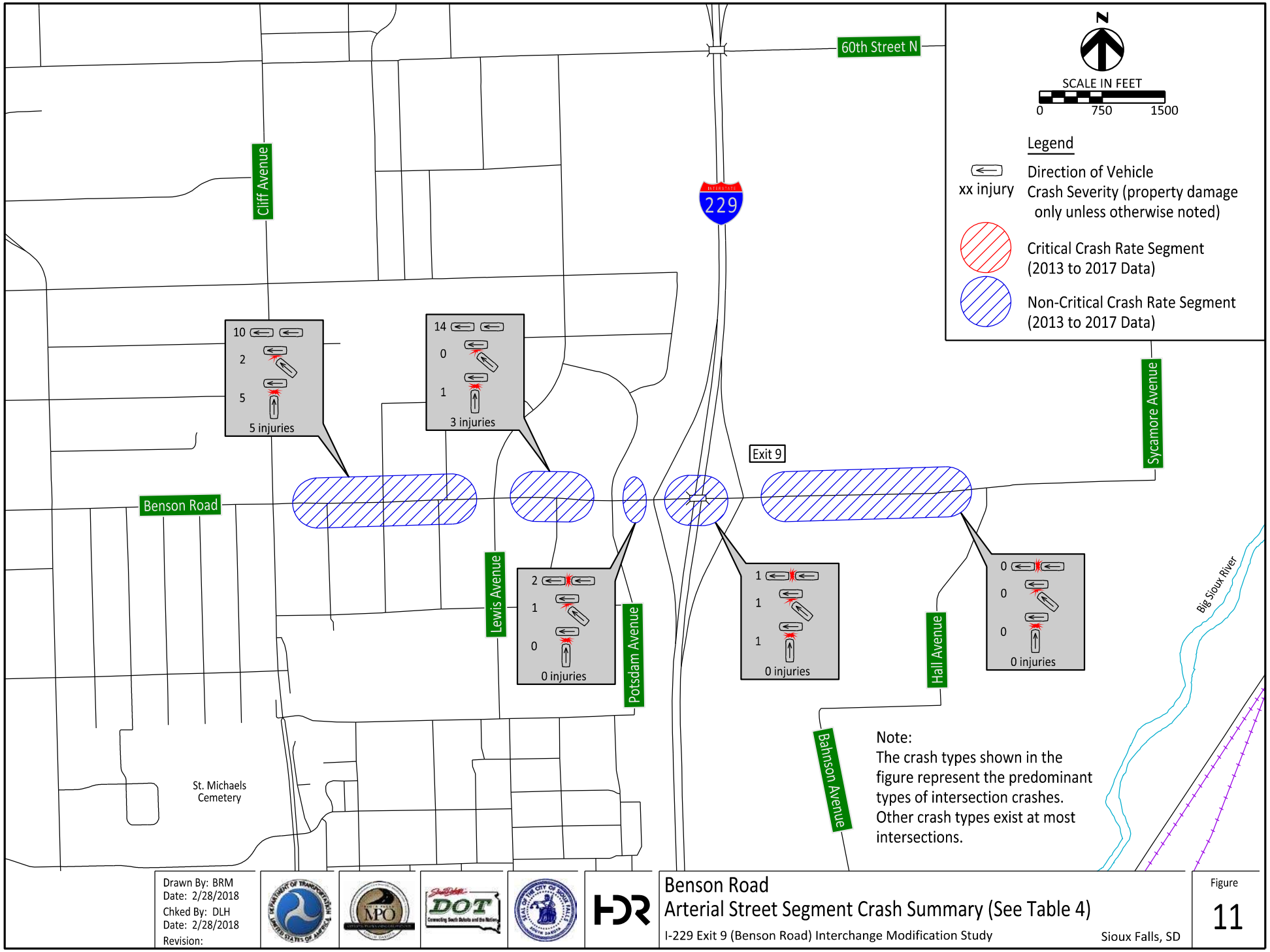
I-229/BENSON INTERSTATE ACCESS STUDY

INTERSECTION	NUMBER CRASHES	DAILY VOLUME	MEV[1]	CRASH RATE	*TEV*R* [2]	CRITICAL RATE	CRASH/CRITICAL RATIO
BENSON/CLIFF	64	25700	46.90	1.36	35068.49	1.10	1.24
BENSON/LEWIS	39	19600	35.77	1.09	21369.86	1.13	0.96
BENSON/POTSDAM	15	16000	29.20	0.51	8219.18	1.16	0.44
BENSON/I-229 SB	9	15600	28.47	0.32	4931.51	1.17	0.27
BENSON/I-229 NB	10	6000	10.95	0.91	5479.45	1.37	0.67
BENSON/HALL	2	1000	1.83	1.10	1095.89	2.27	0.48
RICE/CLIFF	77	27000	49.28	1.56	42191.78	1.09	1.43
RICE/WAYLAND	5	13700	25.00	0.20	2739.73	1.19	0.17
RICE/I-229 SB	7	15400	28.11	0.25	3835.62	1.17	0.21
RICE/I-229 NB	42	21700	39.60	1.06	23013.70	1.12	0.95
RICE/BAHNSON	2	11000	20.08	0.10	1095.89	1.23	0.08
COLUMN TOTAL		172700			149041.10		
WEIGHTED AVERAGE RATE				0.86			

[1]MEV = MILLION ENTERING VEHICLES

[2]TEV*R = TOTAL ENTERING VEHICLES TIMES CRASH RATE

SOURCE: HIGHWAY SAFETY MANUAL, FIRST EDITION, 2010, AASHTO



FILE: ...\Figure 11 (Benson Crash).dgn
PLOTTING DATE: 10-09-2018

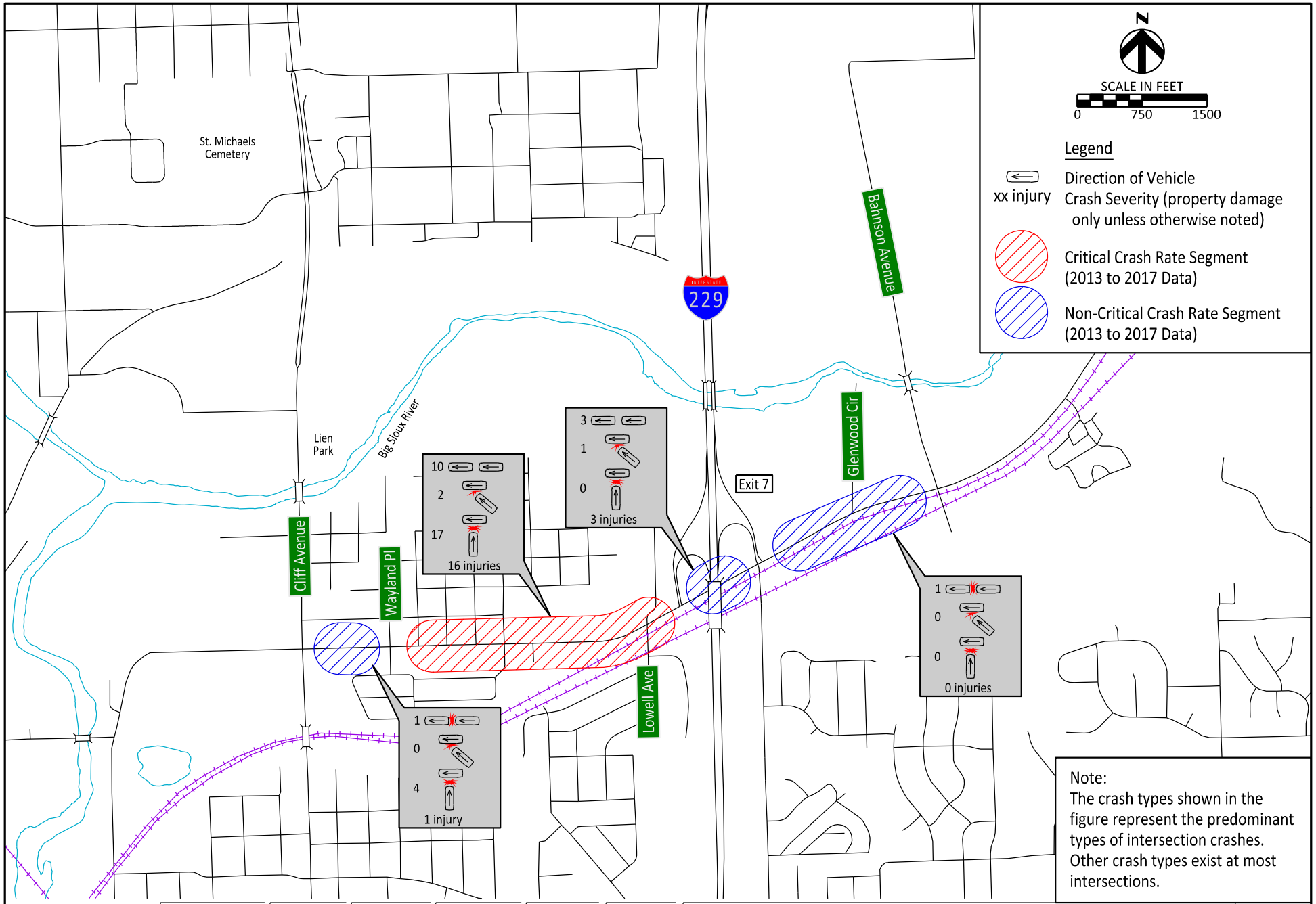
Drawn By: BRM
Date: 2/28/2018
Chked By: DLH
Date: 2/28/2018
Revision:

Benson Road
Arterial Street Segment Crash Summary (See Table 4)

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 11



Drawn By: BRM
Date: 2/28/2018
Chked By: DLH
Date: 2/28/2018
Revision:

Rice Street
Arterial Street Segment Crash Summary (See Table 4)

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 12

FILE: ...\Figure 12 (Rice Crash).dgn
PLOTTING DATE: 10-09-2018

TABLE 4 - ARTERIAL SEGMENT CRASH RATES (2013-2017)

I-229/BENSON RD IMJR

SEGMENT	NUMBER CRASHES	SEGMENT LENGTH	DAILY VOLUME	MVMT[1]	CRASH RATE	*TEV*R* [2]	CRITICAL RATE	CRASH/CRITICAL RATIO
BENSON: CLIFF TO LEWIS	19	0.501	12,200	11.15	1.70	20780.36	2.23	0.76
BENSON: LEWIS TO POTSDAM	15	0.267	14,900	7.26	2.07	30783.44	2.40	0.86
BENSON: POTSDAM TO I-229 SB	3	0.093	14,900	2.53	1.19	17675.65	3.07	0.39
BENSON: I-229 SB TO I-229 NB	3	0.200	14,900	5.44	0.55	8219.18	2.55	0.22
BENSON: I-229 NB TO HALL	1	0.551	1,000	1.01	0.99	994.46	4.12	0.24
RICE: CLIFF TO WAYLAND	5	0.193	12,700	4.47	1.12	14195.47	2.66	0.42
RICE: WAYLAND TO I-229 SB	46	0.655	11,600	13.87	3.32	38481.65	2.16	1.54
RICE: I-229 SB TO I-229 NB	12	0.192	13,900	4.87	2.46	34246.58	2.61	0.94
RICE: I-229 NB TO BAHNSON	2	0.429	10,800	8.46	0.24	2554.52	2.34	0.10
COLUMN TOTALS			106900			167931.30		
WEIGHTED AVERAGE RATE					1.57			

[1]MVMT=MILLION VEHICLE MILES TRAVELED

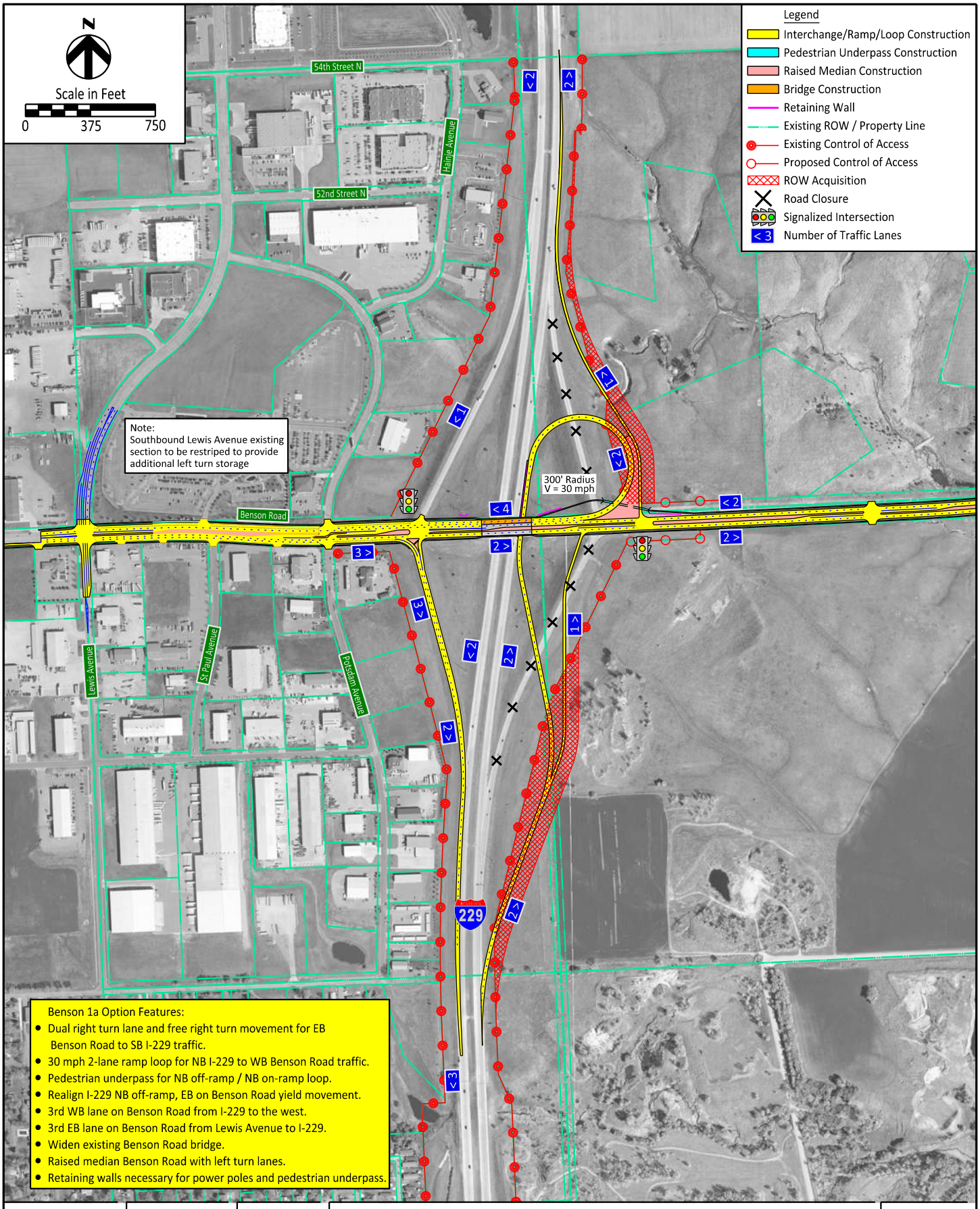
[2]TEV*R = TOTAL ENTERING VEHICLES PER DAY, TIMES OBSERVED CRASH RATE

3.2 Alternatives

Previous studies have identified improvements at the Benson Road Interchange and crossroad to provide adequate roadway capacity and improve safety. The following improvement concepts were developed to address the interchange area needs:

- No-Build
- 2-Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp
- 2-Lane Northeast Quadrant Loop with 2-Lane SB On-Ramp
- 2-Lane Collector-Distributor (CD) Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp
- 2-Lane Partial Cloverleaf Northeast Quadrant with 2-Lane SB On-Ramp
- 2-Lane Partial Cloverleaf Northeast Quadrant with CD lane and 2-Lane SB On-Ramp
- Diverging Diamond Interchange with 3-Lane SB On-Ramp – Add to Existing Overpass (WB Lanes)
- Diverging Diamond Interchange with 3-Lane SB On-Ramp – Separate Structure (EB Lanes)
- Benson Road – WB 3rd Lane from Lewis Avenue to I-229
- Benson Road – 4-Lane Divided Section from I-229 east to Hall Avenue

The interchange alternatives are shown in **Figures I-1 - I-7** and Benson Road crossroad alternatives are shown in **Figures A-1** and **A-2** on the following pages. Each option was evaluated under forecast traffic conditions to determine future traffic operations.



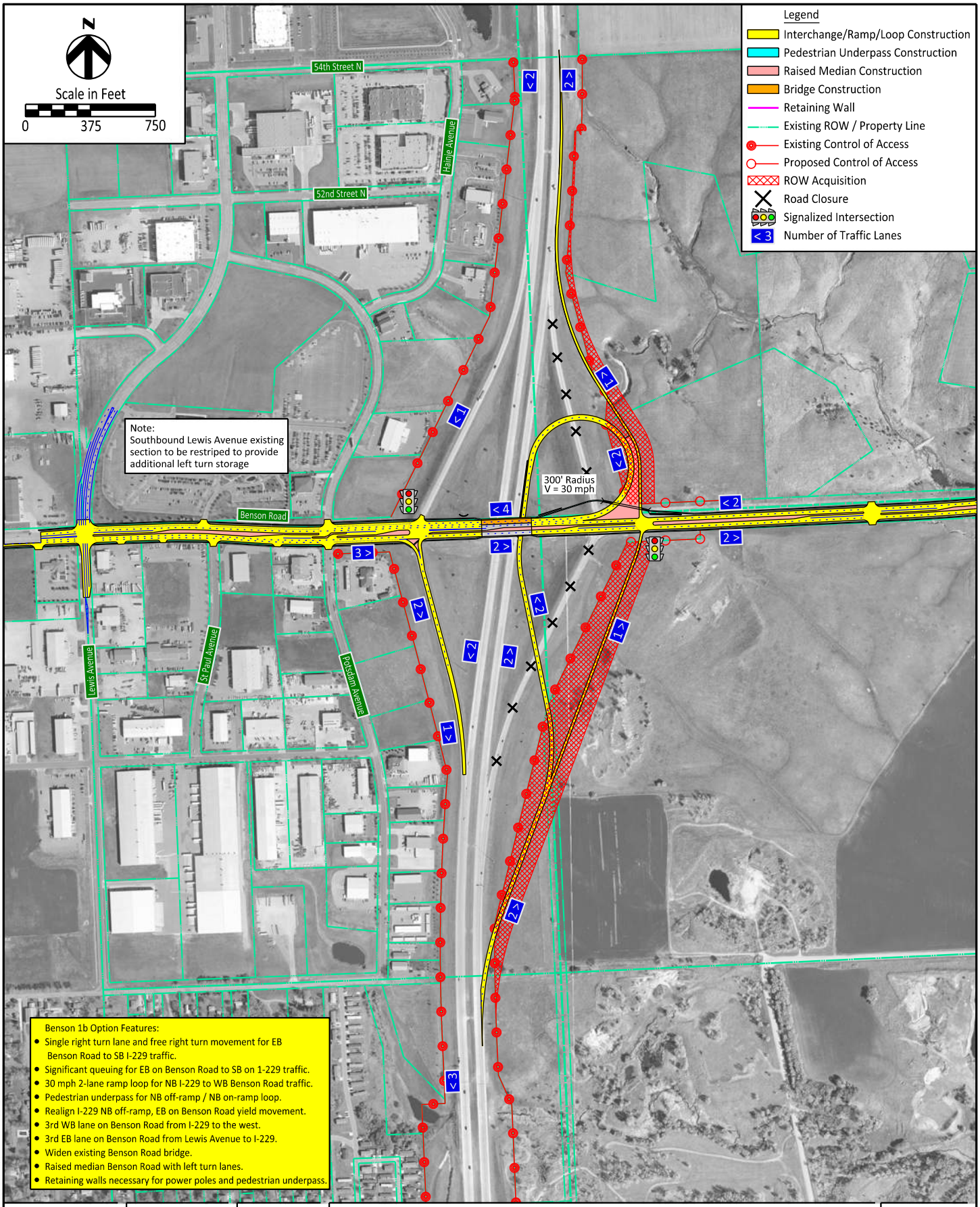
Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/8/2018

Alternative Scenario 1a
2-Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
I-1



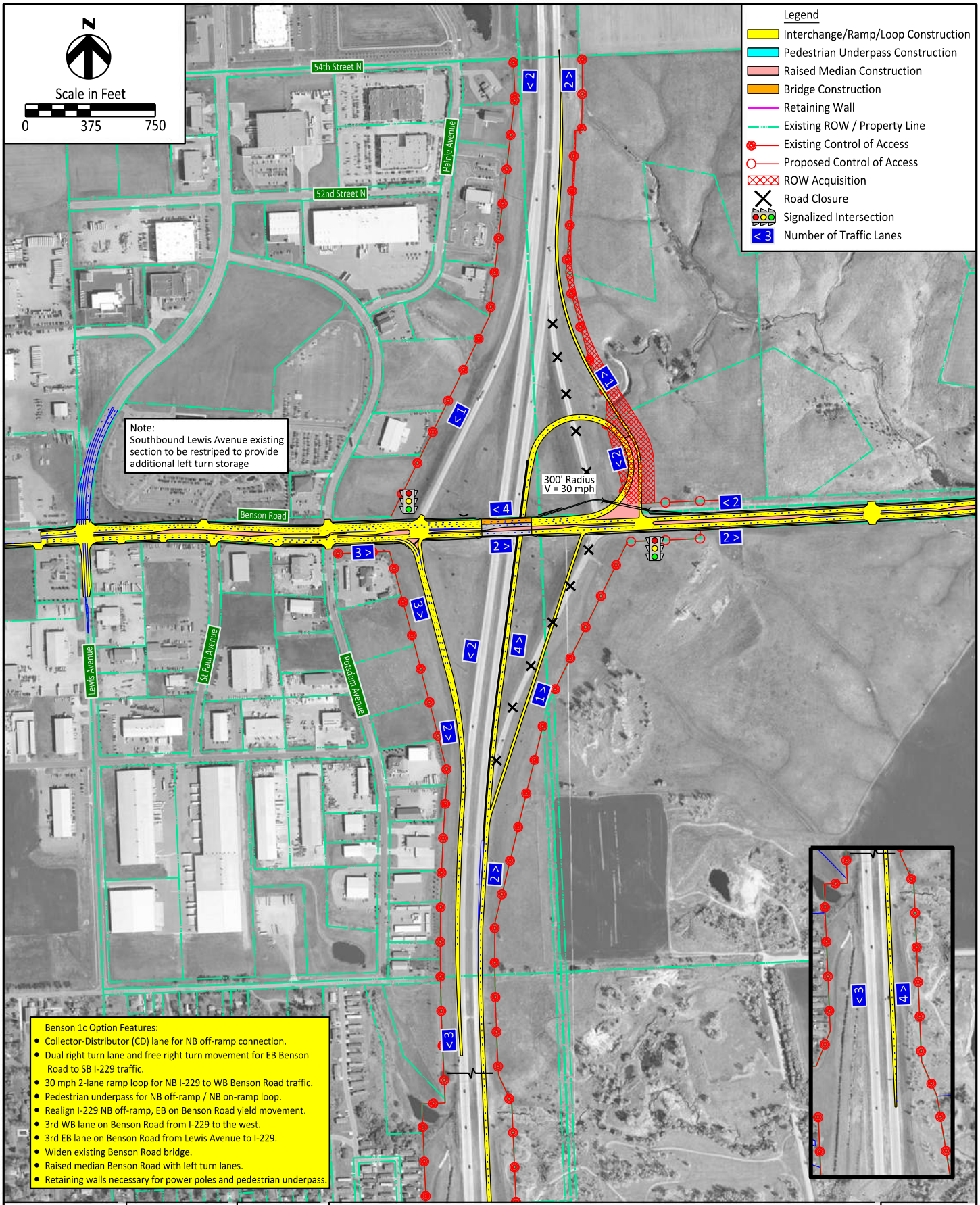
Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/8/2018

Alternative Scenario 1b
2-Lane Northeast Quadrant Loop with 2-Lane SB On-Ramp

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

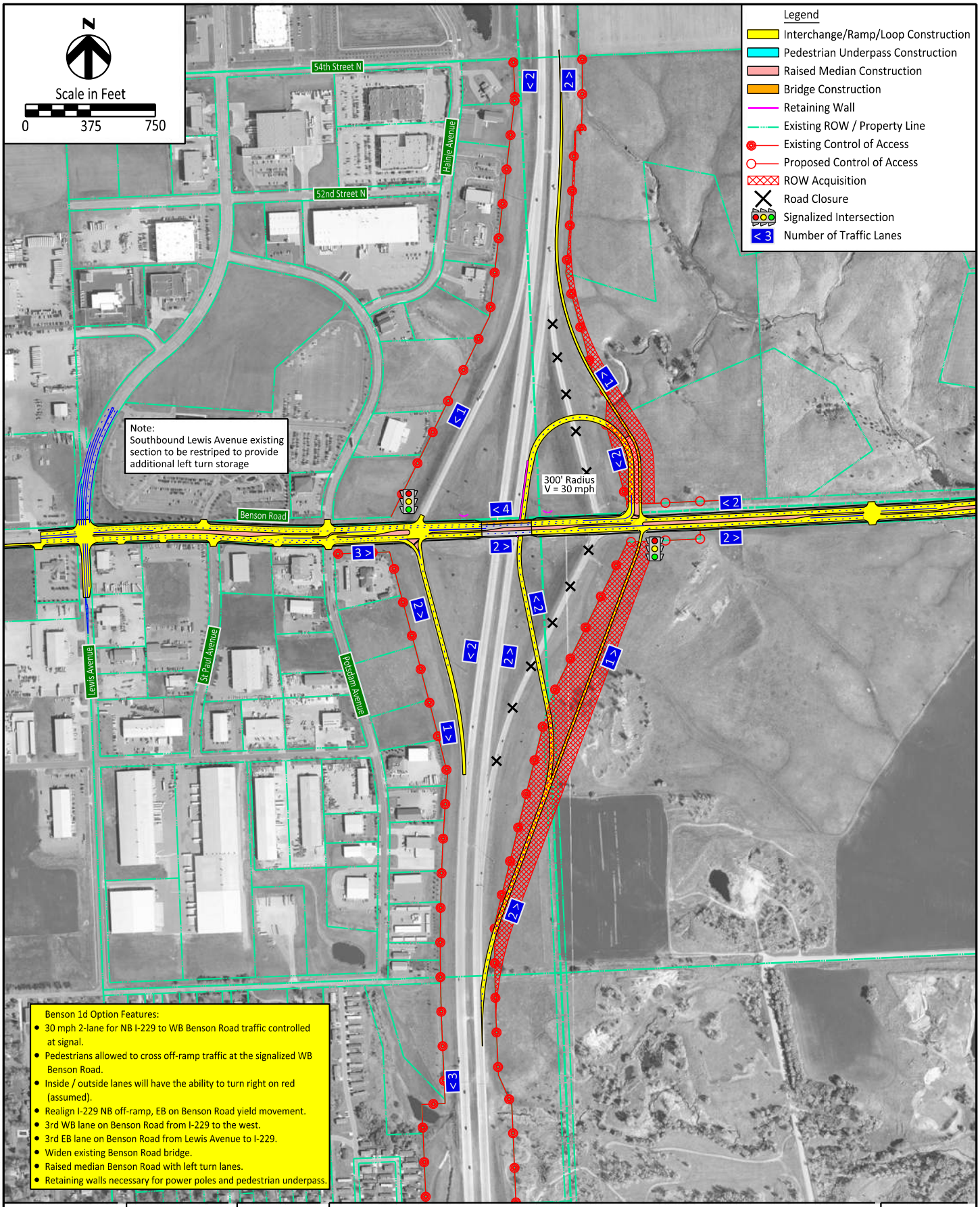
Figure
I-2



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/8/2018

Alternative Scenario 1c
2-Lane Collector - Distributor (CD) Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

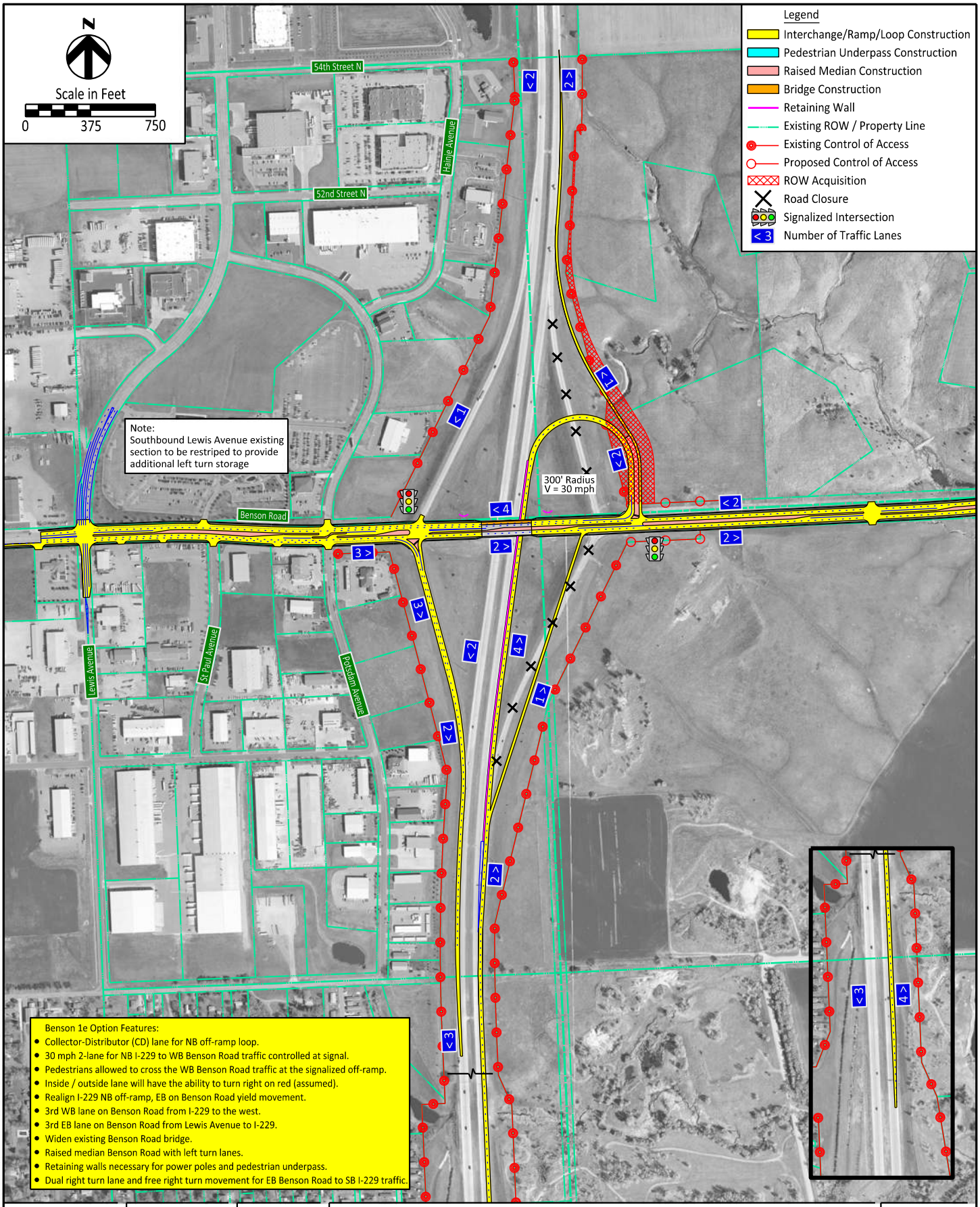
Figure
I-3



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/5/2018

Alternative Scenario 1d
2-Lane Partial Clover Leaf Northeast Quadrant Loop with 2-Lane SB On-Ramp
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

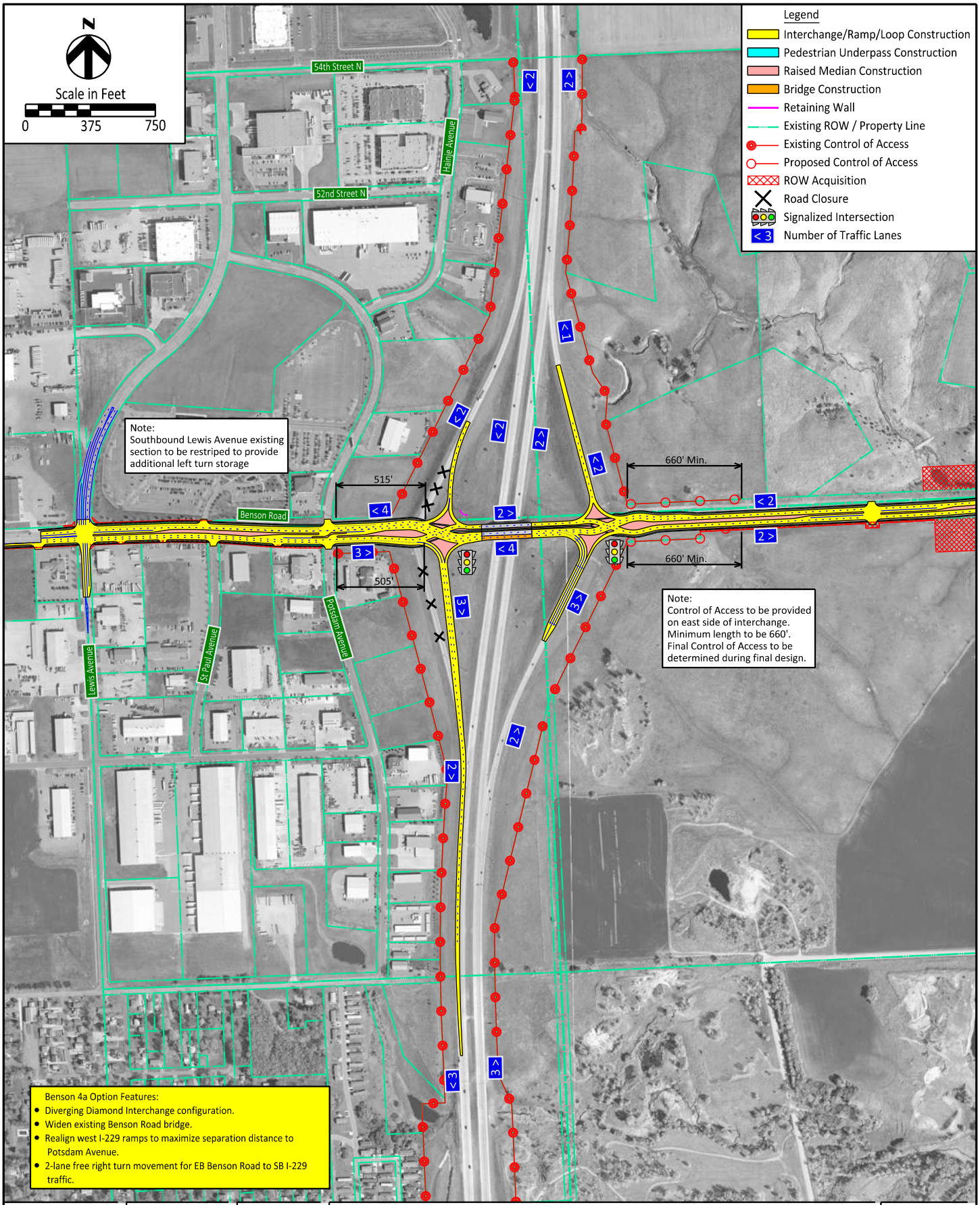
Figure
I-4



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/8/2018

Alternative Scenario 1e
2-Lane Partial Clover Leaf Northeast Quadrant with CD Lane and 2-Lane SB On-Ramp
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

