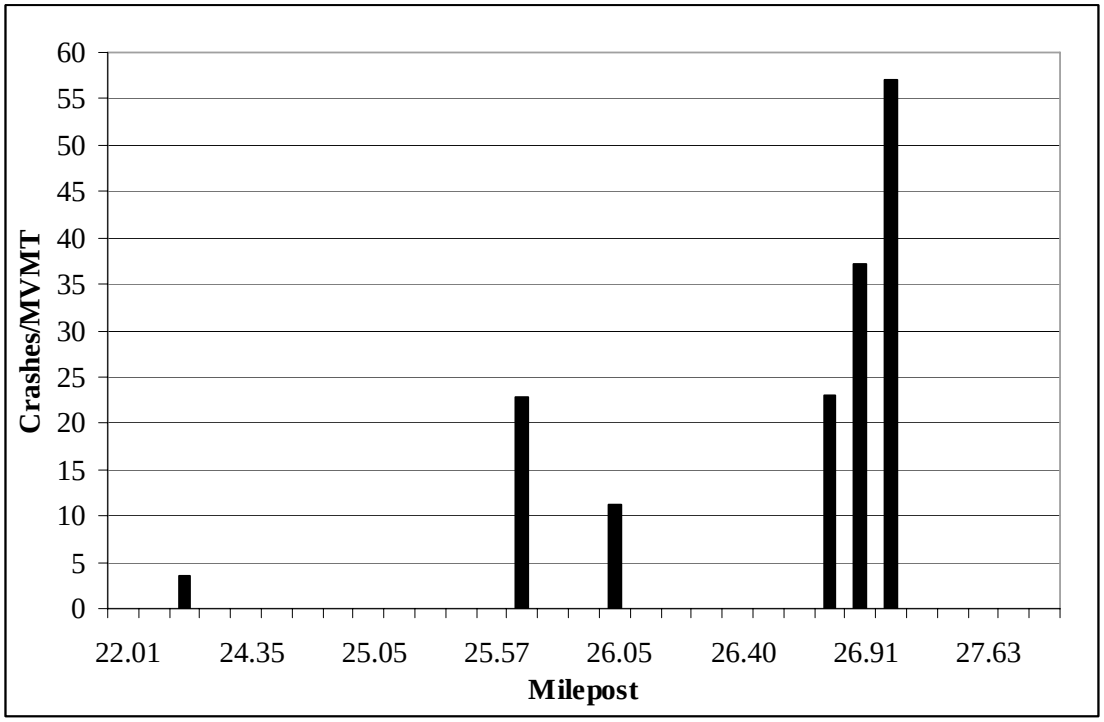

Figure 4-29: Plot of Crash History of US-6 Study Section (Crashes/MVMT), MP 22-MP 28 (2003-2005)

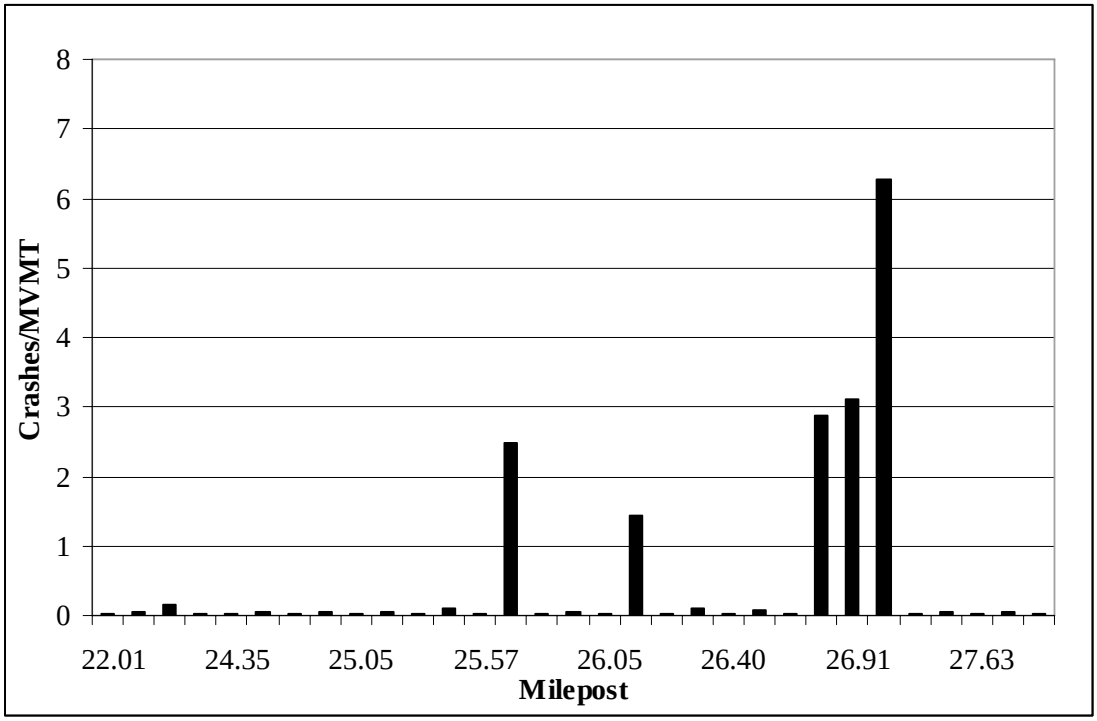

Figure 4-30: Plot of the Difference Between the CPM Results of US-6 Study Section in Crashes/MVMT Analyzed With and Without Crash History

A summary of statistics of the difference between the CPM results analyzed with and without crash history is shown in Table 4-14. It shows that the mean difference in the number of crashes between the two methods is less than 0.563, and the standard error of the mean is very small (0.245), resulting in the confidence interval of 0.083 and 1.043 at the 95 percent confidence level. Unlike the US 40 study section, these differences are more distinct. A large number of crashes near MP 27 may have skewed the results.

Table 4-14: Statistics Summary of the Difference between the CPM Results in Crashes/MVMT Analyzed With and Without Crash History of US-6 Study Section

Mean	0.563
Standard Error	0.245
Median	0.040
Standard Deviation	1.365
Sample Variance	1.864
Kurtosis	10.212
Skewness	3.080
Range	6.260
Minimum	0.020
Maximum	6.280
Confidence Interval of the Mean (at the 95% Confidence Level)	0.083 – 1.043

4.2.4 Analysis of Crash Prediction Results of the US-6 Study Section

As mentioned previously, the crash prediction results are not expected to perfectly match the crash history; they are predicted values for the future. What is important to the user is to identify if the trend presented by CPM is similar to the crash history in general, thus identifying potential “hot spots” for safety audits before sending out a group of experts to the field.

Unlike the US-40 study section, the US-6 study section does not have any wild-animal related collisions. Table 4-15 gives a summary of the crash history of the US-6 study section. Only one domestic-animal related collision was reported during the study period while the others are either run-off-road or fixed-object-collisions.

Table 4-15: Crash History Summary of the US-6 Study Section, MP 22-MP28 (2003-2005)

Year	Direction	Milepost	Severity	Accident Type 1	Accident Type 2	Accident Type 3
2003	E	26.72	No Injury	Ran Off Roadway-Right	Other Non-Collision	MV-Fixed Object
2004	E	25.61	Broken bones or bleeding wounds	Ran Off Roadway-Right	MV-Fixed Object	Overturned
2004	W	26.92	Bruises And Abrasions	Ran Off Roadway-Right	MV-Fixed Object	Overturned
2004	W	26.98	Bruises And Abrasions	Ran Off Roadway-Right	Overturned	NULL
2004	W	27	Broken bones or bleeding wounds	MV-Fixed Object	Ran Off Roadway-Right	MV-Fixed Object
2004	W	27.01	Broken bones or bleeding wounds	MV-Fixed Object	Ran Off Roadway-Right	Overturned
2005	E	23	No Injury	Ran Off Roadway-Right	MV-MV	NULL
2005	E	26.9	Bruises And Abrasions	Ran Off Roadway-Left	MV-Fixed Object	NULL
2005	W	22.2	No Injury	MV-Animal (Domestic)	NULL	NULL
2005	W	26.1	Bruises And Abrasions	MV-Fixed Object	Ran Off Roadway-Right	Overturned
2005	W	26.9	Possible Injury	Ran Off Roadway-Right	Overturned	NULL

The US-6 study section has provided a better platform to evaluate the effectiveness of the CPM of IHSDM since the majority of the crashes in the study period did not contain any wild animal related collisions. Because most of the reported crashes were non-animal crashes, this study section seemed to be more related to highway design

issues. The CPM prediction results are therefore potentially more relevant and reliable for the type of use of this module, which is finding "hot spots" without every time collecting crash data.

By observing Figure 4-23 through Figure 4-28 one can see a pattern. At the beginning of the study section there appears to be a small increase in crash occurrence and rate, around MP 22 to MP 24, followed by a decrease up to approximately MP 26 where the crash occurrence and rate reach the highest point and decrease abruptly after that point. Only Figure 4-24 contradicts this general tendency, in which the crash prediction result is presented in number of crashes per segment without crash history. This difference raised concern that CPM's predicted results obtained without the crash history might be unreliable. Referring to Figure 4-28, which is the CPM crash prediction results analyzed without crash history but presented in crashes per MVMT, one can see that the trend in Figure 4-28 fits the general tendency, though weakly, that the plots shown in the other figures.

4.3 SR-150 Study Section

The SR-150 study section is located in UDOT Region 1, which is a portion of a highway called the "Mirror Lake Highway." It is a rural, recreational, and scenic route.

4.3.1 Current Condition of the SR-150 Study Section

The overall condition of the study section is good; the pavement markings are clearly visible, and the pavement is still in excellent condition. Two sets of photos are shown to help acquaint the reader with the study section. Figure 4-31 shows the photos taken during summer 2006 by UDOT's photolog specialist (UDOT 2007a). From Figure 4-31 one can see the road is in good condition. The photos in Figure 4-32, on the other hand, were taken in fall 2007 on a rainy day. The inclement weather actually provided the authors an opportunity to inspect the road from a different perspective, where the driver visibility was lower as well as lower friction between the tires and the pavement existed. Although the pavement appeared to be more slippery and dangerous to drive on, the authors did not feel particularly unsafe driving on this stretch.

(a) MP 1, Eastbound (b) MP 13, Westbound

Figure 4-31: Photos of the SR-150 Study Section in Summer 2005 (UDOT 2007a)

(a) MP 2, Eastbound (b) MP 14, Westbound

Figure 4-32: Photos of the SR-150 Study Section in Fall 2007 (Taken by Kaitlin Chuo)

The section of SR-150 selected for the study contains locations where high crash rates occurred. Figure 4-33 shows the location of the SR-150 study section.

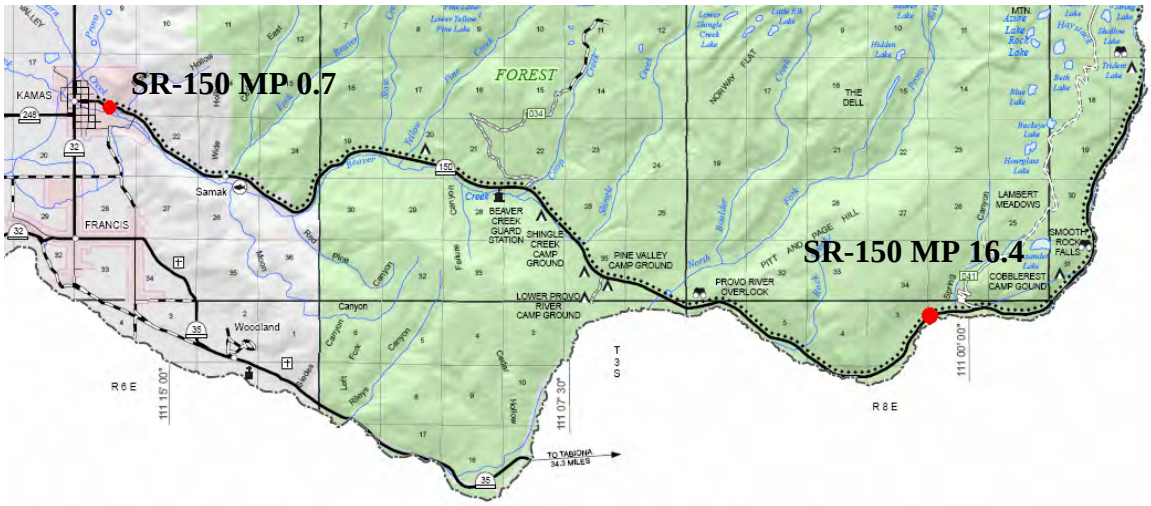

Figure 4-33: Location of the SR-150 Study Section (UDOT 2008)

4.3.2 Centerline Alignments of SR-150 Study Section

To be consistent with the other two study sections, the same method described in Appendix was used for obtaining surrogate horizontal and vertical alignments of the SR-150 study section. Table 4-16 shows the horizontal alignment and Table 4-17 shows the vertical alignment of the centerline of the study section. Figure 4-34 shows a plot of the surrogate centerline alignment of the study section with mileposts. Comparing Figure 4-33 and Figure 4-34 shows the similarity of the actual and surrogate horizontal alignments.

Table 4-16: Horizontal Alignment of the SR-150 Study Section

Segment	Milepost		Radius (ft)
	From	To	
Tangent	0.70	0.71	
Simple Curve	0.71	0.78	800
Tangent	0.78	0.81	
Simple Curve	0.81	0.88	1250
Tangent	0.88	0.97	
Simple Curve	0.97	1.05	1500
Tangent	1.05	1.13	
Simple Curve	1.13	1.27	2000
Tangent	1.27	1.38	
Simple Curve	1.38	1.44	2500
Tangent	1.44	1.47	
Simple Curve	1.47	1.54	1500
Tangent	1.54	1.59	
Simple Curve	1.59	1.66	2200
Tangent	1.66	1.72	
Simple Curve	1.72	1.81	1050
Tangent	1.81	2.09	
Simple Curve	2.09	2.17	6300
Tangent	2.18	2.50	
Simple Curve	2.50	2.60	1100
Tangent	2.60	2.69	
Simple Curve	2.69	2.79	2000
Tangent	2.79	2.85	
Simple Curve	2.85	2.94	1800
Tangent	2.94	3.04	
Simple Curve	3.04	3.09	2500
Tangent	3.09	3.23	

Table 4-16: Horizontal Alignment of the SR-150 Study Section (continued)

Segment	Milepost		Radius (ft)
	From	To	
Simple Curve	3.23	3.32	900
Tangent	3.32	3.54	
Simple Curve	3.54	3.64	2300
Tangent	3.64	3.78	
Simple Curve	3.78	3.82	5000
Tangent	3.82	3.94	
Simple Curve	3.94	4.08	6000
Tangent	4.08	4.13	
Simple Curve	4.13	4.34	980
Tangent	4.34	4.40	
Simple Curve	4.40	4.49	1100
Tangent	4.49	4.56	
Simple Curve	4.56	4.61	1500
Tangent	4.61	4.62	
Simple Curve	4.62	4.68	1500
Tangent	4.68	4.86	
Simple Curve	4.86	5.04	1600
Tangent	5.04	5.18	
Simple Curve	5.18	5.32	1120
Tangent	5.32	5.37	
Simple Curve	5.37	5.50	800
Tangent	5.50	5.55	
Simple Curve	5.55	5.69	1150
Tangent	5.69	5.71	
Simple Curve	5.71	6.08	3700
Tangent	6.08	7.24	
Simple Curve	7.24	7.46	2400
Tangent	7.46	7.51	
Simple Curve	7.51	8.12	4600
Tangent	8.12	8.52	
Simple Curve	8.52	8.94	2300
Tangent	8.94	9.14	
Simple Curve	9.14	9.29	5000
Tangent	9.29	9.89	
Simple Curve	9.89	10.09	2800
Tangent	10.09	10.21	
Simple Curve	10.21	10.73	2850
Tangent	10.73	11.13	
Simple Curve	11.13	11.29	3300
Tangent	11.29	12.00	
Simple Curve	12.00	12.24	1900

