Stantec

Memo

To:	File	From:	Dale Grove
			6188 Rome Circle NW Rochester, MN 55901
File:	I-90 Roadway Segment Safety Analysis - MRM 38.0 to MRM 39.3	Date:	February 23, 2018

Reference: I-90 Roadway Segment Safety Analysis - MRM 38.0 to MRM 38.7

DIAGNOSIS & CONTRIBUTING FACTORS

The purpose of this memo is to identify safety issues, suggest contributing factors, and propose countermeasures to improve safety for a curved segment of I-90 between reference mile-points 38.0 and 38.7. Geometric features of the 0.7-mile roadway segment include a horizontal curve with a length of 932.48 feet in the eastbound direction and 1023.22 feet in the westbound direction. Additional geometric data is summarized in **Appendix A**. **Figure 1** shows the location of focus area.

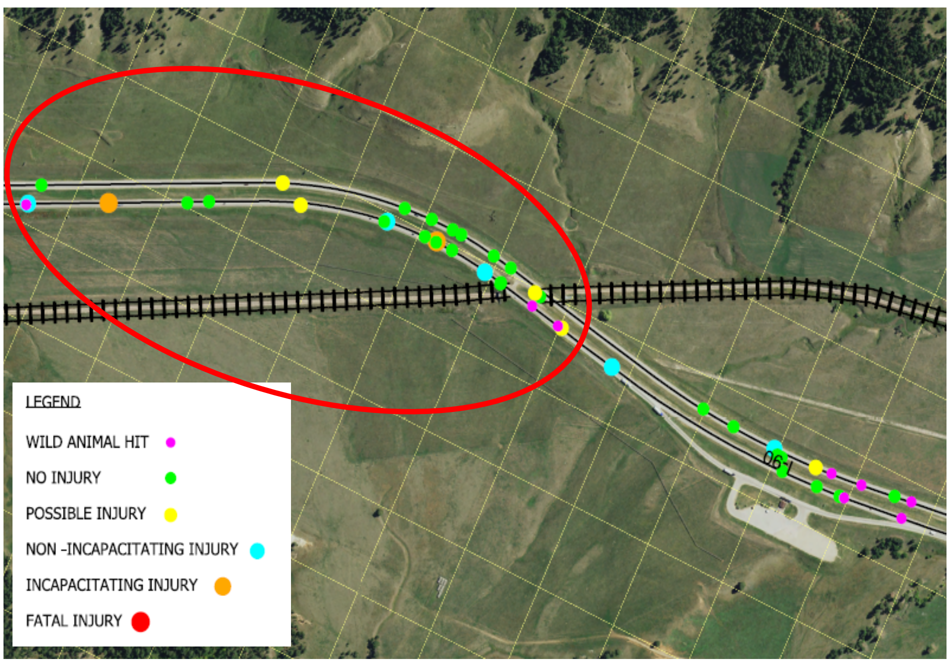


Figure 1 – Study Area Map

Thirty-four (34) crashes were recorded from 2012-2017 with the predominant crash type being run-off the road (ROR) crashes (74%, 25 crashes). Although the curve ranked second in the list of crash hot spots in terms of crash frequency (as identified in the Crash Analysis memo), it ranked first in terms of crash severity with two (2) incapacitating injuries and five (5) non-incapacitating injuries. When compared to segments of similar length within the corridor, it consists of the highest proportion of single vehicle crashes. Table 1 shows that the frequency of ROR crashes per year is consistent during the analysis period, except for 2016 in which none occurred. The study segment was determined to have a crash rate of 151, the highest among I-90 segments of similar length and exceeding the statewide average crash rate of 129 for rural interstates.

Table 1 – ROR Crashes by Year by Direction (2012-2017)

Location	ROR Crashes by Year					
	2012	2013	2014	2015	2016	2017
EB I-90 - MRM 38.0 to MRM 38.7	2	5	2	2	0	1
WB I-90 - MRM 38.0 to MRM 38.7	4	0	1	3	0	5

Contributing factors to ROR crashes typically include: inadequate lane width, slippery pavement, inadequate median width, poor delineation, and excessive speed. Of the thirty (25) recorded ROR crashes, eighteen (18) cases involved excessive speeds. While most ROR crashes did not involve a collision with a fixed object, ten (10) incidents involved cases where the vehicles overturned resulting in severe injuries to occupants. Weather related crashes accounted for sixty percent (60%) of ROR crashes along the curve segment. Due to the consistency of ROR and overturning crashes along this segment, countermeasures to reduce crash frequency and severity seem to be warranted.

COUNTERMEASURES

Highway safety could be improved by deploying countermeasures that reduce the severity of ROR crashes, or inform motorists of adverse weather conditions. Countermeasures include:

- Improved Roadside Design - installation of cable barrier, proper grading of roadside embankments, improved roadway wearing surface, and installation of curve warning signs.
- Intelligent Transportation Systems (ITS) - Installation of Road Weather Management Systems

Roadside Design

Higher performance guardrail is recommended due to the horizontal curvature and crash history of the roadway segment. Installation would adhere to guidelines outlined in the AASHTO Roadside Design Guide Figures 5-1a to 5-3b and SDDOT RDM Chapter 10. An average median width of 80 feet in the study area, combined with an ADT of 17,570, suggests that median barriers are considered optional according to the AASHTO Roadside Design Guide Figure 6-1 or SDDOT Figure 10-7. While ROR crashes consistently occurred along the study segment, only two cross median crashes occurred within the 5-year period being investigated. Typically, this suggests that median barrier may not be necessary. Additionally, there is not a significant elevation difference between the eastbound and westbound directions of I-90 to justify a special circumstance. However, SDDOT should continue to monitor the occurrence of cross median crashes in this section of roadway to determine whether median barrier would be justified in the future.