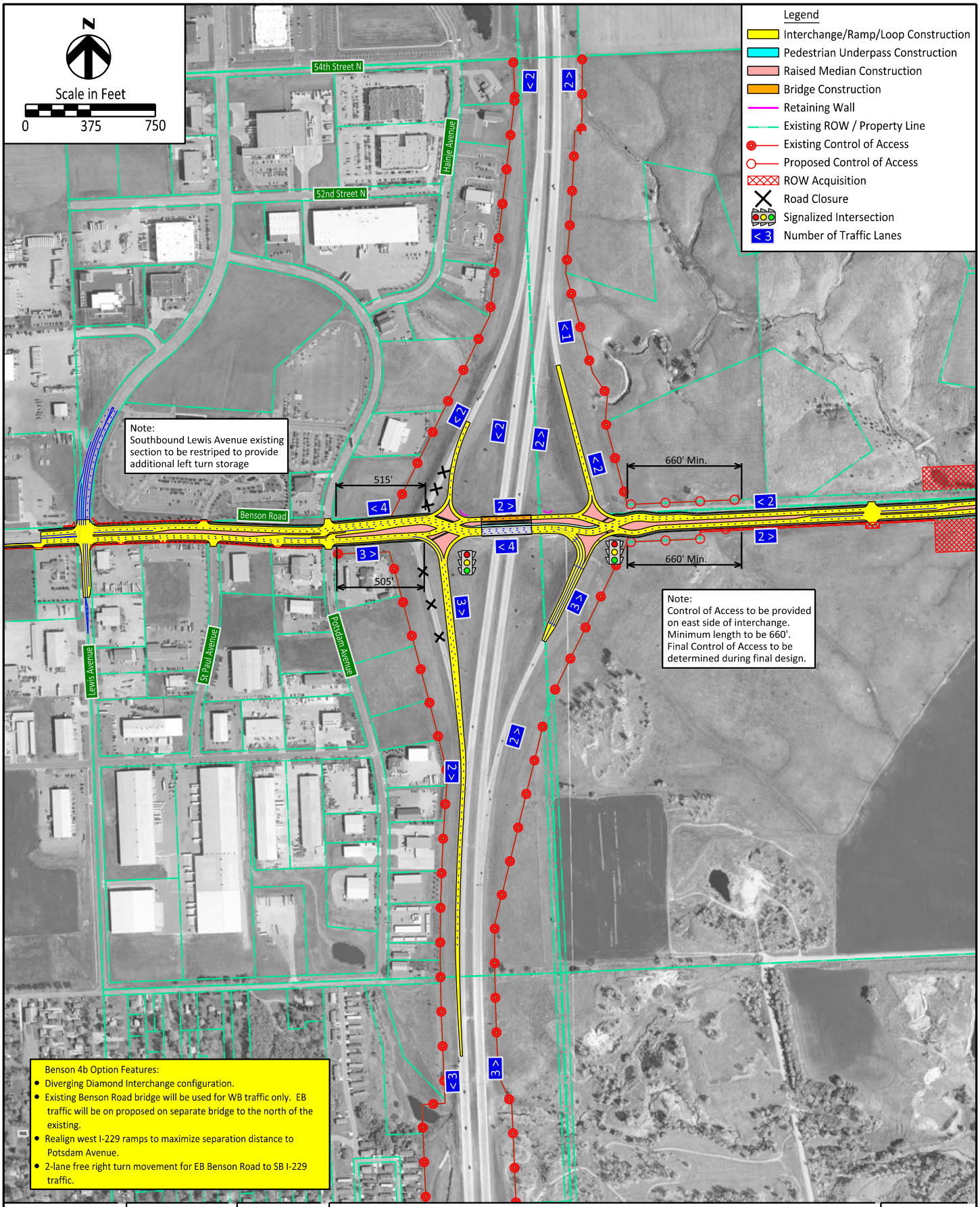
Figure
I-5



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 12/4/2018

Alternative Scenario 4a
Diverging Diamond Interchange with 3-Lane SB On-Ramp
Add 2 WB Lanes to Existing Overpass.
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

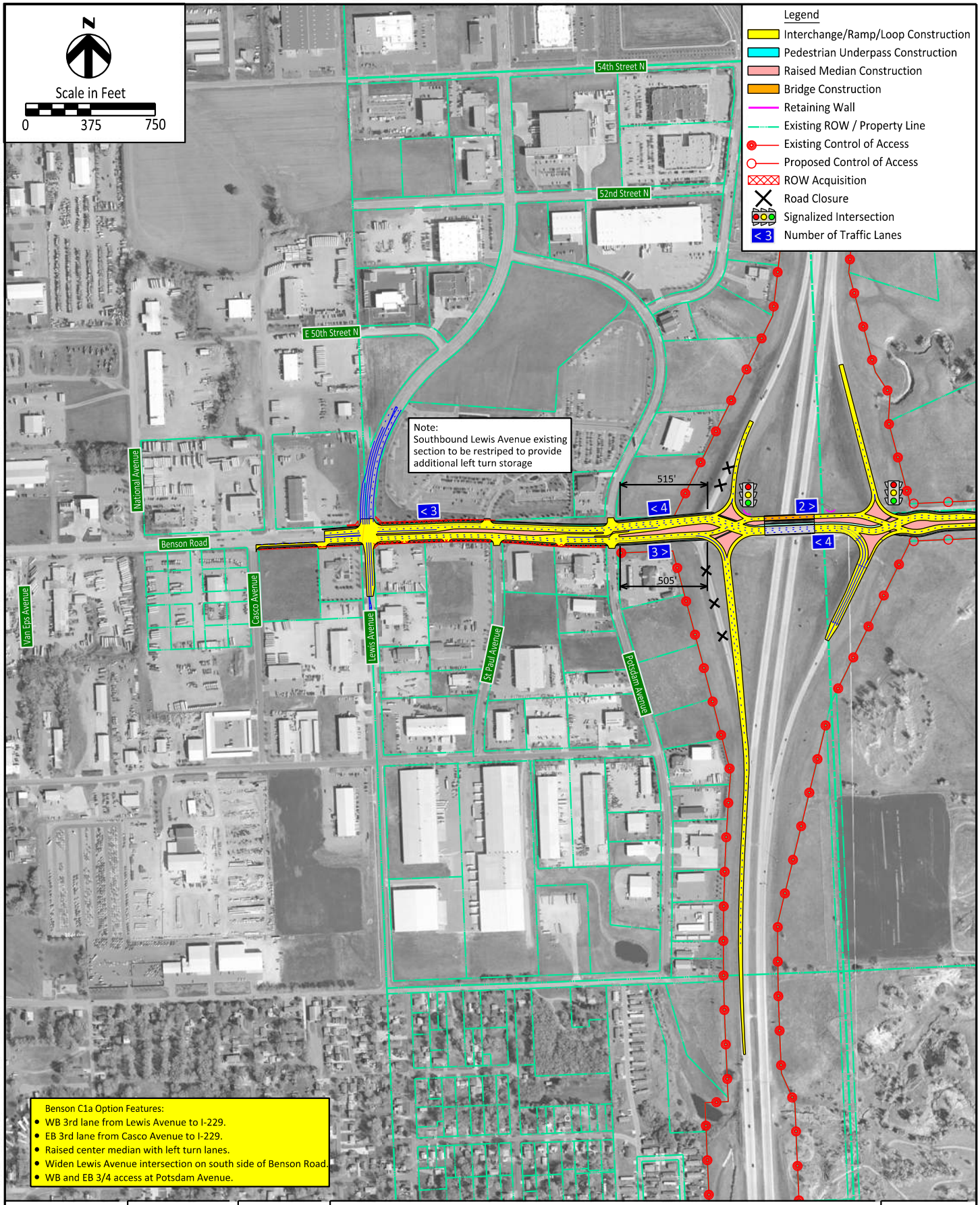
Figure
I-6



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 12/4/2018

Alternative Scenario 4b
Diverging Diamond Interchange with 3-Lane SB On-Ramp
Add a Separate Structure for 2 EB Lanes
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

Figure
I-7



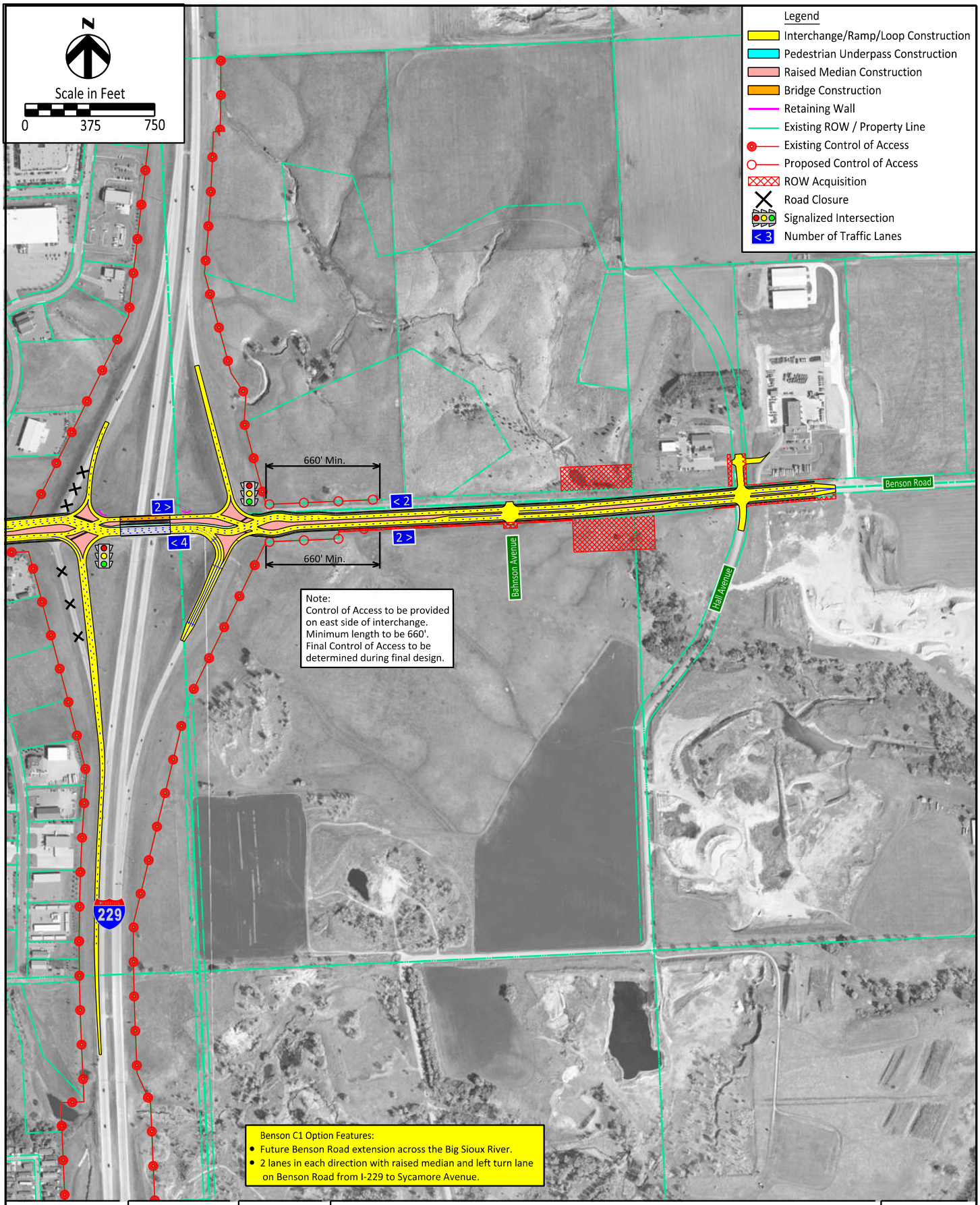
Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/8/2018

Alternative Scenario Benson Road
Westbound 3rd Lane from Lewis Avenue to I-229

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
A-1



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 12/4/2018

Alternative Scenario Benson Road
4-Lane Divided Section to Hall Avenue east of I-229

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
A-2

3.3 Future Year Traffic

Traffic forecasts for 2023 and 2045 were prepared using the regional travel demand model maintained by the City of Sioux Falls and the Sioux Falls Metropolitan Planning Organization. The forecasts were based on the latest land development information and modeling updated from the 2040 model used in the I-229 Major Investment Study. Future year traffic demand reflects planned improvements. It is assumed in the 2023 volume projections that a Benson Road extension, east to Rice Street, will not occur prior to 2023. Also, as a result of the build condition with a raised median on Benson Road, the through movements and left turns at Potsdam Avenue were re-routed to the Lewis Avenue intersection and the left turns for the HSBC driveway were also re-routed through the Lewis Avenue intersection.

Operational Performance

Level of service on I-229 was calculated for ramp merge-diverge, and weave areas for peak hours under 2023 and 2045 conditions in the immediate vicinity of the Benson Road interchange. The level of service results for the No-Build scenario are shown in **Figures 13 - 22**. Note that ramp merge-diverge segments for the I-229 SB Benson merge and I-229 NB Benson diverge are reported as part of the weaving segment between Benson Road and Rice Street. If it was determined that the segment satisfied the conditions for weaving, the weaving level of service was reported and indicated by an asterisk (*) next to the level of service result.

Interstate volumes and level of service for peak hours under 2023 and 2045 Build conditions are shown in **Figures 23 - 29**. Intersection peak hour turning volumes and level of service for 2023 and 2045 are shown in **Figures 30-36** and **44-50** respectively for Benson Road. Multimodal levels of service for the Benson Road arterial corridor are shown in **Figures 37 - 43** and **51 – 57**, respectively for 2023 and 2045 Build conditions.

The 2023 operational analysis revealed the following findings:

- Interstate facilities within the Benson Road interchange area continue to operate at an acceptable level of service, LOS C or better for all build conditions scenarios analyzed
- Arterial Street system performs at acceptable level of service for all build conditions scenarios analyzed, with the exception of Alternate 1D and 1E at the I-229 ramp terminals. This is a result of the northbound loop ramp traffic being controlled by the traffic signal at the I-229 northbound ramp terminal and negatively impacts signal timing at the downstream intersection (I-229 southbound ramp terminal). Allowing right on red for the dual southbound rights at the I-229 northbound ramp terminal may improve operations associated with Alternatives 1D and 1E. Alternatives 1A, 1B, and 1C address this deficiency by allowing free right turn movements for the southbound right turn at the I-229 northbound ramp terminal.
- Peak hour congestion (LOS E) or worse is experienced on the arterial network at the following locations:
    - Benson Road/Potsdam Avenue (PM) – STOP controlled intersection
    - Benson Road/Hall Avenue (PM) – STOP controlled intersection

2023 Intersection levels of service for the interchange build alternatives are summarized in **Table 5**.

Table 5: 2023 Build Alternatives Intersection Level of Service

	2023 CONDITIONS																	
	Existing		No Build		Alt. 1A		Alt. 1B		Alt 1C		Alt. 1D		Alt. 1E		Alt. 4A		Alt. 4B	
Intersection	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Benson/Cliff	B	B	B	C	B	C	B	C	B	C	B	C	B	C	C	C	C	C
Benson/Lewis	B	C	B	C	B	C	B	D	B	C	B	C	B	C	B	D	B	D
Benson/Potsdam	F	F	F	F	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Benson/I-229 SB Ramp	D	A	F	C	B	A	B	A	B	A	F	A	F	A	B	A	B	A
Benson/I-229 NB Ramp	F	B	F	C	A	A	B	A	A	A	C	B	C	B	B	B	B	B
Benson/Hall	A	B	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F

Certain movements experienced low levels of service or queues that exceeded the length of the available storage during particular peak hours. The southbound left turn during the PM peak hour at Benson Road/Lewis Avenue is an example of this characteristic. Queues however do not impact adjacent streets or accesses and the overall intersection level of service achieves the minimum requirement for LOS D with a specific movement no worse than LOS E. The existing left turn storage could likely be extended over the existing pavement surface by striping modifications.

A northbound right turn lane is necessary at the Benson Road and Lewis Avenue intersection in order to address low levels of service in the PM peak hour. The Benson Road/Hall Avenue intersection low level of service is addressed by the installation of a traffic signal in the 2045 scenario.

Multimodal level of service continues to vary throughout the Benson Road corridor.

The 2045 operational analysis revealed the following findings:

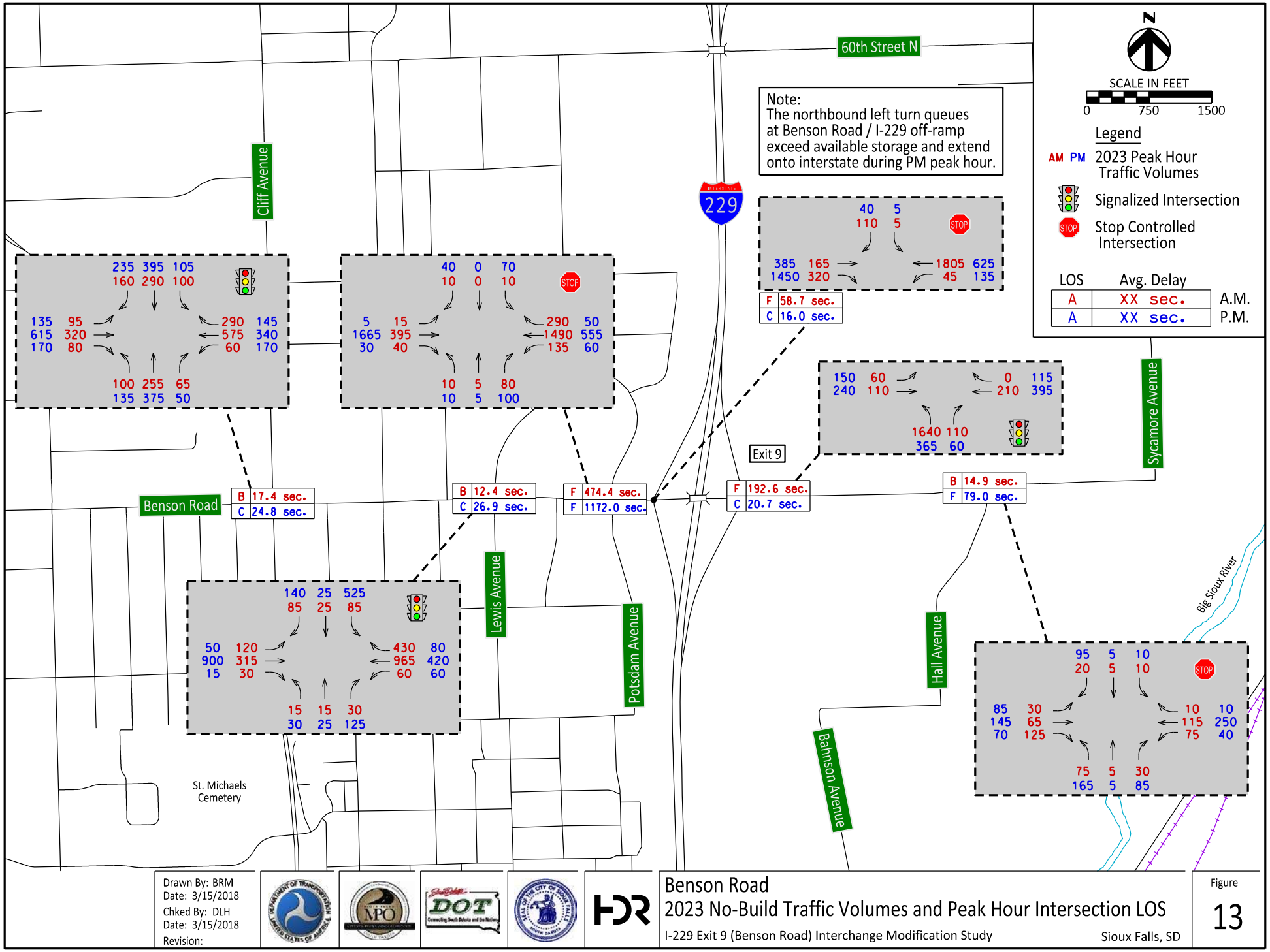
- Interstate facilities within the Benson Road interchange area continue to operate at an acceptable level of service, LOS C or better for all build conditions scenarios analyzed
- The arterial street system performs at acceptable level of service for all build conditions scenarios analyzed, with the exception of Alternatives 1D and 1E at the I-229 ramp terminals. This is a result of the northbound loop ramp traffic being controlled by the traffic signal at the I-229 northbound ramp terminal and negatively impacts signal timing at the downstream intersection (I-229 southbound ramp terminal). Allowing right on red for the dual southbound rights at the I-229 northbound ramp terminal may improve operations associated with Alternatives 1D and 1E. Alternatives 1A, B, and C address this deficiency by allowing free right turn movements for the southbound right turn at the I-229 northbound ramp terminal.

2045 Intersection levels of service under each interchange build alternatives are summarized in **Table 6**.

Table 6: 2045 Build Alternatives Intersection Level of Service

	2045 CONDITIONS																	
	Existing		No Build		Alt. 1A		Alt. 1B		Alt 1C		Alt. 1D		Alt. 1E		Alt. 4A		Alt. 4B	
Intersection	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Benson/Cliff	B	B	B	C	B	C	B	C	B	C	C	C	C	C	C	C	C	C
Benson/Lewis	B	C	B	C	B	C	C	C	B	C	B	C	B	C	B	D	B	D
Benson/Potsdam	F	F	F	F	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Benson/I-229 SB Ramp	D	A	F	F	B	B	B	B	B	B	F	B	F	B	B	A	B	A
Benson/I-229 NB Ramp	F	B	F	B	A	A	B	A	A	A	D	A	E	B	B	B	B	B
Benson/Hall	A	B	F	F	B	B	B	C	B	B	B	B	B	B	C	B	C	B

The analysis for the 2045 traffic forecast conditions requires similar improvements at the Benson Road and Lewis Avenue intersection as under 2023 traffic forecast conditions. The improvements include re-striping of Lewis Avenue to provide additional southbound left turn storage and providing a northbound right turn lane on Lewis Avenue. Additionally, a traffic signal will likely be warranted at the Benson Road and Hall Avenue intersection based upon 2045 forecast traffic volumes.



Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

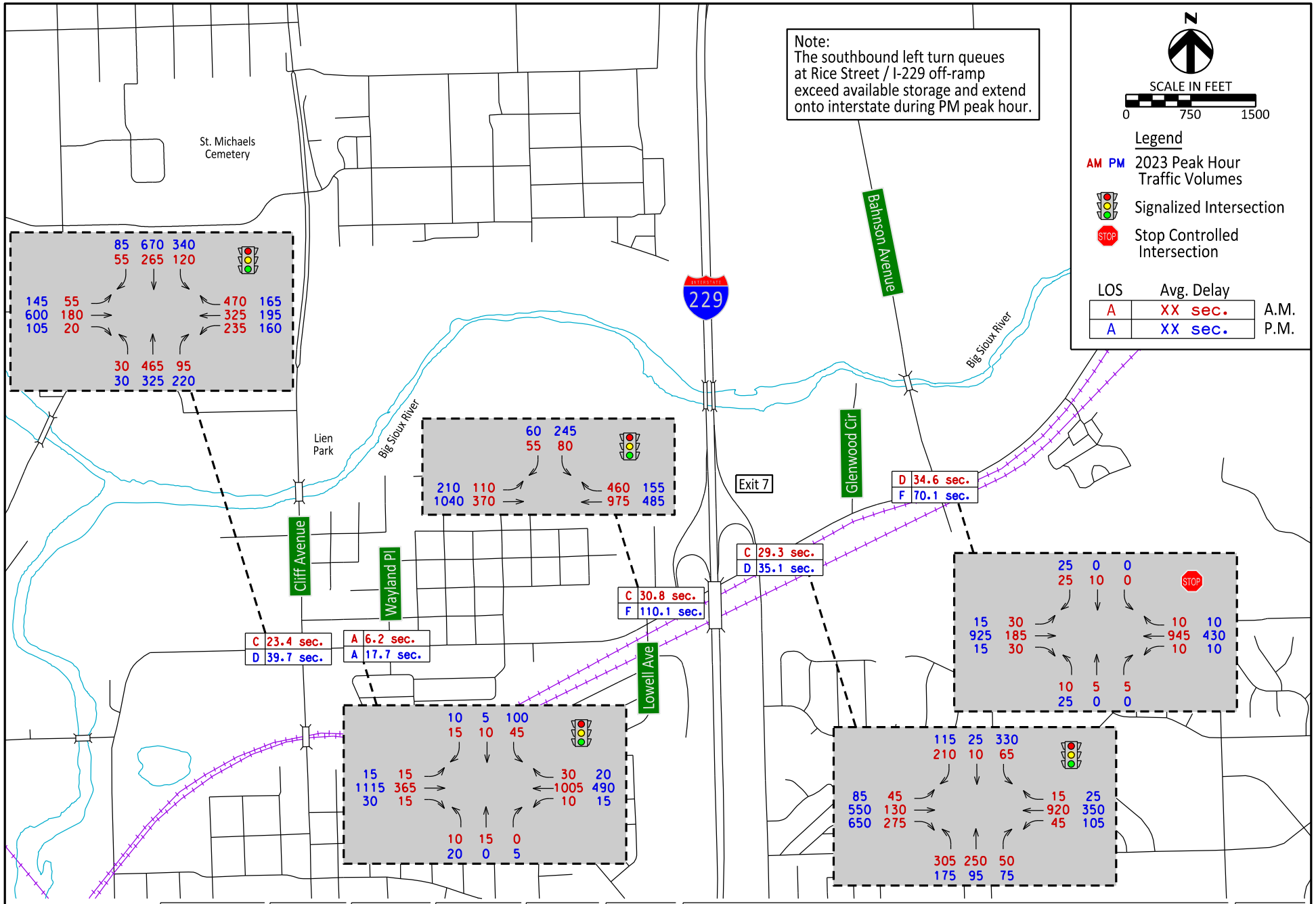
FILE: ...\Figure 13 (Benson 2023).dgn
PLOTTING DATE: 10-09-2018

Benson Road
2023 No-Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 13

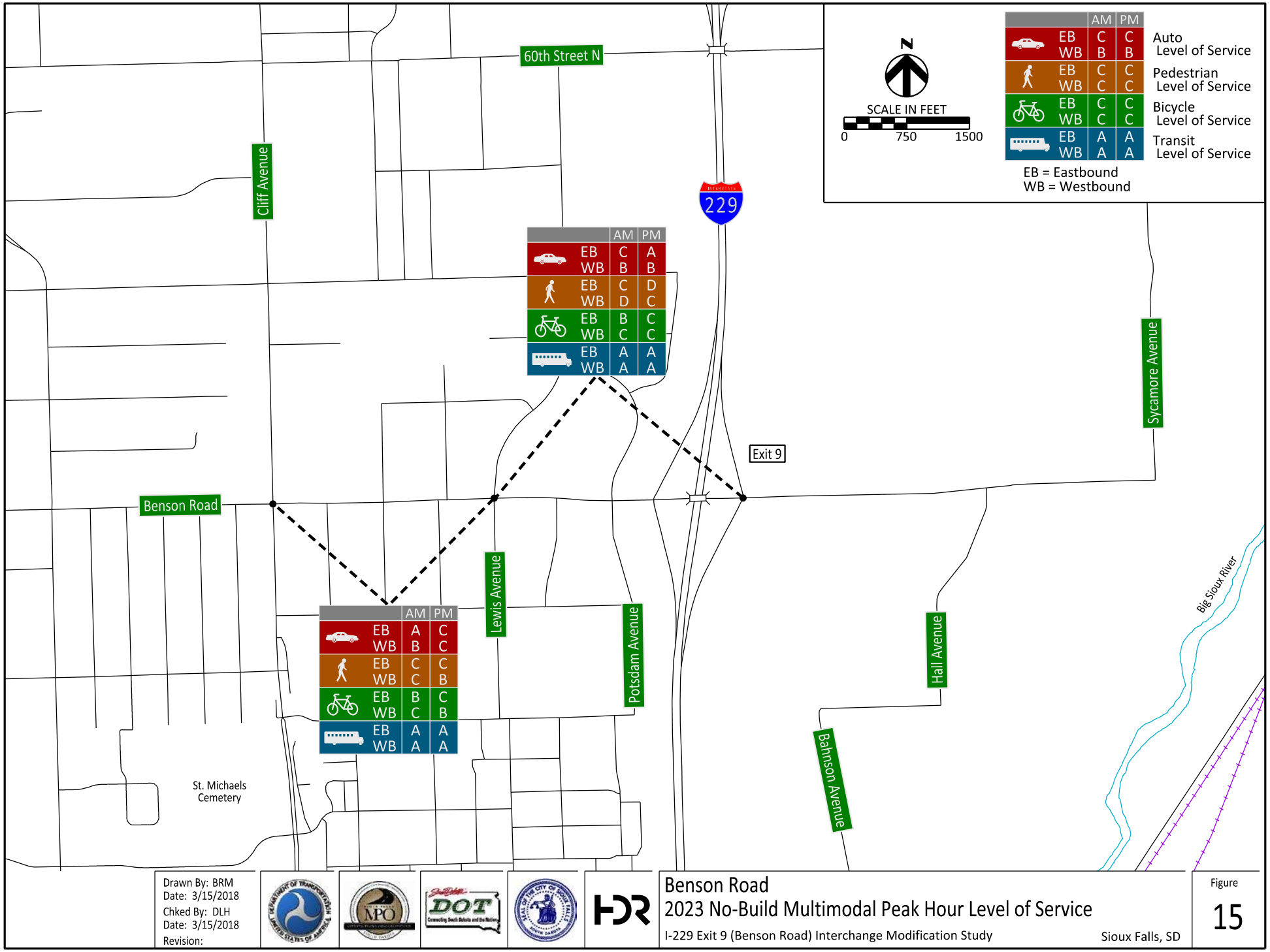


Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

Rice Street
2023 No-Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 14

FILE: ...\Figure 14 (Rice 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

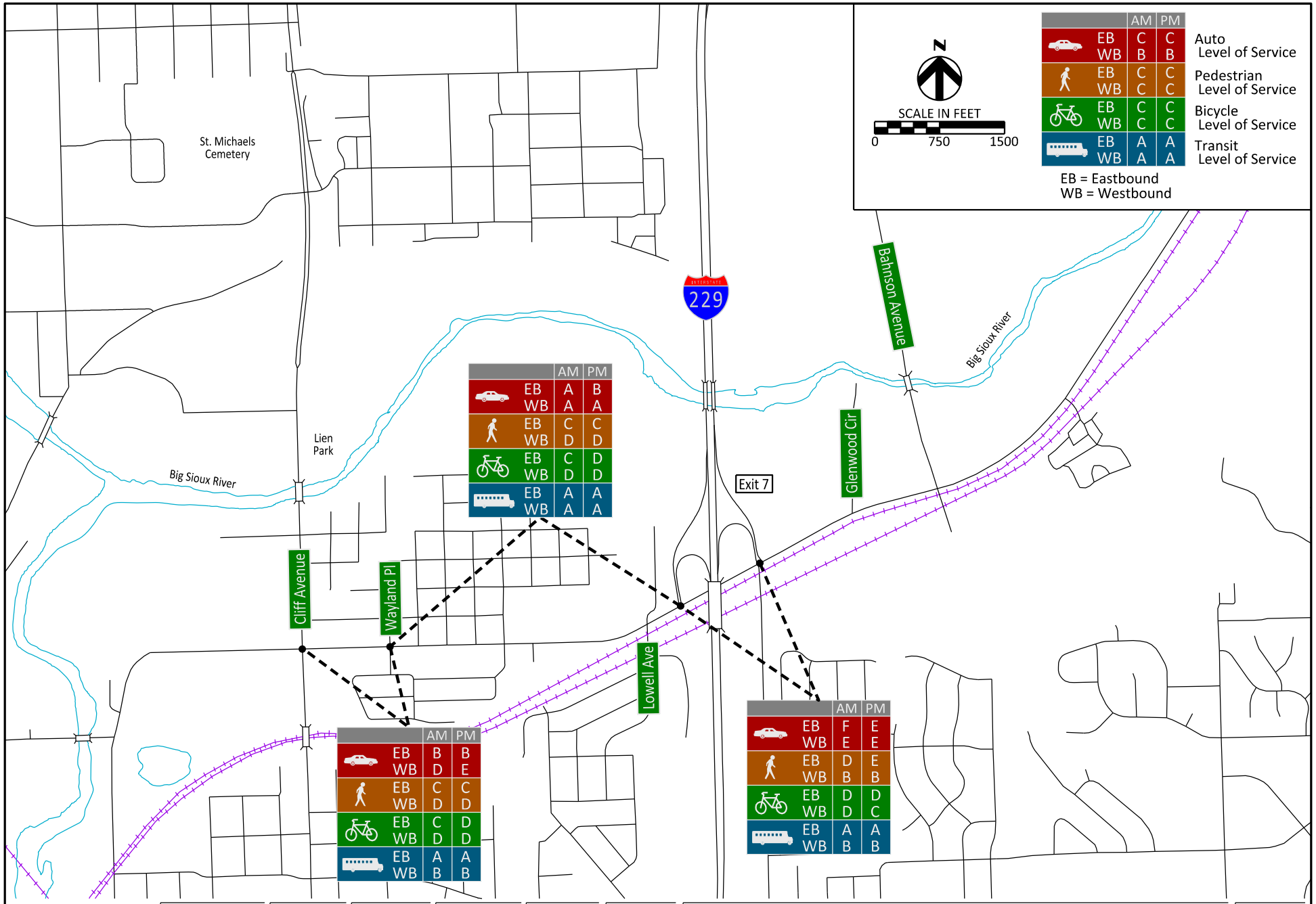
Benson Road
2023 No-Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 15