Table 4-16: Horizontal Alignment of the SR-150 Study Section (continued)

Segment	Milepost		Radius (ft)
	From	To	
Tangent	12.24	12.60	
Simple Curve	12.60	12.74	1190
Tangent	12.74	12.91	
Simple Curve	12.91	13.00	1500
Tangent	13.00	13.19	
Simple Curve	13.19	13.32	12000
Tangent	13.32	13.59	
Simple Curve	13.59	13.73	1650
Tangent	13.73	13.89	
Simple Curve	13.89	14.21	3300
Tangent	14.21	14.27	
Tangent	15.20	15.41	
Simple Curve	15.41	15.54	1700
Tangent	15.54	15.65	
Simple Curve	15.65	15.92	5500
Tangent	15.92	16.08	
Simple Curve	16.08	16.24	1450
Tangent	16.24	16.33	
Simple Curve	16.33	16.38	1300
Tangent	16.38	16.39	

Table 4-17: Vertical Alignment of the SR-150 Study Section

Milepost	Back Grade (%)	Back Length (ft)	Forward Grade (%)	Forward Length (ft)
0.83	6.36	434.33	0.75	434.33
0.95	0.75	11.00	1.85	11.00
0.97	1.85	21.84	1.22	21.84
1.08	1.22	330.51	-0.52	330.51
1.27	-0.52	484.40	0.62	484.40
1.68	0.62	349.31	3.12	349.31
2.07	3.12	437.72	-1.26	437.72
2.25	-1.26	209.54	0.59	209.54
2.56	1.21	362.01	5.47	362.01
2.78	5.47	425.15	-0.61	425.15
2.96	-0.61	252.35	4.44	252.35
3.07	4.44	216.49	1.55	216.49
4.33	2.84	50.00	3.86	50.00
4.37	3.86	10.00	1.98	10.00

Table 4-17: Vertical Alignment of the SR-150 Study Section (continued)

Milepost	Back Grade (%)	Back Length (ft)	Forward Grade (%)	Forward Length (ft)
4.46	1.98	28.80	0.83	28.80
4.49	0.83	19.02	2.73	19.02
4.50	2.73	2.93	1.56	2.93
4.51	1.56	6.93	2.25	6.93
4.53	2.25	75.12	1.25	75.12
4.81	1.25	93.82	2.82	93.82
4.91	2.82	26.99	3.49	26.99
4.96	3.49	180.00	1.09	180.00
5.09	1.09	4.39	1.53	4.39
5.35	1.53	5.67	1.72	5.67
5.98	1.72	38.01	3.24	38.01
6.32	3.24	49.77	4.90	49.77
6.69	4.90	504.33	-2.31	504.33
6.88	-2.31	130.32	0.30	130.32
6.94	0.30	144.07	2.22	144.07
7.25	2.22	37.85	0.96	37.85
7.43	0.96	71.57	1.80	71.57
7.66	1.80	124.42	3.88	124.42
7.81	3.88	53.81	2.08	53.81
7.93	2.08	94.68	3.35	94.68
8.25	3.35	231.43	5.36	231.43
8.38	5.36	379.42	0.30	379.42
8.47	0.30	45.77	1.82	45.77
8.57	1.82	82.85	3.90	82.85
8.63	3.90	179.65	2.46	179.65
8.75	2.46	117.92	0.10	117.92
8.86	0.10	108.81	1.31	108.81
8.98	1.31	197.76	4.35	197.76
9.13	4.35	5.00	3.04	5.00
9.20	3.04	30.00	4.44	30.00
9.23	4.44	95.00	2.36	95.00
9.27	2.36	65.00	3.27	65.00
9.32	3.27	15.00	3.82	15.00
9.42	3.82	75.00	2.94	75.00
9.48	2.94	50.00	4.54	50.00
9.50	4.54	5.00	3.26	5.00
9.50	3.26	2.50	4.22	2.50
9.52	4.22	50.00	3.82	50.00
9.60	3.82	125.00	6.01	125.00
9.93	6.01	500.00	-1.99	500.00
10.13	-1.99	300.00	-0.88	300.00

Table 4-17: Vertical Alignment of the SR-150 Study Section (continued)

Milepost	Back Grade (%)	Back Length (ft)	Forward Grade (%)	Forward Length (ft)
10.26	-0.88	350.00	-2.30	350.00
10.42	-2.30	40.00	-1.80	40.00
10.56	-1.80	100.00	-5.17	100.00
10.61	-5.17	135.00	-3.43	135.00
10.66	-3.43	25.00	-4.12	25.00
10.72	-4.12	50.00	-1.93	50.00
10.77	-1.93	175.00	-0.43	175.00
11.12	-1.57	50.00	-0.71	50.00
11.19	-0.71	200.00	-3.03	200.00
11.31	-3.03	175.00	0.99	175.00
11.47	0.99	100.00	-1.03	100.00
11.61	-1.03	150.00	4.51	150.00
11.80	4.51	200.00	5.78	200.00
11.92	5.78	200.00	3.59	200.00
12.04	3.59	190.00	5.77	190.00
12.16	5.77	50.00	4.84	50.00
12.24	4.84	250.00	0.55	250.00
12.33	0.55	200.00	1.24	200.00
12.38	1.24	15.00	0.68	15.00
12.55	0.68	150.00	2.74	150.00
12.63	2.74	50.00	-1.80	50.00
12.73	-1.80	40.00	-5.79	40.00
12.76	-5.79	100.00	-2.98	100.00
12.82	-2.98	50.00	1.84	50.00
12.89	1.84	100.00	3.84	100.00
12.92	3.84	10.00	0.53	10.00
12.94	0.53	35.00	-1.28	35.00
12.95	-1.28	0.50	0.32	0.50
12.95	0.32	7.50	-0.25	7.50
12.96	-0.25	2.50	-0.83	2.50
12.96	-0.83	2.50	-1.17	2.50
12.96	-1.17	0.50	1.30	0.50
12.96	1.30	5.00	0.80	5.00
12.97	0.80	0.01	1.10	0.01
12.97	1.10	5.00	0.51	5.00
12.97	0.51	1.50	0.20	1.50
12.97	0.20	0.25	2.12	0.25
12.97	2.12	12.50	0.94	12.50
12.98	0.94	5.00	0.36	5.00
12.98	0.36	0.10	1.66	0.10
12.99	1.66	15.00	0.50	15.00

Table 4-17: Vertical Alignment of the SR-150 Study Section (continued)

Milepost	Back Grade (%)	Back Length (ft)	Forward Grade (%)	Forward Length (ft)
12.99	0.50	2.50	1.77	2.50
13.00	1.77	15.00	0.68	15.00
13.00	0.68	5.00	1.46	5.00
13.01	1.46	2.50	2.28	2.50
13.02	2.28	2.50	1.97	2.50
13.04	1.97	40.00	3.32	40.00
13.16	3.32	140.00	0.50	140.00
13.34	0.50	50.00	1.59	50.00
13.57	1.59	150.00	1.38	150.00
13.75	1.38	100.00	2.73	100.00
13.82	2.73	50.00	0.44	50.00
13.85	0.44	25.00	1.48	25.00
13.89	1.48	50.00	-0.70	50.00
13.93	-0.70	100.00	0.84	100.00
14.03	0.84	100.00	0.25	100.00
14.13	0.25	50.00	-0.43	50.00
14.15	-0.43	10.00	0.45	10.00
14.16	0.45	16.00	-0.59	16.00
14.18	-0.59	30.00	0.56	30.00
14.26	0.56	20.00	-0.01	20.00
14.37	-0.01	50.00	1.21	50.00
14.50	1.21	50.00	2.26	50.00
14.64	2.26	150.00	3.50	150.00
14.71	3.50	105.00	0.47	105.00
14.76	0.47	50.00	-0.81	50.00
14.85	-0.81	150.00	1.88	150.00
14.92	1.88	5.00	0.75	5.00
14.93	0.75	10.00	1.69	10.00
14.93	1.69	1.00	0.00	1.00
14.94	0.00	15.00	1.38	15.00
14.94	1.38	7.50	-0.72	7.50
14.95	-0.72	10.00	0.32	10.00
14.95	0.32	15.00	-0.47	15.00
14.96	-0.47	12.00	0.81	12.00
14.96	0.81	1.50	1.42	1.50
14.96	1.42	0.50	0.33	0.50
14.97	0.33	10.00	1.82	10.00
14.97	1.82	0.40	2.18	0.40
14.97	2.18	0.40	2.48	0.40
14.97	2.48	0.50	1.02	0.50
14.98	1.01	7.50	1.73	7.50

Table 4-17: Vertical Alignment of the SR-150 Study Section (continued)

Milepost	Back Grade (%)	Back Length (ft)	Forward Grade (%)	Forward Length (ft)
14.98	1.73	5.00	2.58	5.00
14.98	2.58	0.10	2.95	0.10
14.98	2.95	0.50	3.28	0.50
14.98	3.28	0.10	1.83	0.10
14.99	1.83	0.50	1.97	0.50
14.99	1.97	1.00	2.89	1.00
14.99	2.89	0.10	1.45	0.10
15.00	1.45	0.10	1.99	0.10
15.00	1.99	0.05	1.29	0.05
15.01	1.29	0.10	2.08	0.10
15.01	2.08	0.01	1.54	0.01
15.02	1.54	0.25	2.40	0.25
15.02	2.40	0.25	2.08	0.25
15.25	2.08	15.00	1.49	15.00
15.29	1.49	100.00	2.33	100.00
15.32	2.33	2.50	2.74	2.50
15.35	2.74	50.00	2.04	50.00
15.37	2.04	10.00	2.54	10.00
15.39	2.54	5.00	1.83	5.00
15.42	1.83	10.00	3.27	10.00
15.46	3.27	2.50	2.83	2.50
15.48	2.83	2.50	-1.35	2.50
15.53	-1.35	10.00	7.73	10.00
15.56	7.73	2.50	4.48	2.50
15.60	4.48	5.00	1.37	5.00
15.66	1.37	20.00	2.15	20.00
15.76	2.15	25.00	0.35	25.00
15.80	0.35	50.00	2.28	50.00
15.85	2.28	50.00	1.15	50.00
15.91	1.15	50.00	2.83	50.00
16.01	2.83	25.00	2.25	25.00
16.06	2.25	10.00	0.99	10.00
16.10	0.99	100.00	4.08	100.00
16.17	4.08	100.00	1.12	100.00
16.20	1.12	50.00	5.26	50.00
16.25	5.26	10.00	3.21	10.00
16.29	3.21	20.00	-2.35	20.00
16.30	-2.35	5.00	3.90	5.00

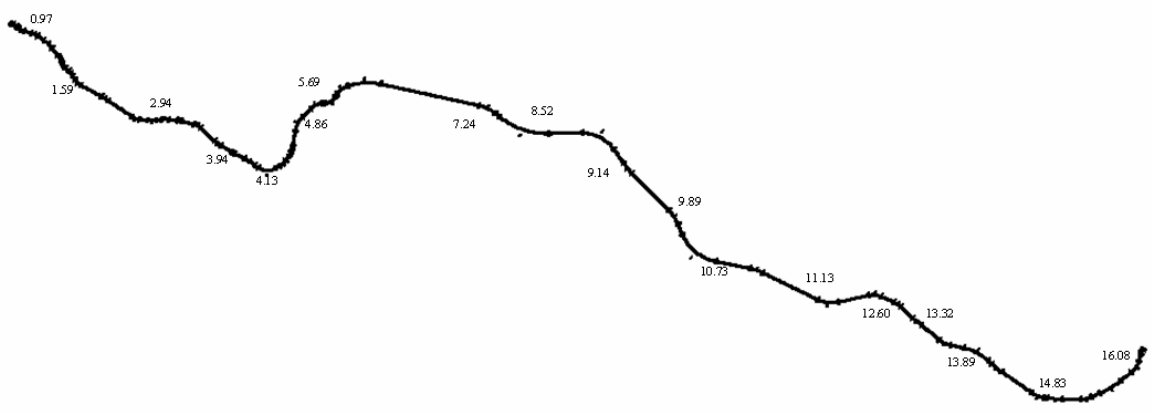

Figure 4-34: Surrogate horizontal Alignment of the SR-150 Study Section with Mileposts

4.3.3 Crash Prediction Results of the SR-150 Study Section

The centerline alignments of the SR-150 study section were entered into the CPM together with necessary data. The results of crash prediction in number of crashes are shown in Table 4-18. The results shown in Table 4-18 are graphically presented in Figure 4-35 and Figure 4-36, and Figure 4-37. These three figures show that segments near MP 5.7 seem to have a very high occurrence of crashes. Figure 4-38 is the graph that shows the difference between the CPM results analyzed with and without crash history.