While curve geometrics meet requirements for the posted speed of 75 mph, it does not for 80 mph although it is recommended that horizontal curves are designed for the posted speed plus 5 mph to reflect possible operating speeds. As reflected in the crash history, it is possible that horizontal curvature may be difficult to perceive due to its proximity to the high point of the vertical curvature. Due to the combination of adverse factors at the curve, it is recommended that SDDOT explore additional countermeasures for mitigating crashes within the focus area. A recent improvement was made to I-90 in 2017 when a high friction wearing course was applied to the eastbound lanes. It is not yet possible to determine the effects of the treatment.

ITS (Road Weather Management Systems)

Road Weather Management systems improve safety along roadways by actively mitigating the impacts of adverse weather conditions. They typically fall into the following three categories:

- Advisory Strategies – Provide information on prevailing weather conditions to the motorist using Dynamic Messaging Signs.
- Control Strategies – Monitors pavement conditions and alters traffic flow using variable speed limits or other control strategies.
- Treatment Strategies – Applies treatments to roads such as salt or anti-icing chemicals to minimize weather impacts.

Current ITS infrastructure along the I-90 corridor includes SDDOT's Maintenance Decision Support System (which routinely collects data within the project limits), dynamic message signs (DMS) located in both directions from Exits 32 to 34, and road closure gates located at the Sturgis exits. The use of dynamic advisory speed signs is currently being investigated along I-90 from Exit-37 to 2-miles south of Tilford. There are currently no environmental sensor stations for monitoring roadway conditions within the analysis area. Some potential drawbacks of the existing systems are summarized in Table 2.

Table 2 – Limitations of Existing ITS Infrastructure

ITS System	Drawbacks
Road Closure Gates	• Not fully automated • Restricts access to local traffic
Maintenance Decision Support System (MDSS)	• No 24/7 operation • Limited coverage area • Mainly used as a maintenance tool
Dynamic Advisory Speed Signs	• Costly implementation
Traveler Information Systems (DMS)	• Limited by scope of MDSS system • Inconsistent coverage

Another possible ITS advisory strategy for reducing the number of ROR crashes at the focus area is outlined in the sections that follow.

Advisory Strategy – SDDOT Adverse Weather Warning System

This option would utilize a combination of environmental sensor stations to detect icy/snowy roadway conditions and warning signs with flashing beacons or traveler information systems (DMS) to provide a real-time alert to motorists when slippery conditions are either possible or present. The intended outcome would be for motorists to reduce speeds during adverse weather conditions, leading to a reduction in the number of crashes. An example schematic of the warning system is provided in Appendix B. A similar strategy was implemented by the California Department of Transportation (Caltrans), on a five-mile segment of State Highway 36, which reduced annual crashes by eighteen percent (18%) with an estimated safety benefit of $1.7 million dollars[1].

[1] FHWA, Best Practices for Road Weather Management, 2012

Reference: I-90 Roadway Segment Safety Analysis: - MRM 38.0 to MRM 38.7

System Components & Operations

The system would consist of in-roadway sensors, warning signs with flashing beacons or DMS, and a Road Weather Information System (RWIS). The sensors would detect pavement data such as temperature and condition (icy, wet). The remote processing unit component of the RWIS continuously evaluates the condition of the pavement sensors to determine whether to send a signal for activation of the flashing warning signs or DMS. The system could eventually be expanded to integrate with SDDOT's proposed dynamic advisory speed signs. Installed environmental sensors as part of the curve warning system could be used to feed pavement condition data to the future proposed variable speed limit system. The curve warning system could complement the dynamic advisory speed signs to prevent crashes.

Placement

The sensors would be placed at the beginning or midpoint of the curve, whereas the flashing warning sign and DMS screen would be placed in advance of the curve to give motorists sufficient time to adjust their speed.

Possible Implementation Issues

Due to the rural nature of I-90 in this area, a fixed power supply may not be available. As a result, the field equipment would need to operate on solar power. Additionally, system monitoring and communications between components may need to be done utilizing wireless technology due to the possibly prohibitive cost of trenching cables.

Monitoring

The system would need to be periodically monitored using speed and crash reductions as performance measures. Crash reduction could be assessed through observational before-after studies.

STANTEC CONSULTING SERVICES INC.