FILE: ...\Figure 15 (Benson 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

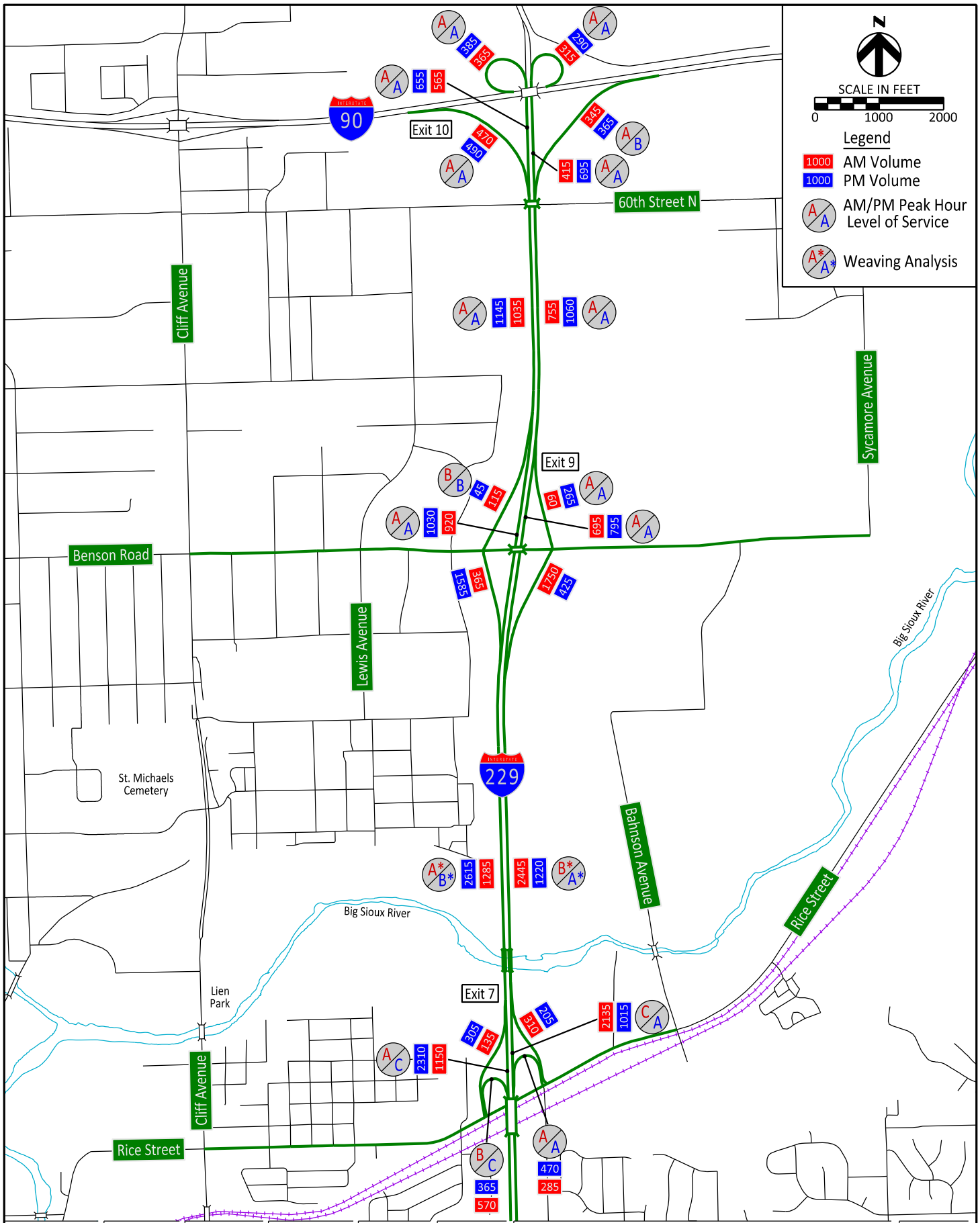
Rice Street
2023 No-Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 16

FILE: ...\Figure 16 (Rice 2023).dgn
PLOTTING DATE: 10-09-2018



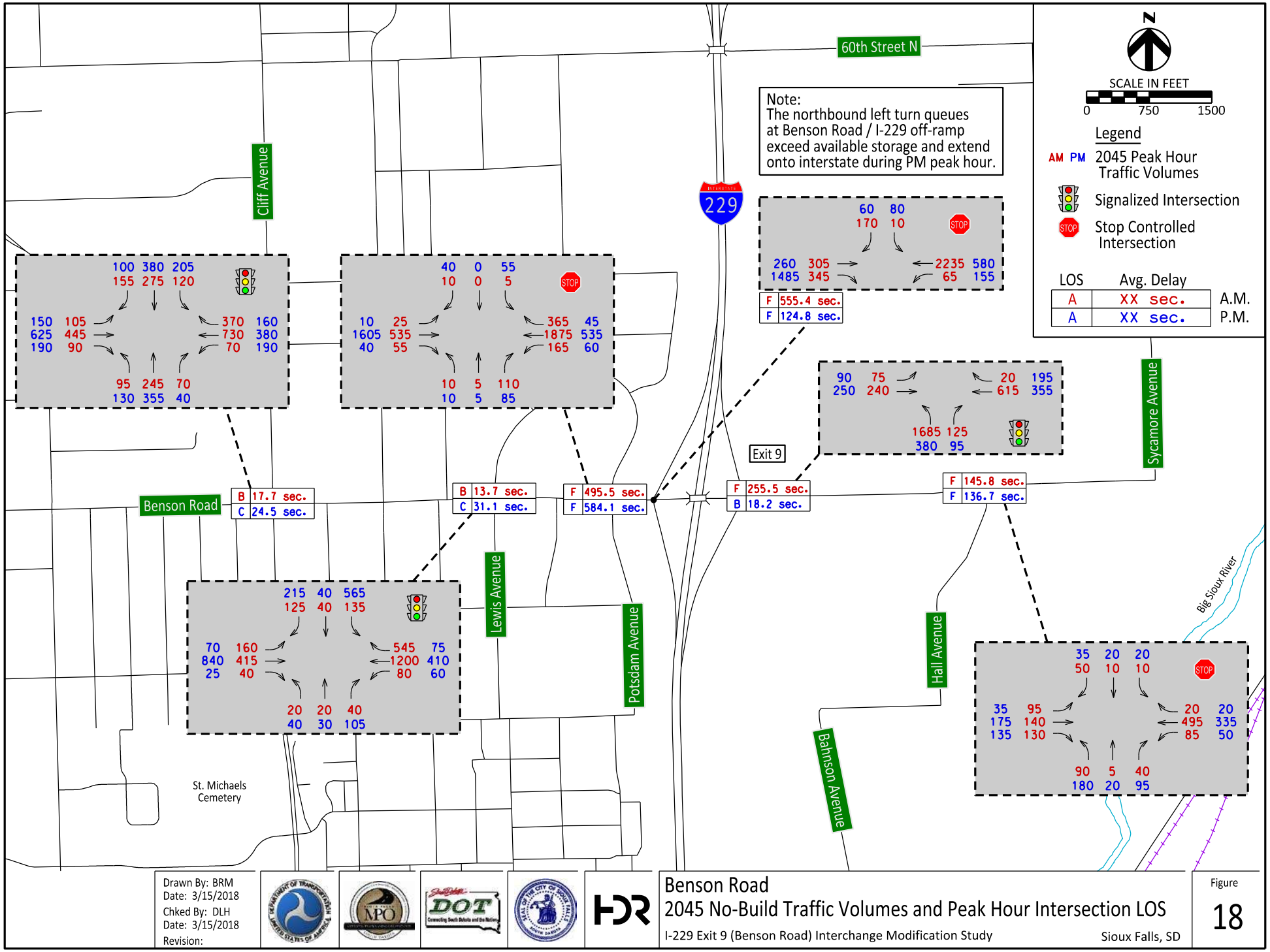
FILE: ...\Figure 17 (Interstate Vol 2023).dgn
PLOTTING DATE: 10-09-2018

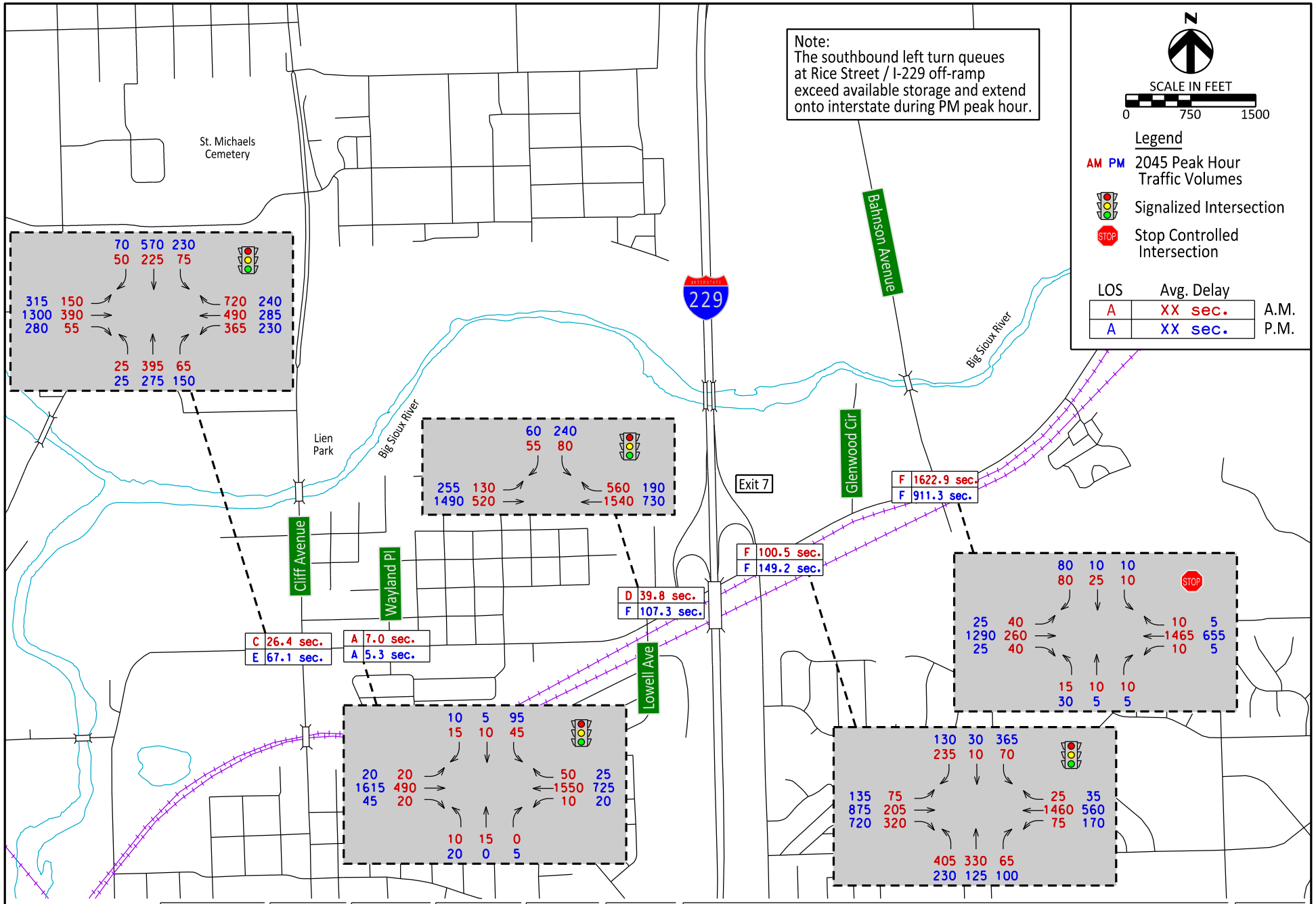
Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

2023 No-Build Peak Hour Balanced Traffic Volumes and Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 17


60th Street N
Cliff Avenue
Benson Road
Lewis Avenue
Potsdam Avenue
Exit 9
Sycamore Avenue
Hall Avenue
Bahnson Avenue
Big Sioux River
St. Michaels Cemetery
INTERSTATE 229
Note:
The northbound left turn queues at Benson Road / I-229 off-ramp exceed available storage and extend onto interstate during PM peak hour.
SCALE IN FEET
0 750 1500
Legend
AM PM 2045 Peak Hour Traffic Volumes
Signalized Intersection
Stop Controlled Intersection
LOS Avg. Delay
A XX sec. A.M.
A XX sec. P.M.
100 380 205
155 275 120
150 105
625 445
190 90
370 160
730 380
70 190
95 245 70
130 355 40
40 0 55
10 0 5
10 25
1605 535
40 55
365 45
1875 535
165 60
10 5 110
10 5 85
60 80
170 10
260 305
1485 345
2235 580
65 155
F 555.4 sec.
F 124.8 sec.
90 75
250 240
20 195
615 355
1685 125
380 95
B 17.7 sec.
C 24.5 sec.
B 13.7 sec.
C 31.1 sec.
F 495.5 sec.
F 584.1 sec.
F 255.5 sec.
B 18.2 sec.
F 145.8 sec.
F 136.7 sec.
215 40 565
125 40 135
70 160
840 415
25 40
545 75
1200 410
80 60
20 20 40
40 30 105
35 20 20
50 10 10
35 95
175 140
135 130
20 20
495 335
85 50
90 5 40
180 20 95
Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:
Benson Road
2045 No-Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD
Figure
18
FILE: ...\Figure 18 (Benson 2045).dgn
PLOTTING DATE: 10-09-2018

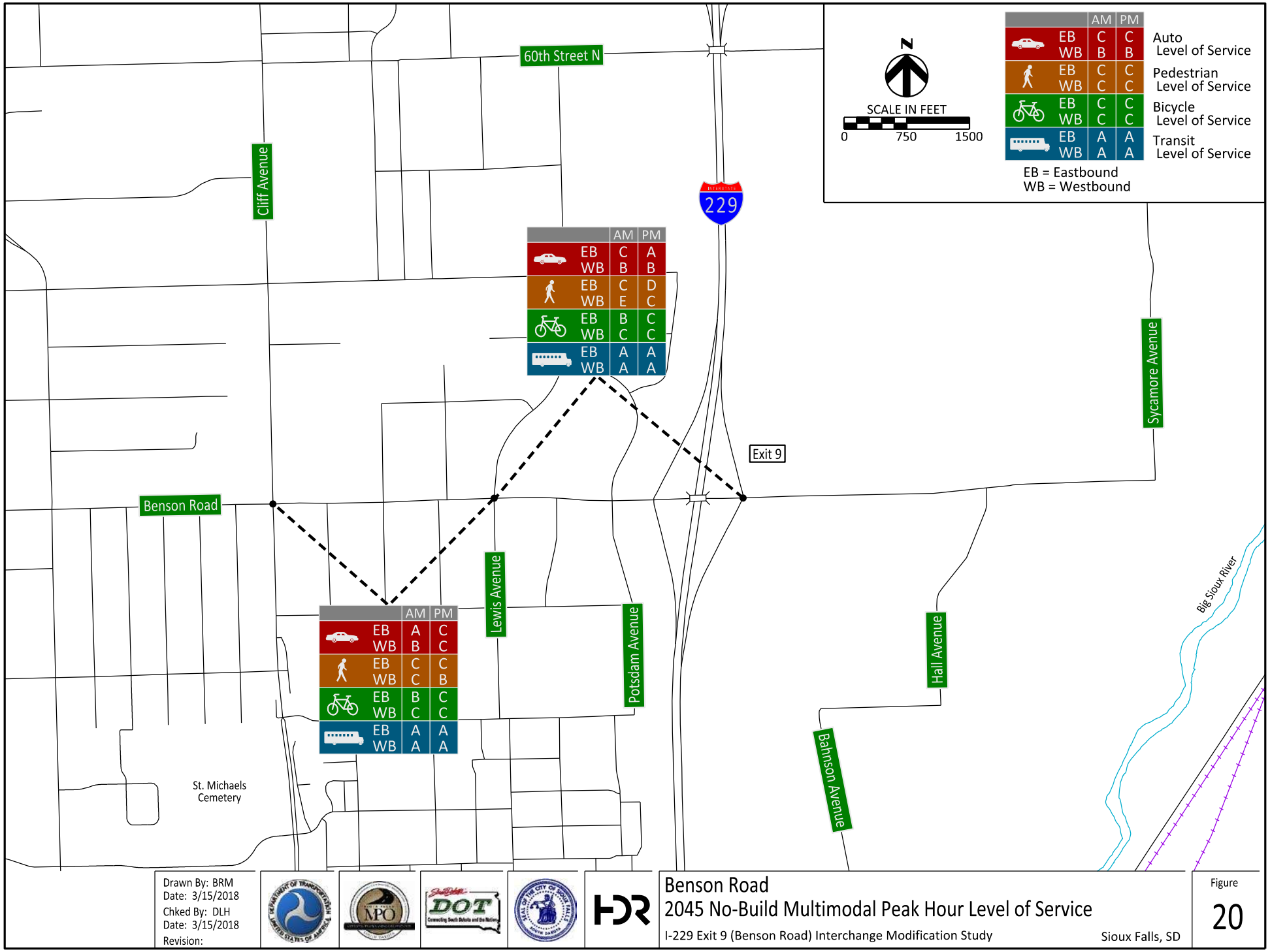


Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

Rice Street
2045 No-Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 19

FILE: ...\Figure 19 (Rice 2045).dgn
PLOTTING DATE: 10-09-2018

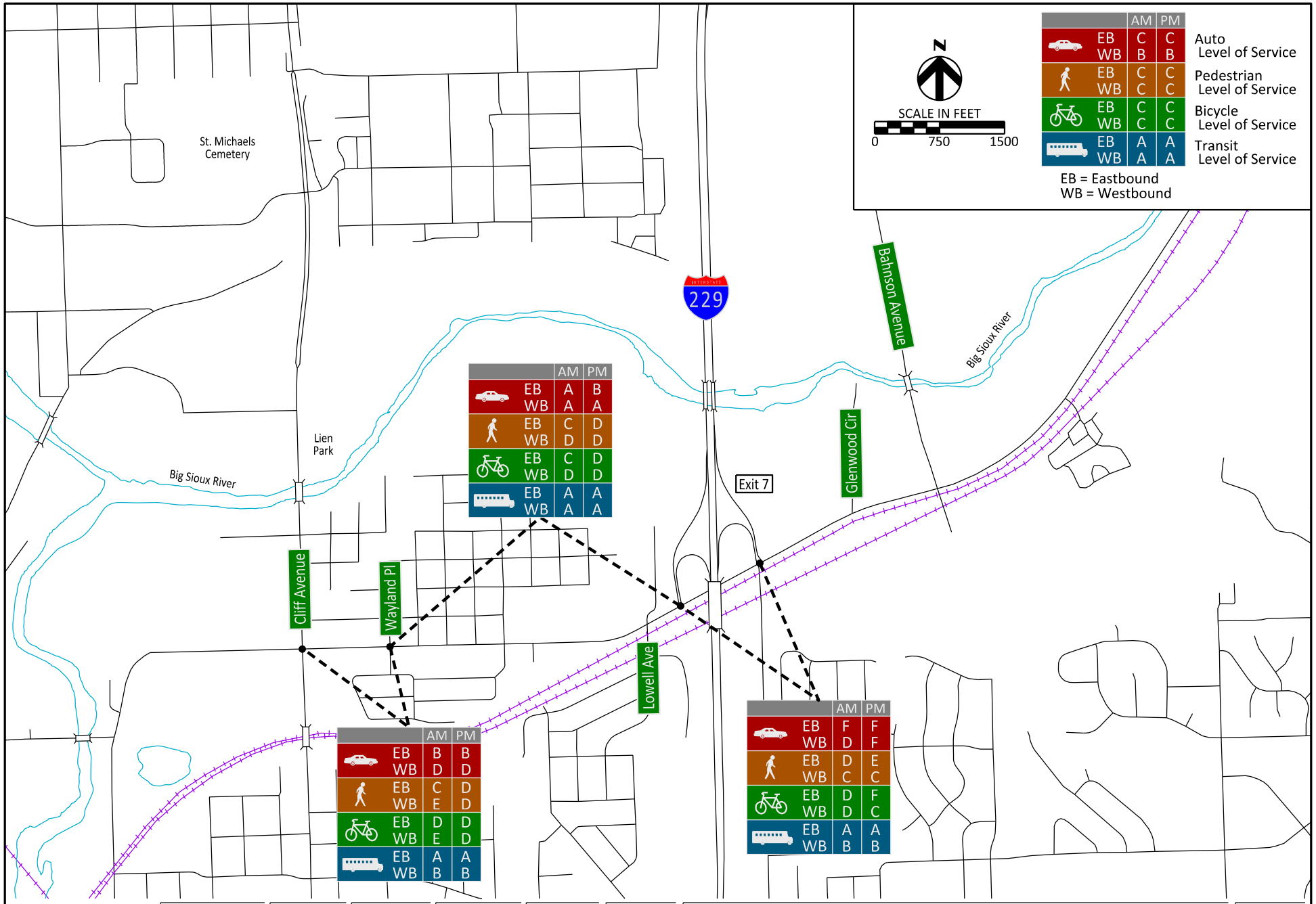


Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

Benson Road
2045 No-Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 20

FILE: ...\Figure 20 (Benson 2045).dgn
PLOTTING DATE: 10-09-2018

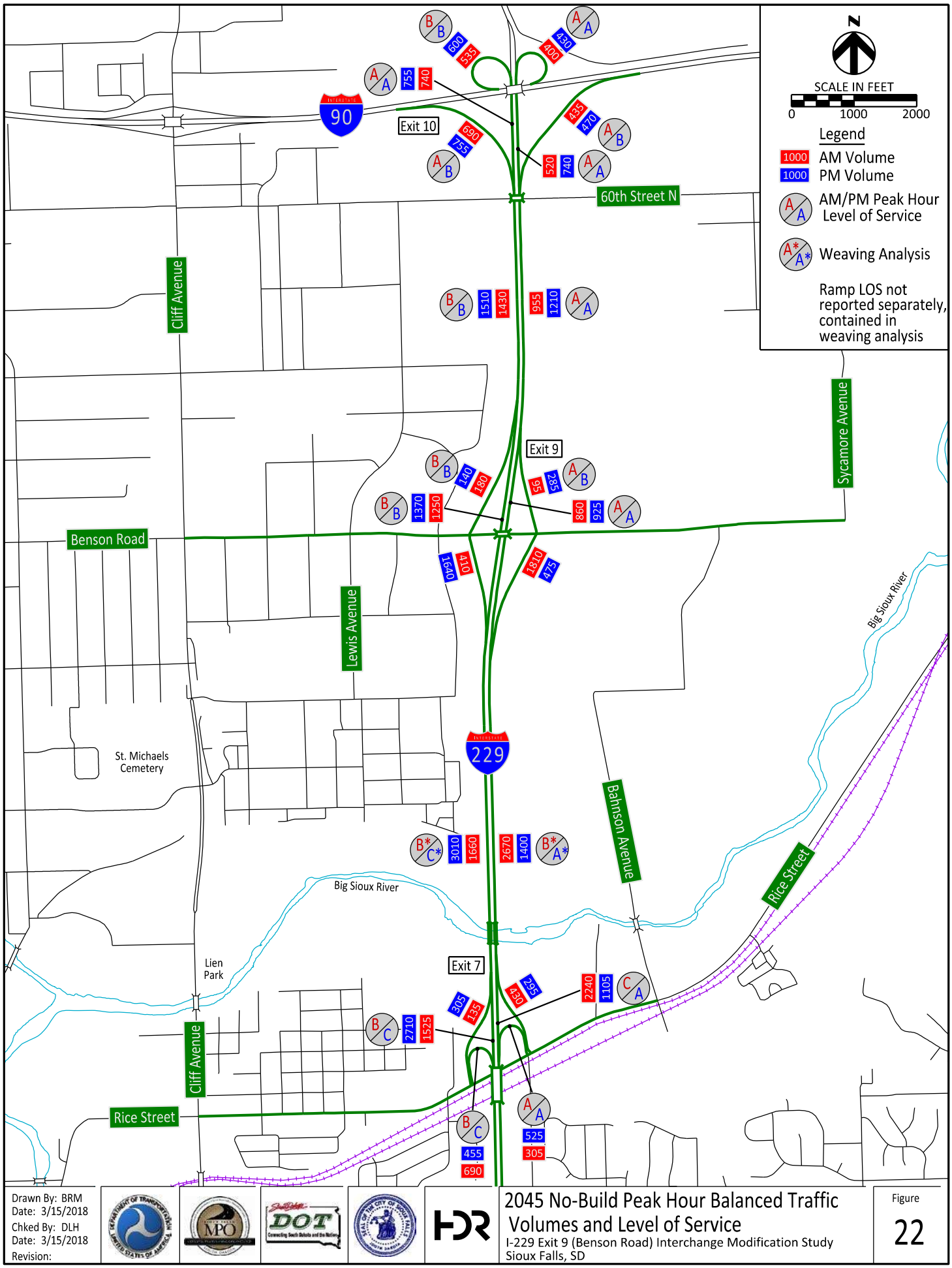


Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

Rice Street
2045 No-Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 21

FILE: ...\Figure 21 (Rice 2045).dgn
PLOTTING DATE: 10-09-2018



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PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 3/15/2018
Chked By: DLH
Date: 3/15/2018
Revision:

2045 No-Build Peak Hour Balanced Traffic Volumes and Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 22

FILE: ...\Figure 23 (Alt 1a).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 1a
2-Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure
23

FILE: ...\Figure 24 (Alt 1b).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 1b
2-Lane Northeast Quadrant Loop with 2-Lane SB On-Ramp.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure
24

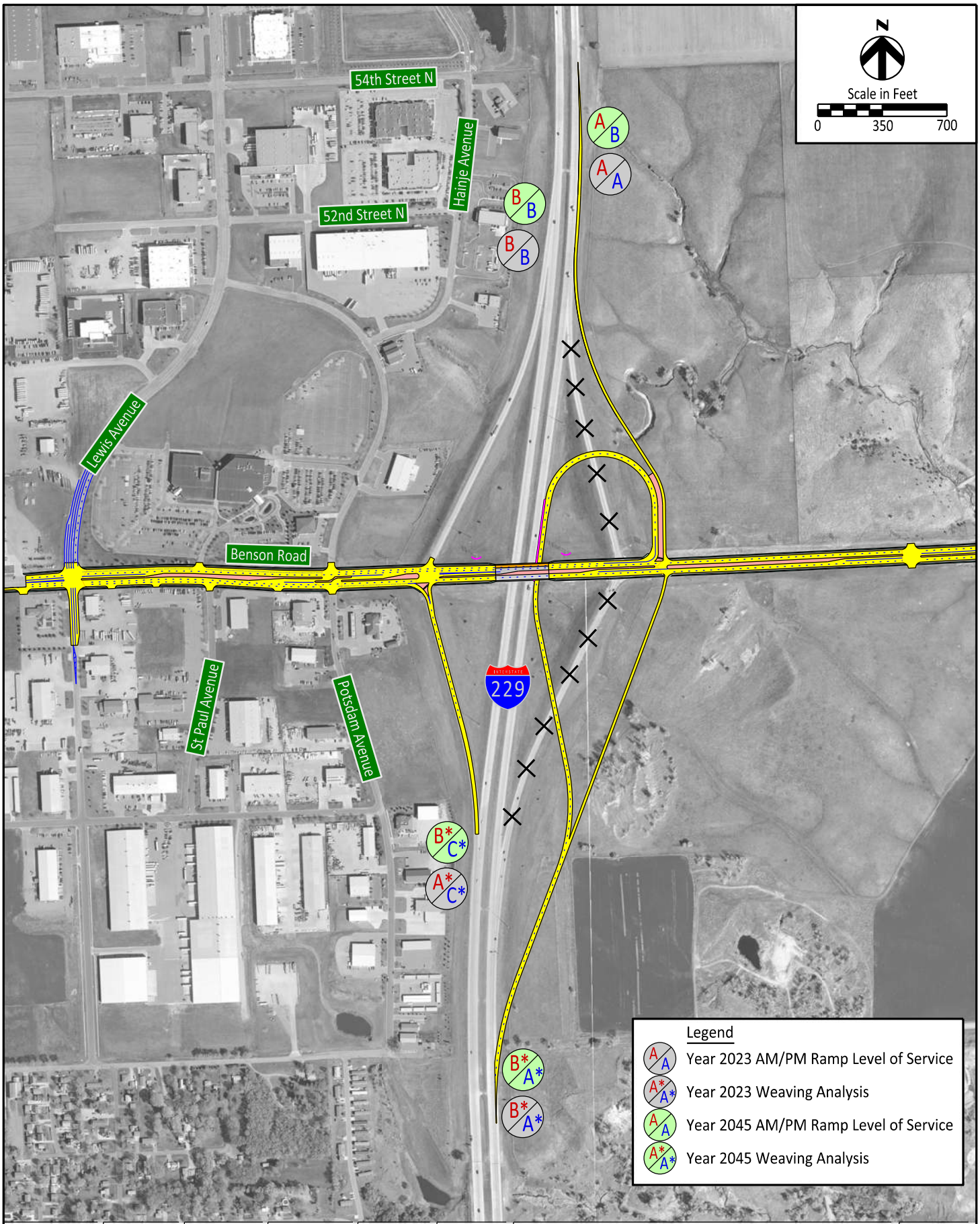
FILE: ...\Figure 25 (Alt 1c).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 1c -- 2-Lane Collector-Distributor (CD) Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 25



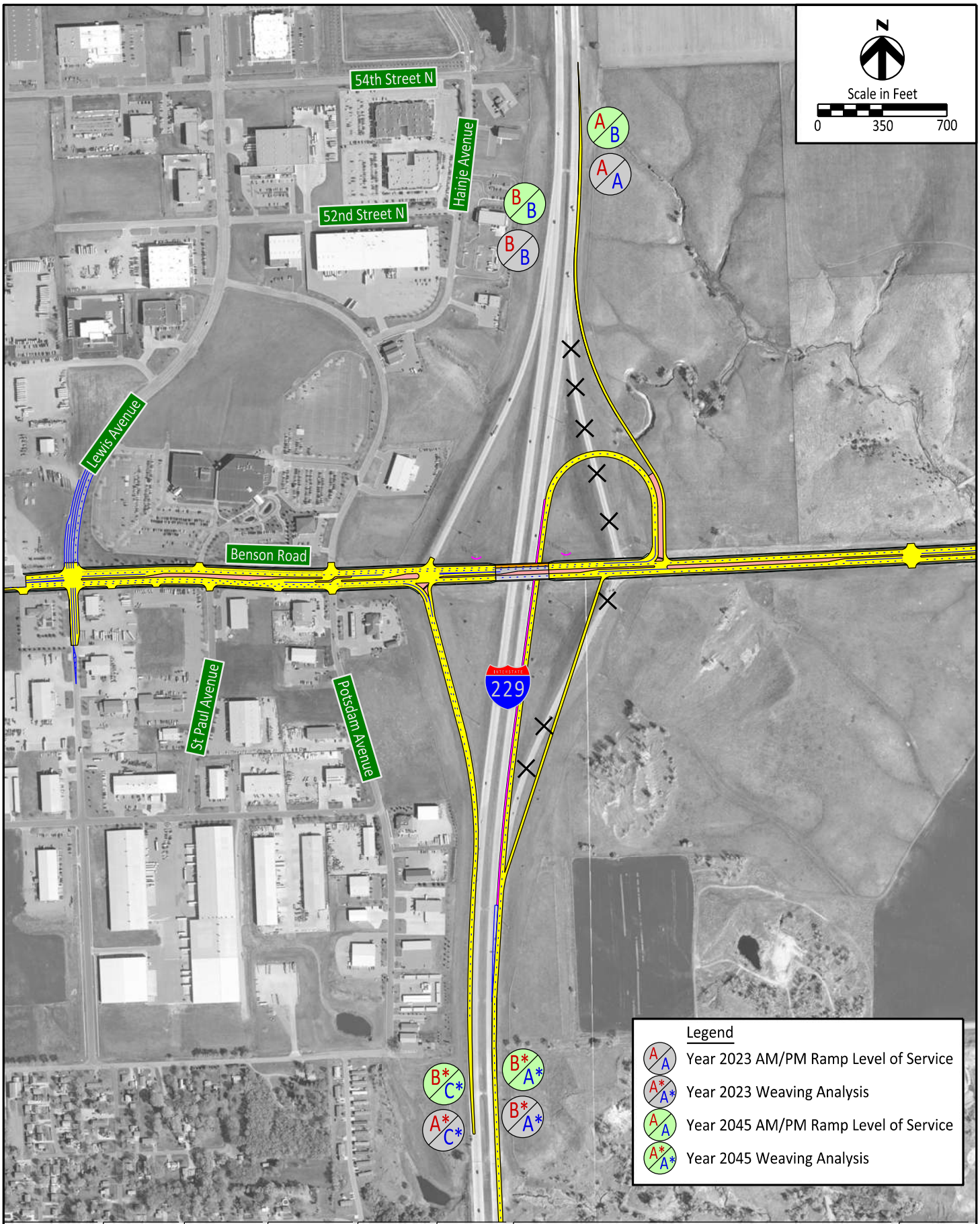
FILE: ...\Figure 26 (Alt 1d).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 1d -- 2-Lane Partial Clover Leaf Northeast Quadrant Loop with 2-Lane SB On-Ramp.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 26