Table 4-18: Crash Prediction Results for SR-150 Study Section, MP 0.7-MP 16.4 (Number of Crashes)

Milepost		No. of Crashes (2006-2008)			No. of Crashes (2003-2005)
From	To	with Crashes	w/o Crashes	Diff.	Crash History
0.7	0.71	0.00	0.01	0.01	0.00
0.71	0.78	0.10	0.14	0.04	0.00
0.78	0.81	0.02	0.02	0.00	0.00
0.81	0.88	0.09	0.12	0.03	0.00
0.88	0.97	0.21	0.06	0.15	2.00
0.97	1.05	0.33	0.11	0.22	0.00
1.05	1.13	0.06	0.07	0.01	0.00

Table 4-18: Crash Prediction Results for SR-150 Study Section, MP 0.7-MP 16.4 (Number of Crashes) (continued)

Milepost		No. of Crashes (2006-2008)			No. of Crashes (2003-2005)
From	To	with Crashes	w/o Crashes	Diff.	Crash History
1.13	1.27	0.12	0.15	0.03	0.00
1.27	1.38	0.07	0.09	0.02	0.00
1.38	1.44	0.06	0.08	0.02	0.00
1.44	1.47	0.02	0.02	0.00	1.00
1.47	1.54	0.33	0.10	0.23	0.00
1.54	1.59	0.03	0.04	0.01	0.00
1.59	1.66	0.07	0.09	0.02	0.00
1.66	1.72	0.20	0.05	0.15	1.00
1.72	1.81	0.11	0.14	0.03	0.00
1.81	2.09	0.34	0.22	0.12	1.00
2.09	2.17	0.06	0.08	0.02	0.00
2.18	2.50	0.37	0.25	0.12	1.00
2.50	2.60	0.10	0.14	0.04	0.00
2.60	2.69	0.06	0.08	0.02	0.00
2.69	2.79	0.33	0.13	0.20	1.00
2.79	2.85	0.03	0.04	0.01	0.00
2.85	2.94	0.08	0.11	0.03	0.00
2.94	3.04	0.23	0.08	0.15	1.00
3.04	3.09	0.06	0.07	0.01	0.00
3.09	3.23	0.09	0.11	0.02	0.00
3.23	3.32	0.10	0.14	0.04	0.00
3.32	3.54	0.14	0.17	0.03	0.00
3.54	3.64	0.09	0.11	0.02	0.00
3.64	3.78	0.09	0.11	0.02	0.00
3.78	3.82	0.24	0.04	0.20	1.00
3.82	3.94	0.08	0.10	0.02	0.00
3.94	4.08	0.28	0.13	0.15	1.00
4.08	4.13	0.03	0.04	0.01	0.00
4.13	4.34	0.43	0.26	0.17	1.00
4.34	4.40	0.04	0.04	0.00	0.00
4.4	4.49	0.36	0.14	0.22	1.00
4.49	4.56	0.04	0.05	0.01	0.00

Table 4-18: Crash Prediction Results for SR-150 Study Section, MP 0.7-MP 16.4 (Number of Crashes) (continued)

Milepost		No. of Crashes (2006-2008)			No. of Crashes (2003-2005)
From	To	with Crashes	w/o Crashes	Diff.	Crash History
4.62	4.68	0.07	0.1	0.03	0.00
4.68	4.86	0.12	0.14	0.02	0.00
4.86	5.04	0.38	0.21	0.17	0.00
5.04	5.18	0.09	0.10	0.01	1.00
5.18	5.32	0.14	0.18	0.04	0.00
5.32	5.37	0.03	0.04	0.01	0.00
5.37	5.5	0.14	0.19	0.05	0.00
5.5	5.55	0.03	0.04	0.01	0.00
5.55	5.69	0.14	0.19	0.05	0.00
5.69	5.71	0.01	0.01	0.00	0.00
5.71	6.08	0.47	0.35	0.12	1.00
6.08	7.24	1.42	0.92	0.50	4.00
7.24	7.46	0.18	0.22	0.04	0.00
7.46	7.51	0.04	0.05	0.01	0.00
7.51	8.12	0.45	0.55	0.10	0.00
8.12	8.52	0.42	0.31	0.11	1.00
8.52	8.94	0.53	0.42	0.11	1.00
8.94	9.14	0.14	0.16	0.02	0.00
9.14	9.29	0.12	0.14	0.02	0.00
9.29	9.89	0.58	0.49	0.09	1.00
9.89	10.09	0.16	0.20	0.04	0.00
10.09	10.21	0.08	0.10	0.02	0.00
10.21	10.73	0.59	0.50	0.09	1.00
10.73	11.13	0.42	0.31	0.11	1.00
11.13	11.29	0.13	0.16	0.03	0.00
11.29	12.00	0.95	0.56	0.39	3.00
12.00	12.24	0.42	0.28	0.14	1.00
12.24	12.6	0.23	0.27	0.04	0.00
12.60	12.74	0.14	0.19	0.05	0.00
12.74	12.91	0.11	0.13	0.02	0.00
12.91	13.00	0.09	0.12	0.03	0.00
13.00	13.19	0.13	0.15	0.02	0.00

Table 4-18: Crash Prediction Results for SR-150 Study Section, MP 0.7-MP 16.4 (Number of Crashes) (continued)

Milepost		No. of Crashes (2006-2008)			No. of Crashes (2003-2005)
From	To	with Crashes	w/o Crashes	Diff.	Crash History
13.19	13.32	0.09	0.11	0.02	0.00
13.32	13.59	0.17	0.21	0.04	0.00
13.59	13.73	0.13	0.17	0.04	0.00
13.73	13.89	0.10	0.12	0.02	0.00
13.89	14.21	0.42	0.30	0.12	1.00
14.21	14.27	0.04	0.05	0.01	0.00
14.27	14.41	0.10	0.12	0.02	0.00
14.41	14.83	0.44	0.33	0.11	1.00
14.83	14.99	0.14	0.17	0.03	0.00
14.99	15.03	0.03	0.03	0.00	0.00
15.03	15.2	0.13	0.16	0.03	0.00
15.20	15.41	0.14	0.16	0.02	0.00
15.41	15.54	0.35	0.16	0.19	1.00
15.54	15.65	0.07	0.08	0.01	0.00
15.65	15.92	0.20	0.24	0.04	0.00
15.92	16.08	0.10	0.12	0.02	0.00
16.08	16.24	0.15	0.19	0.04	0.00
16.24	16.33	0.06	0.07	0.01	0.00
16.33	16.38	0.07	0.10	0.03	0.00
16.38	16.39	0.01	0.01	0.00	0.00

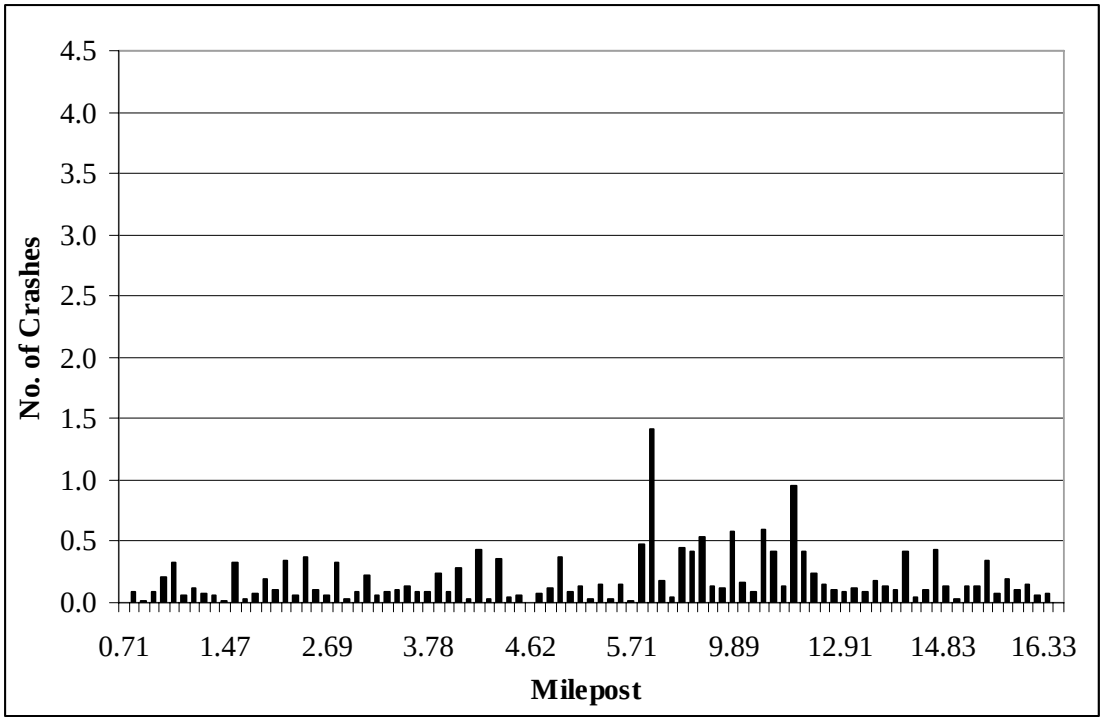

Figure 4-35: Plot of CPM Prediction Results of the SR-150 Study Section (Number of Crashes), MP 0.7-MP 16.4 (2006-2008), Analyzed with Crash History

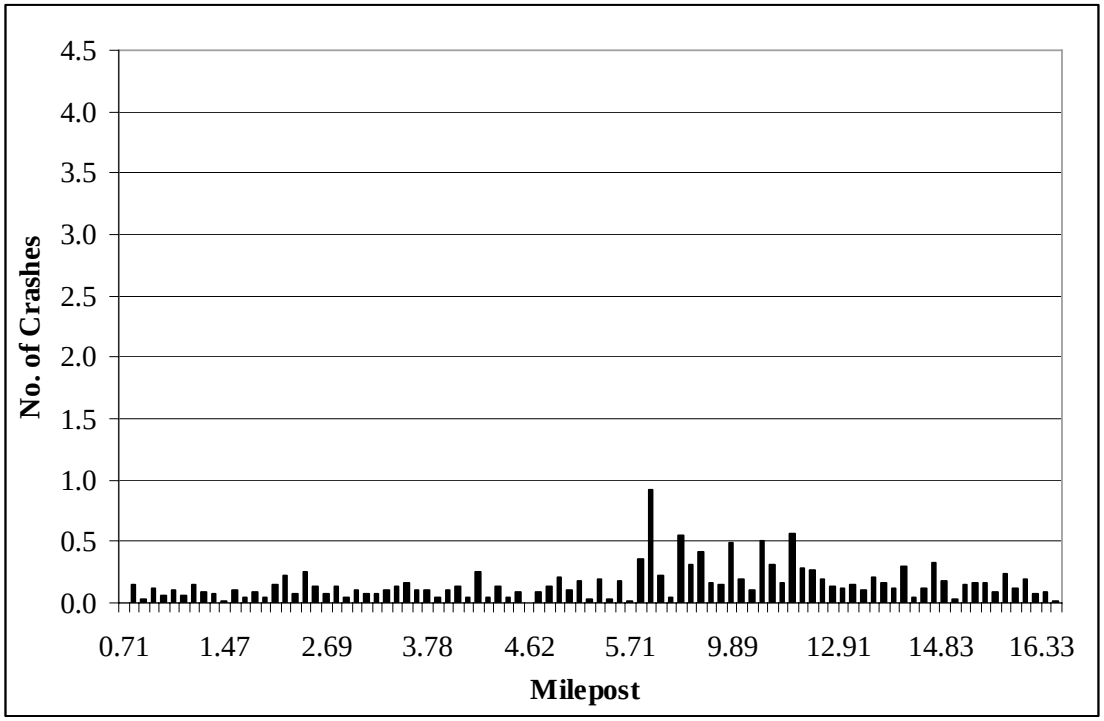

Figure 4-36: Plot of CPM Prediction Results of the SR-150 Study Section (Number of Crashes), MP 0.7-MP 16.4 (2006-2008), Analyzed without Crash History

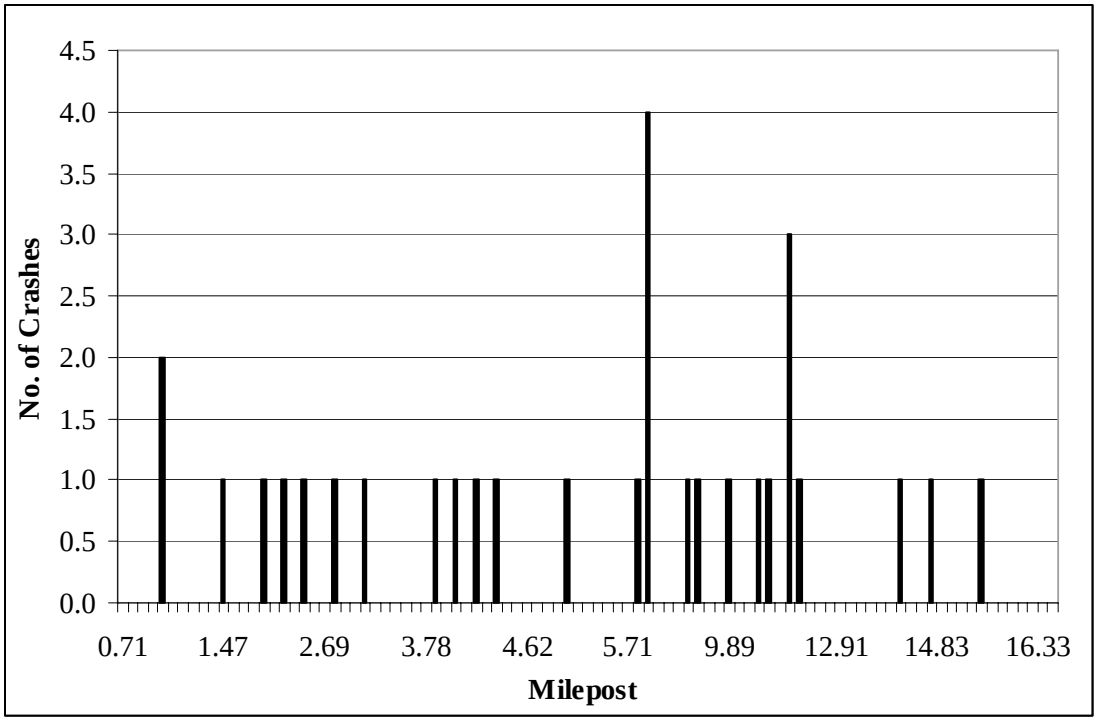

Figure 4-37: Plot of Crash History of SR-150 Study Section (Number of Crashes), MP 0.7-MP 16.4 (2003-2005)

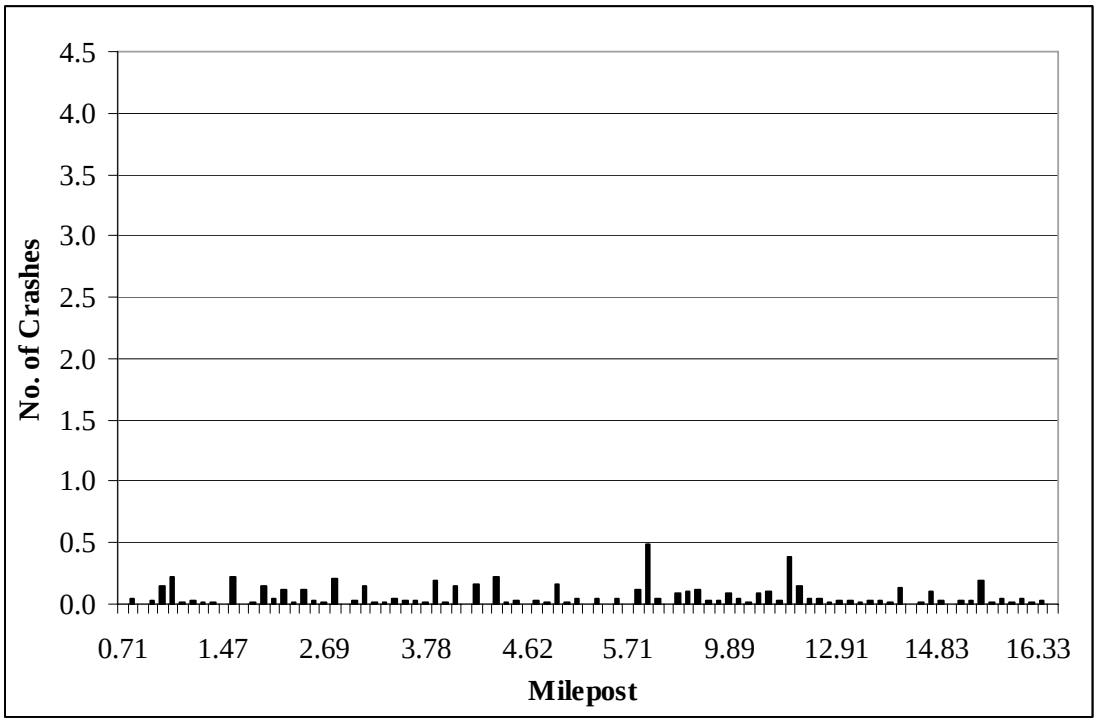

Figure 4-38: Plot of the Difference Between the CPM Results of SR-150 Study Section in Number of Crashes Analyzed With and Without Crash History

A summary statistics of the difference between the CPM results analyzed with and without crash history is shown in Table 4-19. It shows that the mean difference in the number of crashes between the two methods is 0.064, and the standard error of the mean is very small (0.009), resulting in the confidence interval of 0.046 and 0.082 at the 95 percent confidence level. These differences are much smaller than the differences found at the US 40 and US 6 study sections.