Dale Grove
Principal/Project Manager

Phone: (507) 529-6039
Dale.Grove@stantec.com

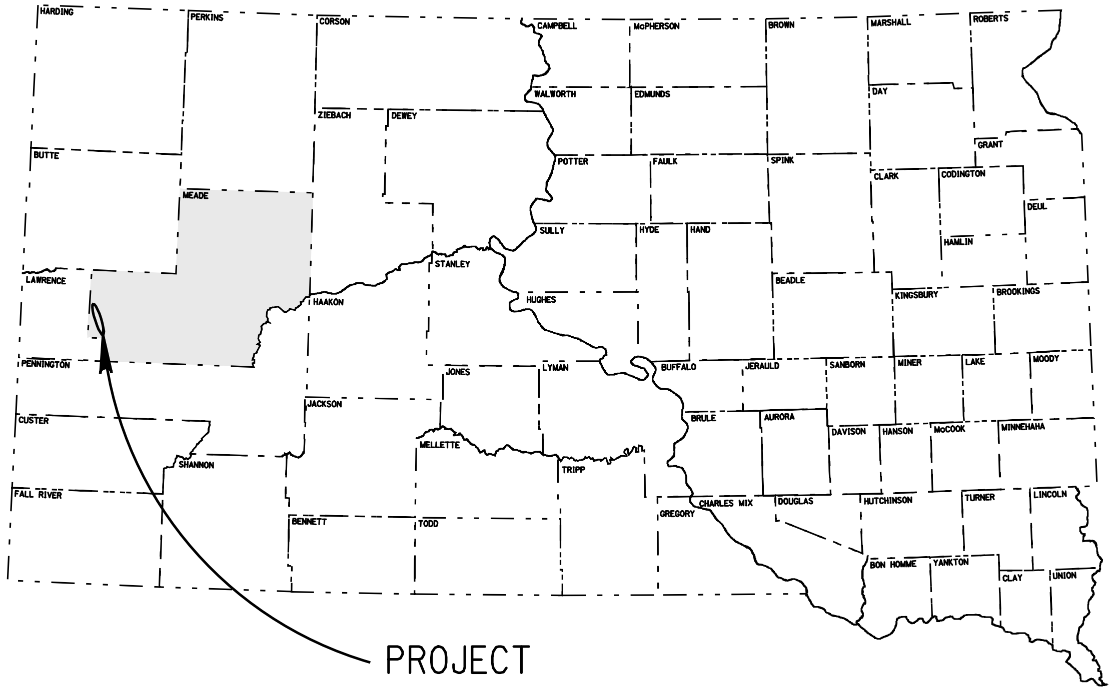
Attachment: Appendix A – Geometric Data
Appendix B – ITS Solution