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PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 1e --2-Lane Partial Clover Leaf Northeast Quadrant with CD Lane and 2-Lane SB On-Ramp.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure
27

FILE: ...\Figure 28 (Alt 4a).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 4a -- Diverging Diamond Interchange with 3-Lane SB On-Ramp. Add 2 WB Lanes to Existing Overpass.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 28

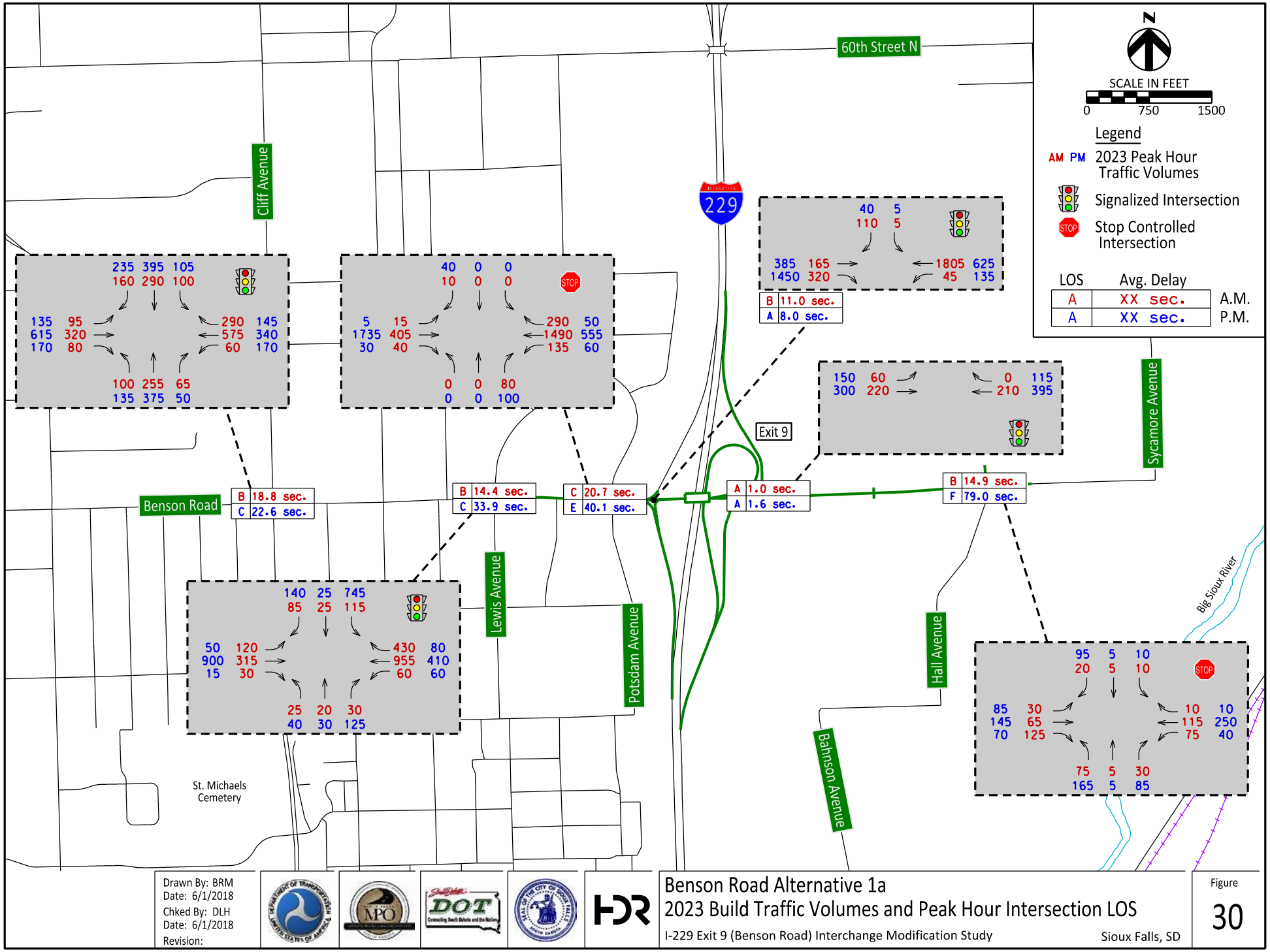
FILE: ...\Figure 29 (Alt 4b).dgn
PLOTTING DATE: 10-09-2018

Drawn By: BRM
Date: 5/29/2018
Chked By: DLH
Date: 5/29/2018
Revision:

Alternative Scenario 4b -- Diverging Diamond Interchange with 3-Lane SB On-Ramp. Add a Separate Structure for 2 EB Lanes.

I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 29



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

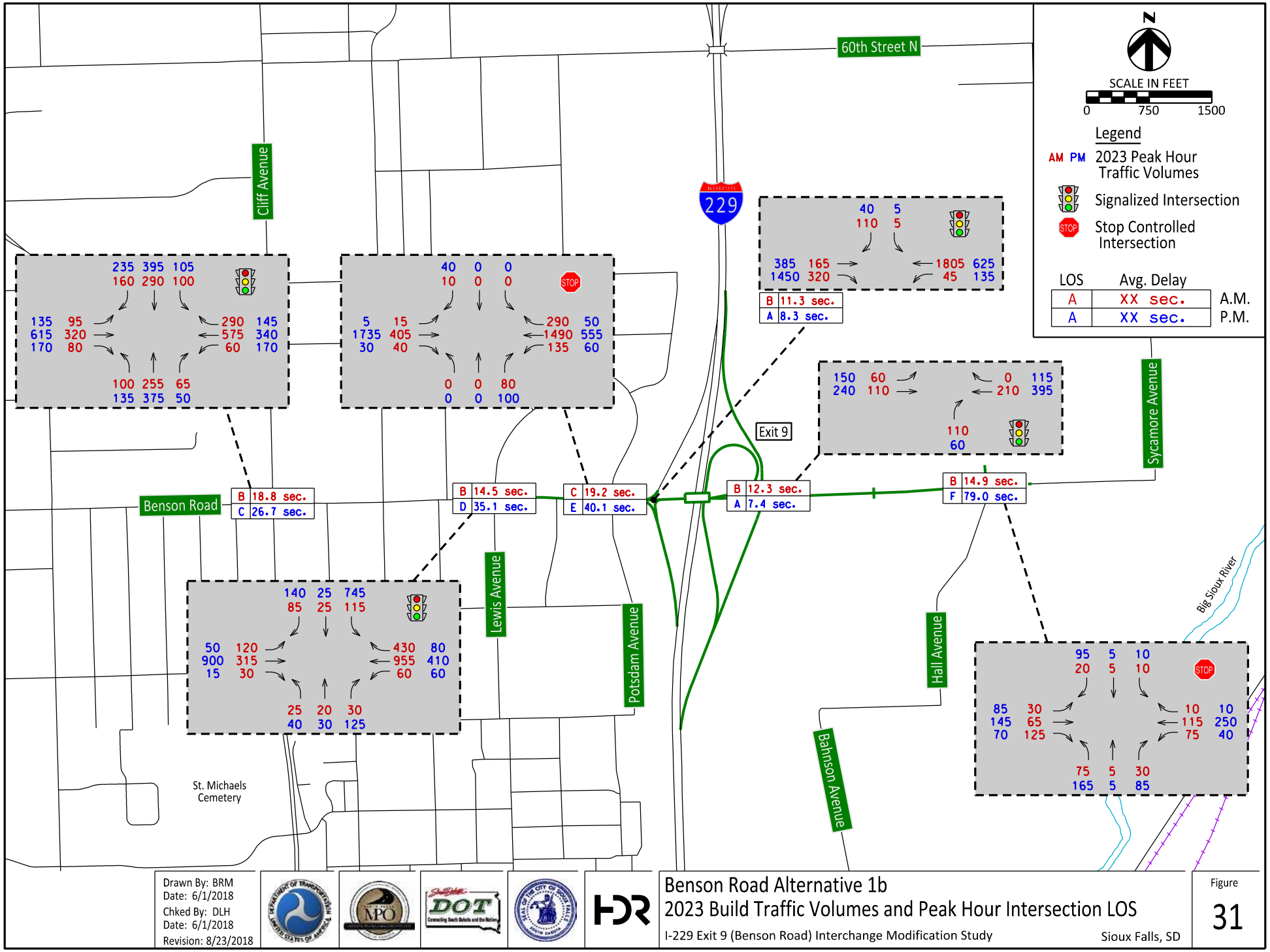
Benson Road Alternative 1a
2023 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 30

FILE: ...\Figure 30 (2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision: 8/23/2018

Benson Road Alternative 1b
2023 Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 31

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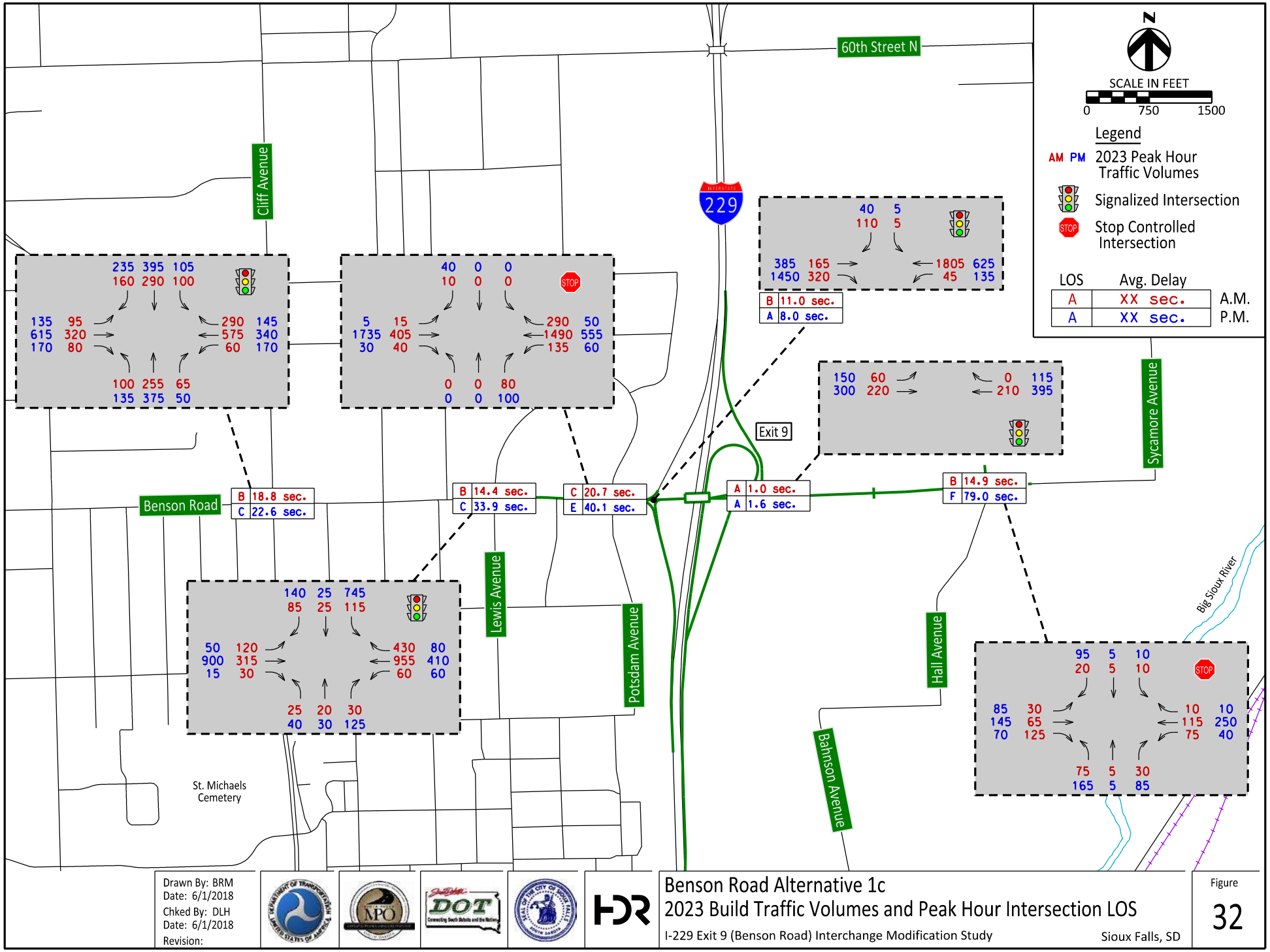

Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1c
2023 Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 32

FILE: ...\Figure 32 (2023).dgn
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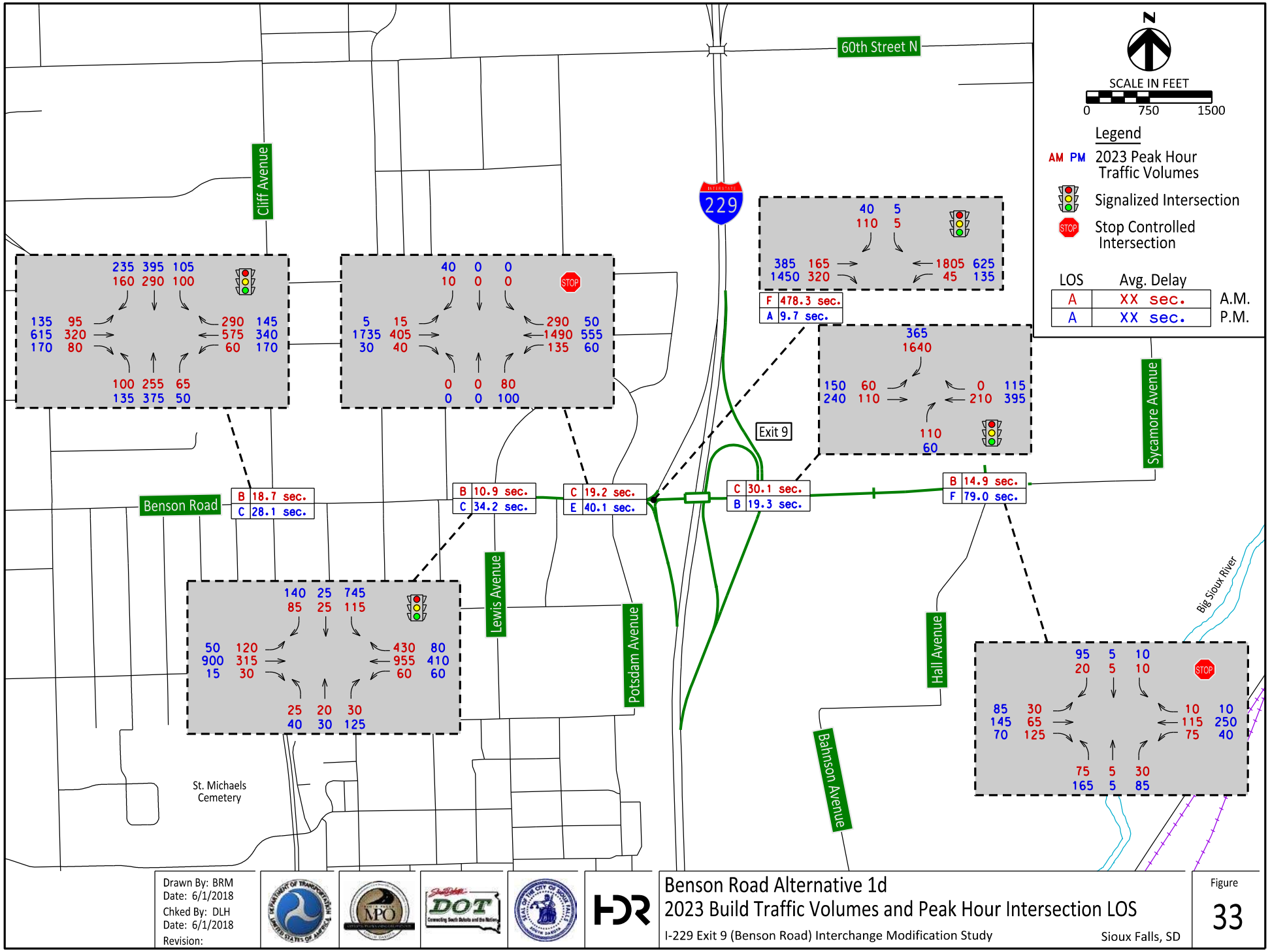


Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

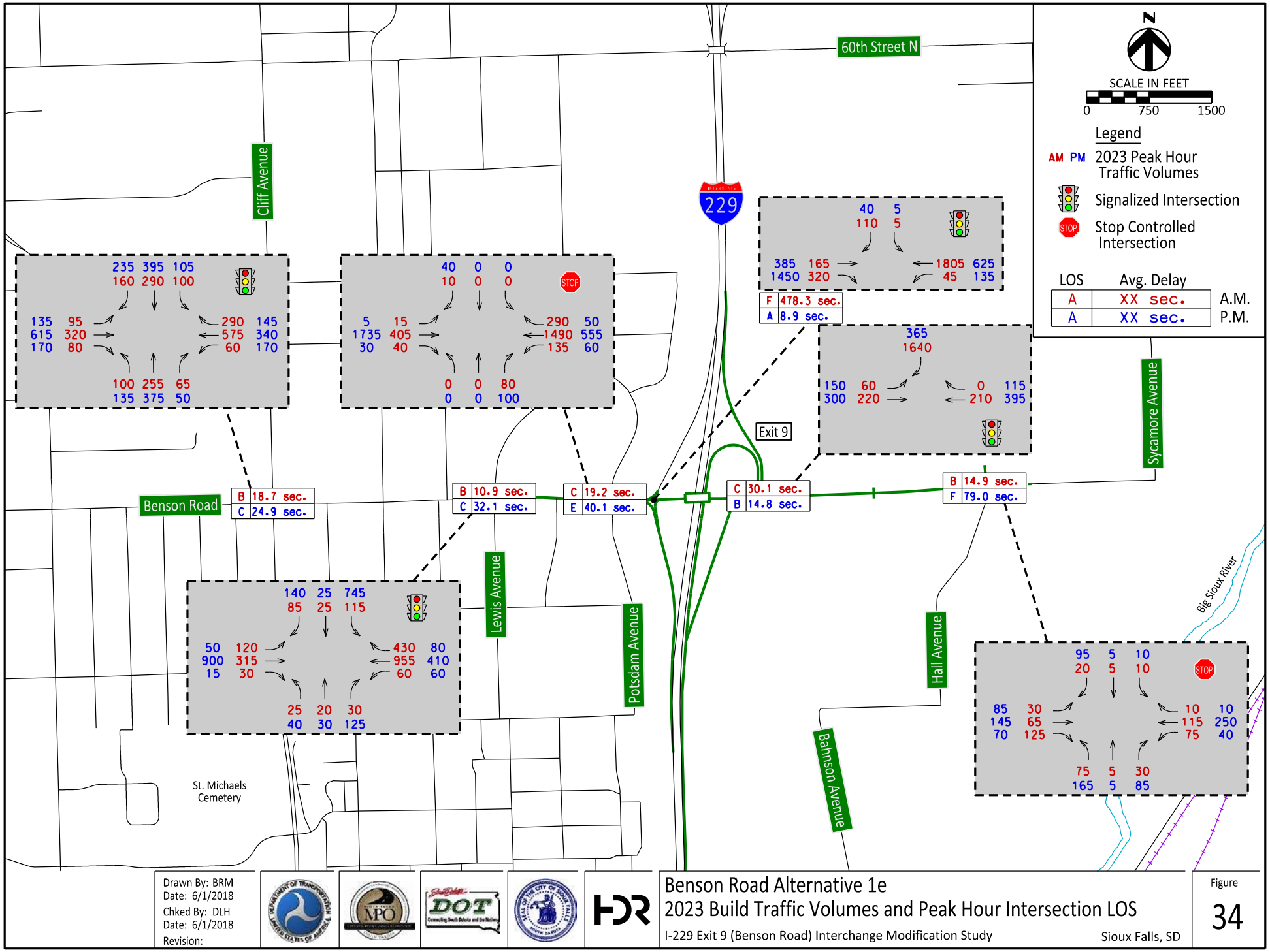
Benson Road Alternative 1d
2023 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 33

FILE: ...\Figure 33 (2023).dgn
PLOTTING DATE: 10-09-2018



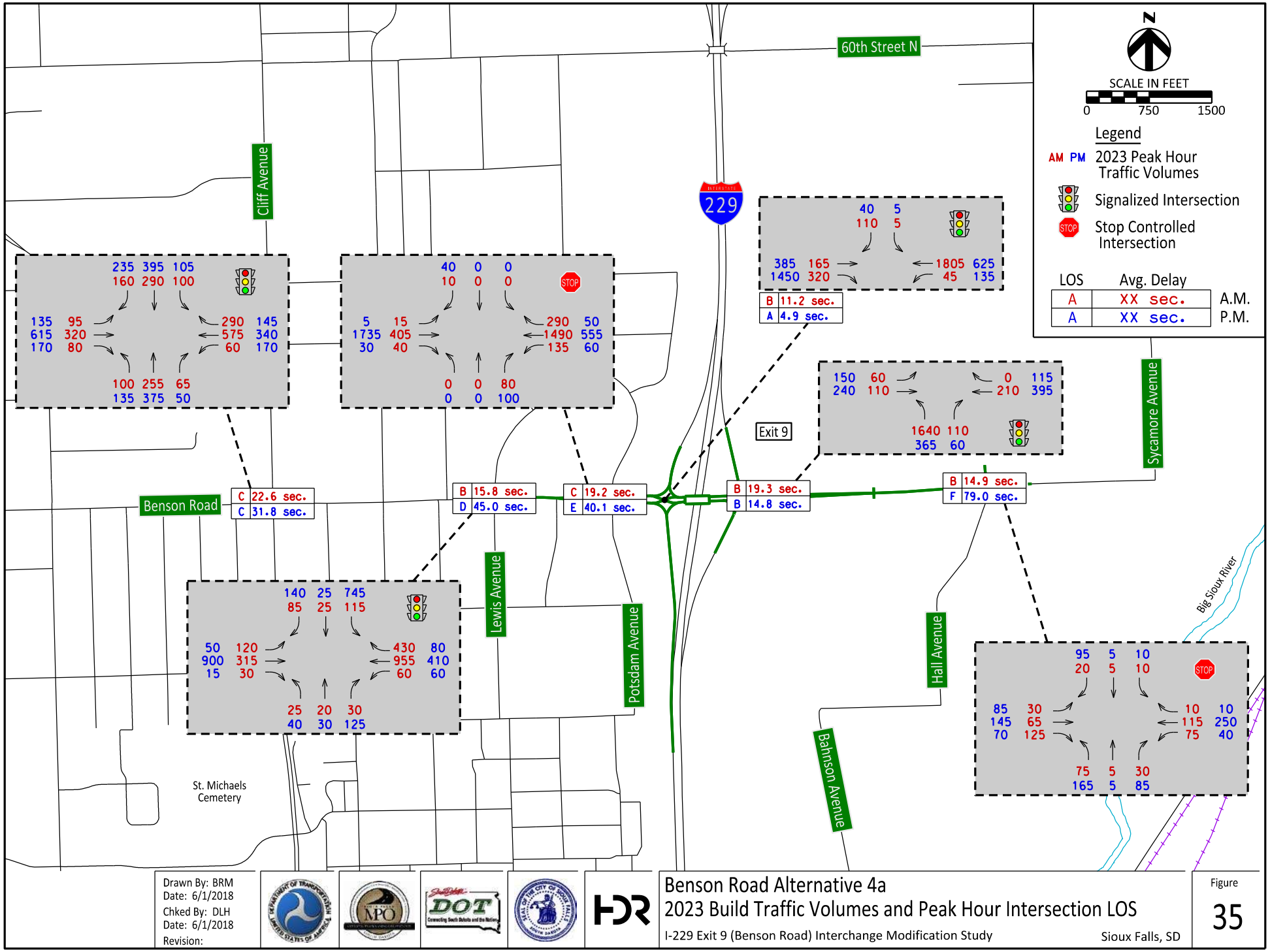
Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1e
2023 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study — Sioux Falls, SD

Figure 34

FILE: ...\Figure 34 (2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

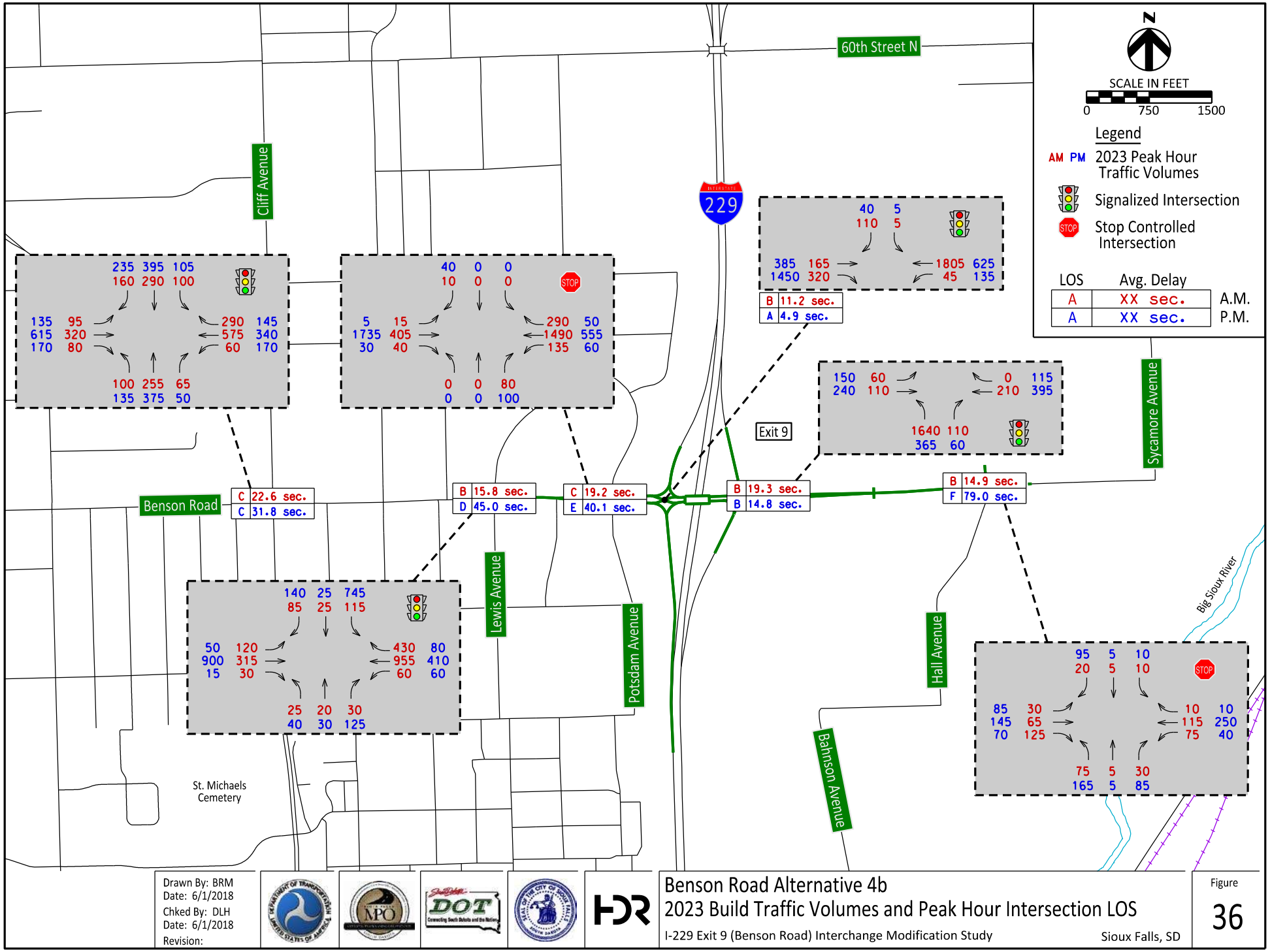
Benson Road Alternative 4a
2023 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 35

FILE: ...\Figure 35 (2023).dgn
PLOTTING DATE: 10-09-2018

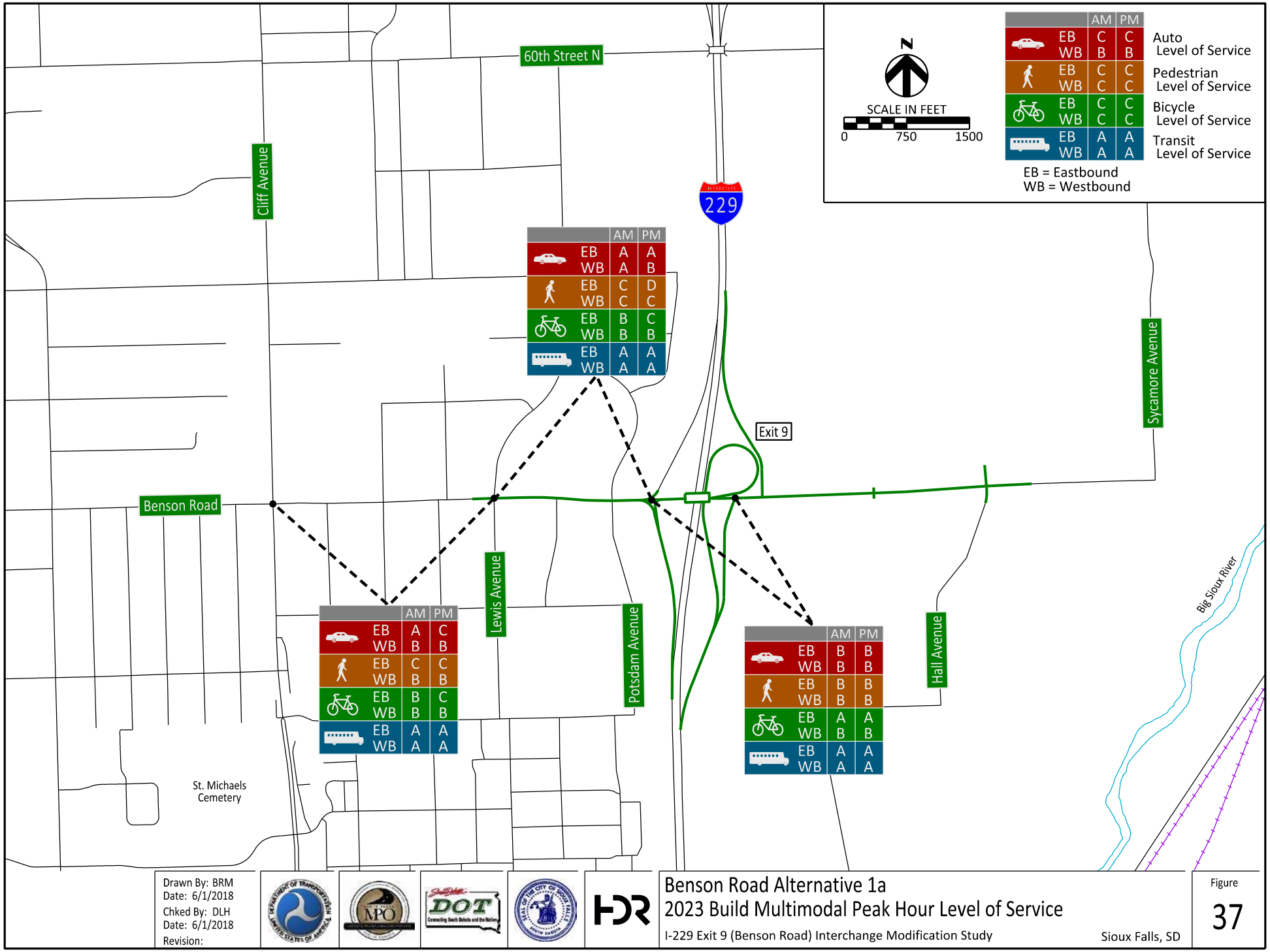


Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 4b
2023 Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 36