Table 4-19: Statistics Summary of the Difference between the CPM Results in Number of Crashes Analyzed With and Without Crash History of SR-150 Study Section

Mean	0.064
Standard Error	0.009
Standard Deviation	0.083
Sample Variance	0.007
Kurtosis	9.379
Skewness	2.659
Range	0.500
Minimum	0.000
Maximum	0.500
Confidence Interval of the Mean (at the 95% Confidence Level)	0.046 – 0.082

Again, the prediction results are presented in crashes/MVMT for comparison. Table 4-20 displays the prediction results, along with the crash history, also in crashes per MVMT. Figure 4-39 and Figure 4-40, show graphically the prediction results with and without crash history and Figure 4-41 shows the crash history itself. Figure 4-42 shows the differences in crashes/MVMT between the CPM results with and without crash history.

Table 4-20: Crash Prediction Results for SR-150 MP 0.7-MP 16.4 (Crashes/MVMT)

Milepost		Length (mi)	Expected Crash Rate (2006-2008) (MVMT)			Crash Rate (2003-2005) (MVMT)
From	To		with crashes	w/o Crashes	Diff.	Crash History
0.70	0.71	0.01	0.48	0.58	0.10	0.00
0.71	0.78	0.07	0.95	1.40	0.45	0.00

Table 4-20: Crash Prediction Results for SR-150 MP 0.7-MP 16.4 (Crashes/MVMT) (continued)

Milepost		Length (mi)	Expected Crash Rate (2006-2008) (MVMT)			Crash Rate (2003-2005) (MVMT)
From	To		with Crashes	w/o Crashes	Diff.	Crash History
0.78	0.81	0.03	0.48	0.58	0.10	0.00
0.81	0.88	0.08	0.77	1.05	0.28	0.00
0.88	0.97	0.08	1.73	0.53	1.20	16.82
0.97	1.05	0.08	2.89	0.95	1.94	0.00
1.05	1.13	0.09	0.45	0.53	0.08	0.00
1.13	1.27	0.13	0.61	0.77	0.16	0.00
1.27	1.38	0.11	0.45	0.53	0.08	0.00
1.38	1.44	0.06	0.66	0.84	0.18	0.00
1.44	1.47	0.03	0.45	0.53	0.08	24.75
1.47	1.54	0.07	3.13	0.97	2.16	0.00
1.54	1.59	0.05	0.45	0.53	0.08	0.00
1.59	1.66	0.07	0.66	0.85	0.19	0.00
1.66	1.72	0.06	2.37	0.54	1.83	12.11
1.72	1.81	0.09	0.77	1.05	0.28	0.00
1.81	2.09	0.27	0.86	0.55	0.31	2.54
2.09	2.17	0.09	0.52	0.63	0.11	0.00
2.18	2.5	0.33	0.77	0.53	0.24	2.12
2.50	2.60	0.09	0.76	1.02	0.26	0.00
2.60	2.69	0.09	0.48	0.57	0.09	0.00
2.69	2.79	0.10	2.19	0.86	1.33	6.68
2.79	2.85	0.05	0.45	0.53	0.08	0.00
2.85	2.94	0.09	0.67	0.87	0.20	0.00
2.94	3.04	0.10	1.59	0.56	1.03	6.98
3.04	3.09	0.06	0.69	0.90	0.21	0.00
3.09	3.23	0.14	0.45	0.54	0.09	0.00
3.23	3.32	0.09	0.80	1.09	0.29	0.00
3.32	3.54	0.22	0.45	0.53	0.08	0.00
3.54	3.64	0.10	0.62	0.78	0.16	0.00
3.64	3.78	0.14	0.45	0.53	0.08	0.00
3.78	3.82	0.04	4.36	0.76	3.60	18.30

Table 4-20: Crash Prediction Results for SR-150 MP 0.7-MP 16.4 (Crashes/MVMT) (continued)

Milepost		Length (mi)	Expected Crash Rate (2006-2008) (MVMT)			Crash Rate (2003-2005) (MVMT)
From	To		with Crashes	w/o Crashes	Diff.	Crash History
3.82	3.94	0.12	0.46	0.55	0.09	0.00
3.94	4.08	0.14	1.33	0.61	0.72	4.80
4.08	4.13	0.05	0.45	0.53	0.08	0.00
4.13	4.34	0.21	1.40	0.85	0.55	3.32
4.34	4.40	0.05	0.46	0.55	0.09	0.00
4.40	4.49	0.10	2.55	1.00	1.55	7.10
4.49	4.56	0.06	0.46	0.54	0.08	0.00
4.56	4.61	0.05	0.79	1.08	0.29	0.00
4.61	4.62	0.01	0.45	0.54	0.09	0.00
4.62	4.68	0.07	0.75	1.01	0.26	0.00
4.68	4.86	0.18	0.46	0.54	0.08	0.00
4.86	5.04	0.18	1.41	0.79	0.62	0.00
5.04	5.18	0.13	0.45	0.54	0.09	5.17
5.18	5.32	0.14	0.68	0.89	0.21	0.00
5.32	5.37	0.05	0.46	0.54	0.08	0.00
5.37	5.50	0.13	0.75	1.01	0.26	0.00
5.50	5.55	0.04	0.46	0.54	0.08	0.00
5.55	5.69	0.15	0.68	0.88	0.20	0.00
5.69	5.71	0.01	0.46	0.54	0.08	0.00
5.71	6.08	0.38	0.86	0.64	0.22	1.84
6.08	7.24	1.16	0.85	0.55	0.30	2.40
7.24	7.46	0.21	0.57	0.70	0.13	0.00
7.46	7.51	0.06	0.46	0.54	0.08	0.00
7.51	8.12	0.61	0.51	0.62	0.11	0.00
8.12	8.52	0.39	0.74	0.55	0.19	1.78
8.52	8.94	0.42	0.87	0.68	0.19	1.64
8.94	9.14	0.20	0.47	0.56	0.09	0.00
9.14	9.29	0.15	0.53	0.65	0.12	0.00
9.29	9.89	0.60	0.66	0.57	0.09	1.16
9.89	10.09	0.20	0.57	0.70	0.13	0.00

Table 4-20: Crash Prediction Results for SR-150 MP 0.7-MP 16.4 (Crashes/MVMT) (continued)

Milepost		Length (mi)	Expected Crash Rate (2006-2008) (MVMT)			Crash Rate (2003-2005) (MVMT)
From	To		with Crashes	w/o Crashes	Diff.	Crash History
10.09	10.21	0.13	0.45	0.54	0.09	0.00
10.21	10.73	0.52	0.79	0.66	0.13	1.34
10.73	11.13	0.40	0.72	0.54	0.18	1.74
11.13	11.29	0.16	0.56	0.69	0.13	0.00
11.29	12.00	0.71	0.93	0.55	0.38	2.96
12.00	12.24	0.25	1.19	0.77	0.42	2.82
12.24	12.6	0.35	0.45	0.53	0.08	0.00
12.6	12.74	0.15	0.68	0.88	0.20	0.00
12.74	12.91	0.17	0.46	0.55	0.09	0.00
12.91	13.00	0.09	0.70	0.92	0.22	0.00
13.00	13.19	0.19	0.46	0.55	0.09	0.00
13.19	13.32	0.14	0.47	0.56	0.09	0.00
13.32	13.59	0.26	0.45	0.54	0.09	0.00
13.59	13.73	0.14	0.63	0.81	0.18	0.00
13.73	13.89	0.15	0.46	0.54	0.08	0.00
13.89	14.21	0.32	0.91	0.64	0.27	2.17
14.21	14.27	0.06	0.45	0.53	0.08	0.00
14.27	14.41	0.14	0.50	0.6	0.10	0.00
14.41	14.83	0.43	0.71	0.54	0.17	1.64
14.83	14.99	0.15	0.62	0.79	0.17	0.00
14.99	15.03	0.04	0.46	0.54	0.08	0.00
15.03	15.20	0.18	0.51	0.61	0.10	0.00
15.20	15.41	0.21	0.46	0.54	0.08	0.00
15.41	15.54	0.13	1.83	0.84	0.99	5.30
15.54	15.65	0.10	0.47	0.56	0.09	0.00
15.65	15.92	0.28	0.50	0.61	0.11	0.00
15.92	16.08	0.16	0.46	0.55	0.09	0.00
16.08	16.24	0.16	0.65	0.84	0.19	0.00
16.24	16.33	0.09	0.47	0.56	0.09	0.00
16.33	16.38	0.06	0.85	1.19	0.34	0.00

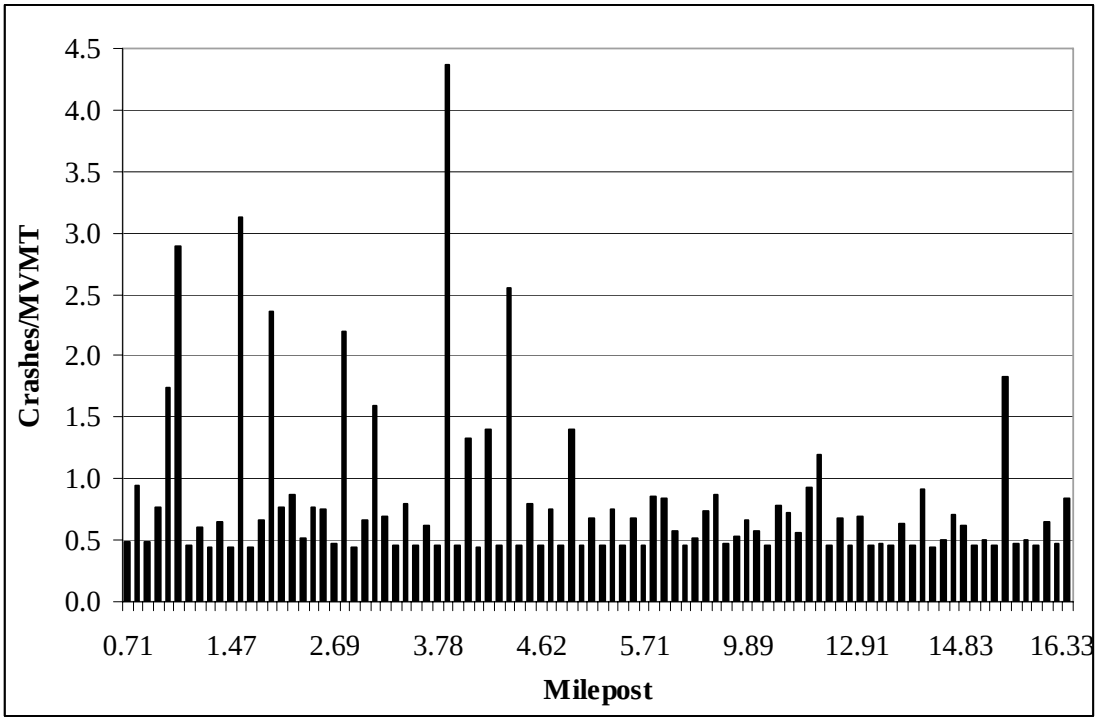

Figure 4-39: Plot of CPM Prediction Results of the SR-150 Study Section (Crashes/MVMT), MP 0.7-MP 16.4 (2006-2008), Analyzed with Crash History

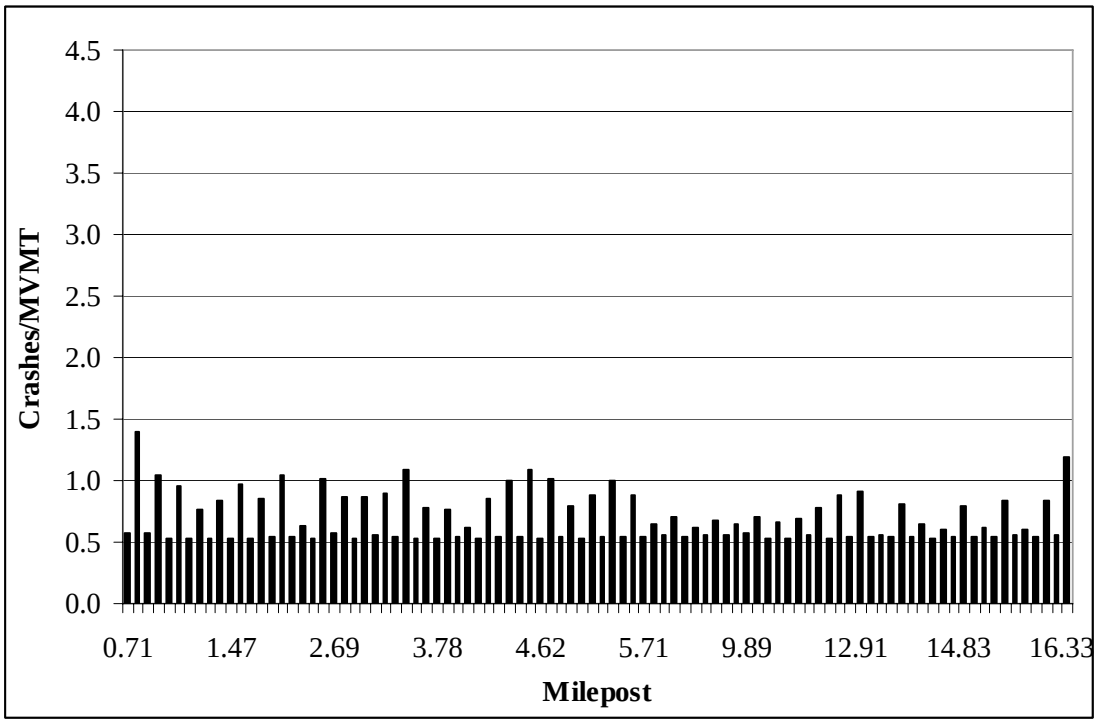

Figure 4-40: Plot of CPM Prediction Results of the SR-150 Study Section (Crashes/MVMT), MP 0.7-MP 16.4 (2006-2008), Analyzed without Crash History

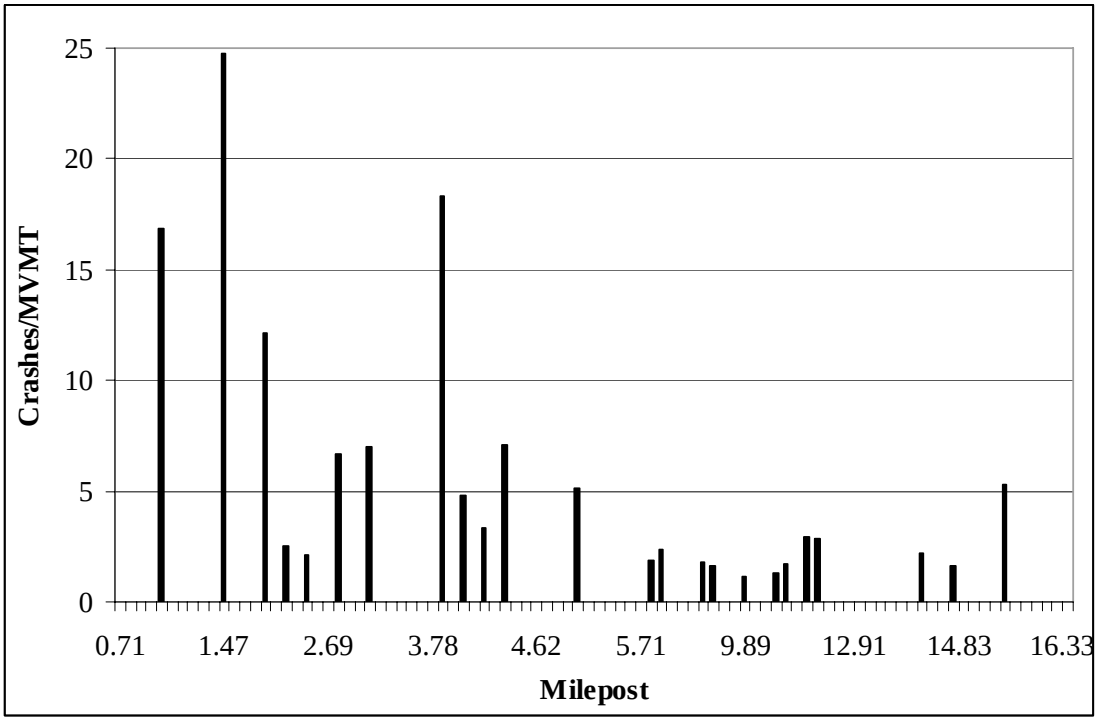

Figure 4-41: Plot of Crash History of SR-150 Study Section (Crashes/MVMT), MP 0.7-MP 16.4 (2003-2005)