cc. Aaron M. Cook

APPENDIX A – CURVE GEOMETRICS

STATE OF SOUTH DAKOTA	PROJECT	SHEET	TOTAL SHEETS
	IM 0901(120)33	1	319

Plotting Date: 27-NOV-2007



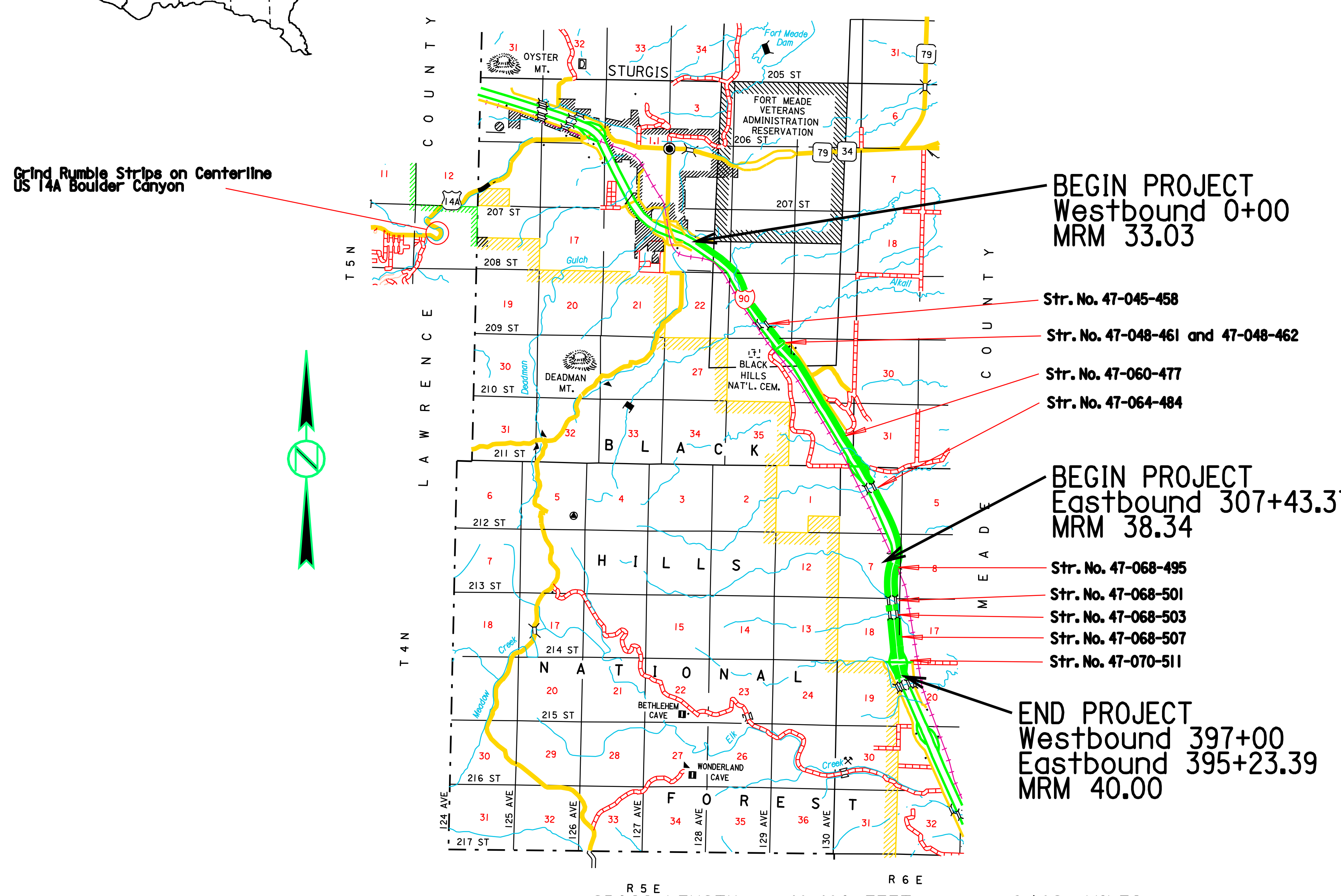
STATE OF SOUTH DAKOTA
DEPARTMENT OF TRANSPORTATION
PLANS FOR PROPOSED

PROJECT IM 0901(120)33
INTERSTATE 90
MEADE COUNTY

PCCP, Grading, Multiplate Extension,
Reinforced Concrete Box Culvert Extensions & R.O.W.

PCN 6180

INDEX OF SECTIONS



SCALES

		RURAL	SUBURBAN	URBAN
PLAN		1"=200'	1"=100'	1"=40'
PROFILE,	HORIZONTAL:	1"=200'	1"=100'	1"=40'
	VERTICAL:	1"=20'	1"=20'	1"=10'
CROSS SECTIONS	HORIZONTAL:	1"=40'	1"=20'	1"=20'
	VERTICAL:	1"=20'	1"=10'	1"=10'

DESIGN DESIGNATION

ADT (2004)	17075
ADT (2024)	27475
DHV	3900
D	50%
T DHV	6.6%
T ADT	14.4%
V	70 mph

STORM WATER PERMIT

Major Stream: Alkali Creek & Pleasant Valley Creek
Area Disturbed: 89.7 Acres
Project Area: 168.8 Acres

GROSS LENGTH	48,480 FEET	9.182 MILES
LENGTH OF EXCEPTIONS	119 FEET	0.023 MILES
NET LENGTH	48,361 FEET	9.159 MILES

5

STATE OF SOUTH DAKOTA	PROJECT	SHEET	TOTAL SHEETS
	IM 0901(120)33	B18	B69

HORIZONTAL ALIGNMENT DATA

MAINLINE WEST BOUND LANE

Type	Station			Northing	Easting
POB	0+00.00			223586.822	1054604.083
		TL= 2334.38	S 53°41'56" E		
PC	23+34.38			222204.807	1056485.400
PI	33+20	R = 2851.00	Delta = 38°09'43" R	221620.958	1057280.186
PT	42+33.29			220670.810	1057544.348
		TL= 564.06	S 15°32'14" E		
PC	47+97.35			220127.366	1057695.437
PI	57+46.98	R = 5709.64	Delta = 18°53'10" L	219212.438	1057949.807
PT	66+79.38			218429.103	1058486.633
		TL= 1030.60	S 34°25'23" E		
PC	77+09.97			217578.980	1059069.229
PI	81+48.35	R = 11372.77	Delta = 4°24'54" L	217217.365	1059317.047
PT	85+86.30			216875.900	1059591.965
		TL= 3395.65	S 38°50'17" E		
PC	119+81.95			214230.959	1061721.449
PI	124+46.26	R = 5865.25	Delta = 09°03'09" R	213869.298	1062012.628
PT	129+08.64			213466.326	1062243.277
		TL= 10302.63	S 29°47'08" E		
PC	232+11.27			204524.767	1067361.162
PI	239+91.14	R = 11688.66	Delta = 07°38'03" R	203847.927	1067748.566
PT	247+68.70			203125.620	1068042.618
		TL= 4044.00	S 22°09'05" E		
PC	288+12.70			199380.103	1069567.423
PI	296+54.28	R = 2659.32	Delta = 35°07'18" R	198600.635	1069884.746
PT	304+42.83			197780.523	1069695.867
		TL= 1023.22	S 12°58'13" W		
PC	314+66.05			196783.405	1069466.199
PI	322+37.66	R = 5070.83	Delta = 17°18'15" L	196031.479	1069293.015
PT	329+97.53			195262.074	1069351.327
		TL= 3276.97	S 04°20'03" E		
PC	362+47.50			191994.473	1069598.972
PI	368+37.02	R = 48685.31	Delta = 01°19'26" R	191433.557	1069641.483
PT	373+99.50			190871.808	1069671.022
		TL= 210.87	S 03°00'36" E		
PC	376+10.37			190661.228	1069682.095
PI	382+65.28	R = 56940.14	Delta = 01°19'05" L	190007.219	1069716.486
PT	389+20.14			189354.174	1069765.910
		TL= 92.71	S 04°19'41" E		
PC	390+12.84			189261.733	1069772.906
PI	399+40.83	R = 5662.15	Delta = 18°36'55" L	188336.387	1069842.238
PT	408+52.47			187481.807	1070204.690
		TL= 4147.33	S 22°56'36" E		
POE	449+99.80			183662.574	1071821.408