FILE: ...\Figure 36 (2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

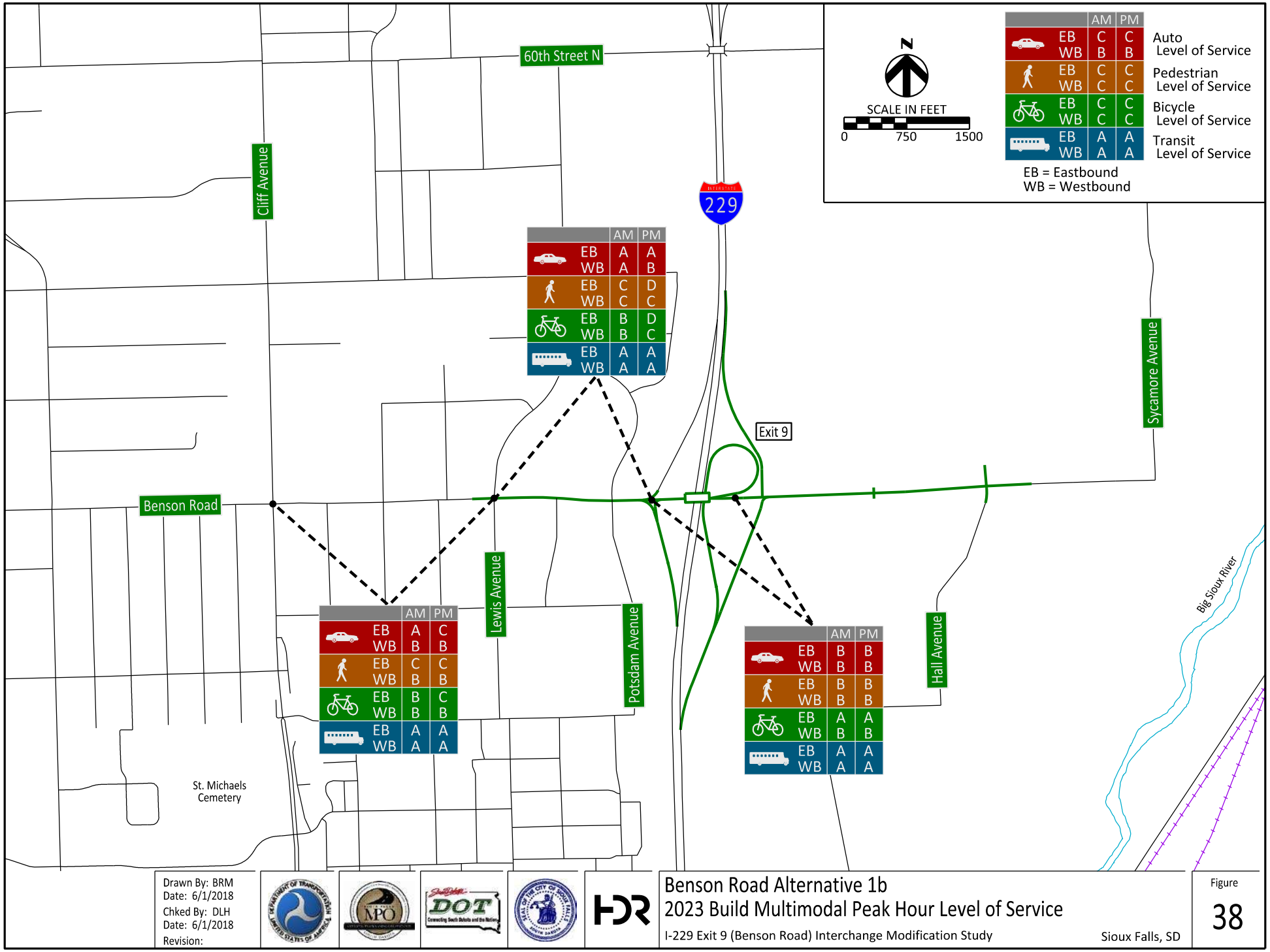
Benson Road Alternative 1a
2023 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 37

FILE: ...\Figure 37 (MM 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

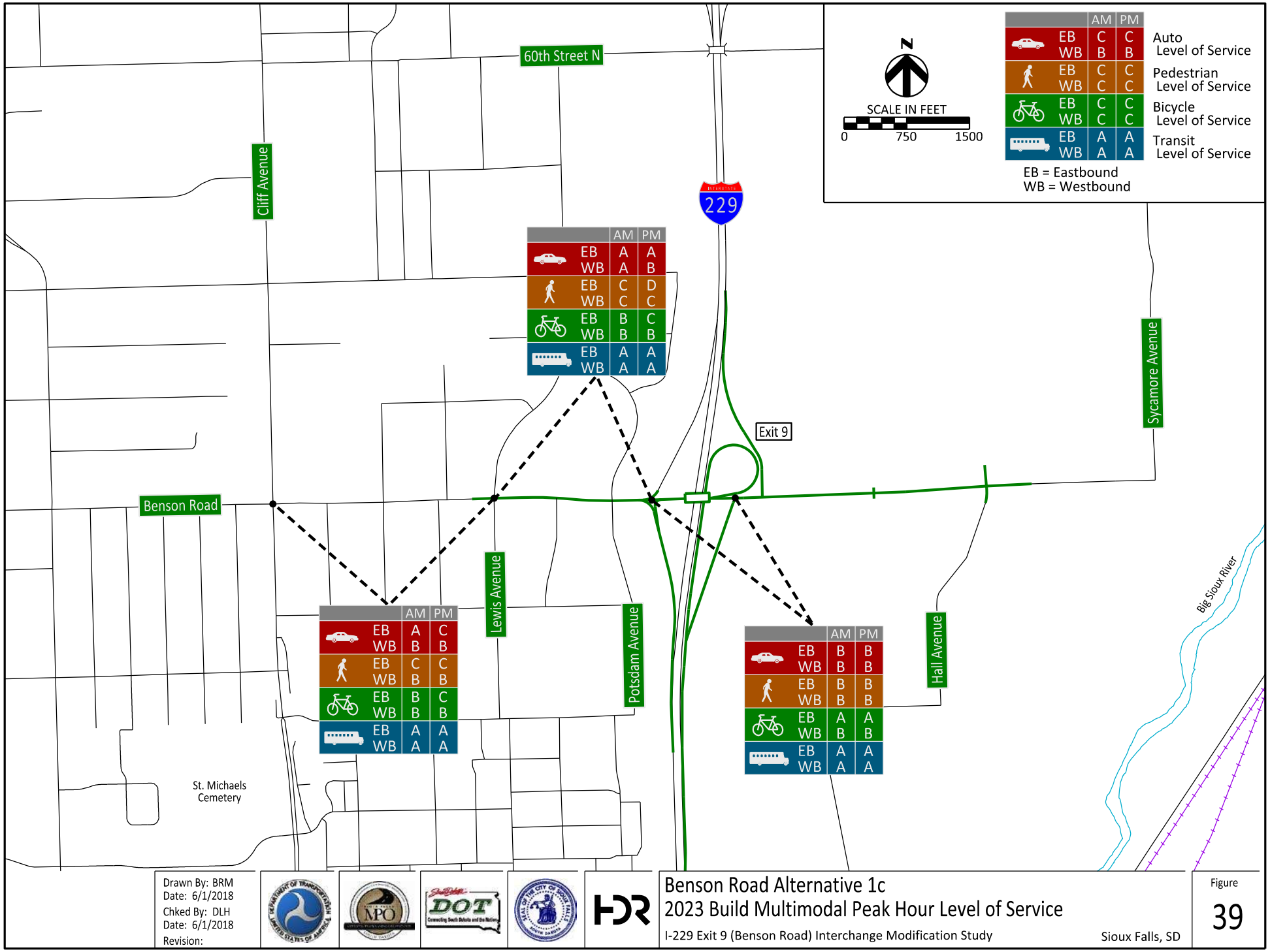
Benson Road Alternative 1b
2023 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 38

FILE: ...\Figure 38 (MM 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

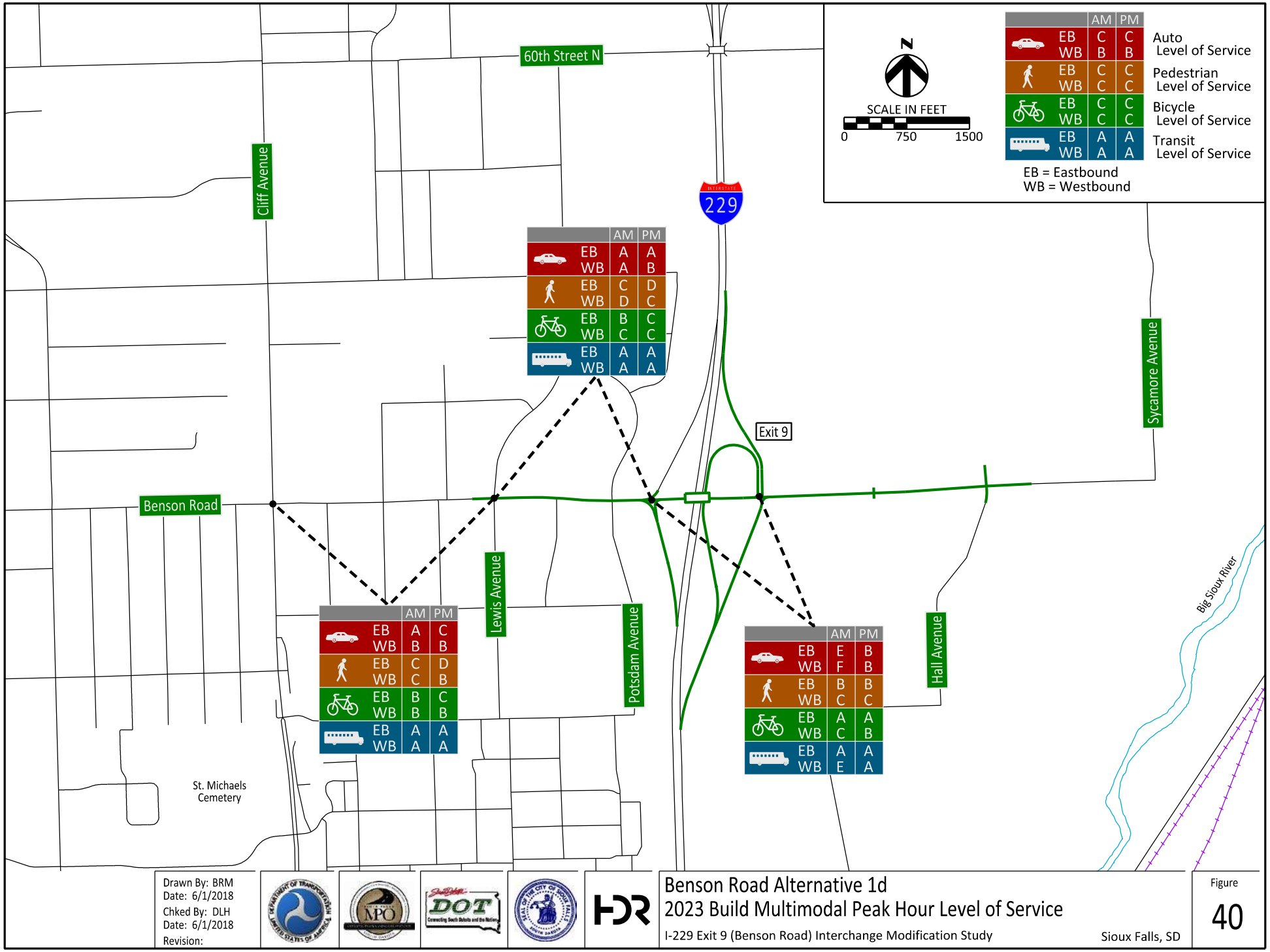
Benson Road Alternative 1c
2023 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 39

FILE: ...\Figure 39 (MM 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

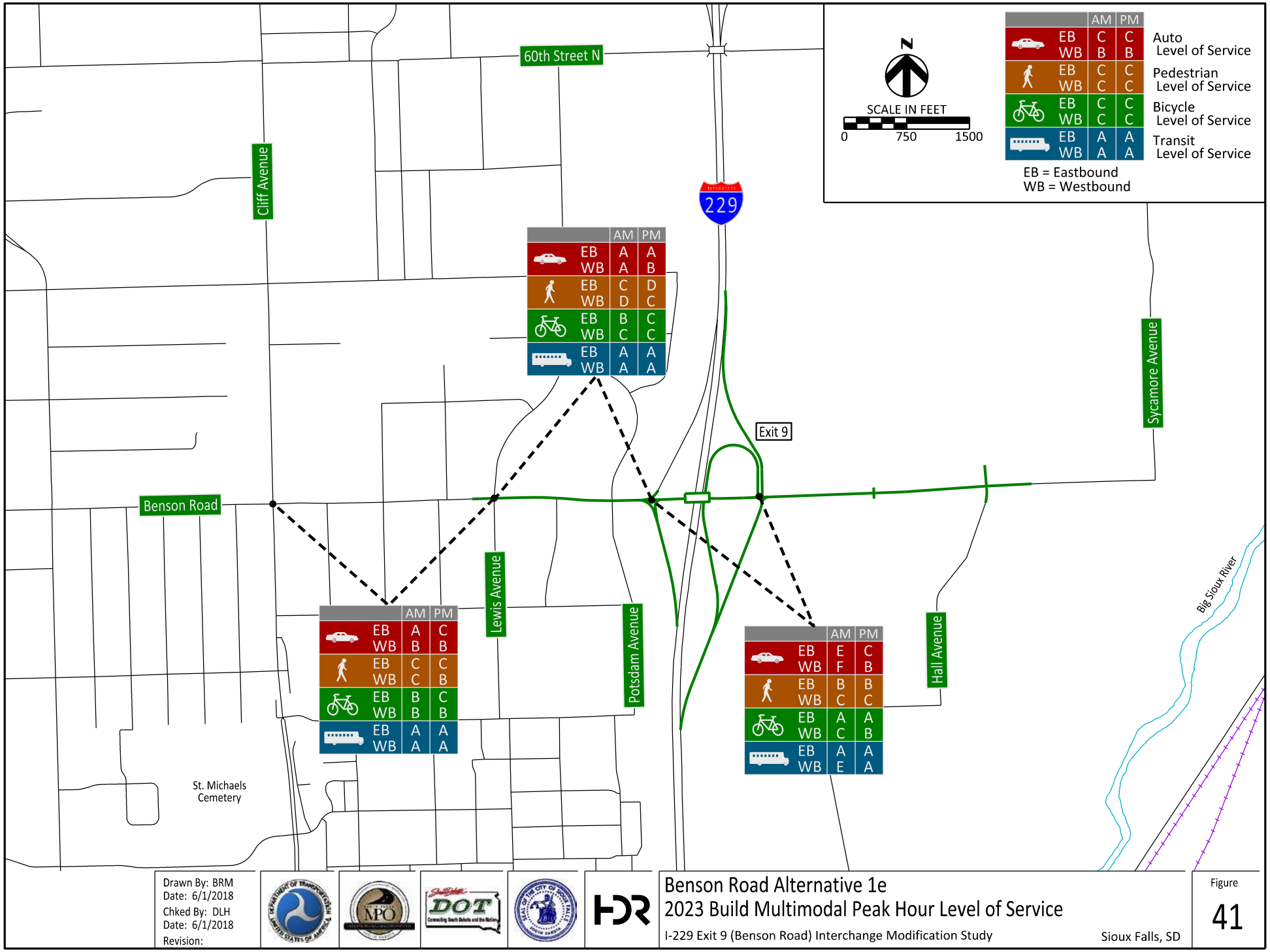
Benson Road Alternative 1d
2023 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 40

FILE: ...\Figure 40 (MM 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

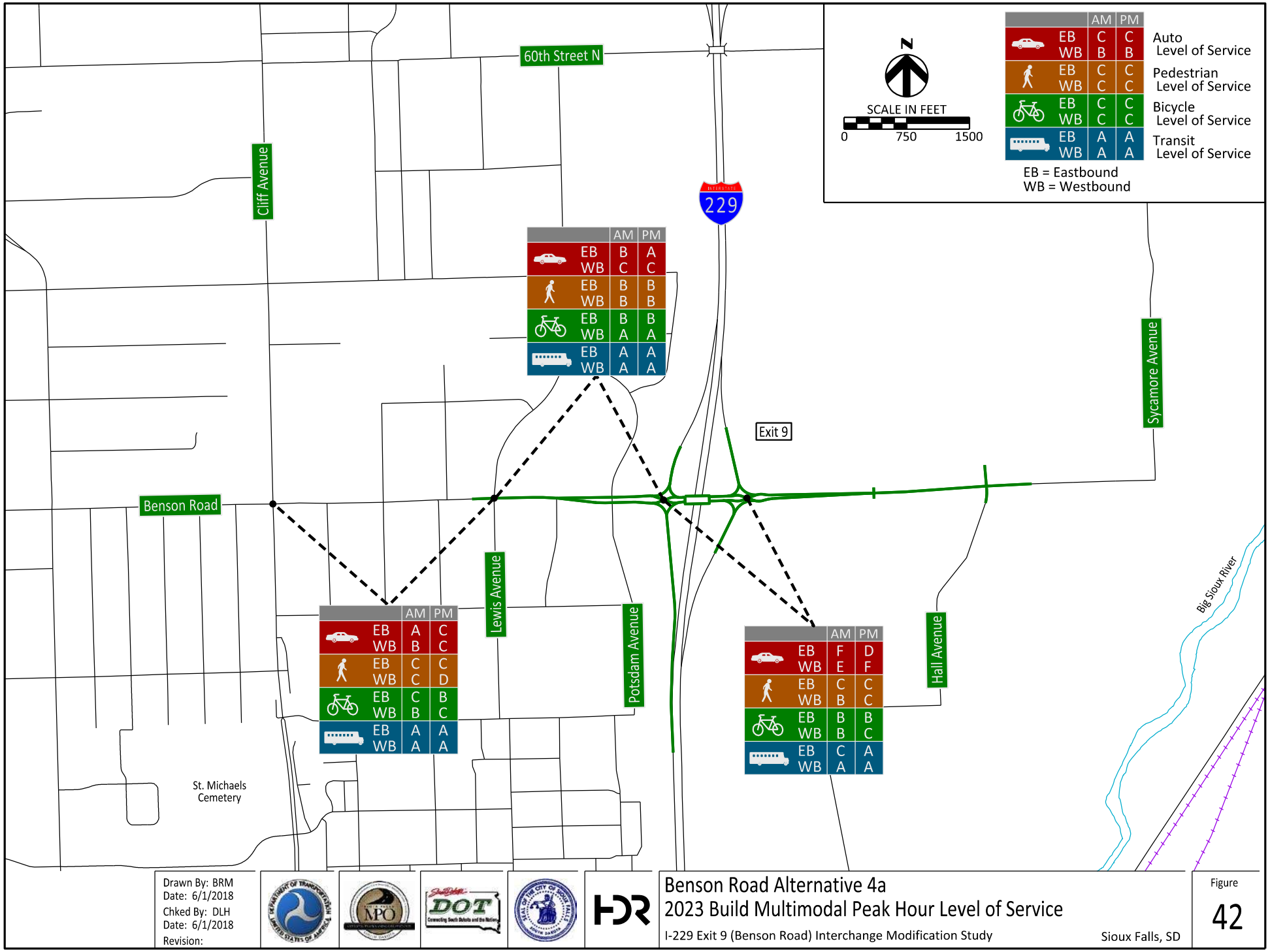
Benson Road Alternative 1e
2023 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 41

FILE: ...\Figure 41 (MM 2023).dgn
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

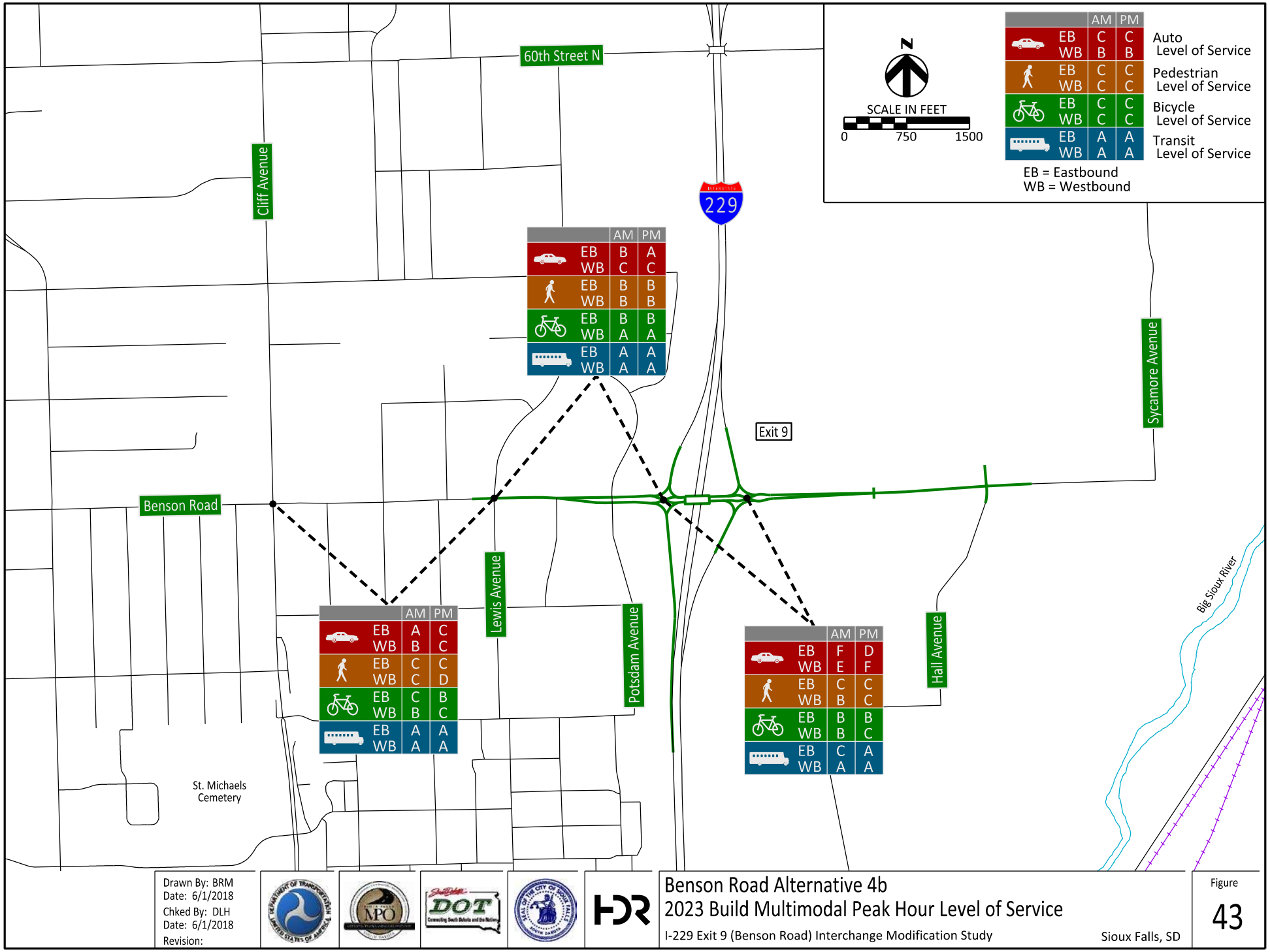
Benson Road Alternative 4a
2023 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 42

FILE: ...\Figure 42 (MM 2023).dgn
PLOTTING DATE: 10-09-2018

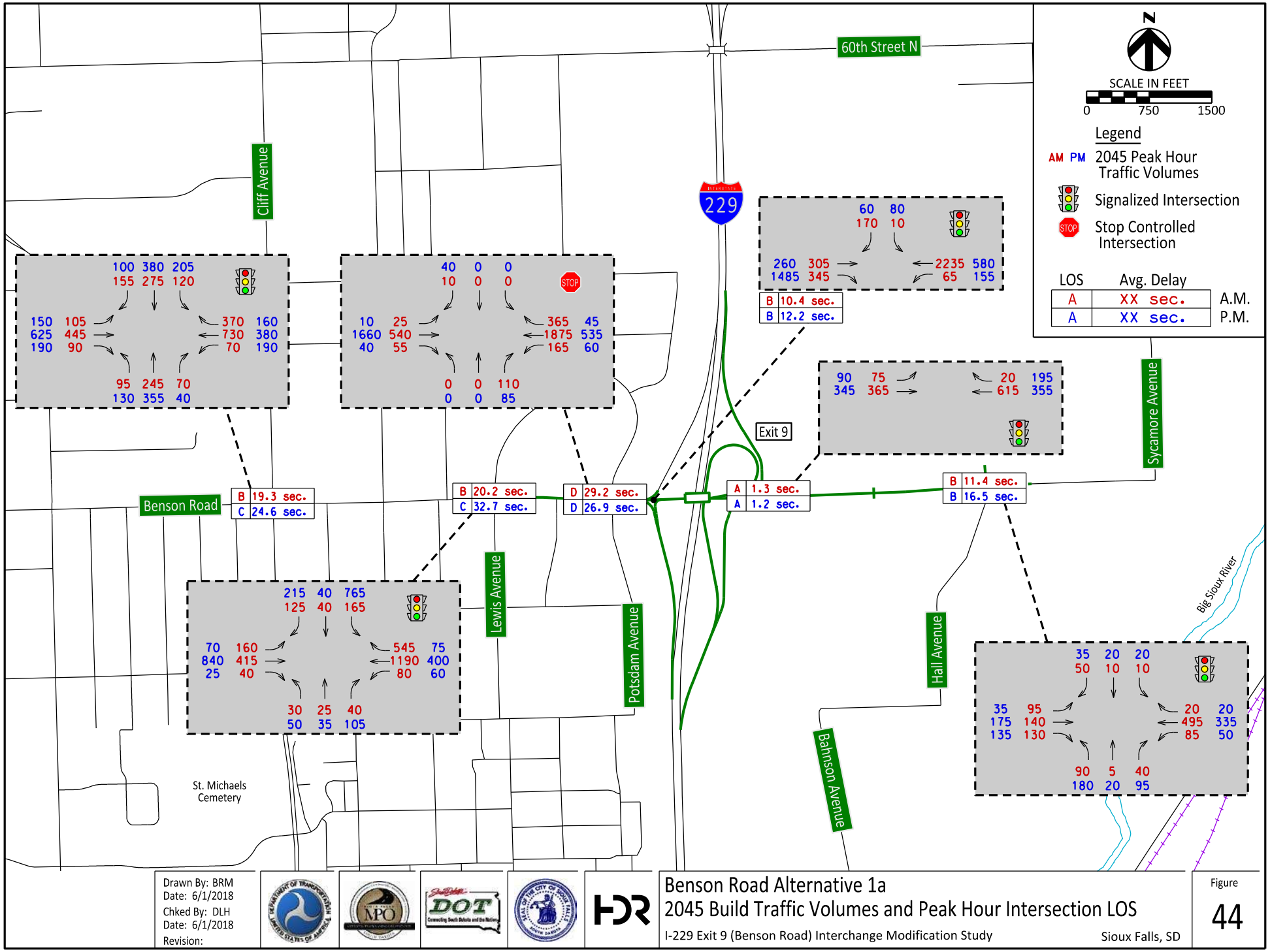


Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 4b
2023 Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 43

FILE: ...\Figure 43 (MM 2023).dgn
PLOTTING DATE: 10-09-2018

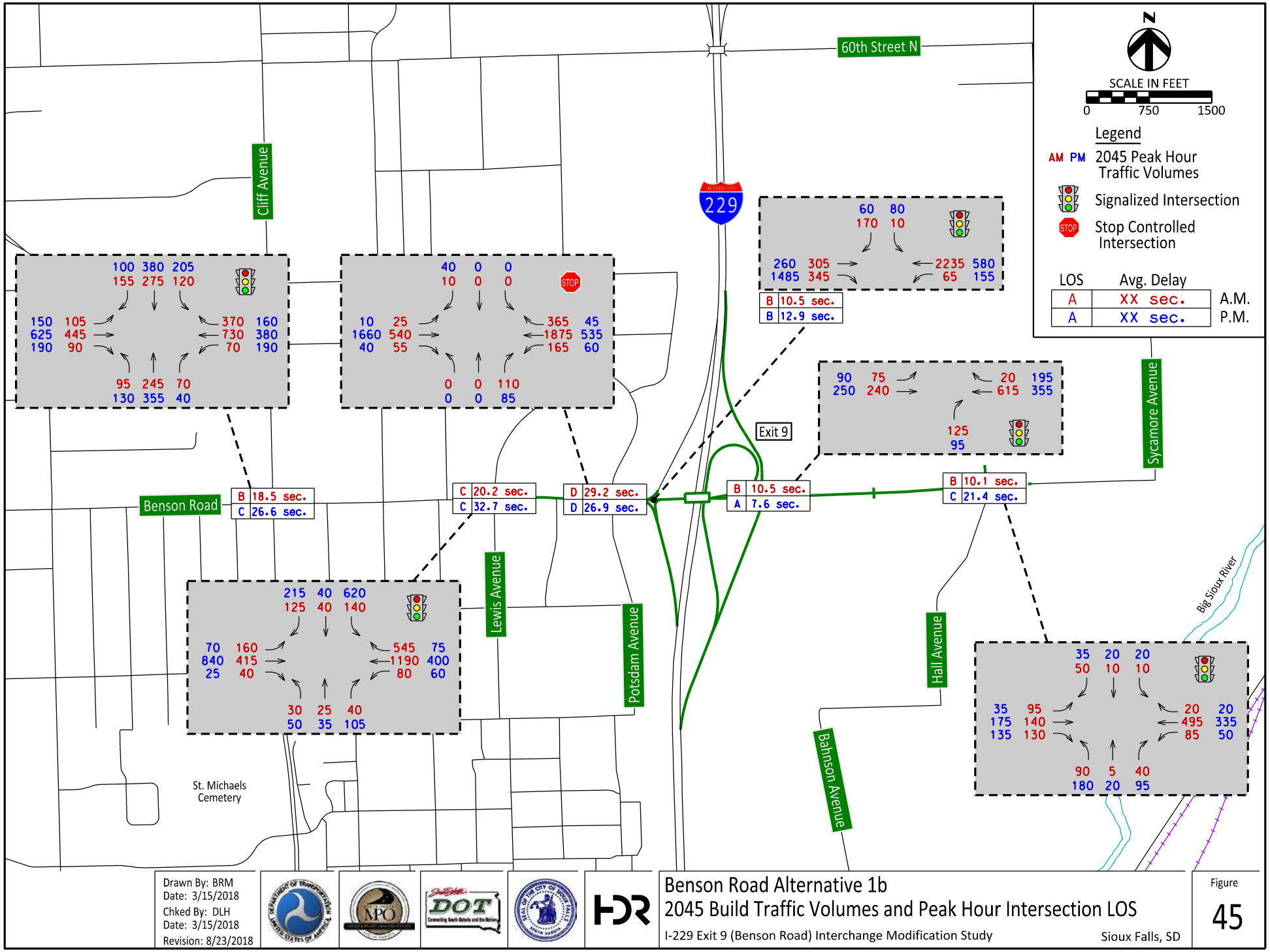


Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1a
2045 Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 44

FILE: ...\Figure 44 (2045).dgn
PLOTTING DATE: 10-09-2018



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PLOTTING DATE: 10-09-2018

Drawn By: BRM
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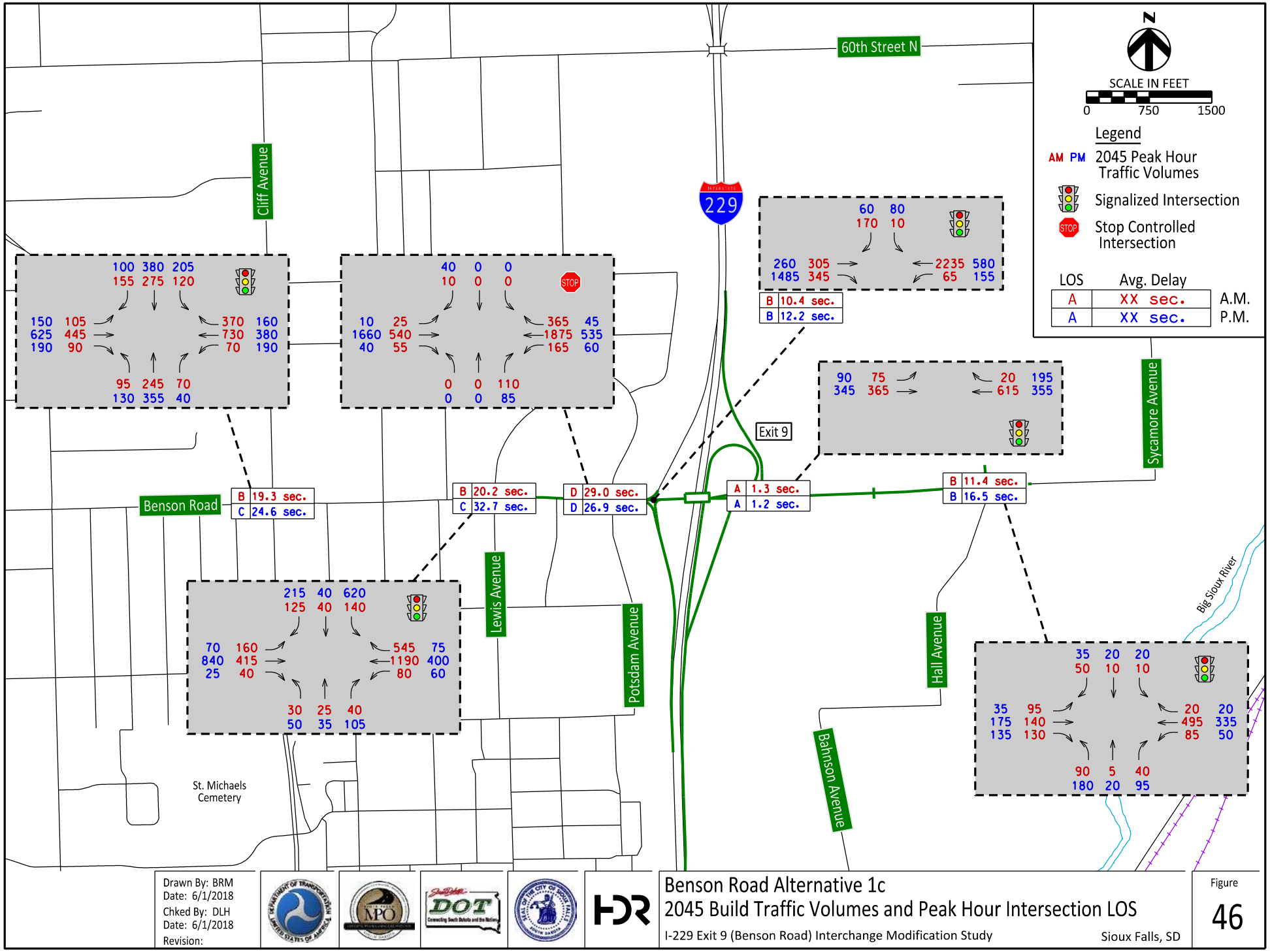
Revision: 8/23/2018