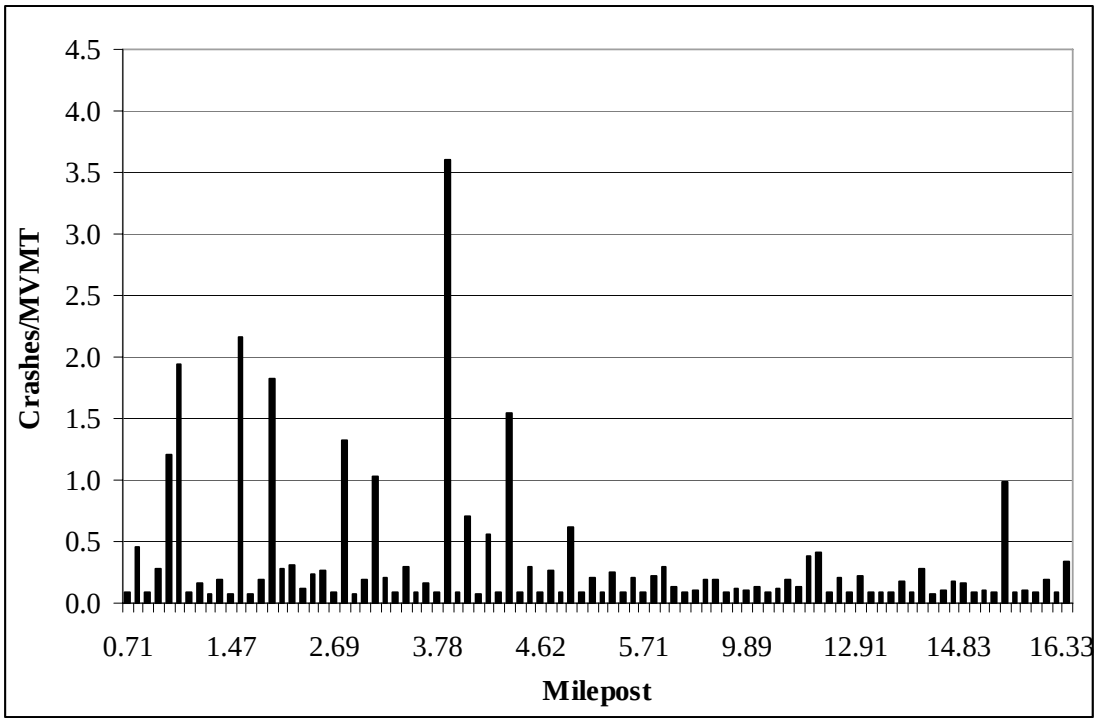

Figure 4-42: Plot of the Difference Between the CPM Results of SR-150 Study Section in Crashes/MVMT Analyzed With and Without Crash History

The statistical summary of the difference between the CPM result analyzed with and without crash history is shown in Table 4-21. It shows that the mean difference in the number of crashes between the two methods is 0.325, and the standard error of the mean is very small (0.056), resulting in the confidence interval of 0.215 and 0.435 at the 95 percent confidence level. These differences are similar to the differences found at the US 40 study section.

Table 4-21: Statistics Summary of the Difference between the CPM Results in Crashes/MVMT Analyzed With and Without Crash History of SR-150 Study Section

Mean	0.325
Standard Error	0.056
Standard Deviation	0.539
Sample Variance	0.290
Kurtosis	16.773
Skewness	3.772
Range	3.520
Minimum	0.080
Maximum	3.600
Confidence Interval of the Mean (at the 95% Confidence Level)	0.215 – 0.435

4.3.4 Analysis of Crash Prediction Results of the SR-150 Study Section

The SR-150 study section, just like the US-40 study section, contains a large number of animal related crashes as shown in Table 4-22. Fifty-seven percent of the crashes from 2003 to 2005 were animal related. However, many of these crashes were domestic-animal collisions, which is unique to this section. Non-animal crashes in this study section were run-off-the-road and multi-vehicle collisions, which indicate that the alignments may be potentially problematic.

The high percentage of animal-related crashes appears to have affected the crash prediction results. The crash prediction results in number of crashes, shown in Figure 4-35, Figure 4-36, and Figure 4-37, display similar trends, whereas the prediction results in crash rate (crashes/MVMT), shown in Figure 4-39, Figure 4-40, and Figure 4-41, do not have the same level of similarity found in the prediction results in number of crashes. Similar to the US-40 study section, when the crash history contains many animal-related

crashes, the analysis results may be skewed. In the SR-150 study section, the crashes distributed evenly between the two directions as shown in Table 4-22.

Table 4-22: Crash History Summary of the US-150 Study Section, MP 0.7-MP 16.4 (2003-2005)

Year	Milepost	Direction	Severity	Accident Type
2003	11.00	E	No Injury	MV-Animal (Domestic)
2004	14.64	E	No Injury	MV-Animal (Domestic)
2003	1.99	E	Possible Injury	MV-Animal(Wild)
2004	5.04	E	No Injury	MV-Animal(Wild)
2004	7.01	E	No Injury	MV-Animal(Wild)
2004	11.4	E	No Injury	MV-Animal(Wild)
2003	6.22	E	No Injury	MV-MV
2003	14.00	E	No Injury	MV-MV
2004	2.29	E	No Injury	MV-MV
2004	6.32	E	No Injury	Ran Off Roadway-Right
2005	0.90	E	Broken bones or bleeding wounds	Ran Off Roadway-Right
2005	6.03	E	Bruises And Abrasions	Ran Off Roadway-Right
2003	6.62	W	No Injury	MV-Animal (Domestic)
2004	9.62	W	No Injury	MV-Animal (Domestic)
2005	4.21	W	No Injury	MV-Animal (Domestic)
2005	8.61	W	No Injury	MV-Animal (Domestic)
2005	10.32	W	No Injury	MV-Animal (Domestic)
2003	11.63	W	No Injury	MV-Animal(Wild)
2003	12.03	W	No Injury	MV-Animal(Wild)
2004	4.41	W	No Injury	MV-Animal(Wild)
2004	8.50	W	No Injury	MV-Animal(Wild)
2004	11.65	W	No Injury	MV-Animal(Wild)
2005	3.80	W	No Injury	MV-Animal(Wild)
2005	1.47	W	No Injury	MV-MV
2005	4.07	W	No Injury	MV-MV
2004	1.69	W	No Injury	Ran Off Roadway-Left

Table 4-22: Crash History Summary of the US-150 Study Section, MP 0.7-MP 16.4 (2003-2005) (continued)

Year	Milepost	Direction	Severity	Accident Type
2003	3.00	W	Bruises And Abrasions	Ran Off Roadway-Right
2005	0.97	W	Broken bones or bleeding wounds	Ran Off Roadway-Right
2005	2.70	W	Bruises And Abrasions	Ran Off Roadway-Right
2005	15.44	W	Possible Injury	Ran Off Roadway-Right

4.4 Chapter Summary

In this chapter the results of the evaluation of the CPM were presented using three two-lane rural highway study sections selected by the TAC members. The evaluation provided some insights in the capability of the CPM. The CPM comes with various input assistance tools and some of the input data come with default values. When site specific data required for the module are not available, the CPM provides default values. The analysis was performed with the goal of determining if the CPM could be used as a tool for safety audits of two-lane rural highways. The findings from the analysis of the three study sections are summarized.

From the analysis of the US-40 study section, from MP 35 to MP 45, it was learned that the content of the input data can greatly affect the quality of the prediction outputs. In the case of the US-40 study section, animal-related collisions comprised the majority of the crashes (about 60 percent) and consequently this affected the crash prediction outputs. The default prediction model considers animal-related crashes to be about 30 percent of the total number of crashes. The US-6 study section, from MP 22 to MP 28, had only one animal-related crash; hence the analysis results began to show the capability of the CPM. With the data from this study section the CPM produced reasonably accurate crash prediction values and thus manifested the potential for CPM in assisting transportation engineers in identifying crash prone segments within the study section. As for the SR-150 study section, just like the US-40 study section, the large number of animal-related crashes skewed the outcome of the analysis.

From these findings, it can be concluded that the CPM can be used in safety audits of two-lane rural highways in identifying potential “hot spots” that require special attention as a function of crash numbers, with some caution when using crash rates. In all cases, the general trends of predicted crash occurrences along the study sections with and without showed some similarity. The statistics of the difference in number of crashes with and without crash history turned out to be small, thus indicating the possibility of using the CPM without crash history to predict the number of crashes for alternative alignments.

What is important is that users need to make sure that appropriate surrogate alignments reflecting the existing alignments at reasonable accuracy are used and be able to interpret the analysis results carefully using their knowledge in highway design and engineering experience.

5 Application of IRM to Selected Intersections

As mentioned in Section 2.1.5, the IRM is a separate module that requires a different set of data and an independent file set to run. This chapter discusses the findings obtained from the application of IRM to two selected intersections on two-lane rural highways that were recommended by the TAC members of the study.

5.1 Need for IRM

Generally speaking, UDOT does not have many four-leg rural highway intersections consisting of two two-lane rural highways that are suitable for analysis by the IRM of IHSDM. There are, however, many three-leg T-intersections consisting of two two-lane rural highways. Although the analysis required four-leg intersections to identify the applicability of IRM to safety audits, three-leg intersections were used for this analysis.

5.2 Application of IRM to the Intersections of US-6, SR-174, and SR-136

After discussing with the TAC members of the study about this portion of the study, two intersections were chosen to apply the IRM. Unlike the study sections used for the CPM evaluation which were selected because of their high crash rates, these two intersections were chosen for their ideal characteristics required for the analysis.

The two intersections are located in central Utah, about 50 miles west of the City of Elberta. Figure 5-1 shows the location of the two intersections (UDOT 2008) and Figure 5-2 shows a schematic drawing of the relationship between the two intersections.

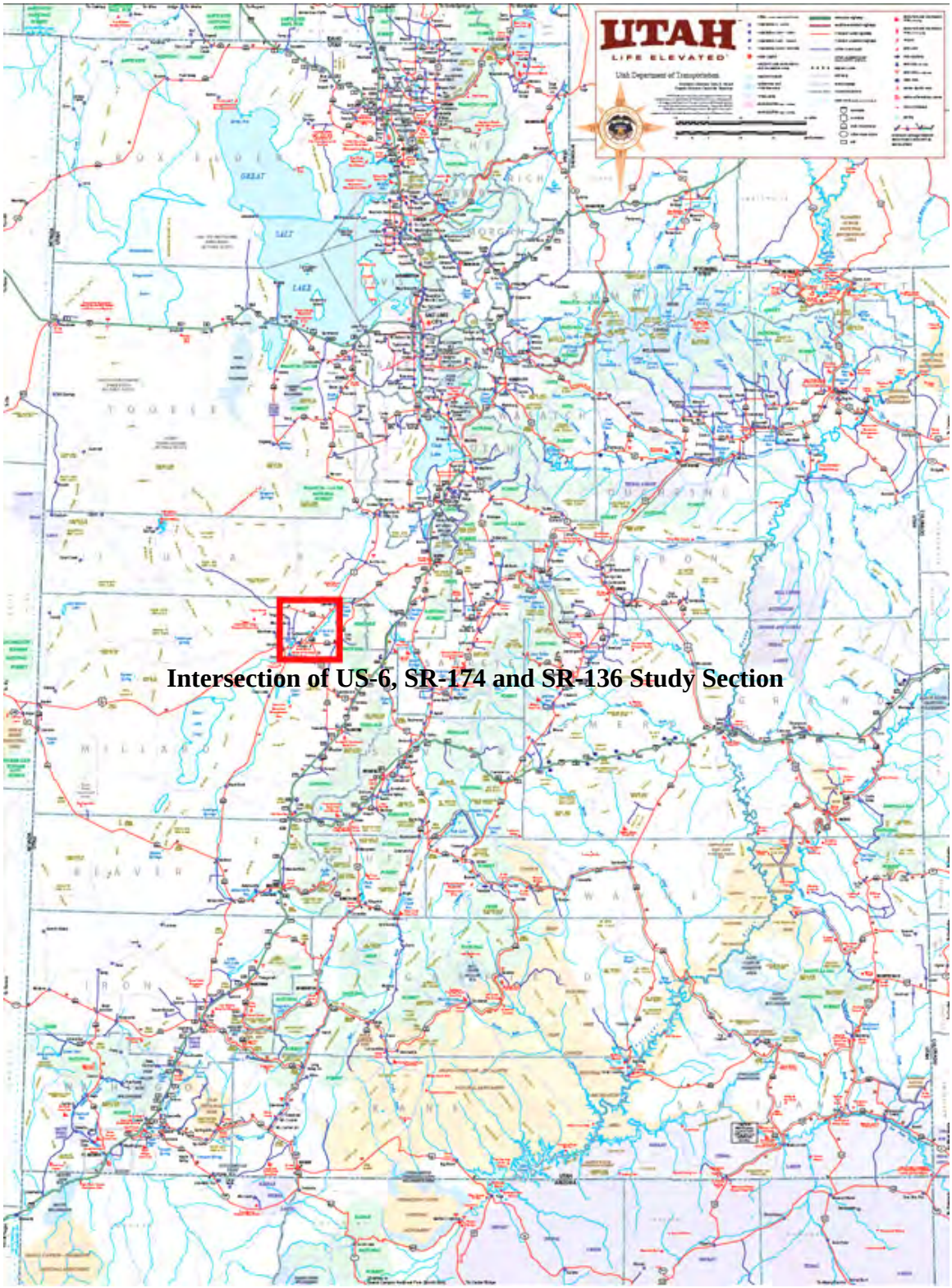

Figure 5-1: Location of the Intersections of US-6, SR-174, and SR-136 (UDOT 2008)