MAINLINE EAST BOUND LANE

Type	Station			Northing	Easting
POB	0+00.00			223519.054	1054554.228
		TL= 1593.94	S 53°41'08" E		
PC	15+93.94			222575.095	1055838.591
PI	21+30.56	R = 2341.38	Delta = 25°49'03" R	222257.299	1056270.989
PT	26+48.96			221782.911	1056521.827
		TL= 2687.50	S 27°52'05" E		
PC	53+36.47			219407.088	1057778.069
PI	58+07.25	R = 8120.56	Delta = 06°38'09" L	218990.904	1057998.131
PT	62+76.98			218602.939	1058264.812
		TL= 1336.09	S 34°30'15" E		
PC	76+13.07			217501.884	1059021.661
PI	80+40.60	R = 11309.44	Delta = 04°19'47" L	217149.564	1059263.841
PT	84+67.72			216816.534	1059531.928
		TL= 3481.22	S 38°50'02" E		
PC	119+48.94			214104.777	1061714.877
PI	124+03.27	R = 5741.37	Delta = 09°02'56" R	213750.871	1061999.769
PT	128+55.70			213356.562	1062225.453
		TL= 8857.21	S 29°47'05" E		
PC	228+12.91			204714.731	1067171.641
PI	235+93.13	R = 11684.46	Delta = 07°38'26" R	204037.580	1067559.212
PT	243+71.04			203314.911	1067853.310
		TL= 4293.42	S 22°08'40" E		
PC	286+64.47			199338.185	1069471.684
PI	294+71.06	R = 2549.47	Delta = 35°06'45" R	198591.085	1069775.725
PT	302+26.85			197805.060	1069594.717
		TL= 932.48	S 12°58'05" W		
PC	311+59.33			196896.366	1069385.461
PI	320+35.96	R = 5761.70	Delta = 17°18'08" L	196042.094	1069188.737
PT	328+99.25			195167.969	1069254.985
		TL= 5925.06	S 04°20'03" E		
PC	388+24.31			189259.855	1069702.750
PI	397+67.21	R = 5750.12	Delta = 18°37'30" L	188319.651	1069774.006
PT	406+93.47			187451.443	1070141.805
		TL= 4133.35	S 22°57'32" E		
POE	448+26.82			183645.517	1071754.108

The coordinates shown on this sheet are based on the South Dakota State Plane Coordinate System. North Zone (NAD 83/96) SF = 0.99987445

CONTROL DATA

STATE OF SOUTH DAKOTA	PROJECT	SHEET	TOTAL SHEETS
	IM 0901(120)33	B19	B69

HORIZONTAL AND VERTICAL CONTROL POINTS

POINT	STATION	OFFSET	DESCRIPTION	NORTHING	EASTING	ELEVATION
CP 100	305+96.62	79.48' L	Harn I90-038.6	197612.8134	1069738.7857	3712.73
CP 19	439+65.29	109.64' L	USGS Bench Notes MRM I90-41.13	184657.9802	1071519.1056	3570.72
CP 20	394+75.27	34.13' R	Rebar And Cap Median Ditch Block S. STR. MRM 40.32	188797.2142	1069792.8748	3618.79
CP 21	394+39.74	163.98' L	USGS Bench Notes MRM I90-40.31	188862.3220	1069983.2484	3613.99
CP 22	385+83.19	37.87' R	BM #12 Notes Rebar and Cap Median Ditch N of STR. MRM 40.153	189687.5939	1069703.6979	3620.09
CP 23	342+37.97	79.28' L	USGS Bench Notes MRM I90-39.29	194031.1702	1069524.1257	3638.05
CP 27	292+63.22	113.17' L	USGS Bench Notes MRM I90-38.3	198974.8578	1069811.7284	3704.47
CP 28	237+78.70	112.46' L	USGS Bench Notes MRM I90-37.35	204076.7173	1067731.1713	3637.04
CP 30	214+27.22	69.06' L	Rebar and Cap Notes BM# 8 MRM 36.90 W of On Ramp Exit 37	206107.43	1066534.8650	3647.06
CP 31	211+55.44	112.40' L	MRM I90-36.80 E of WBL Exit 37 On Ramp R/W Feonce	206364.8328	1066437.4680	3648.02
CP 32	191+22.12	111.72' L	USGS Bench Notes MRM I90-36.45	208129.1992	1065426.8211	3669.88
CP 33	142+62.96	110.97' L	USGS Bench Notes MRM I90- 35.54	212346.0470	1063012.3500	3652.13
CP 37	91+59.01	104.70' L	USGS Bench Notes MRM I90-34.6 WB On Ramp R/W Fence	216495.4669	1060032.6732	3615.36
CP 39	45+15.61	36.65' R	BM #3 Rebar and Cap W of WBL & 3 Cable Median MRM 33.70	220388.9926	1057584.6628	3642.16
CP 40	42+15.12	70.29' L	USGS Bench Notes MRM I90-33.65 E of WBL Toe of Back Slope	220707.5541	1057607.0238	3636.27
CP 42	37+82.33	71.21' R	BM #4 Rebar and Cap W 50ft of WBL SH. & # Cable Median MRM 33.50	221064.3086	1057325.0183	3619.13