Benson Road Alternative 1b
2045 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 45



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PLOTTING DATE: 10-09-2018

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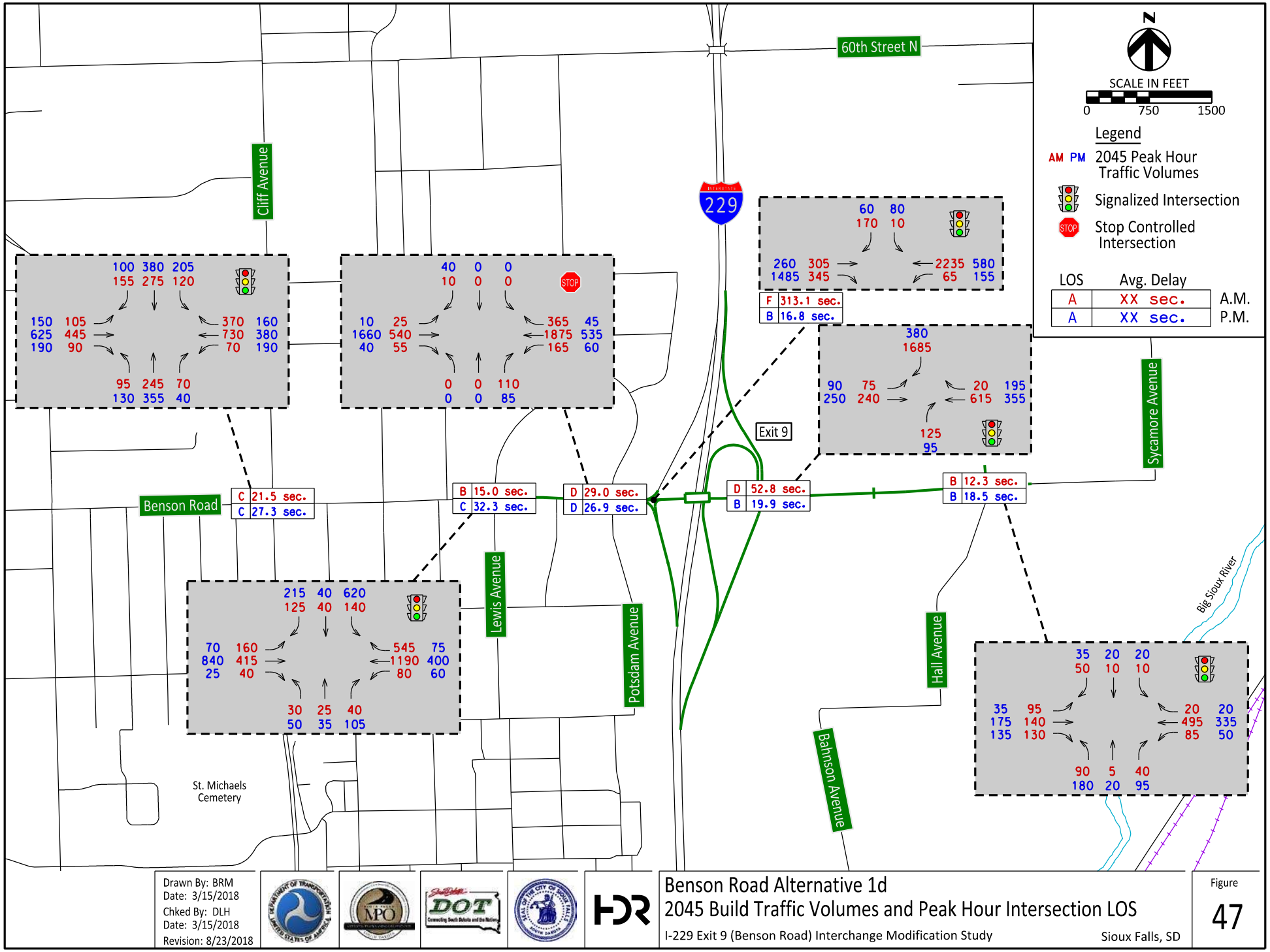
Benson Road Alternative 1c
2045 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 46



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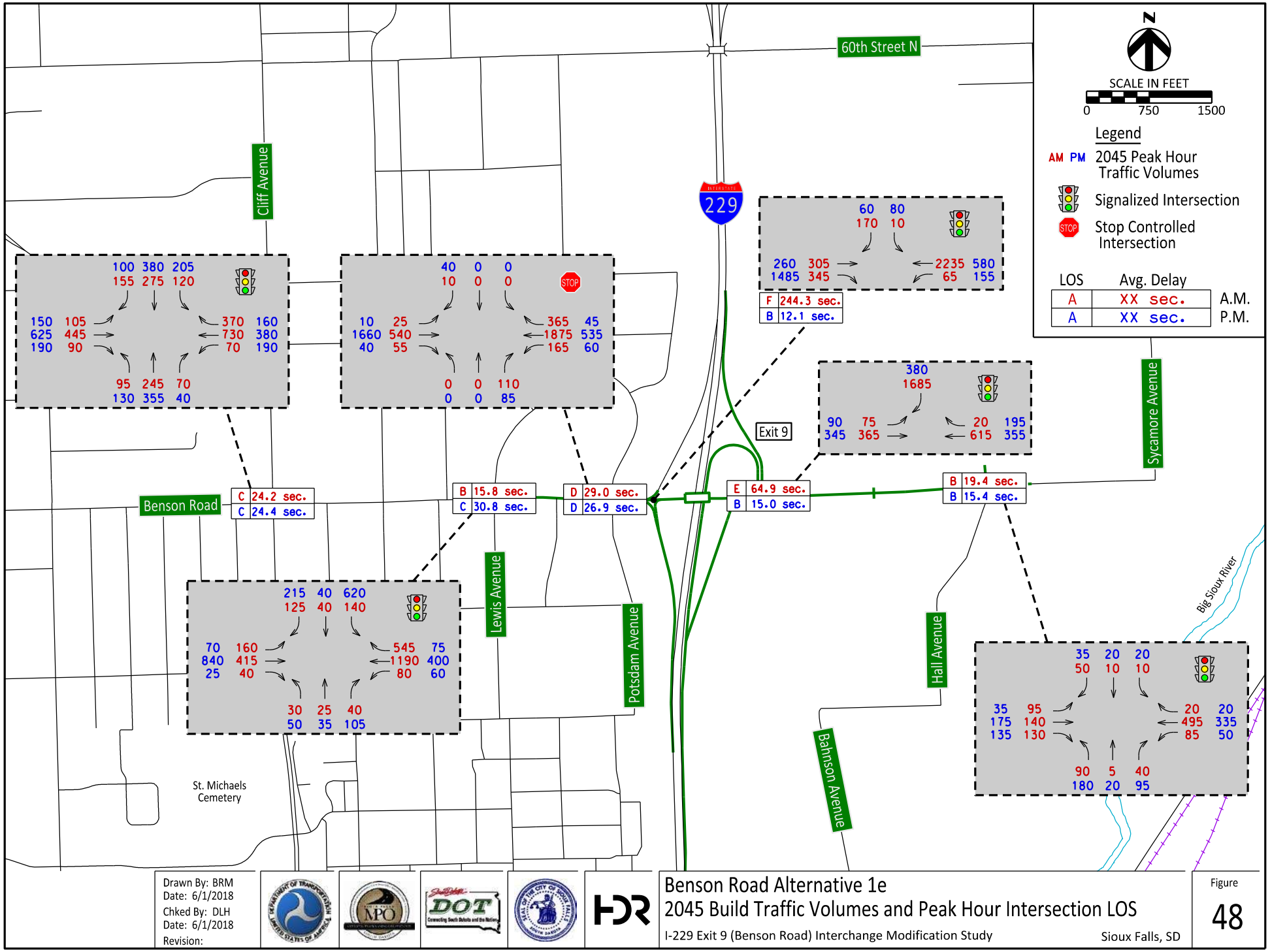
Benson Road Alternative 1d
2045 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 47



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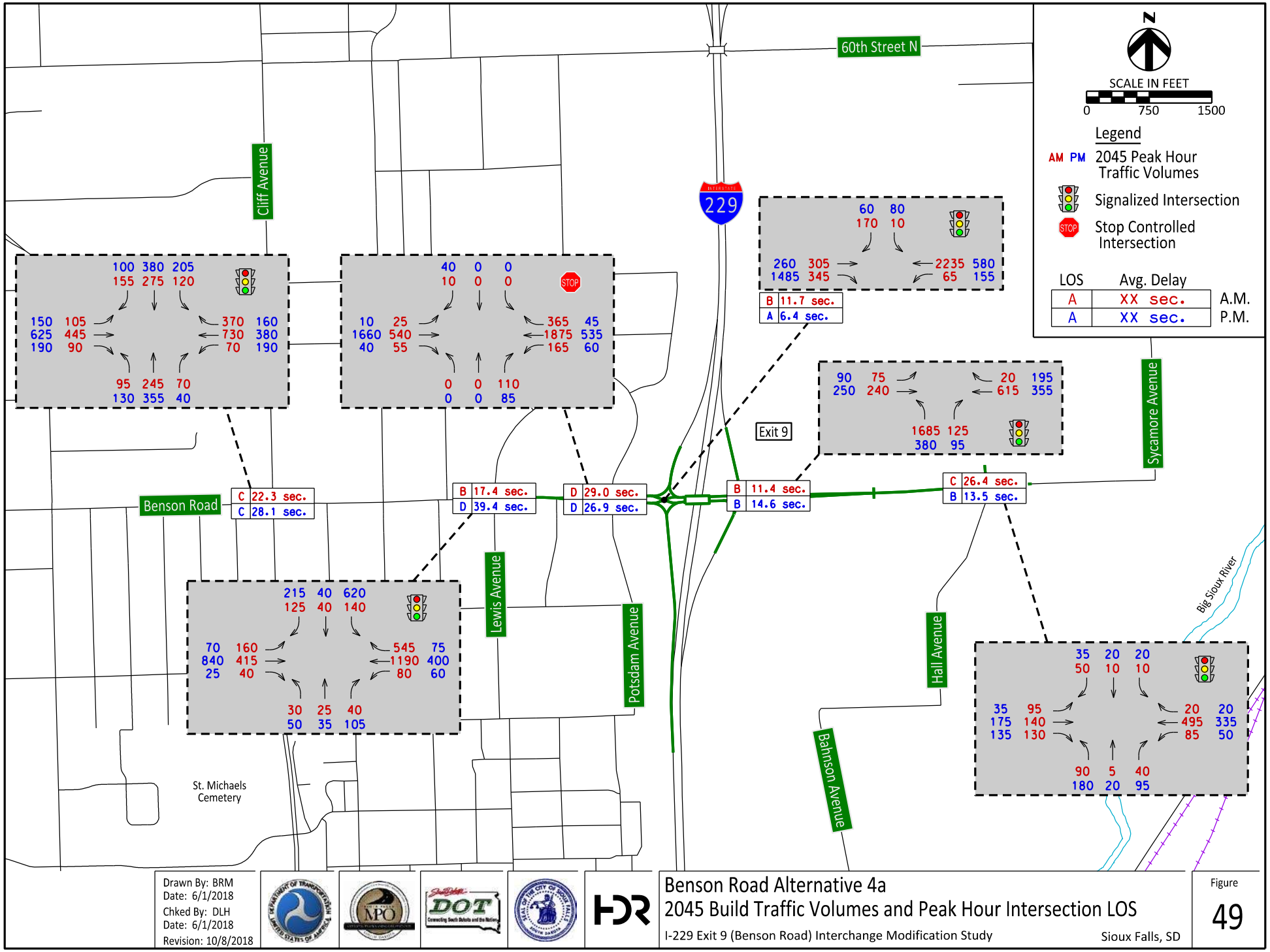
Revision:

Benson Road Alternative 1e
2045 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study — Sioux Falls, SD

Figure 48



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PLOTTING DATE: 10-10-2018

Drawn By: BRM
Date: 6/1/2018
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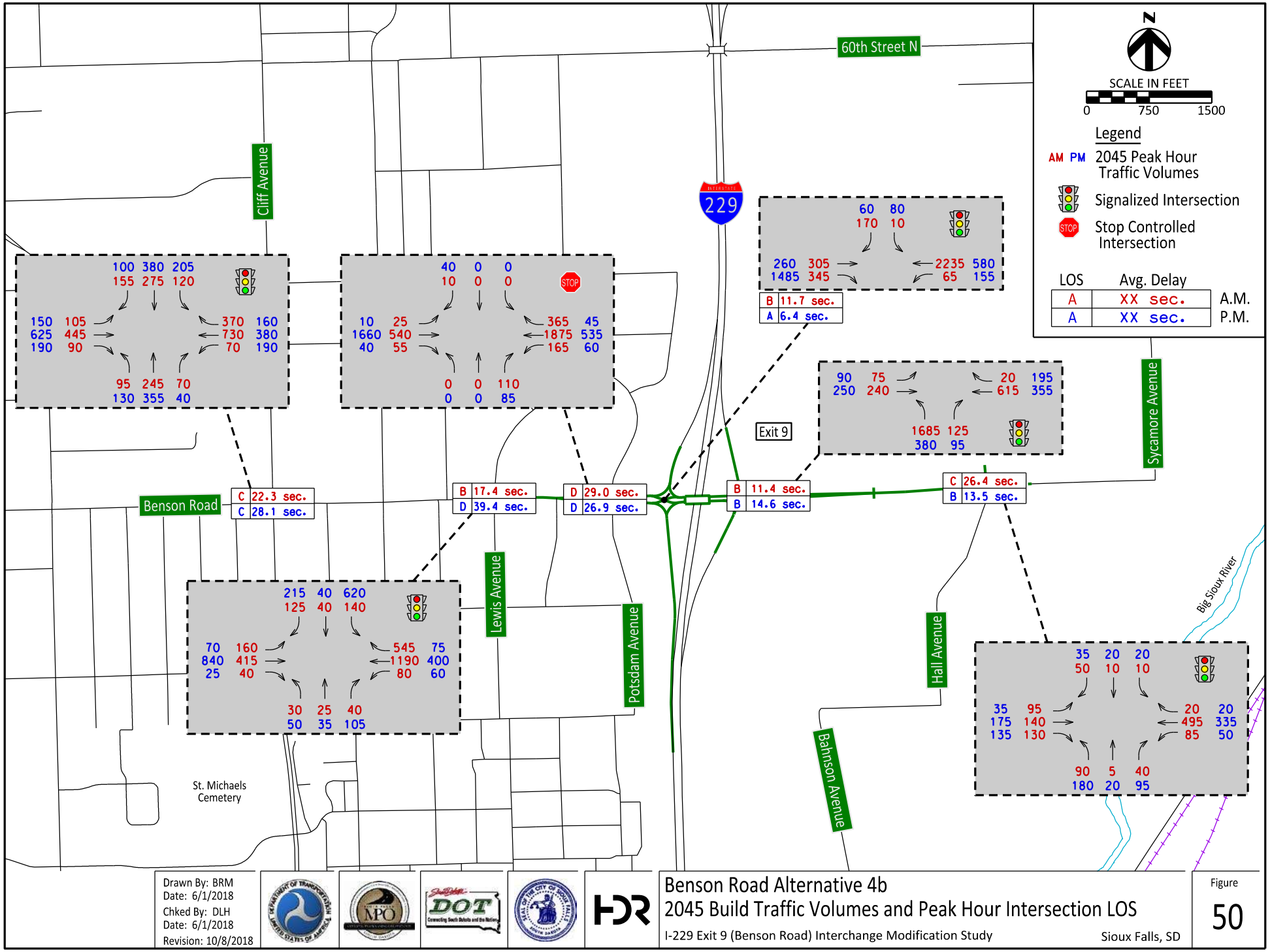
Date: 6/1/2018
Revision: 10/8/2018

Benson Road Alternative 4a
2045 Build Traffic Volumes and Peak Hour Intersection LOS

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 49


60th Street N
Cliff Avenue
Benson Road
Lewis Avenue
Potsdam Avenue
Exit 9
Sycamore Avenue
Hall Avenue
Bahnson Avenue
Big Sioux River
St. Michaels Cemetery
100 380 205
155 275 120
150 105
625 445
190 90
370 160
730 380
70 190
95 245 70
130 355 40
40 0 0
10 0 0
10 25
1660 540
40 55
365 45
1875 535
165 60
0 0 110
0 0 85
60 80
170 10
260 305
1485 345
2235 580
65 155
B 11.7 sec.
A 6.4 sec.
90 75
250 240
20 195
615 355
1685 125
380 95
C 22.3 sec.
C 28.1 sec.
B 17.4 sec.
D 39.4 sec.
D 29.0 sec.
D 26.9 sec.
B 11.4 sec.
B 14.6 sec.
C 26.4 sec.
B 13.5 sec.
215 40 620
125 40 140
70 160
840 415
25 40
545 75
1190 400
80 60
30 25 40
50 35 105
35 20 20
50 10 10
35 95
175 140
135 130
20 20
495 335
85 50
90 5 40
180 20 95
N
SCALE IN FEET
0 750 1500
Legend
AM PM 2045 Peak Hour Traffic Volumes
Signalized Intersection
Stop Controlled Intersection
LOS Avg. Delay
A XX sec. A.M.
A XX sec. P.M.
Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision: 10/8/2018
Benson Road Alternative 4b
2045 Build Traffic Volumes and Peak Hour Intersection LOS
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD
Figure
50
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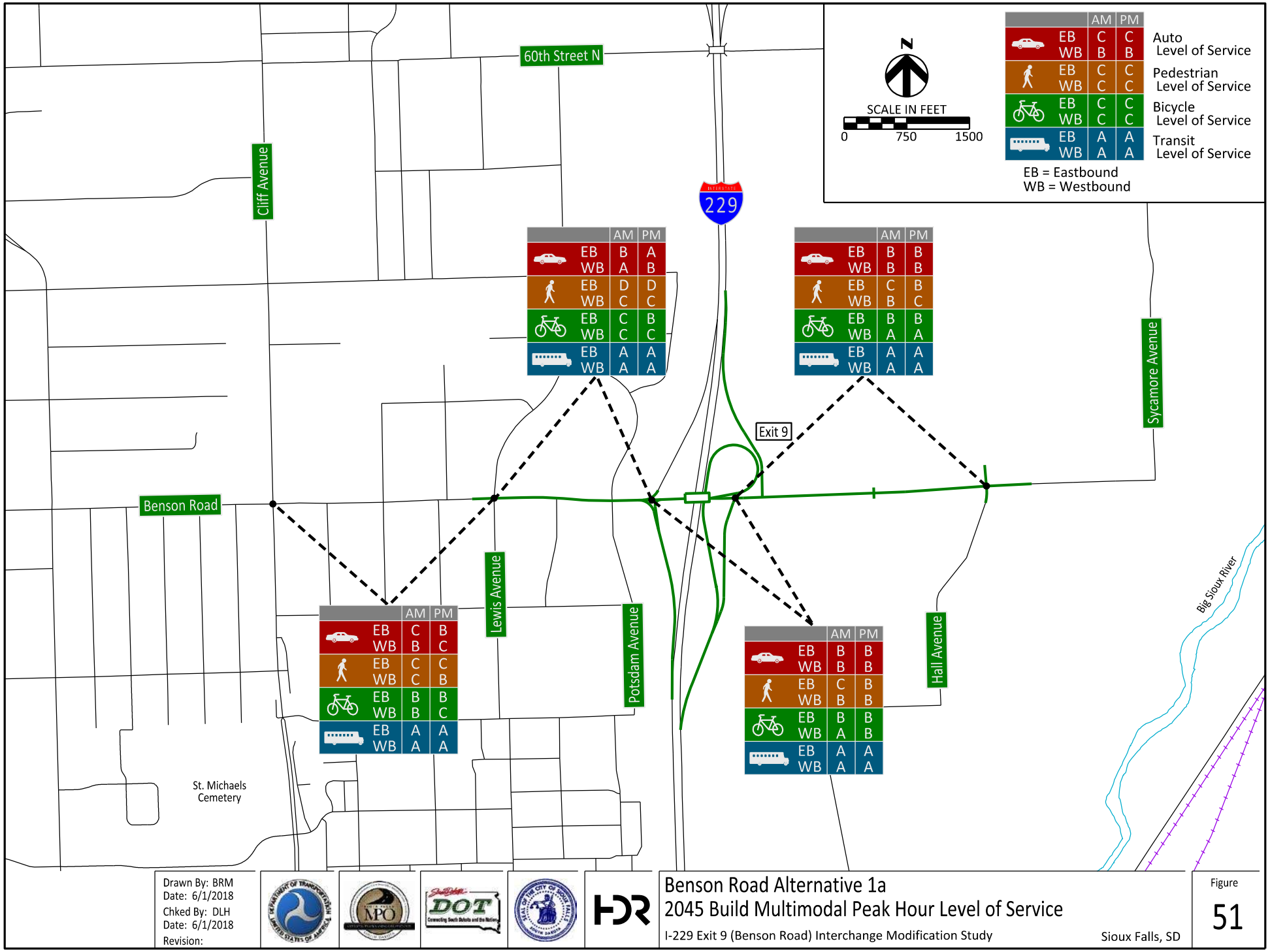

Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1a
2045 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 51

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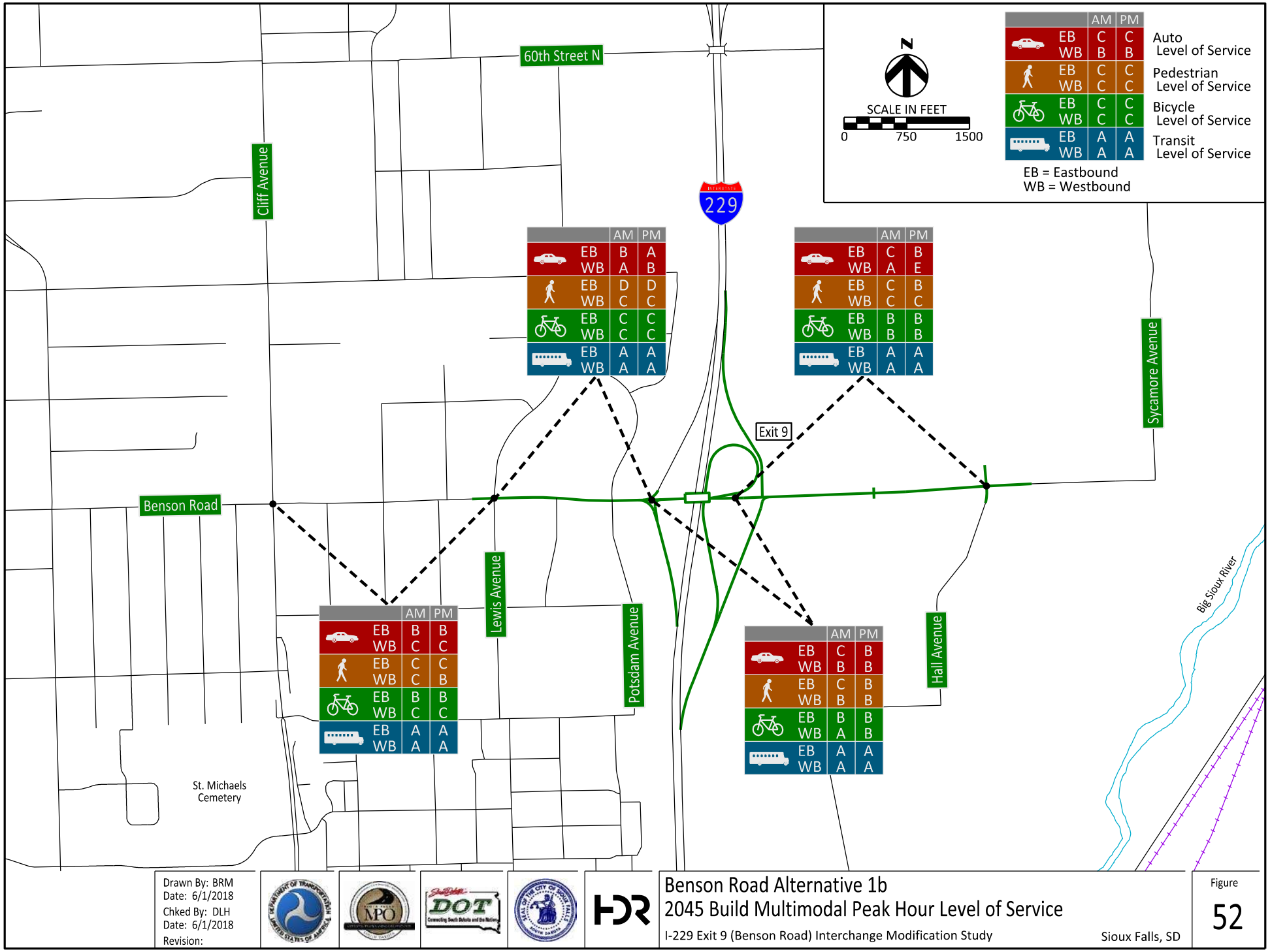
PLOTTING DATE: 10-09-2018



Drawn By: BRM
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1b
2045 Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 52

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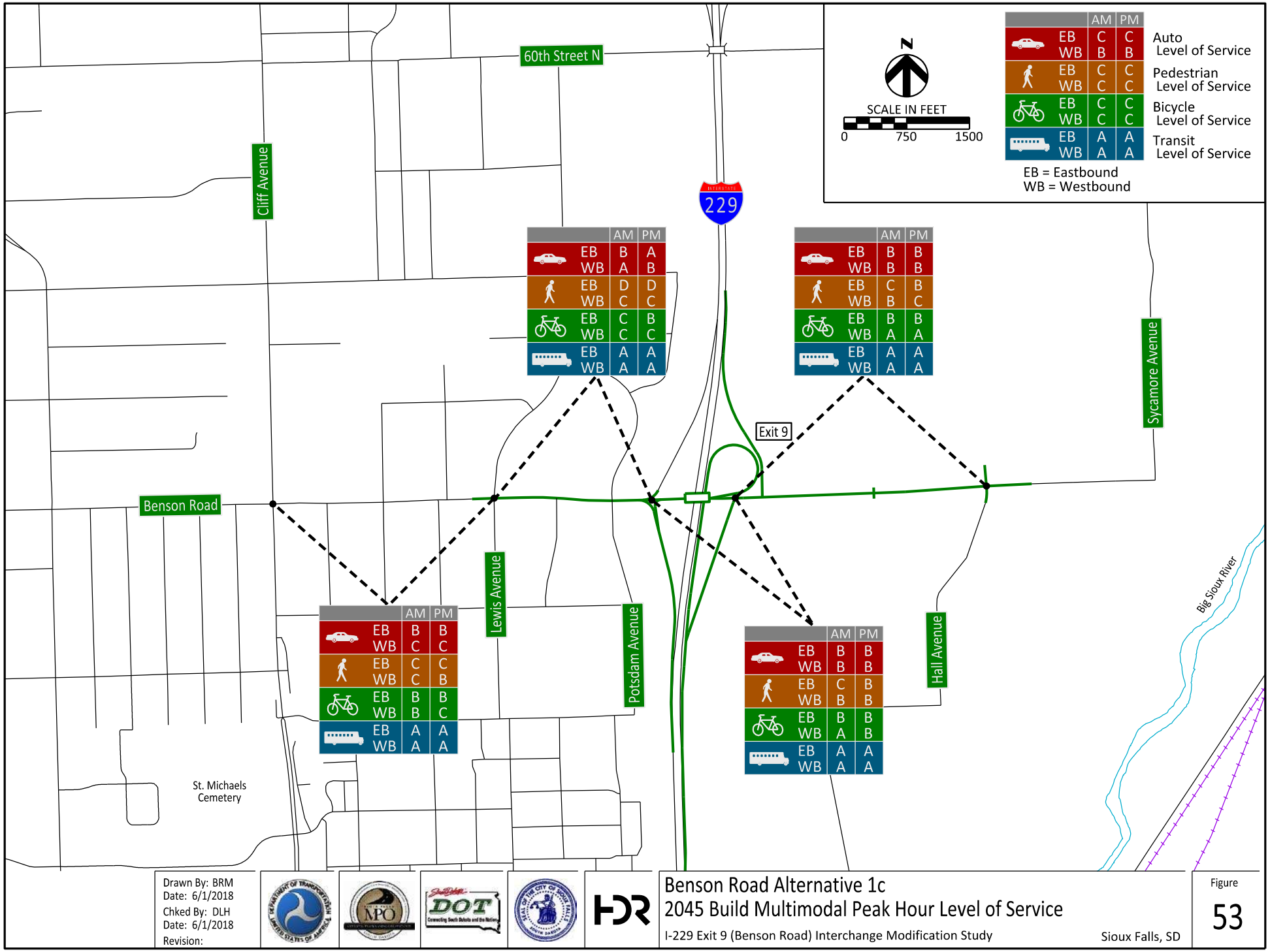
PLOTTING DATE: 10-09-2018



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PLOTTING DATE: 10-09-2018

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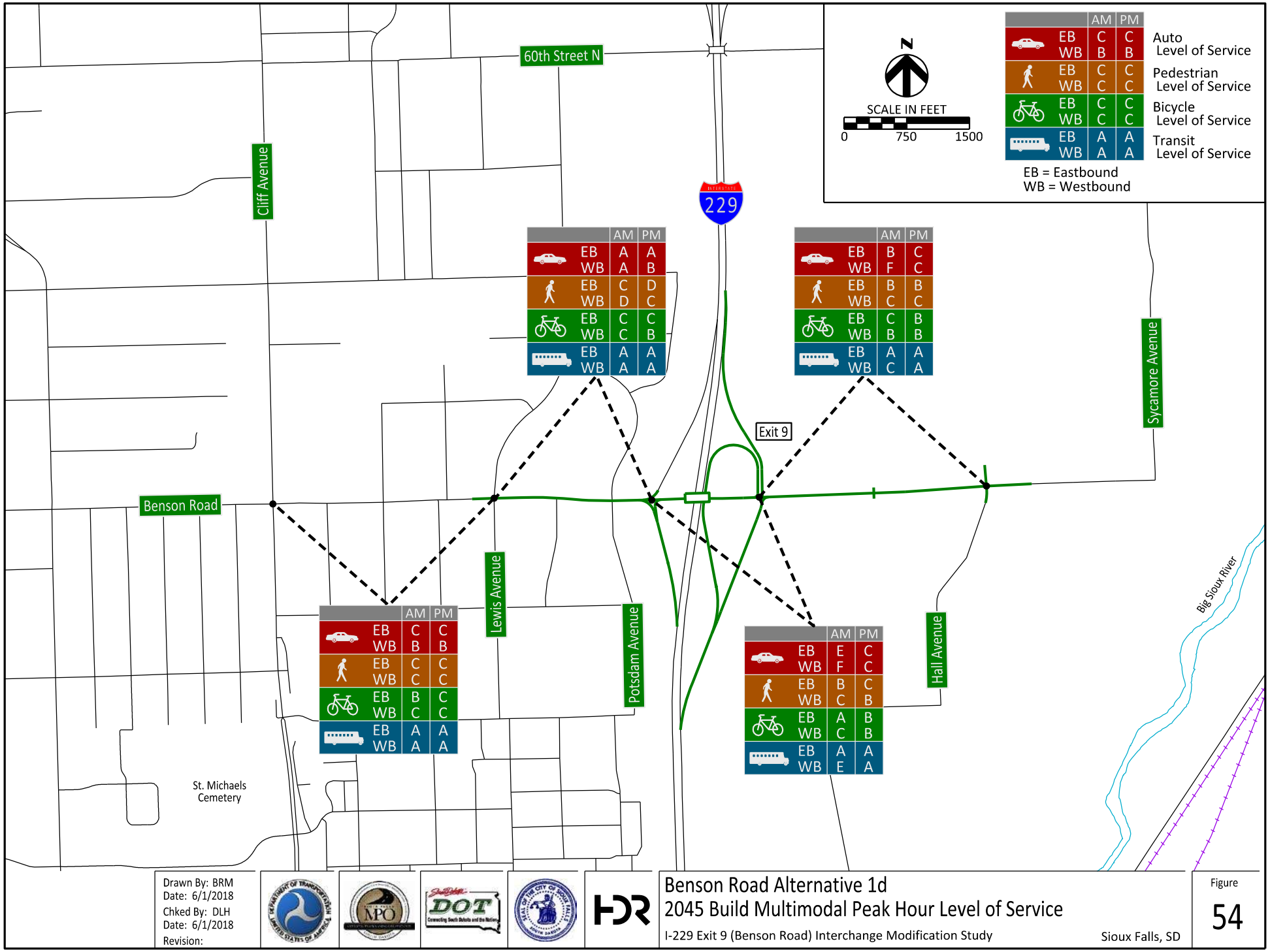
Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1c
2045 Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 53



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Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 1d
2045 Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 54