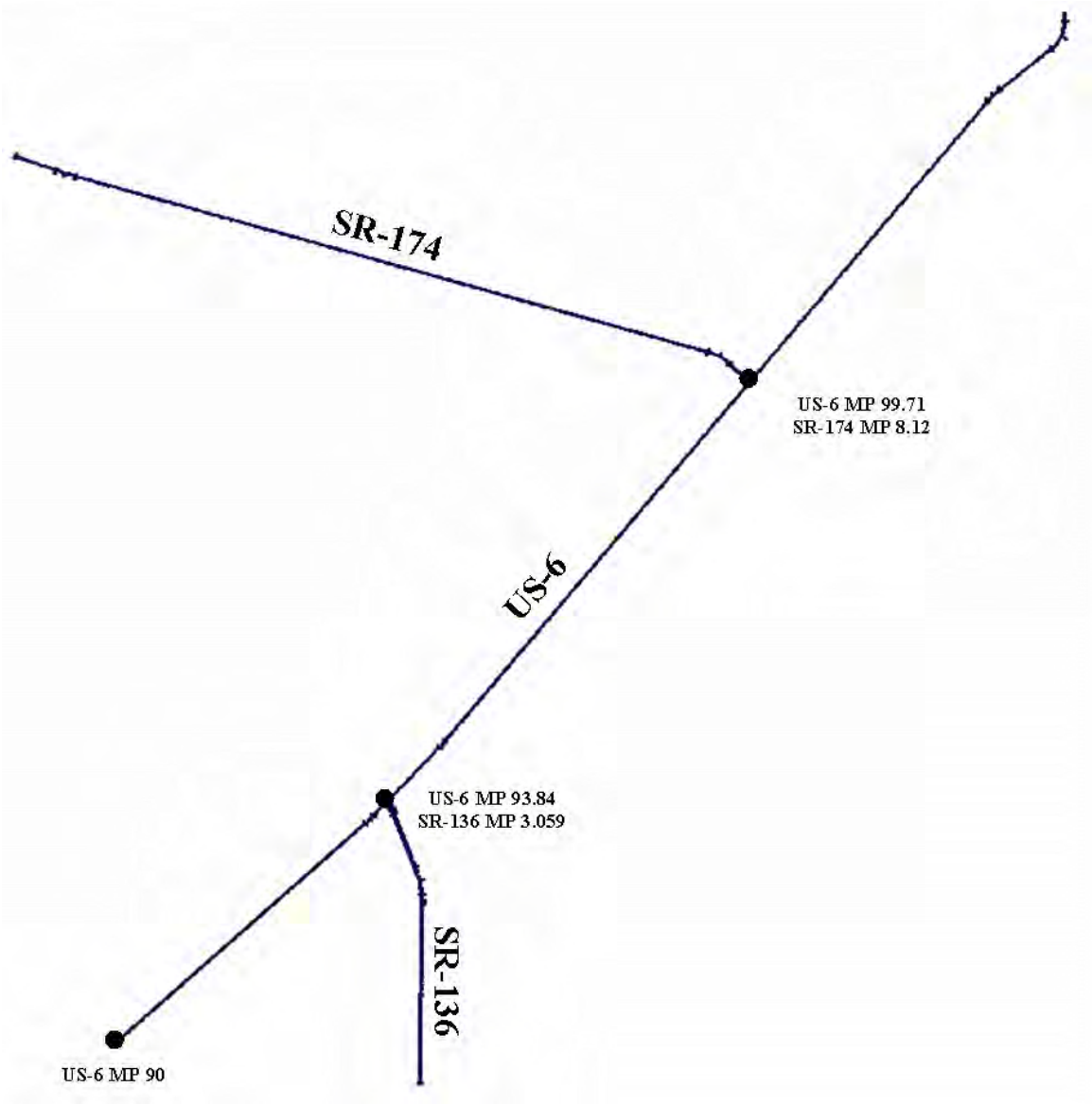

Figure 5-2: Plot of the Intersections of US-6, SR-174, and SR-136

5.2.1 Current Conditions of the Intersections

A trip was made to investigate the conditions of the intersections. Figure 5-3 shows two photos obtained from the Roadview website (UDOT 2007a) and Figure 5-4 shows two photos taken during the author's field visit to the site in December 2007. These two figures were prepared for comparison purposes.

(a) Intersection of US-6 and SR-174

(b) Intersection of US-6 and SR-136

Figure 5-3: Photos of the Intersections, during summer 2005 (UDOT 2007a)

(a) Intersection of US-6 and SR-136

(b) Intersection of US-6 and SR-174

Figure 5-4: Photos of the Intersections, during winter 2007 (Taken by Kaitlin Chuo)

From these photos it can be seen that the quality of the pavement appears to be declining. Apart from this decline in their pavement quality, the general conditions of the intersections appeared relatively good.

5.2.2 Alignments of US-6, SR-174, and SR-136

The biggest difference in data entry between IRM and CPM is that IRM requires multiple highway alignments be entered separately and they are connected with the IHSDM function “New Intersection” to form intersections. IRM users only need to provide the stations of the roads where they cross the other road(s) to build an intersection. Table 5-1 presents the surrogate centerline horizontal alignments of all three road sections and Table 5-2 gives the vertical alignments. These alignments were prepared in the manners presented in Appendix and in the same manner that the centerline alignments were created for the CPM analysis.

Table 5-1: Alignments of US-6 MP 90-MP 108, SR-174 MP 0-MP 8.1, and SR-136 MP 0-MP 3.1

Segment	Milepost		Radius
	From	To	
US-6			
Tangent	93.57	97.09	
Simple Curve	97.09	97.22	
Tangent	97.22	98.21	8000
Simple Curve	98.21	98.30	
Tangent	98.30	107.16	7000
Simple Curve	107.16	107.35	
Tangent	107.35	108.03	5000
Simple Curve	108.03	108.36	
Tangent	108.36	108.55	2000
SR-174			
Tangent	0.00	0.45	
Simple Curve	0.45	0.67	20000
Tangent	0.67	7.56	
Simple Curve	7.56	7.82	3000
Tangent	7.82	8.10	
SR-136			
Tangent	0.00	0.01	
Simple Curve	0.01	0.01	400
Tangent	0.01	0.03	
Simple Curve	0.03	0.05	1500
Tangent	0.05	0.05	
Simple Curve	0.05	0.09	1000
Tangent	0.09	0.10	
Simple Curve	0.10	0.14	1300
Tangent	0.14	0.74	
Simple Curve	0.74	1.05	5500
Tangent	1.05	1.12	
Simple Curve	1.12	1.13	1000
Tangent	1.13	3.06	

Table 5-2: Vertical Alignments of US-6 MP 90-MP 108, SR-174 MP 0-MP 8.1, and SR-136 MP 0-MP 3.1

VPI Station	Back Grade	Back Length	Forward Grade	Forward Length
US-6				
93.73	-0.20	125	2.17	125
93.94	2.17	100	0.55	100
94.05	0.55	200	1.59	200
94.22	1.59	100	0.82	100
94.37	0.82	75	0.00	75
94.42	0.00	50	0.31	50
94.46	0.31	50	1.34	50
94.74	1.34	200	-0.15	200
94.89	-0.15	150	1.20	150
94.98	1.20	125	-0.12	125
95.05	-0.12	75	0.71	75
95.12	0.71	75	0.37	75
95.15	0.37	50	1.30	50
95.23	1.30	100	1.59	100
95.29	1.59	150	0.07	150
95.35	0.07	50	-0.49	50
95.38	-0.49	50	-0.11	50
95.43	-0.11	25	-0.65	25
95.46	-0.65	100	0.25	100
95.51	0.25	25	0.69	25
95.58	0.69	50	1.18	50
95.69	1.18	75	0.36	75
95.73	0.36	25	0.59	25
95.98	0.59	500	0.05	500
96.19	0.05	250	0.97	250
96.58	0.97	350	-0.51	350
96.68	-0.51	175	0.02	175
97.20	0.02	250	-4.05	250
97.57	-4.05	100	-2.89	100
97.78	-2.89	450	3.37	450
97.92	3.37	140	6.17	140
98.12	6.17	400	0.28	400
98.29	0.28	100	0.72	100
98.38	0.72	50	-0.10	50
98.54	-0.10	150	0.82	150
98.68	0.82	100	2.76	100
98.82	2.76	500	-0.22	500
99.02	-0.22	50	0.70	50
99.10	0.70	100	0.11	100

Table 5-2: Vertical Alignments of US-6 MP 90-MP 108, SR-174 MP 0-MP 8.1, and SR-136 MP 0-MP 3.1 (continued)

VPI Station	Back Grade	Back Length	Forward Grade	Forward Length
99.32	0.11	175	-1.29	175
99.47	-1.29	100	-0.24	100
99.56	-0.24	175	-2.99	175
99.69	-2.99	150	0.28	150
99.82	0.28	150	2.05	150
99.96	2.05	200	0.16	200
100.24	0.16	100	1.24	100
100.42	1.24	150	0.15	150
101.18	0.15	150	-0.77	150
101.40	-0.77	600	0.45	600
101.85	0.45	350	-0.10	350
102.14	-0.10	250	0.29	250
102.47	0.29	350	0.12	350
102.73	0.12	150	0.00	150
102.92	0.00	45	0.25	45
103.18	0.25	150	-0.03	150
103.69	-0.03	750	0.14	750
104.17	0.14	200	-0.17	200
104.33	-0.17	500	0.05	500
105.87	0.05	150	-0.49	150
106.30	-0.4	200	-1.61	200
106.50	-1.61	400	0.35	400
106.96	0.35	250	0.15	250
107.24	0.15	150	0.79	150
107.38	0.79	100	0.00	100
107.45	0.00	50	1.10	50
107.57	1.10	150	-0.65	150
107.66	-0.65	200	0.00	200
107.77	0.00	50	0.81	50
107.84	0.81	50	0.22	50
107.95	0.22	100	0.57	100
108.00	0.57	50	-0.39	50
108.04	-0.39	75	0.55	75
108.08	0.55	100	0.07	100
108.29	0.07	25	-0.77	25
108.35	-0.77	75	0.41	75
108.38	0.41	25	-0.60	25
108.40	-0.60	40	0.08	40
SR-174				
0.11	0.16	200	-0.06	200

Table 5-2: Vertical Alignments of US-6 MP 90-MP 108, SR-174 MP 0-MP 8.1, and SR-136 MP 0-MP 3.1 (continued)

VPI Station	Back Grade	Back Length	Forward Grade	Forward Length
0.29	-0.06	25	0.06	25
0.72	0.06	550	1.26	550
0.97	1.26	500	2.95	500
1.28	2.95	1000	0.13	1000
1.99	0.13	500	0.34	500
2.34	0.34	250	-0.48	250
2.58	-0.48	1000	0.65	1000
2.92	0.65	750	-0.29	750
3.38	-0.29	600	0.40	600
3.78	0.40	500	-0.09	500
4.40	-0.09	1000	0.63	1000
5.02	0.63	1000	-0.80	1000
5.38	-0.80	850	0.87	850
5.71	0.87	400	0.09	400
5.88	0.09	450	0.57	450
6.14	0.57	250	0.27	250
6.52	0.27	450	0.06	450
7.07	0.06	500	-0.15	500
7.37	-0.15	500	0.33	500
7.60	0.33	50	-0.56	50
7.64	-0.56	50	0.22	50
7.83	0.22	100	-0.69	100
7.90	-0.69	100	-0.02	100
SR-136				
0.06	0.39	125	1.86	125
0.12	1.86	50	2.65	50
0.28	2.65	50	2.00	50
0.49	2.00	900	-1.03	900
0.84	-1.03	450	0.64	450
1.00	0.64	200	-0.08	200
1.12	-0.08	50	-0.90	50
1.27	-0.90	450	1.24	450
1.54	1.24	475	-1.19	475
1.66	-1.19	150	-2.25	150
1.83	-2.25	400	0.09	400
2.03	0.09	150	-0.39	150
2.25	-0.39	400	0.55	400
2.59	0.55	1150	-1.41	1150
2.91	-1.41	400	-0.41	400

5.2.3 Analysis of the IRM Results

In the IRM, the output results are in a different format compared to the outputs of the CPM. IRM's goal is to "emulate the knowledge of a human expert" (FHWA 2006). Instead of giving predicted numbers of crashes, IRM gives a "Diagnostic Summary." The diagnostic summary has two components: policy review (not available in the version of IHSDM used for the study); and diagnostic review, the focus of the analysis in this study. When IRM is run, four elements of the intersection are checked: corner radius, turn lane design, intersection angle, and intersection sight triangle. In the IRM diagnostic summary, Level 1 refers to the concerns that could "indicate a potential safety issue" and Level 2 refers to the concerns that could "indicate potential for significant design improvement" (FHWA 2006). Table 5-3 shows the diagnostic summary of the intersection at US-6 and SR-174 and Table 5-4 shows the diagnostic summary of the intersection at US-6 and SR-136.

Table 5-3: Diagnostic Summary of the Intersection at US-6 and SR-174

Scope	Status	Concern	Feature			Comment	Treatment	
			Category	Road	Threshold		Design	Mitigation
Intersection concern	Not a concern	Large intersection pavement area						
Leg #1 - NE US-6	Not a concern	Approach alignment differs						
Leg #2 - SW US-6	Not a concern	Insufficient SSD on vertical curve				Crest vertical curve		
		Insufficient DSD						
		Approach alignment differs						
Leg #3 - NW US-174	Level 1	Insufficient ISD to right (Case B1)	ISD (vertical)	403.54 feet	647.17 feet	The required time for the maneuver used in the ISD calculations are for passenger cars only ; crest vertical curve	1. Remove roadside obstacles within sight triangle. 2. Close approach. 3. Relocate approach. 4. Make leg one-way away from intersection. 5. Lengthen vertical curve.	1. Remove roadside obstacles within sight triangle. 2. Signalize intersection. 3. Convert to all-way STOP. 4. Post advisory speed on major road. 5. Review speed limit on major road. 6. Install
	Not a concern	Insufficient ISD to left (Case B2)				The required time for the maneuver used in the ISD calculations are for passenger cars only		
		Approach alignment differs						

Table 5-4: Diagnostic Summary of the Intersection at US-6 and SR-136

Scope	Status	Concern	Feature			Comment	Treatment	
			Category	Road	Threshold		Design Improvement	Mitigation Measures
Intersection concern	No policy					Acceptable approach volume for speed 65 miles/hour, opposing volume 1,025 vehicles/hour, left turn percent 17.65 percent		
	Not a concern	Large intersection pavement area						
Leg #1 - NE US-6	Not a concern	Insufficient ISD for left turn from major road (Case F)				The required time for the maneuver used in the ISD calculations are for passenger cars only		
		Insufficient SSD on horizontal curve				Horizontal curve		
		Insufficient SSD on vertical curve				Crest vertical curve		
		Insufficient DSD on horizontal curve				Horizontal curve		
		Insufficient DSD on vertical curve				Crest vertical curve		
		Warranted left turn lane is not present						
		Loss of control potential due to				Horizontal curve		
		Approach alignment differs between opposing						
Leg #2 - SE US-136	Level 1	Insufficient ISD to right (Case B1)	ISD (vertical)	32.81 feet	647.17 feet	The required time for the maneuver used in the ISD calculations are for passenger cars only ; crest vertical curve	1. Remove roadside obstacles within sight triangle. 2. Close approach. 3. Relocate approach. 4. Make leg one-way away from intersection. 5. Lengthen vertical curve.	1. Remove roadside obstacles within sight triangle. 2. Signalize intersection. 3. Convert to all-way STOP. 4. Post advisory speed on major road. 5. Review speed limit on major road. 6. Install
	No data					Could not calculate actual horizontal stopping sight distance		
						Could not calculate actual stopping sight distance		
						Actual horizontal sight distance unavailable		
	Not a concern	Insufficient ISD to left (Case B2)				The required time for the maneuver used in the ISD calculations are for passenger cars only		
		Insufficient SSD on horizontal curve				Horizontal curve		
		Insufficient DSD on horizontal curve						
		Insufficient visibility to stop sign	SD (horizontal)		659.86 feet			
		Increased crossing distance	Skewed angle	87.87053 degrees	50.00000 degrees			
		Approach alignment differs between opposing approaches						

Table 5-4: Diagnostic Summary of the Intersection at US-6 and SR-136 (continued)

Scope	Status	Concern	Feature			Comment	Treatment	
			Category	Road	Threshold		Design Improvement	Mitigation Measures
		Uneven, discontinuous minor-road profile through intersection						
Leg #3 - SW US-6	Level 1	Warranted right turn lane is not present		181 vehicles/hour	40 vehicles/hour		1. Provide right-turn lane. 2. Provide channelized right-turn roadway. 3. Provide right-turn acceleration lane.	1. Restripe or reallocate approach lane configuration. 2. Install advance warning sign.
	Not a concern	Approach alignment differs between opposing approaches						

In Table 5-3 and Table 5-4, the terms ISD, SSD, and DSD are defined as intersection sight distance, stopping sight distance, and decision sight distance. It is advised that the reader refer to *A Policy on Geometric Design of Highways and Streets* by AASHTO for detailed definitions and equations for these terms (AASHTO 2004).