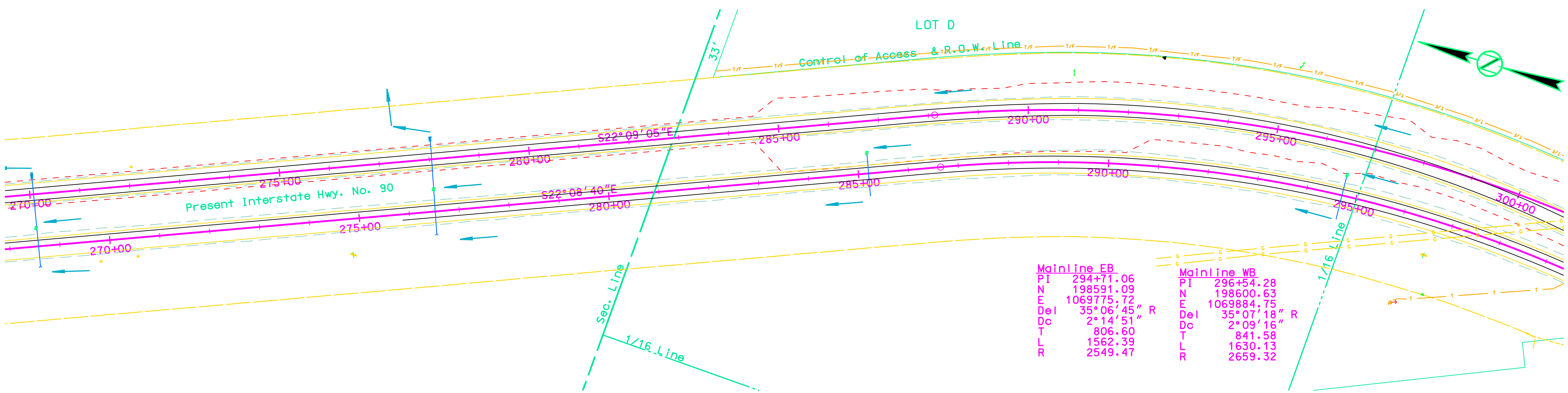
The coordinates shown on this sheet are based on the South Dakota State Plane Coordinate System.
North Zone (NAD 83/96) SF = 0.99987445

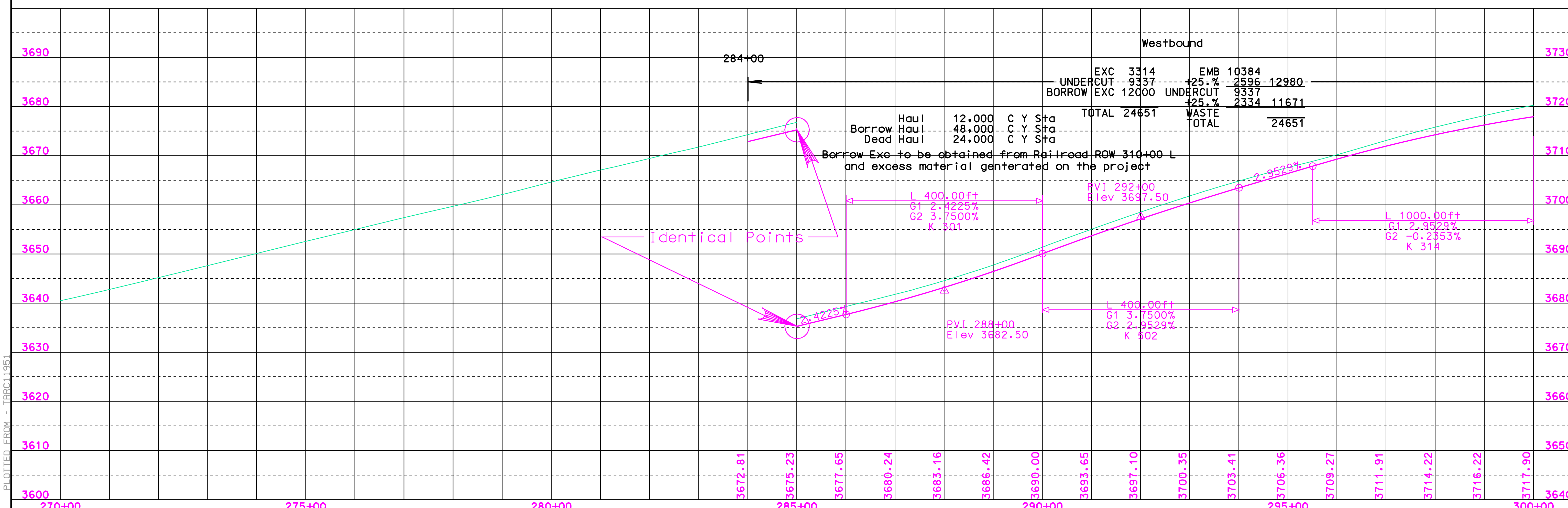
STATE OF SOUTH DAKOTA	PROJECT	SHEET	TOTAL SHEETS
	IM 0901(120)33	B28	B69

Plotting Date: 19-NOV-2007

270+07 (Westbound)
Retain 18"- 166' RCP
Remove for Reset 1 Flared End
Install 18"- 10' RCP
& Reset 1 Flared End

278+05 (Westbound)
Retain 24"- 174' RCP
Remove 1 Flared End
Install 24"- 6' RCP
& Install 1 Sloped End