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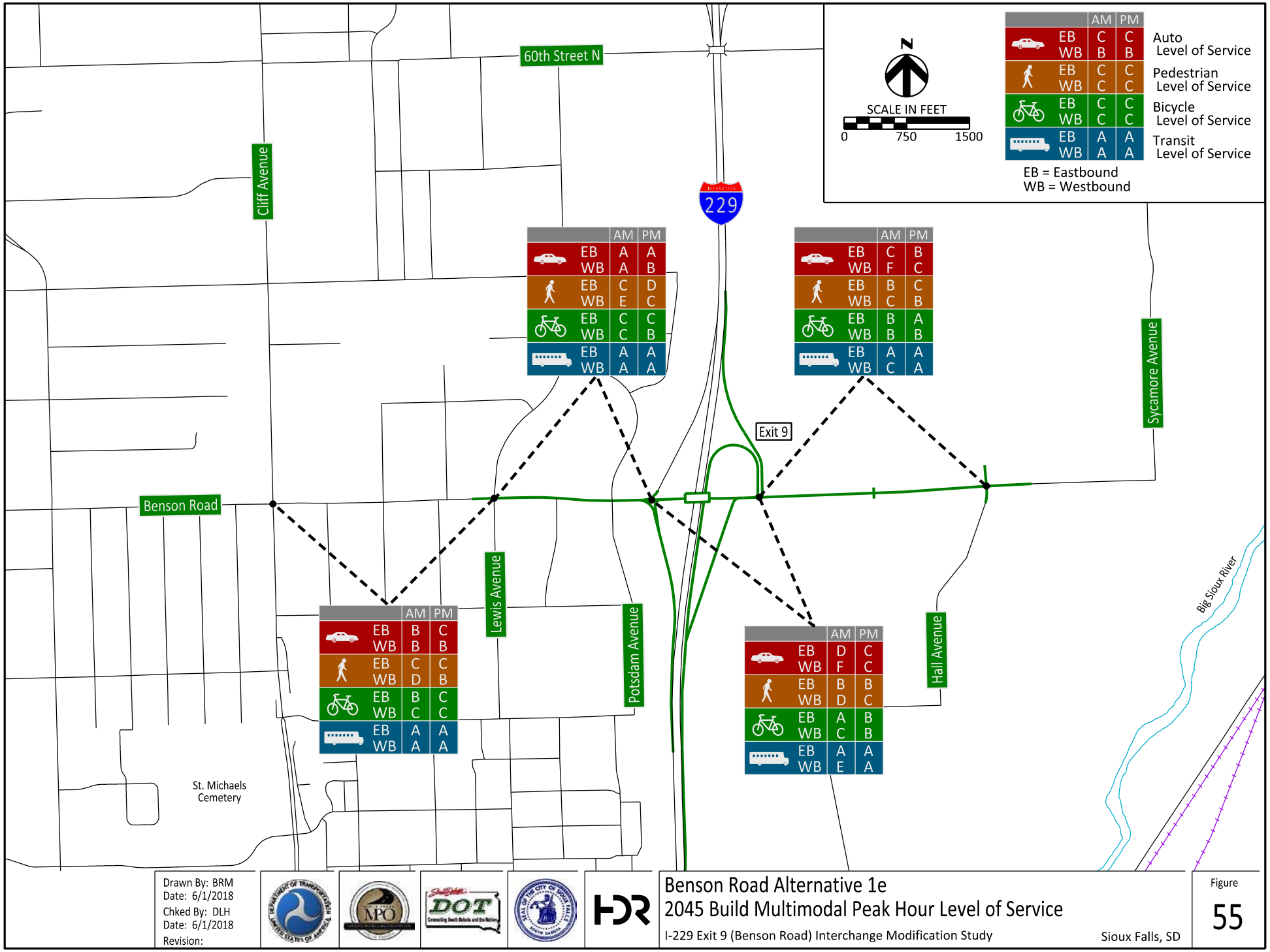
PLOTTING DATE: 10-09-2018



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Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

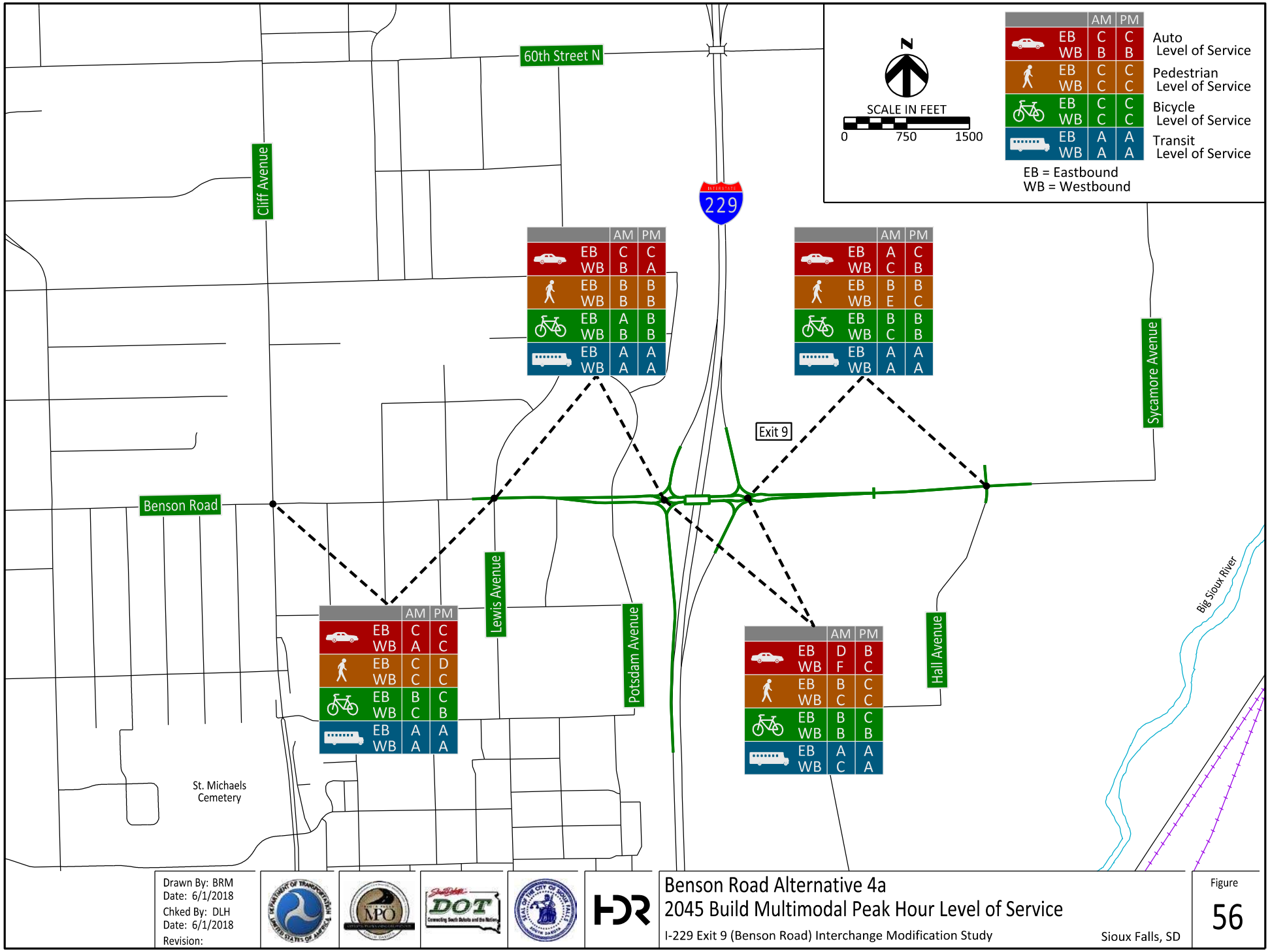
Benson Road Alternative 1e
2045 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 55

FILE: ...\Figure 55 (MM 2045).dgn
PLOTTING DATE: 10-09-2018



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Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 4a
2045 Build Multimodal Peak Hour Level of Service
I-229 Exit 9 (Benson Road) Interchange Modification Study
Sioux Falls, SD

Figure 56

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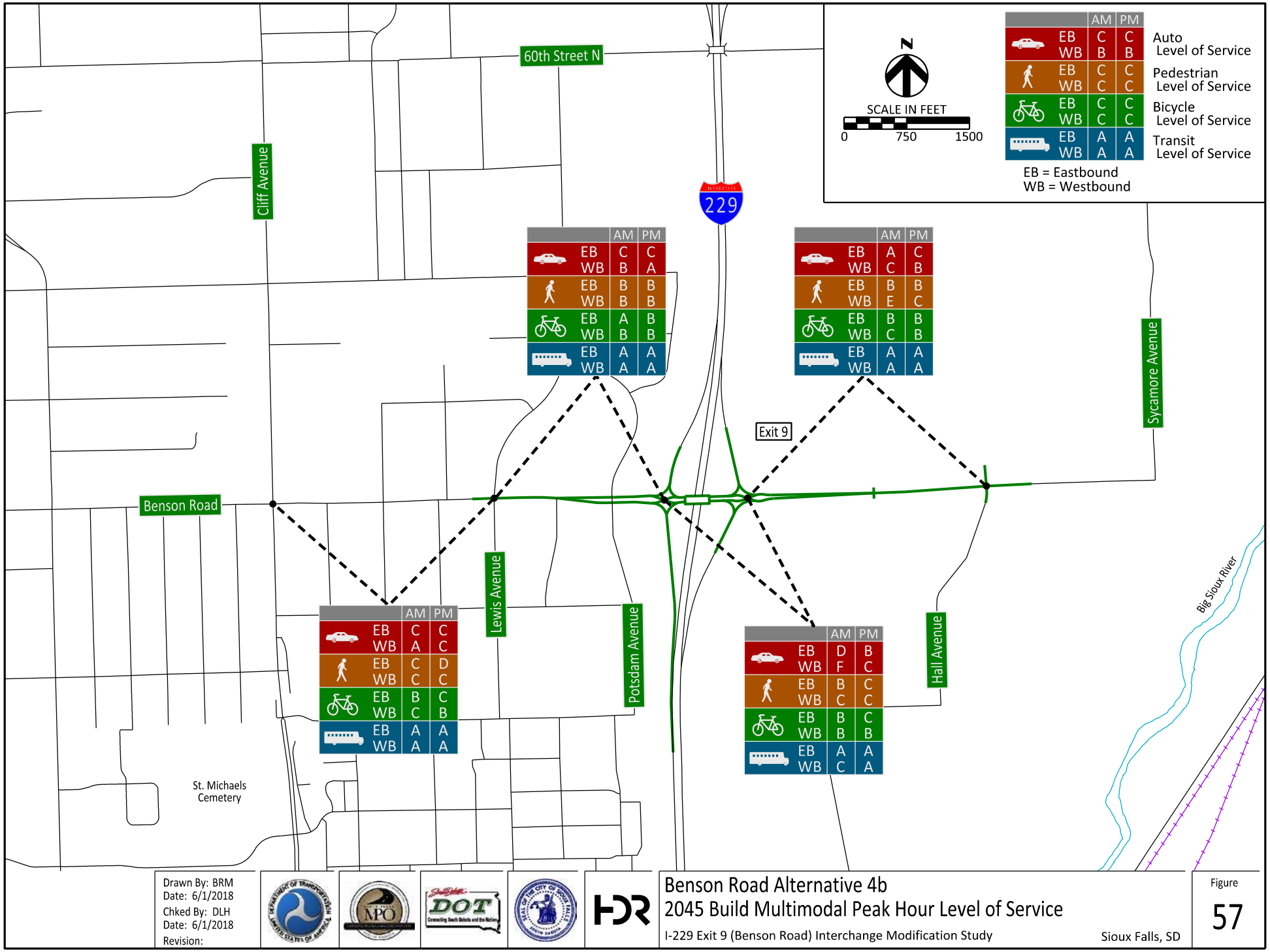
PLOTTING DATE: 10-09-2018



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Date: 6/1/2018
Chked By: DLH
Date: 6/1/2018
Revision:

Benson Road Alternative 4b
2045 Build Multimodal Peak Hour Level of Service

I-229 Exit 9 (Benson Road) Interchange Modification Study

Sioux Falls, SD

Figure 57

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PLOTTING DATE: 10-09-2018

Safety

The build alternatives are a modified diamond interchange containing a dual-lane loop ramp (DLLR) in the northeast quadrant and a Diverging Diamond Interchange (DDI), which would replace the existing diamond interchange.

The analysis limits for the predictive safety analysis are focused on the immediate interchange area as shown in **Figure 58**. On I-229, the limits extend from the interchange of I-229 / Rice Street to the interchange of I-229 / I-90, for a total distance of 2.3 miles. In addition to the freeway, the four interchange ramps and the two ramp terminals were analyzed.

Three alternatives were evaluated with this predictive safety analysis. The “No-Build” alternative maintains the existing diamond interchange layout. The second alternative adds a dual-lane loop ramp in the northeast quadrant to serve northbound I-229 traffic turning west onto Benson Road. This alternative would also reconfigure the alignments and lane layouts for other ramps, but they would still maintain the traditional diamond interchange layout. The third alternative would convert the interchange to a diverging diamond interchange. Within these general configurations, the IMJR includes review of several variations of the DLLR and DDI. However, the crash prediction analysis herein is based on the DLLR concept numbered 1a and the DDI concept denoted 4a.

The predictive crash analysis presented in this memorandum is based on the principles and methods of the Highway Safety Manual (HSM) 2010 edition with 2014 supplement published by AASHTO as discussed in detail below. It presents a comparative analysis of the predicted crashes anticipated within the interchange area for the “No-Build” future condition (maintain diamond interchange) and the planned build alternatives (DLLR and DDI). The results are intended to verify the assumption that the construction of a DLLR or DDI at this location will not result in a decrease in overall safety performance in the interchange area.

Figure 58 – IHSDM Analysis Limits

Source: Google Earth, April 2018

Safety Methodology

This predictive safety analysis was completed using the American Association of State Highway and Transportation Officials (AASHTO) HSM method, including the National Cooperative Highway Research Program (NCHRP) Report 17-45 method for evaluating freeways and interchanges, which is now part of the HSM as a supplemental volume published in 2014.

FHWA supports, and in many cases now requires, the use of the method for the evaluation of proposed freeway facility improvements, including new or modified Interstate access. According to the HSM preface: *"The focus of the HSM is to provide quantitative information for decision making. The HSM assembles currently available information and methodologies on measuring, estimating, and evaluating roadways in terms of crash frequency (number of crashes per year) and crash severity (level of injures due to crashes). The HSM presents tools and methodologies for consideration of 'safety' across the range of highway activities …"*

For this study, the HSM predictive method was used. *"The predictive method provides a quantitative measure of expected crash frequency under both existing conditions and conditions which have not yet occurred. This allows proposed roadway conditions to be quantitatively assessed …"* (HSM, 2010)

The HSM method crash prediction estimates are developed using safety performance functions (SPFs) for specific facility types. The SPFs take into account the daily traffic volume information, but they assume that other geometric and traffic control features match a theoretical base condition for that facility type. Therefore, crash modification factors (CMFs) are used to make adjustments to the initial SPF results, to account for differences between the actual analysis condition and the theoretical base condition. A CMF of 1 means the analysis condition and the theoretical base condition will predict the same number of crashes. Thus, if a CMF is greater than 1, that will increase the number of predicted crashes, while if it is less than 1, it will decrease the number of predicted crashes. For example, if a depressed freeway median is narrower than the assumed 60-foot base condition, then a CMF greater than 1 is applied to adjust the SPF results for the segment.

The HSM methodology has been in development for many years and is rapidly advancing; however, there are still many limitations where the available tools do not yet offer SPFs and/or CMFs for certain conditions. Where this is the case, recent research and crash data were also considered to refine the results as described later in this section.

Facilities, Segmentation and Data Inputs:

In keeping with the site based HSM analysis approach, each type of facility was examined separately. This involved segmenting the I-229 mainline and the I-229 ramps into functional elements. The Interactive Highway Safety Design Model (IHSDM) software automatically segments highways (including freeway segments, ramps and C-D roads) following HSM guidance. The ramp terminal intersections were also considered individually. IHSDM reports provided in **Appendix 6** list all freeway, ramp, and ramp terminal intersection sites that were reviewed.

The HSM method requires several geometric and operational inputs to accurately compute the SPFs and apply the correct CMFs. This includes information such as segment length, daily traffic volume, ramp locations, merge distances, and horizontal curvature. The geometric inputs were primarily obtained from the conceptual design files and aerial photography. The traffic volume data was based on data and design year volume forecasts from the 2040 Sioux Falls Travel Demand Model.

I-229 Mainline Segments

The I-229 mainline segments were evaluated using HSM methods implemented using the Interactive Highway Safety Design Model (IHSDM) version 13.1.0 software provided by FHWA.

I-229 Entrance and Exit Ramps

The I-229 entrance and exit ramps were also evaluated using HSM methods in the IHSDM software. Consistent with this method, each ramp was evaluated as one or more specific ramp segments, taking into account the ramp geometry. Some of the ramps were subdivided into multiple segments to account for changes in number of lanes or shoulder widths.

In the DLLR alternative, the I-229 Northbound exit ramp traverses a portion of two-lane ramp alignment with a tight curve radius before intersecting Benson Road. The condition is uncommon in practice and was very likely unobserved or under-sampled in the development of the HSM crash prediction models. Past research for SDDOT on this gap in the crash prediction methodology led to the "Crash Prediction Analysis Procedures for Diverging Diamond Interchange (DDI) and Two-Lane Loop Ramp" memo dated November 4th, 2015. In the memo, it is recommended to analyze the two-lane loop ramp, now called DLLR, with standard HSM procedures with greater scrutiny unless the research results of NCHRP 03-105 should develop enhanced models / guidance. The referenced research project was published in 2017 as NCHRP Web-Only Document 227: Design of Interchange Loop Ramps and Pavement/Shoulder Cross-Slope Breaks. The report includes a chapter reviewing the HSM procedure for loop ramps against directional ramps, but does not make recommendations on the specific DLLR geometry. The report's most poignant comment on loop ramp crash prediction is that *"HSM prediction models for ramp crashes do a better job of predicting diamond ramp crashes than predicting loop ramp crashes",* which the researchers arrived at through advanced statistical analysis of geometry and crash data.

Benson Road Ramp Terminals

For the No-Build and Build options, the ramps connect to Benson Road at signalized and non-signalized intersections. Interchange ramp terminals are evaluated using the HSM ramp terminal procedure in IHSDM. The IHSDM ramp terminal method does not, however, address DDIs. It only predicts crashes for a variety of more typical diamond and partial cloverleaf interchange ramp terminals. Therefore, it was necessary to develop an estimate for an "operationally-similar" diamond interchange design and then use CMFs from HDR's "Crash Prediction Analysis Procedures for Diverging Diamond Interchange (DDI) and Two-Lane Loop Ramp" memo dated November 4th, 2015 to modify the results to estimate the predictions for a DDI design. Based on research done in Missouri on safety evaluations of DDIs, the preliminary CMF for conversion of a traditional diamond interchange to a DDI is 0.37 for Fatal + Injury (F+I) crashes at ramp terminal intersections and 0.49 for Property Damage Only (PDO) crashes at ramp terminal intersections.

Benson Road Segments

Crash prediction for an interchange study area within a typical urban footprint can be almost entirely described by evaluating the crashes from the freeway, freeway ramps, and ramp terminal intersections due to how the HSM defines the influence area for those types of sites. For that reason, this analysis does not report urban arterial crashes outside of those estimated directly through ramp terminal analysis. Given the emerging nature of both the DLLR and DDI configurations in crash prediction practice, it is likely that the base HSM models would struggle

to replicate the crash patterns for the proposed Benson Road configuration between the interchange ramp terminals.

Calibration Factors:

According to the HSM, *"the predictive models were developed from the most complete and consistent data sets available."* However, the report also recommends that the equations be calibrated for each jurisdiction because *"the general level of crash frequencies may vary substantially from one jurisdiction to another."* However, SDDOT has not yet conducted the extensive analyses required to develop a complete set of HSM related calibration factors. Therefore, using the national HSM equations is proposed as the best approach for this current analysis.

Empirical Bayes Approach: Considering Historical Crash Data:

The HSM method includes an optional step called the Empirical Bayes (EB) approach, which combines "*the estimate from a predictive model with observed crash data to obtain a more reliable estimate of the expected average crash frequency."* (HSM, 2010) Essentially, the historical crash data is used to adjust the future crash prediction. Typically, the EB method is only used when it can be applied equally to all of the alternatives under consideration. Thus the improvements being considered must be moderate, so that the historical crash data is reasonable to consider for the No-Build and Build conditions. When major alignment or traffic control changes are proposed (such as the proposed DLLR or DDI), it is not used because *"there is typically a small difference in the results obtained from the predictive method when it is used with and without the EB Method."* Therefore, *"if the EB Method is not applied consistently, such differences will likely introduce a small bias in the comparison of expected crash frequency among alternatives."* (HSM Supplement, 2014) Therefore, the results are presented without the EB method adjustment.

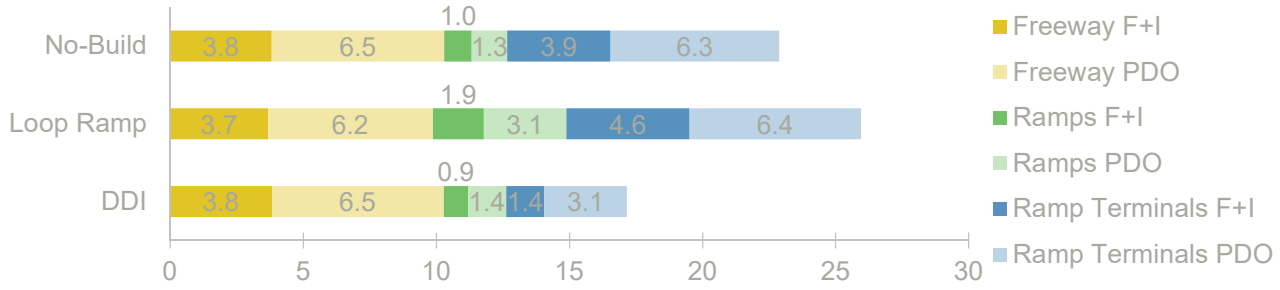
Safety Analysis Results

The No-Build and Build interchange alternatives were evaluated and the predicted number of crashes was compared for the 2023 to 2045 analysis period. As mentioned previously, the required inputs were derived from design plans, aerial photography, and traffic volume data from the 2040 Sioux Falls Travel Demand Model. The following sections present the details of the analyses.

Build and No-Build Crash Frequency Comparison:

The predicted annual crash frequencies for the No-Build and Build scenarios (2023 to 2045) are presented in **Table 7** including a breakdown of Fatal + Injury (F+I) and Property Damage Only (PDO) crashes. The resulting total number of annual predicted crashes is 26.0 for the DLLR concept, 17.2 for the DDI concept, and 22.9 predicted crashes for the No-Build condition. The No-Build and Build detailed IHSDM results sheets are provided in **Appendix 6**.

Table 7: 2023 to 2045 Predicted Build and No-Build Annual Crash Frequencies



As shown, the majority of predicted crashes for all scenarios occur on the freeway and at the ramp terminal intersections. The freeway crashes for the Build scenarios introduce small changes in the predicted number of crashes versus the No-Build. The ramp crashes are expected to increase due to added lanes and additional length on some of the ramps.

Focusing on the ramp terminals, the DLLR ramp terminal crashes are expected to increase by 8% and the DDI ramp terminal crashes are expected to be reduced by 56%. The reduction for the DDI is consistent with what would be expected from eliminating left-turns with the DDI concept. The DLLR findings are more surprising given that the loop ramp re-aligns a significant amount of traffic from a left turn movement to a right turn movement at the northbound ramp terminal. A more in-depth review of this site does show that the DLLR reduces total crashes from 7 crashes per year to 2.5 crashes per year, consistent with the significant amount of traffic that has moved to the loop ramp and no longer would be in conflict with cross street traffic. This means the net increase in ramp terminal crashes is projected to happen entirely at the southbound ramp terminal. The primary consideration in this increase is the traffic control device at the intersection as the No-Build assumes a continuation of the stop-controlled condition where the DLLR alternative recommends a traffic signal to improve traffic operations. Since there is not a traffic signal planned for the southbound ramp terminal, it was not considered for the No-Build scenario, even though operations would degrade to a failing level of service condition if volumes increased to the 2045 forecasted levels.

Considering predicted crash severity, the DDI concept may decrease the number of F+I crashes at the ramp terminals by 63% while the DLLR concept may increase F+I crashes by 17%. In addition, the DDI concept may decrease the number of PDO crashes at the ramp terminals by 51% while the DLLR concept may increase by 2%. This result took into account the significant reduction in F+I crashes observed at DDIs compared to standard diamond interchanges in the Missouri research (63% reduction).

Safety Conclusions

Based on the preceding HSM analysis, it is concluded that the DDI interchange is likely to exhibit significantly less overall crash frequencies than the existing diamond interchange. The DLLR would likely result in an increase in crashes, but this is due to a longer northbound ramp, and the southbound terminal being signalized instead of stop-controlled. The northbound terminal, in this scenario, would be expected to have a decrease in crashes compared to the No-Build. The freeway crashes for the Build scenarios introduce small changes in the predicted number of crashes versus the No-Build. The ramp crashes are expected to increase due to added lanes and additional length on some of the ramps. The ramp terminal crashes are expected to be reduced by 56% for the DDI and increased by 8% for the DLLR. The DDI has an even better crash benefit when looking at F+I crashes. The DDI reduces F+I crashes at the ramp terminals by 63%, compared to an increase of 19% for the DLLR. The PDO crashes at the ramp terminals are reduced by 51% for the DDI and an increase of 2% for the DLLR. The DDI

alternative would be expected to provide significant safety benefits compared to the No-Build, but the DLLR alternative would likely result in an increase of crashes compared to the No-Build.

3.4 Alternatives Analysis

Option 1a: 2 Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp

Option 1a (Figure I-1) proposes a northbound off-ramp with separation of eastbound and westbound traffic on Benson Road. This separation reduces the amount of vehicles queued at the existing signal and the eastbound off ramp skew supports one-way eastbound turning movement. On Benson Road the additional proposed eastbound lane, increased to three total from Lewis Avenue to the east to I-229 and the three lane southbound on-ramp also reduces queuing significantly.

Benefits of Option 1a:

- Free flow northbound I-229 to westbound Benson Road due to loop and no signal.
- Traffic Level of Service (LOS) B is forecast at the interchange for year 2045 conditions.
- Pedestrian underpass reduces conflict with vehicles using the northbound on ramp and the larger volume of traffic on the loop ramp for the westbound Benson Road traffic.
- Free-flow dual rights on Benson Road eastbound to I-229 southbound reduces congestion/queuing on Benson Road between Lewis Avenue and I-229. Free-flow is only interrupted for pedestrian movement.
- Access management treatments considered with installation of raised median.

Drawbacks of Option 1a:

- The construction of the ramps requires substantial right of way acquisition and grading costs associated with constructing a new loop ramp and removal of the existing ramps.
- Option 1a could result in additional crashes compared to the no-build due to added lanes and additional length on some of the ramps.
- Although the pedestrian underpass in this option reduces conflict, the additional cost per pedestrian and bicycle user is high.
- Due to the increased right of way and grading impacts to environmental resources are higher with this option compared to non-loop ramp options.

It is recommended that Option 1a be eliminated from further evaluation for these reasons:

- *Total right of way necessary to be acquired.*
- *High construction cost*

Option 1b: 2 Lane Northeast Quadrant Loop with 2-Lane SB On-Ramp

Option 1b (Figure I-2) is very similar to Option 1a. Proposes a northbound off-ramp with separation of eastbound and westbound traffic on Benson Road. This separation reduces the amount of vehicles queued at the existing signal and the eastbound off ramp skew supports one-way eastbound turning movement. The proposed Benson Road eastbound lanes and two

southbound on-ramp lanes from Lewis Avenue to the east to the southbound on-ramp also reduces queuing, however, not as efficient as Option 1a.

Benefits of Option 1b:

- Free flow northbound I-229 to westbound Benson Road due to loop and no signal.
- Traffic Level of Service (LOS) B is forecast at the interchange for year 2045 conditions.
- Pedestrian underpass reduces conflict with vehicles using the northbound on ramp and the larger volume of traffic on the loop ramp for the westbound Benson Road traffic.
- Single free-flow right turn lane on Benson Road eastbound to I-229 southbound reduces congestion/queuing on Benson between Lewis Avenue and I-229. Free-flow is only interrupted for pedestrian movement.
- Access management treatments considered with installation of raised median.

Drawbacks of Option 1b:

The construction of the ramps requires a substantial amount of right of way acquisition and grading costs associated with constructing a new loop ramp and removal of existing ramps.

- Option 1b is anticipated to create more crashes compared to the no-build due to added lanes and additional length on some of the ramps.
- Although the pedestrian underpass in this option reduces conflict, the additional cost per pedestrian and bicycle user is high.

It is recommended that Option 1b be eliminated from further evaluation for these reasons:

- *Total right of way necessary to be acquired.*
- *High construction cost.*

Option 1c: 2-Lane Collector – Distributor (CD) Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp

Option 1c (Figure I-3) proposes a northbound off-ramp with separation of eastbound and westbound traffic on Benson Road while reducing the grading and right of way necessary by implementing a Collector-Distributor lane. The separation of eastbound and westbound vehicles on Benson Road is similar to Options 1a and 1b. The additional proposed eastbound lanes, totaling three, on Benson Road from Lewis Avenue to the east to the southbound on-ramp also reduces queuing significantly.

Benefits of Option 1c:

- The CD lane reduces the amount of right of way acquisition and grading costs associated with the northbound off-ramp.
- Free flow northbound I-229 to westbound Benson Road due to loop and no signal.
- Traffic Level of Service (LOS) B is forecast at the interchange for year 2045 conditions.
- Pedestrian underpass reduces conflict with vehicles using the northbound on ramp and the larger volume of traffic on the loop ramp for the westbound Benson Road traffic.
- Dual rights on Benson Road for eastbound to I-229 southbound reduces congestion/queuing on Benson Road eastbound between Lewis Avenue and I-229.

- CD lane enhances safety by allowing more distance and separation for vehicles slowing to exit and remain adjacent to the high-speed mainline.

Drawbacks of Option 1c:

- Option 1c is anticipated to create more crashes compared to the no-build due to added lanes and additional length on some of the ramps.
- Although the pedestrian underpass in this option reduces conflict, the additional cost per pedestrian and bicycle user is high.

It is recommended that Option 1c be eliminated from further evaluation for this reason:

- *High construction cost.*

Option 1d: 2-Lane Partial Clover Leaf Northeast Quadrant Loop with 2-Lane SB On-Ramp

Option 1d (Figure I-4) proposes a signalized loop at the intersection of Benson Road. Right-turn on red would not be allowed.

Benefits of Option 1d

- Access Management treatments considered with installation of raised median

Drawbacks of Option 1d:

- Does not meet Purpose and Need. The Level of Service falls below the acceptable level C because the right turn on red movements would not be allowed to operate as a free-flow movement.
- The construction of the ramps requires substantial right of way acquisition and grading costs associated with constructing a new loop ramp and removal of the existing ramps.

It is recommended that Option 1d be eliminated from further evaluation for these reasons:

- *This option does not meet the acceptable Level of Service.*
- *Total right of way necessary to be acquired.*
- *High construction cost*

Option 1e: 2-Lane Partial Clover Leaf Northeast Quadrant Loop with CD Lane 2-Lane and 2-SB On-Ramp

Option 1e (Figure I-5) proposes is similar to Option 1d with the exception of the CD lane. Right turn on red will not be allowed at the off-ramp for westbound traffic on Benson Road.

Benefits of Option 1e:

- Access management treatments considered with installation of raised median.

Drawbacks of Option 1e:

- Does not meet Purpose and Need. The Level of Service falls below the acceptable level C because the right turn on red movements would not be allowed to operate as a free-flow movement.
- The construction of the ramps requires substantial right of way acquisition.

It is recommended that Option 1e be eliminated from further evaluation for these reasons:

- *This option does not meet the acceptable Level of Service.*
- *Total right of way necessary to be acquired.*

Option 4a: Diverging Diamond Interchange (DDI) with 3-Lane SB On-Ramp; Add 2 WB Lanes to Existing Overpass

Option 4a (Figure I-6) proposes a diverging diamond interchange with a three lane southbound on-ramp for eastbound traffic on Benson Road. This option proposes adding onto the existing structure and converting it to a DDI. The existing structure would be the four westbound lanes.

Benefits of Option 4a:

- Fewer crashes expected compared to the other build alternatives developed. The predicted annual traffic accidents reduces 25% from the no-build option.
- Traffic Level of Service (LOS) C is worst case forecast at the interchange in the morning for the northbound ramp for year 2045 conditions.
- Cost of construction reasonable due to limited amount of grading and reduced right of way acquisition.
- Requires no additional right of way on I-229.
- Fewer impacts to wildlife habitat, wetlands, and other environmental resources due to less grading and right of way.

Drawbacks of Option 4a:

- Adding onto the existing overpass to accommodate the DDI adds cost compared to a new structure over I-229. Cost of this structure is similar but slightly lower compared to other options.
- Out of the two DDI's the construction costs for this option are the higher of the two.

It is recommended that Option 4a be carried forward for further evaluation and refinement for these reasons:

- *Expected reduction in annual total crash numbers resulting in improved safety*
- *Lower construction cost than the other options*
- *Fewer environmental impacts*

Option 4b: Diverging Diamond Interchange (DDI) with 3-Lane SB On-Ramp. Add a Separate Structure for 2 EB Lanes.

Option 4b (Figure I-7) proposes a diverging diamond interchange with a three lane southbound on-ramp for eastbound traffic on Benson Road. This option proposes constructing a new and separate structure for the future two eastbound lanes of the DDI and converting the existing structure into the four lanes for the westbound traffic.

Benefits of Option 4b:

- Least amount of crashes expected compare to other build alternatives developed. The predicted annual traffic accidents reduces 25% from the no-build option.
- Traffic Level of Service (LOS) C is worst case forecast at the interchange in the morning for the northbound ramp for year 2045 conditions.
- This option has the lowest estimated construction cost due to limited amount of grading and reduced right of way lower structure costs.
- Requires no additional right of way on I-229.
- Fewer impacts to wildlife habitat, wetlands, and other environmental resources due to less grading and right of way.
- Out of the two DDI's, using the existing structure for maintenance of traffic creates the least amount of impact.

Drawbacks of Option 4b:

- Adding the proposed structure to the north of the existing structure may require additional coordination with private utilities.

It is recommended that Option 4b be carried forward for further evaluation and refinement for these reasons:

- *Reduced number of annual total crashes; increased safety*
- *Lower construction cost than the other options*
- *Fewer environmental impacts*

The Build Options Evaluation Memo and corresponding evaluation matrix is provided in **Appendix 7**. A summary of the build option recommendations are provided in **Table 8** and **Table 9**.