As these two tables show, the software gives diagnostic (concern), comments, design improvement, and mitigation measures for the evaluated intersections based on the data entered by the user. For the intersection of US-6 and SR-174, the IRM results showed that the northwest (NW) leg had some safety concerns and suggested a few steps for improvements. The other two legs did not have any concerns.

As for the other intersection, at US-6 and SR-136, the southeast (SE) and southwest (SW) legs were evaluated as potentially problematic and mitigation measures were recommended accordingly. Also, the northeast (NE) leg has eight concerns about various issues, although no suggestion for improvements was given.

These comments and suggestions are useful for highway design engineers and traffic safety engineers and provide them with some ideas of the safety conditions of the study sites prior to visiting the sites.

Again, the user needs to remember that none of the modules in IHSDM are meant to substitute professional, engineering judgment. All the outputs and results from the IHSDM modules are to be interpreted and used with caution.

5.3 Chapter Summary

This chapter presented the results of the analysis of two intersections of two-way rural highways on US-6. In its output reports, the IRM provides comments and suggested solutions to the legs of the intersections and the intersection itself that may have potential concerns. In the two specific cases presented here, the intersections were not experiencing high crash rates or driver confusions due to the roadway designs; therefore, it is difficult to determine if the given recommendations are valid and practical. The items diagnosed by the IRM need to be verified by a field visit. Nevertheless, these comments and suggested treatments given in the diagnostic summary of the IRM can be used as the guidelines for identifying possible improvements.

6 Conclusions and Recommendation

Two-lane rural highways comprise 77 percent of the nation's highway systems and they account for 44 percent of the nation's fatal crashes (FHWA 2006). Keeping two-way rural highways safe is an important task of many state departments of transportation. As one method to proactively identify potential problems on highway sections and intersections, roadway safety audits are conducted. However, sending several experts to the study sites without clear ideas is simply costly and time consuming. Hence, a method that will help transportation engineers set a clear goal for inspection prior to field inspections has been sought.

FHWA has worked on the development of IHSDM in an attempt to help highway engineers design safe two-lane highways and to help safety engineers efficiently analyze safety impacts of alternative designs (FHWA 2006). IHSDM is a suite of software developed by FHWA for monitoring and analyzing two-lane rural highways in the United States. IHSDM consists of six modules: PRM, CPM, DCM, TAM, IRM, and DVM, with DVM being still under development at present (see Chapter 2 for the descriptions of these six modules of IHSDM).

As IHSDM is a fairly "young" program a limited amount of research has been conducted to evaluate its practicability and reliability. This study was conducted to determine if IHSDM can be adopted into the engineering decision making process during safety audits of two-way rural highways in Utah. Among the six modules, two modules, CPM and IRM, were chosen for evaluation because of their applicability to safety audits.

Both CPM and IRM require, at minimum, horizontal and vertical alignments. However, plans of two-way rural highways were practically nonexistent because they were constructed many years ago. Furthermore, reconstruction and/or rehabilitation works that might have taken place to these highways; hence, finding their alignments was

practically impossible. Hence, a new method was developed for this study to create surrogate alignments using GPS data collected by UDOT (see Appendix). This method helps the engineers to create surrogate alignments of any two-way rural highways under study as long as GPS data for each direction of the highway sections are available. This new method for creating surrogate alignments is one notable contribution of this study for expanding the use of IHSDM to safety audits of two-way rural highways.

In the following subsections conclusions based on the findings from the evaluation of the CPM and IRM are presented and recommendations for applying these modules to safety audits of two-way rural highways are presented together with recommended future research topics on IHSDM.

6.1 Conclusions

Two modules of IHSDM, CPM and IRM, were evaluated in this study because of their applicability to safety audits of two-lane rural highways in Utah. Three sections of two-lane rural highways were selected by the TAC members for the CPM evaluation, due to their undesirable crash histories. Two adjacent intersections on US-6 were then chosen for the IRM evaluation.

As for CPM, the outputs for the three study sections suggest that the CPM has the ability to duplicate similar trends in number of crashes, if the quality of the input data is maintained. Crashes per MVMT of each segment reflect the characteristics of the segments in the study section. Hence, similar crash rates are expected for tangent segments and different crash rates are determined for curve segments depending on their radii. A large number of crashes involving wild animals negatively affect the ability of the CPM as demonstrated by the US-40. However, the analysis of the SR-150 study section showed that the CPM was able to produce reasonably reliable outputs despite a large number of wild or domestic animal related crashes. As for the IRM, the outputs of the module include suggestions and recommendations to improve the intersections and they require engineering judgment in interpreting them and in selecting improvements presented.

Based on the comparison of the trends in the number of crashes with and without crash history along the highway segments of the three study sections and the mean difference between the number of crashes with and without crash history, the CPM is found to be a capable and useful tool for the highway and safety engineers as they prepare for safety audits of two-way rural highways. The finding on the differences in number of crashes with and without crash history is important. This means the CPM can be used to estimate crash occurrences for alternative improvements to the existing sections. The IRM, on the other hand, can function like a knowledge-based safety inspection assistant by providing diagnostic statements and offering potential crash mitigation measures. As mentioned in Chapter 4 and Chapter 5, however, interpreting the outputs from these modules of IHSDM requires knowledge and experience in highway design and familiarity with *A Policy on Geometric Design of Highway and Streets* by AASHTO (2004).

6.2 Recommendations

The Users' Manual of IHSDM states, "IHSDM is intended as a supplementary tool to augment the design process…This tool is NOT a substitute for engineering judgment…" (FHWA 2006). IHSDM is not to be used as a replacement to engineering experience and decision-making. This notion is especially important when using the CPM, where future crash rates are predicted for the future; the crash rates predicted by the CPM should never be taken as specific numbers of crashes that may take place but they should be taken as indicators of trends in crash occurrence. Also, since the outputs of the IRM are suggestions and recommendations produced by the equations and pre-defined procedures in the program, they need to be used with caution and should not be accepted blindly. Study sites must be visited and their suggestions and recommendations be evaluated for their appropriateness.

Traffic safety engineers at UDOT can incorporate the CPM and IRM modules of IHSDM into their safety audit routine. Running these modules will help them identify potential "hot spots" that require special attention before they send a group of experts to the field. This will help them use their time and resources efficiently and effectively.

Because IHSDM can be downloaded free of charge, the cost for the UDOT engineers to utilize the software is practically none. The software is self-explanatory and relatively easy to learn; however, receiving training on the software provided by FHWA will certainly help the engineer become confident in the use of the software. Since only the CPM and IRM modules of IHSDM were evaluated in this study, the capability and usefulness of the other modules are yet unknown. It is recommended that UDOT engineers explore all six modules of IHSDM to fully appreciate the power of the software and identify how this software can be used to improve the conditions of two-way rural highways.

As for the features of the CPM, the crash prediction models implicitly include the effect of animal-related crashes. There is no feature to adjust the situation for highway sections with over-represented occurrences of animal-related crashes. Therefore, it is recommended to investigate if animal-related crashes can be excluded in order to analyze the highway sections purely from the geometric conditions of the highways.

IHSDM allows the users to calibrate prediction models in the CPM to better reflect the local conditions. This issue was outside the scope of this study; however, such calibration efforts may increase the module's crash prediction capability. It is recommended to conduct a study to determine the values of the calibration factor included in the crash prediction model to make the CPM more responsive to the drivers on Utah's two-way rural highways.

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Oh, J., Lyon, C. Washington, S. Persaud, B. and Bared, J. (2003). Validation of FHWA Crash Models for Rural Intersections. *Transportation Research Record 1840,* Transportation Research Board, Washington D.C., pp. 41-49.

Utah Department of Transportation (UDOT). Accident Records Website. <http://168.178.125.103/udotasset/login/login.asp> Log-in required. (September 28, 2006)

Utah Department of Transportation (UDOT). Mapping Website. <http://www.udot.utah.gov/main/f?p=100:pg:12606567523936569916:::V,T:,230> (February 7, 2008)

Utah Department of Transportation (UDOT). Roadview Explorer 2.0 Website. <http://www.roadview.udot.utah.gov/> (December 21, 2007a)

Utah Department of Transportation (UDOT). Traffic Data Website. <http://168.178.125.103/udotAsset/Login/LoginMain.asp?sid=QFVMMRNHAPQPCPGJKYLVVGVFJB> (February 23, 2007b)

Appendix

Creating Centerline Alignments for Two-Lane Rural Highways Using UDOT's GPS Data

by Michael Mosley

Spring 2007

Note: Although written by Michael Mosley, this Appendix was included in the report because the procedure described in this Appendix was an integral part of the research

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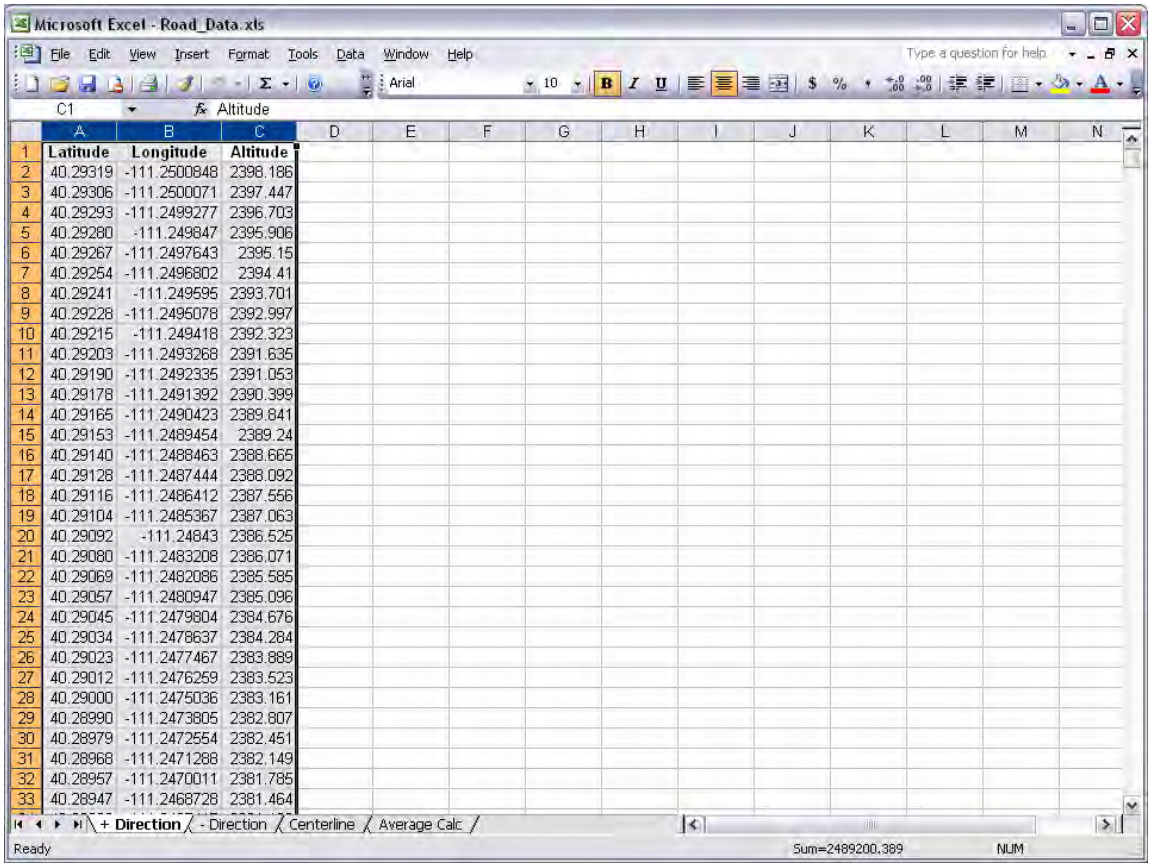
A. 1 How to Import GPS Survey Data Into Bentley's InRoads

The discussions included in this report are based on the assumption that the user uses the Computer Aided Engineering Design and Manufacturing (CAEDM) computing system, which is a computer network system in the College of Engineering and Technology of Brigham Young University (BYU). Please note that what is important is to find out how to convert Geographical Positioning System (GPS) data into InRoads readable data for creating centerline alignments of two-lane rural highways and what kind of data manipulation must be done to achieve this goal of creating a surrogate centerline alignment for two-lane rural highways, whose design plans are hard to obtain, already lost in the archive, or destroyed. Depending on the highway design software the user employs to create surrogate centerline alignments, actual steps that the user has to go through may be different from what are described here. Hence, the user of this manual should focus on what has to be done instead of how it is done.

A.1.1 Convert the GPS Data into InRoads Readable Data

Two steps are involved in the data conversion. First, the GPS data (latitude, longitude, and altitude) provided by the photolog program of the Utah Department of Transportation (UDOT) in an Excel file must be converted into a text file. Then, the GPS data must be converted into survey data (easting, northing, and elevation) that can be read by Bentley's InRoads. In this example we use the Watershed Modeling System (WMS) developed by BYU to convert the GPS data into survey data. As mentioned in the introduction part of this section, a software program that needs to be used for data conversion does not have to be WMS.

In order to use WMS, GPS data must be saved as a text file so that WMS can read them, that is, GPS data given in an Excel file (.xls) from UDOT's photo-logging must be saved as a text file (.txt). Within the Excel file, select the Save As… option and save it as a text file. Figure A-1 shows a screenshots of an Excel file containing GPS data (latitude, longitude, and altitude).



Latitude	Longitude	Altitude
40.29319	-111.2500848	2398.186
40.29306	-111.2500071	2397.447
40.29293	-111.2499277	2396.703
40.29280	-111.249847	2395.906
40.29267	-111.2497643	2395.15
40.29254	-111.2496802	2394.41
40.29241	-111.249595	2393.701
40.29228	-111.2495078	2392.997
40.29215	-111.249418	2392.323
40.29203	-111.2493268	2391.635
40.29190	-111.2492335	2391.053
40.29178	-111.2491392	2390.399
40.29165	-111.2490423	2389.841
40.29153	-111.2489454	2389.24
40.29140	-111.2488463	2388.665
40.29128	-111.2487444	2388.092
40.29116	-111.2486412	2387.556
40.29104	-111.2485367	2387.063
40.29092	-111.24843	2386.525
40.29080	-111.2483208	2386.071
40.29069	-111.2482086	2385.585
40.29057	-111.2480947	2385.096
40.29045	-111.2479804	2384.676
40.29034	-111.2478637	2384.284
40.29023	-111.2477467	2383.889
40.29012	-111.2476259	2383.523
40.29000	-111.2475036	2383.161
40.28990	-111.2473805	2382.807
40.28979	-111.2472554	2382.451
40.28968	-111.2471288	2382.149
40.28957	-111.2470011	2381.785
40.28947	-111.2468728	2381.464

Figure A-1: Screenshot of the Latitude, Longitude, and Altitude Data

When the user selects the Save As… option and tries to save it as a text file, two warning messages will come up, as shown in Figure A-2 and Figure A-3. Answer OK to the first message and YES to the second message. Because we use only one worksheet the first warning is irrelevant so press OK. By these operations, the GPS data were now written in text format in a new file. The data are saved as a text file with a space delimiter.