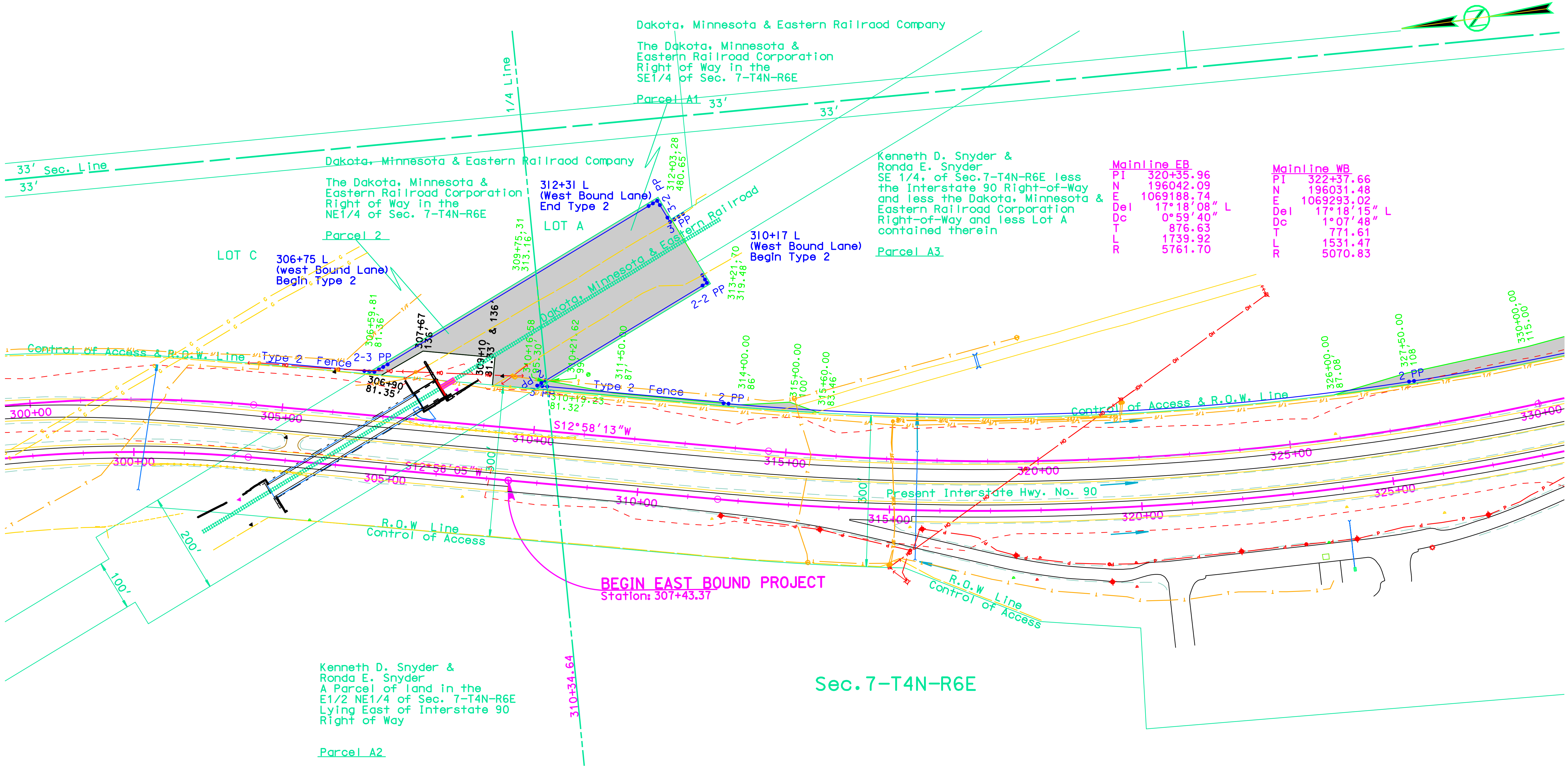
STATE OF SOUTH DAKOTA	PROJECT	SHEET	TOTAL SHEETS
	IM 0901(120)33	B29	B69

Plotting Date: 27-NOV-2007 Revised 2-09-2007 RAT

302+40 (Westbound)
Retain 18" RCP
Remove for Reset 1 Flared End
Install 18"- 18' RCP
& Reset 1 Flared End

307+17.93 (Westbound)
Extend Long Span Structural
Plate High Profile Arch
(See Section E)

317+61 (Westbound)
Retain 30"- 202' RCP
Remove for Reset 1 Flared End
Install 30"- 40' RCP
& Reset 1 Flared End



Parcel 2
306+59.81 to 310+16.58 L
Temporary easement for
Fill containing
0.7, more or less