Table 8 - Build Options to Carry Forward

Options recommended to be carried forward for further refinement and evaluation

Option	Interchange Description	Main reason(s) for carrying forward
4a	Diverging Diamond Interchange (DDI) with 3-Lane SB On-Ramp. Add 2 WB Lanes to Existing Overpass	• Minimal cost and impacts compared to other options • Increase in safety compared to other options • Decrease in traffic accidents compared to no-build by 25% • Less impact to environmental resources
4b	Diverging Diamond Interchange with 3-Lane SB On-Ramp. Add a Separate Structure for 2 EB Lanes	• This option is the least expensive of all the options discussed • Increase in safety in compared to other options • Decrease in traffic accidents compared to no-build by 25% • Less impact to environmental resources

It is recommended that both options be justified within the Interchange Modification Study and final bridge option will be determined during preliminary and final design.

Table 9 - Build Options to Eliminate

Options recommended to be eliminated from further evaluation

Option	Interchange Description	Main reason(s) for not carrying forward
1a	2-Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp	• Additional right of way acquisition • High construction cost
1b	2-Lane Northeast Quadrant Loop with 2-Lane SB On-Ramp	• Additional right of way acquisition • High construction cost
1c	2-Lane Collector – Distributor (CD) Lane Northeast Quadrant Loop with 3-Lane SB On-Ramp	• High construction cost • Greater impact to environmental resources
1d	2-Lane Partial Clover Leaf Northeast Quadrant Loop with 2-Lane SB On-Ramp	• This option does not meet the acceptable Level of Service • Additional right of way acquisition • High construction cost • Greater impact to environmental resources
1e	2-Lane Partial Clover Leaf Northeast Quadrant Loop with CD Lane 2-Lane and 2-SB On-Ramp	• This option does not meet the acceptable Level of Service. • High construction cost • Greater impact to environmental resources

3.5 Conceptual Signing Plan

A conceptual signing plan for each design alternative is provided in **Appendix 8**.

4.0 Funding Plan

The Benson Road Interchange project PE is programmed in the Statewide Transportation Improvement Program (STIP) for 2022 with construction in the 2023-2025 timeframe. Current SDDOT Budget Estimates for the interchange improvements are shown below.

Table 10 - Anticipated Funding Allocation

Project Number	State Funding Category	Federal Funding Category	Federal Funds ($ million)	State Funds ($ million)	Other Funds ($ million)	Total Funds ($ million)
IM 2292(98)6 P, PCN 04XK	Interstate	National Highway Performance Program (NHPP)	15.036	2.464	0	17.5
P 1200 ( ) P, PCN 06MM	Local Urban Systems	Surface Transportation Block Grant (STBG)	9.691	2.809	0	12.5
Total			24.727	5.273	0	30.000

Note: As funding is fluid, category breakdown may be different at time of project authorization.

Inflated costs to year of implementation are calculated at $34.0 million.

5.0 Recommendation

The results of this technical analysis indicate that a modified interchange configuration on I-229 at Benson Road in Sioux Falls, SD will provide future operational and safety benefits. Further, the analysis indicates that a diverging diamond interchange configuration is the recommended option and will have fewer environmental impacts than the other build interchange alternatives. The recommended diverging diamond interchange alternatives are displayed in **Figure I-6** and **Figure I-7** following the considerations and requirements for Interstate access.

The two considerations and requirements for the Interstate access are addressed below:

1. **An operational and safety analysis has concluded that the proposed change in access does not have a significant adverse impact on the safety and operation of the Interstate facility (which includes mainline lanes, existing, new, or modified ramps, and ramp intersections with crossroad) or on the local street network based on both the current and the planned future traffic projections. The analysis should, particularly in urbanized areas, include at least the first adjacent existing or proposed interchange on either side of the proposed change in access (Title 23, Code of Federal Regulations (CFR), paragraphs 625.2(a), 655.603(d) and 771.111(f)). The crossroads and the local street network, to at least the first major intersection on either side of the proposed change in access, should be included in this analysis to the extent necessary to fully evaluate the safety and operational impacts that the proposed change in access and**

other transportation improvements may have on the local street network (23 CFR 625.2(a) and 655.603(d)). Requests for a proposed change in access should include a description and assessment of the impacts and ability of the proposed changes to safely and efficiently collect, distribute, and accommodate traffic on the Interstate facility, ramps, intersection of ramps with crossroad, and local street network (23 CFR 625.2(a) and 655.603(d)). Each request should also include a conceptual plan of the type and location of the signs proposed to support each design alternative (23 U.S.C. 109(d) and 23 CFR 655.603(d)).

The operational and safety analysis contained in this study shows that the proposed Diverging Diamond build scenarios are not expected to adversely affect the safety or efficiency of the Interstate system, including the mainline lanes, modified ramps, ramp intersections with the crossroad, and local street network based upon the current and future traffic projections. The Build and No-build scenarios were evaluated for operational capacity using Highway Capacity Manual 2010 techniques via HCS 2010. All Build scenarios maintain a LOS "C" or better for all Interstate facilities for the build year (2023) and future year (2045) forecast traffic volumes. Additionally, a predictive safety analysis was completed for the Build and No-build scenarios using the AASHTO HSM method, including the NCHRP Report 17-45 method for evaluating freeways and interchanges via the IHSDM version 13.1.0 software. The recommended diverging diamond interchange configuration is likely to exhibit significantly less overall crash frequencies than the existing diamond interchange.

All recommended build alternatives are also expected to improve access management and satisfactorily accommodate design year traffic volumes on the crossroad in the vicinity of the interchange. The crossroad in the vicinity of the interchange (Benson Road) was also evaluated for operational capacity and maintains a minimum LOS "C" at the interchange ramp terminals and meets minimum LOS thresholds as established by the local jurisdiction for signalized intersections on arterial streets under 2045 forecast traffic volumes. Access management on the arterial corridor will be achieved with the installation of a median and limiting left turns to specific street intersections.

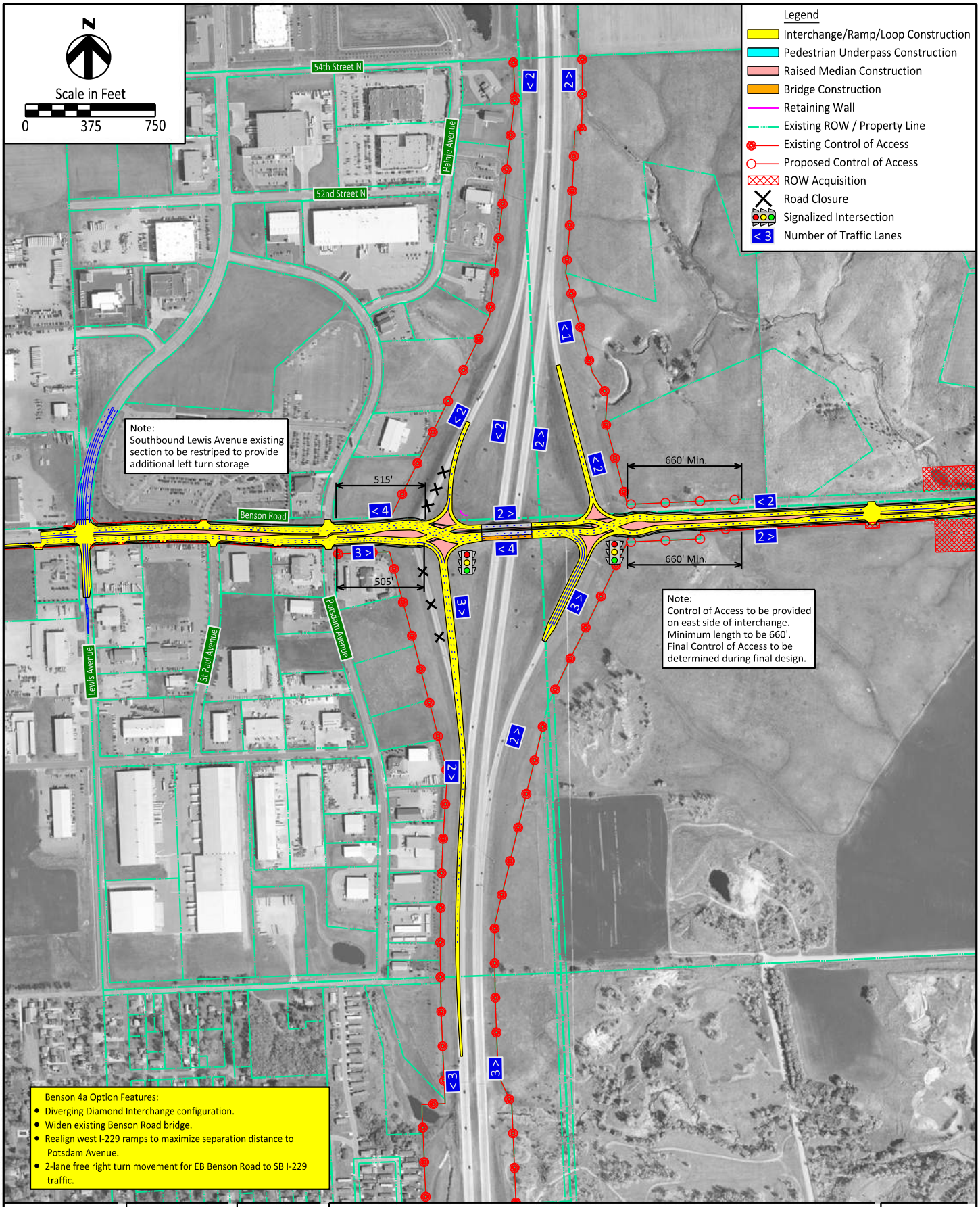
The study area included the interchanges north and south of the Benson Road interchange and extends from Exit 7(Rice Street) to Exit 10 (I-90) on I-229. The adjacent interchange ramps and Interstate segments were analyzed under 2023 and 2045 traffic forecast volumes and are expected to operate at LOS "C" or better.

The conceptual signing plan for the recommended Diverging Diamond alternative is displayed following the considerations and requirements for Interstate access section of this report. A conceptual signing plan has been developed and included in Section 8 of the Appendix for each additional design alternative.

2. **The proposed access connects to a public road only and will provide for all traffic movements. Less than "full interchanges" may be considered on a case-by-case basis for applications requiring special access, such as managed lanes (e.g., transit or high occupancy vehicle and high occupancy toll lanes) or park and ride lots. The proposed access will be designed to meet or exceed current standards (23 CFR 625.2(a), 625.4(a)(2), and 655.603(d)). In rare instances where all basic movements are not provided by the proposed design, the report should include a full-interchange option with a comparison of the operational and safety analyses to the partial-interchange option. The report should also include the mitigation proposed to compensate for the missing movements, including wayfinding signage, impacts on local intersections, mitigation of driver expectation leading to wrong-way movements on ramps, etc. The**

report should describe whether future provision of a full interchange is precluded by the proposed design.

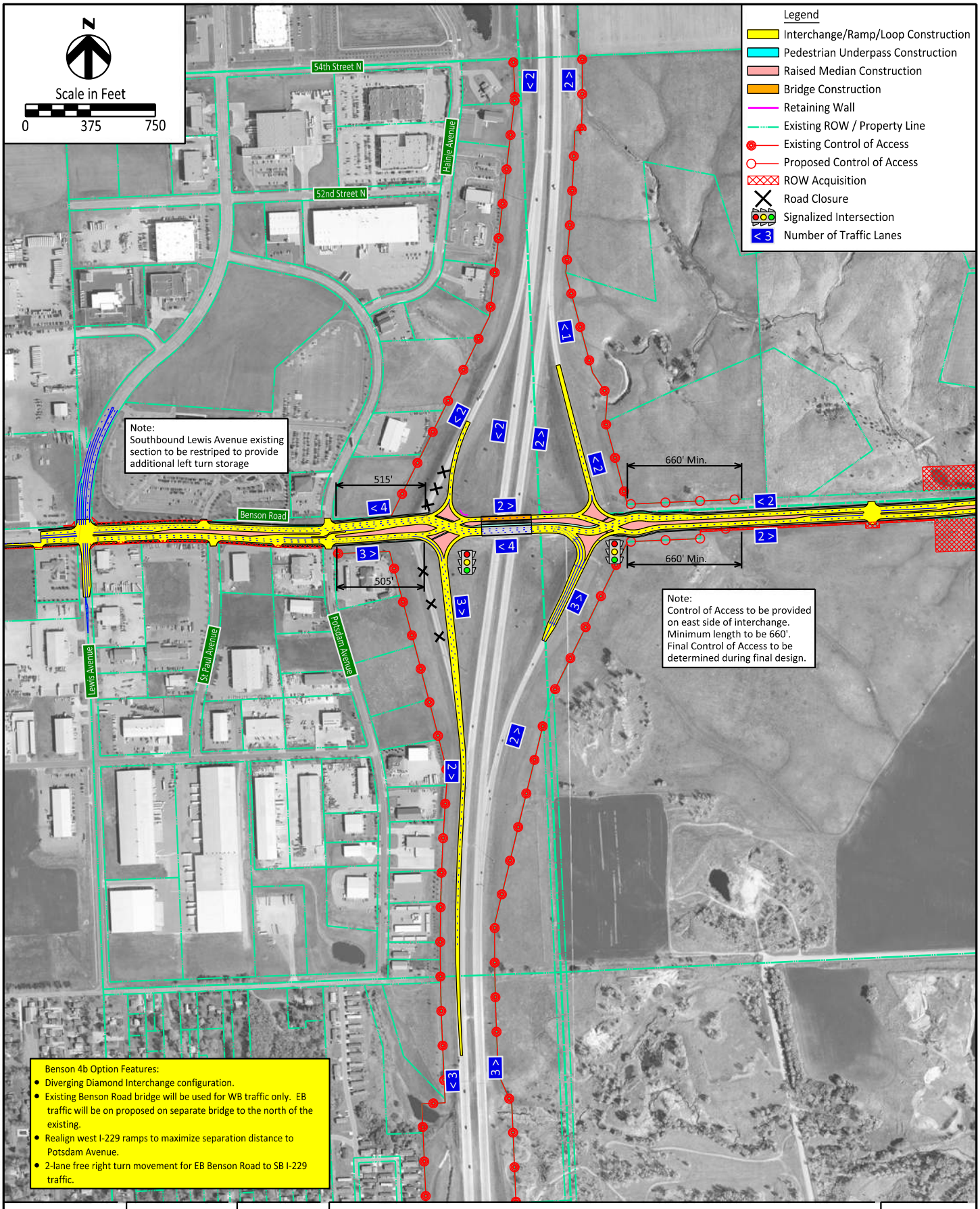
The proposed access is a reconfiguration of an existing interchange with full access to an arterial city street and includes all movements. The proposed change does not result in any new access points on the Interstate Highway System The conceptual drawings have been prepared using current standards and further design using current standards is anticipated. Additional refinement will take place during the environmental and design phases of the project.



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 12/4/2018

Alternative Scenario 4a
Diverging Diamond Interchange with 3-Lane SB On-Ramp
Add 2 WB Lanes to Existing Overpass.
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

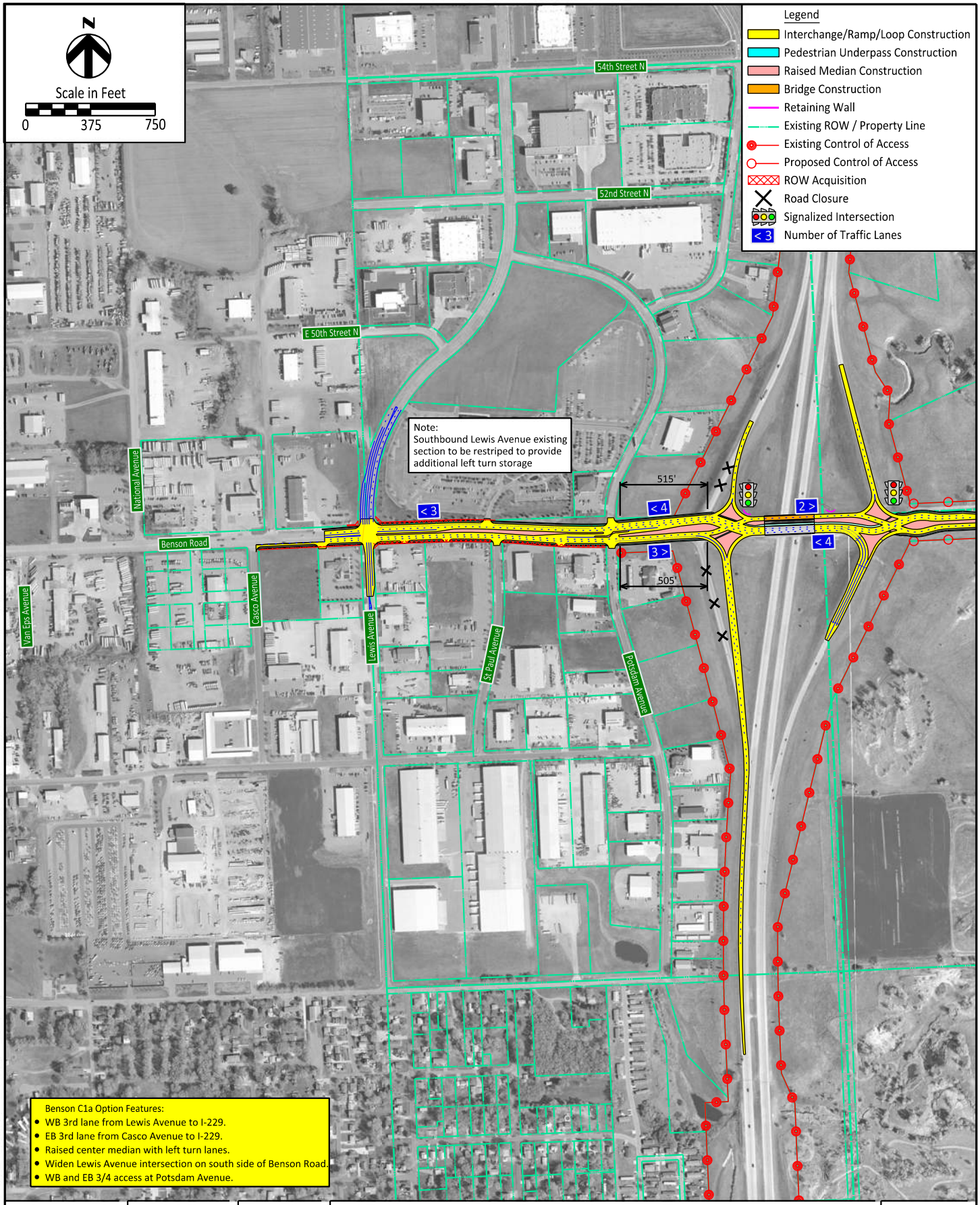
Figure
I-6



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 12/4/2018

Alternative Scenario 4b
Diverging Diamond Interchange with 3-Lane SB On-Ramp
Add a Separate Structure for 2 EB Lanes
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

Figure
I-7



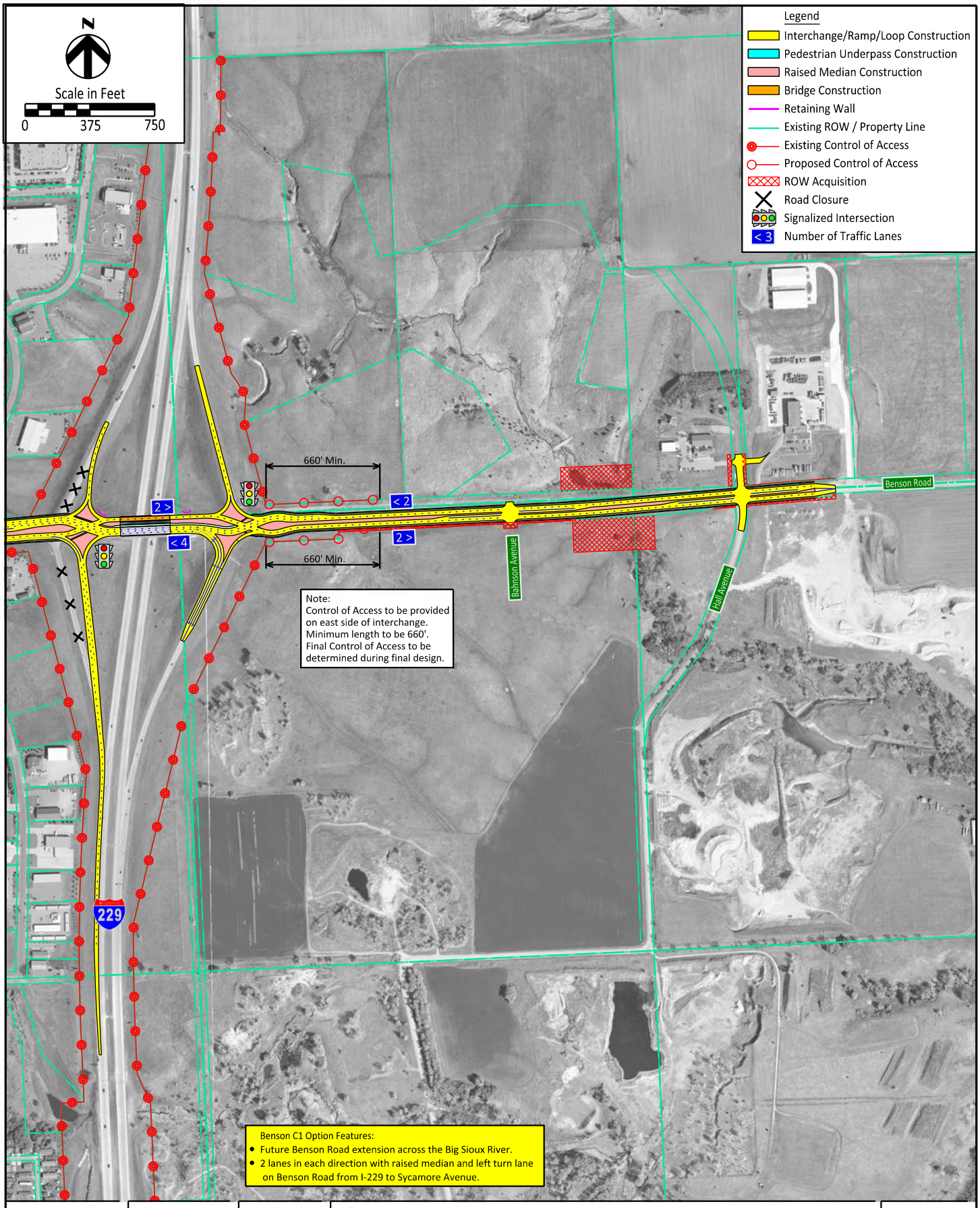
Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 10/8/2018

Alternative Scenario Benson Road
Westbound 3rd Lane from Lewis Avenue to I-229

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
A-1



Drawn By: B.Miller
Date: 5/14/2018
Chked By: P.Sanow
Date: 5/14/2018
Revision: 12/4/2018

Alternative Scenario Benson Road
4-Lane Divided Section to Hall Avenue east of I-229

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
A-2

Legend

- Interchange/Ramp/Loop Construction
- Pedestrian Underpass Construction
- Raised Median Construction
- Bridge Construction
- Road Closure
- Signalized Intersection

N

Scale in Feet

0 200 400

St Paul Avenue

Benson Road

Potsdam Avenue

52nd Street N

54th Street N

Hainje Avenue

RIGHT LANE MUST TURN RIGHT

RIGHT LANE MUST TURN RIGHT

ONLY

ONLY

ONLY

SOUTH

229

SOUTH

229

NORTH

229

NORTH

229

EXIT 9

EXIT 9

West Benson Road

North Lewis Ave

North Potsdam Ave

East Benson Road

229

The existing ½ mile and 1 mile advance guide signs for I-229 SB Exit 9 to remain.

Drawn By: B.Miller
Date: 7/27/2018
Chked By: P.Sanow
Date: 7/27/2018
Revision: 11/15/2018

Alternative Scenario 4a
Diverging Diamond Interchange with 3-Lane SB On-Ramp. Add 2 WB Lanes to Existing Overpass.
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

Figure
S-I-6

Legend

- Interchange/Ramp/Loop Construction
- Pedestrian Underpass Construction
- Raised Median Construction
- Bridge Construction
- Road Closure
- Signalized Intersection

N

Scale in Feet
0 200 400

St Paul Avenue
Benson Road
Potsdam Avenue
52nd Street N
54th Street N
Hainje Avenue

RIGHT LANE MUST TURN RIGHT

RIGHT LANE MUST TURN RIGHT

ONLY

ONLY

ONLY

SOUTH
INTERSTATE
229

SOUTH
INTERSTATE
229

EXIT 9

EXIT 9

NORTH
INTERSTATE
229

NORTH
INTERSTATE
229

INTERSTATE
229

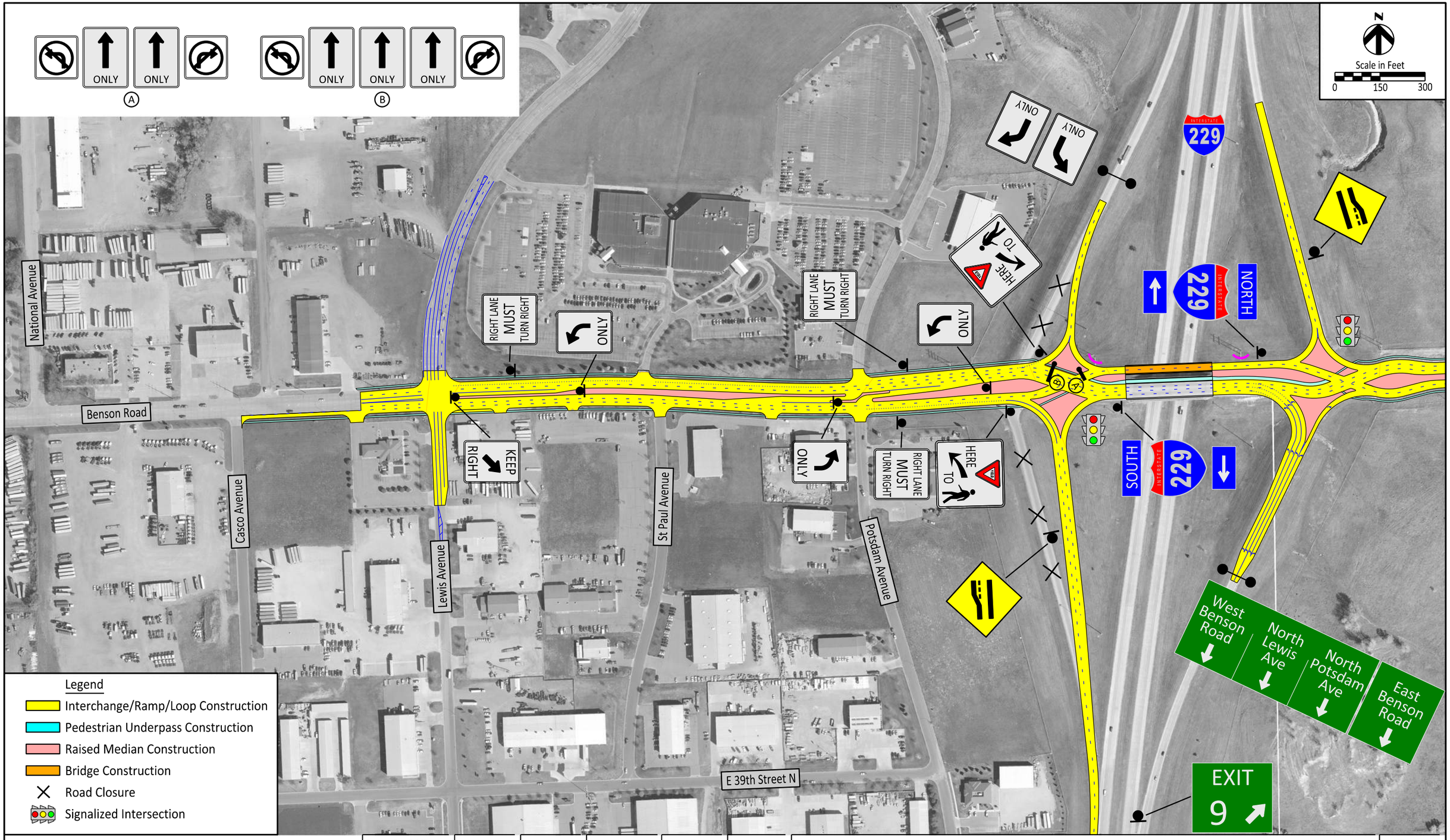
West Benson Road
North Lewis Ave
North Potsdam Ave
East Benson Road

The existing ½ mile and 1 mile advance guide signs for I-229 SB Exit 9 to remain.

Drawn By: B.Miller
Date: 7/30/2018
Chked By: P.Sanow
Date: 7/30/2018
Revision: 11/15/2018

Alternative Scenario 4b
Diverging Diamond Interchange with 3-Lane SB On-Ramp. Add a Separate Structure for 2 EB Lanes.
I-229 Exit 9 (Benson Road) IMJR
Sioux Falls, SD

Figure
S-I-7



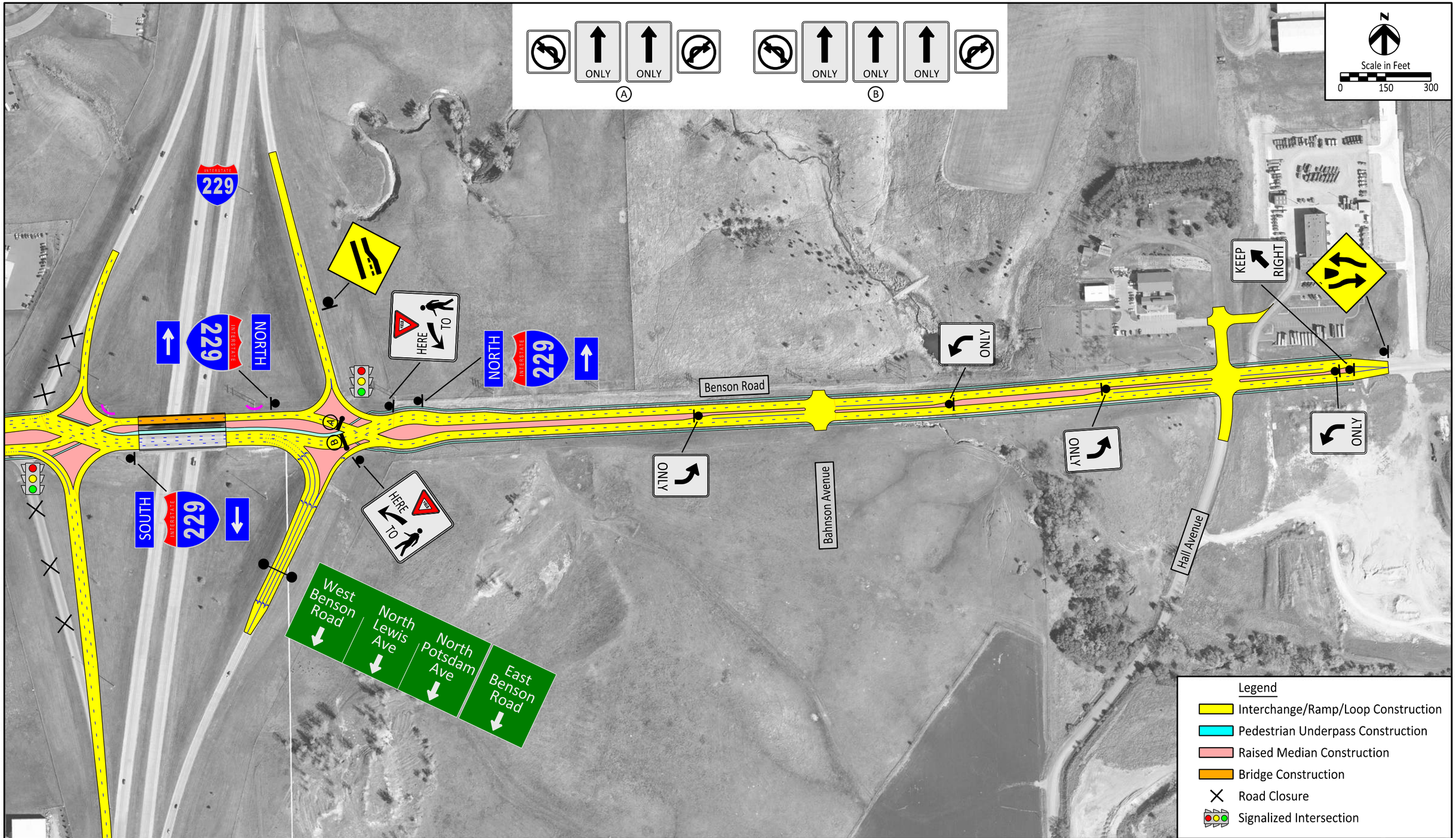
Drawn By: B.Miller
Date: 7/30/2018
Chked By: P.Sanow
Date: 7/30/2018
Revision: 11/15/2018

Alternative Scenario Benson Road
Westbound 3rd Lane from Lewis Avenue to I-229.

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
S-A-1



Drawn By: B.Miller
Date: 7/30/2018
Chked By: P.Sanow
Date: 7/30/2018
Revision: 10/8/2018

Alternative Scenario Benson Road
4-Lane Divided Section to Hall Avenue east of I-229.

I-229 Exit 9 (Benson Road) IMJR

Sioux Falls, SD

Figure
S-A-2

APPENDIX

1 - Purpose and Need

2 - Methods and Assumptions Document

3 – Technical Memo - Existing Traffic Conditions

4 – Technical Memo - Existing Conditions Crash Analysis

5 – Technical Memo - Future Traffic Conditions

6 – Technical Memo - Predictive Crash Analysis

7 – Technical Memo - Interchange Options Evaluation

8 - Conceptual Signing Plans

Appendices are available upon request, but have been removed from the web version to maintain a reasonable file size for downloading.