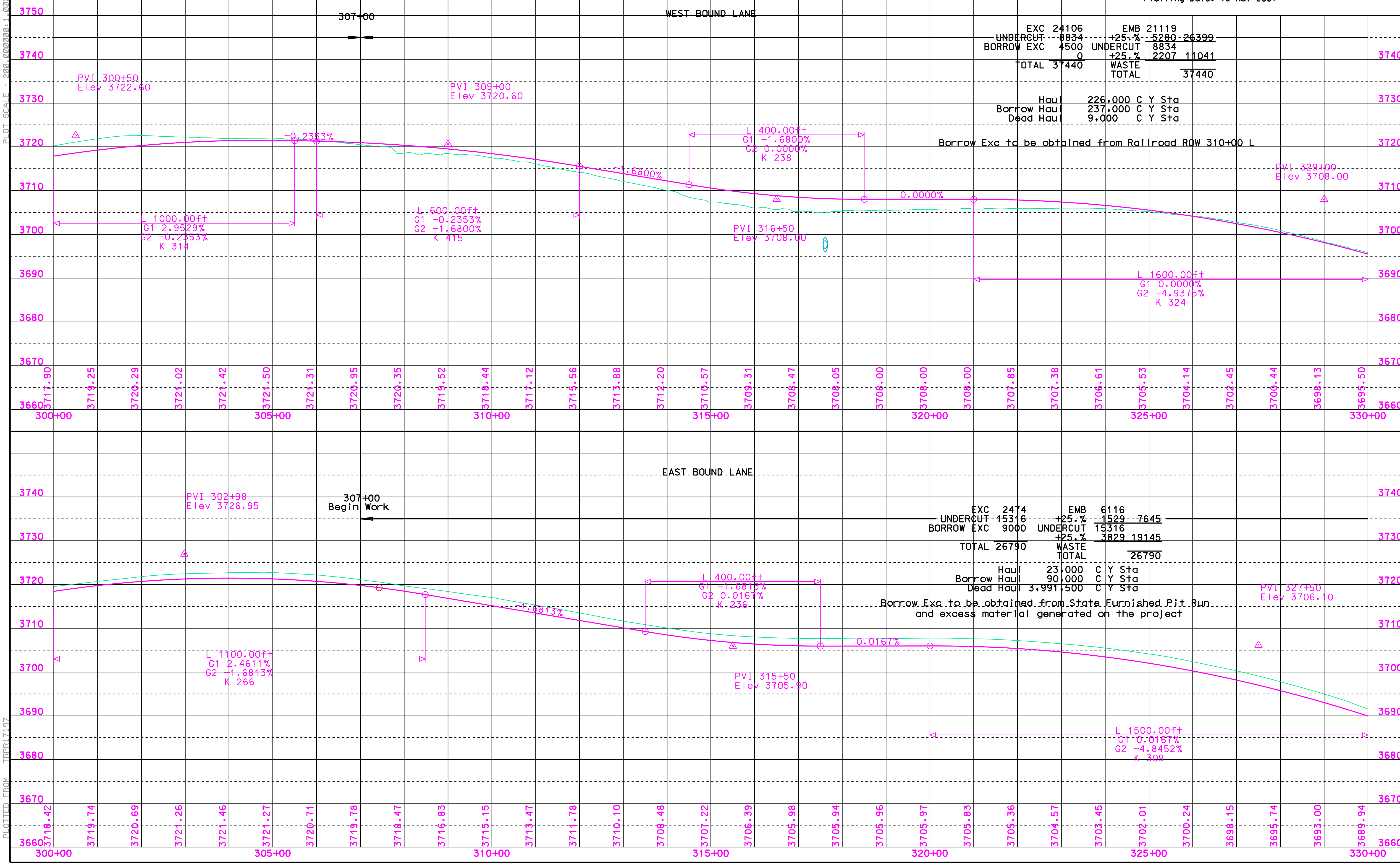
Parcel A1
309+75.31 to 313+21.70 L
Temporary easement for
Fill containing
1.5, more or less

Parcel A2
309+97.55 to 310+19.23 L
Temporary easement for
Fill containing
0.1, more or less

Parcel A3
310+19.23 to 315+60.00 L
Temporary easement for
Fill containing
0.1, more or less

STATE OF SOUTH DAKOTA	PROJECT	SHEET	TOTAL SHEETS
	IM 0901(120)33	B30	B69

Plotting Date: 19-NOV-2007



PLOT SCALE - 200.000000:1.000000

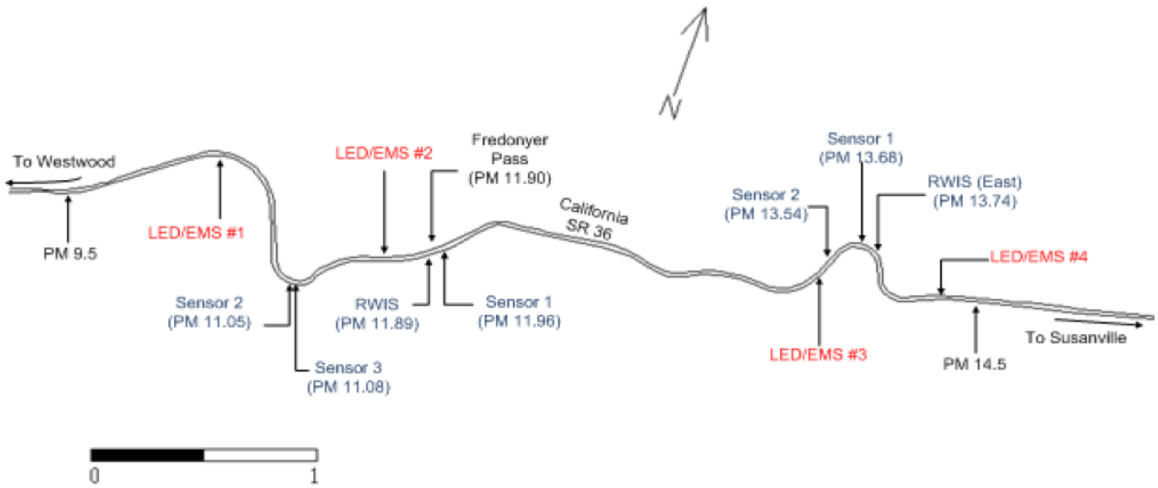
PLOT NAME - 30

FILE - U:\RD\PRJ\MEAD6180\300EBV&WBV.DGN

PLOTTED FROM - TRPR17197

APPENDIX B – ITS SOLUTION

Example – Adverse Weather Warning System



Source: FHWA, Best Practices for Road Weather Management