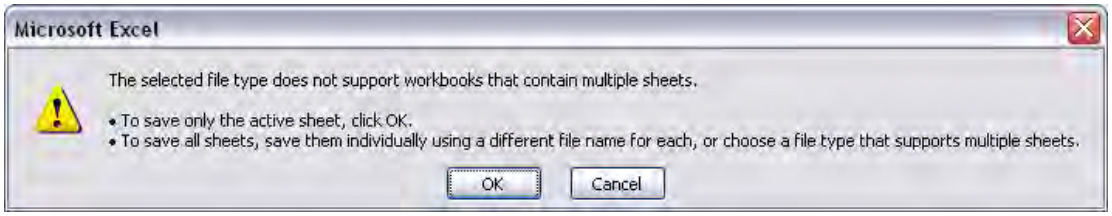


Figure A-2: Screenshot of the Warning Sign

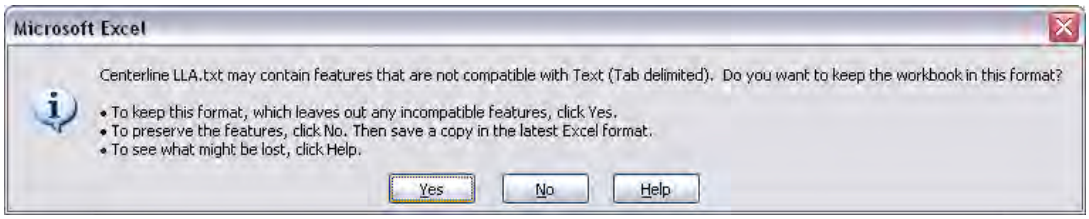


Figure A-3: Screenshot of the Warning Sign

After this operation, the user now uses the WMS software through the CAEDM Citrix server (see Figure A-4 for WMS's user interface). Once the program is loaded, open the text file that the user saved in the previous step.

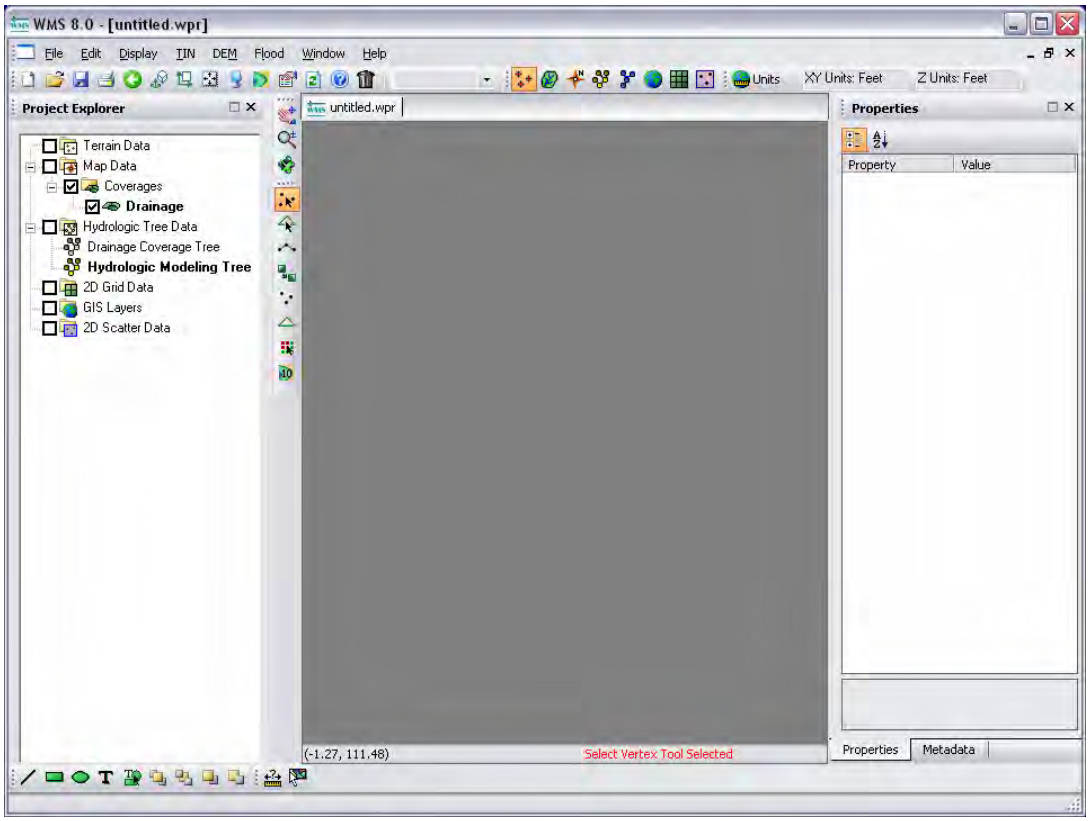


Figure A-4: Screenshot of the WMS software

When opening the text file that was saved in the previous operation, the Import Wizard of WMS will automatically start. Fill in the information as specified. See Figures A-5 and A-6 for the proper setting of the two steps required in the File Import Wizard.

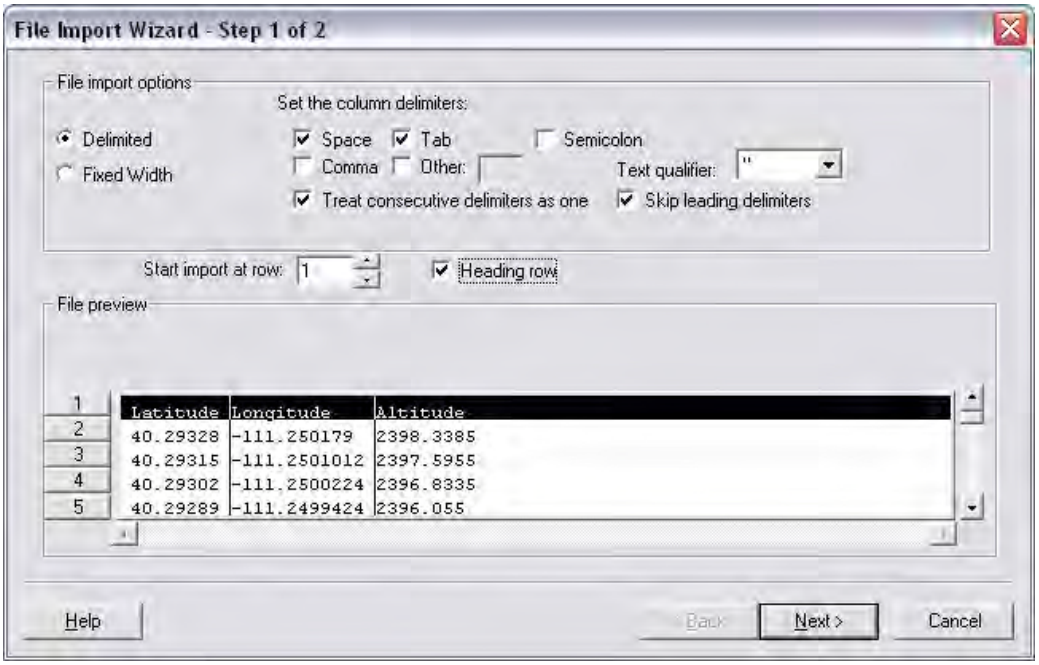


Figure A-5: Screenshot of the File Import Wizard, Step 1

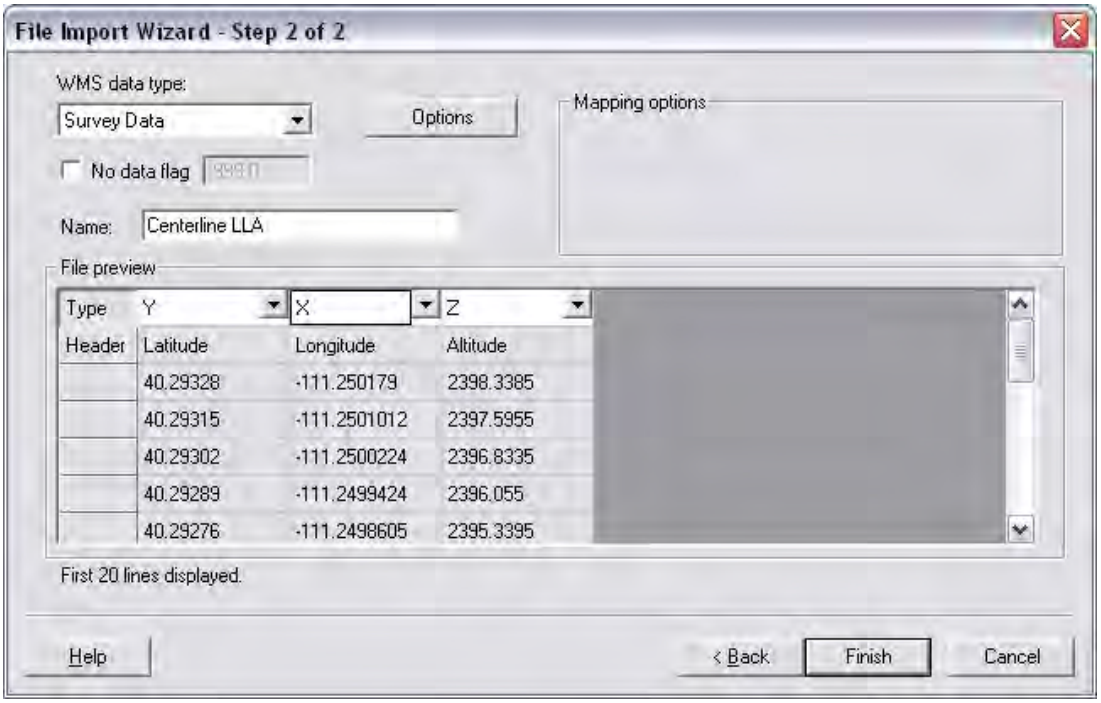


Figure A-6: Screenshot of the File Import Wizard, Step 2

Next, under the EDIT Menu of WMS, select the Coordinate Conversion menu. This will bring up the Coordinate Conversion window that is shown below. Enter the

correct information for the site and the data. For the US- 40 study section near Heber, Utah, the information shown in the screen shot below works.

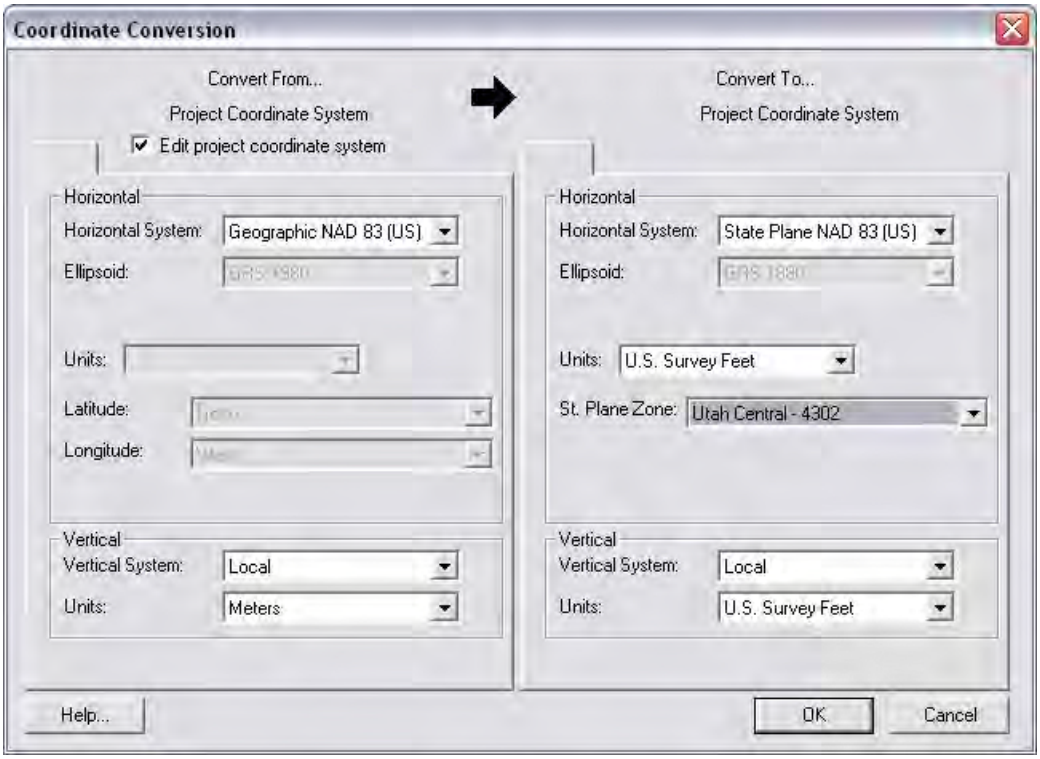


Figure A-7: Screenshot of the Coordinate Conversion Window

Once the conversion is complete, the data are ready to be saved and imported into InRoads. Save the WMS project into a folder where the data for the study section are kept, as shown Figure A-8.

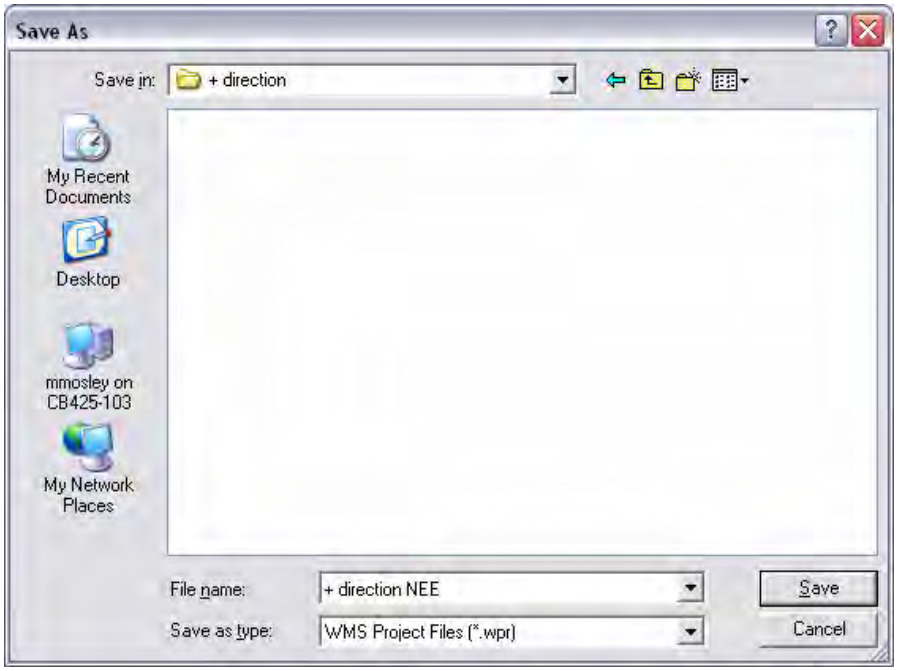


Figure A-8: Screenshot of Save As Window

Once the file is saved, close the file and go to the Windows Explorer. WMS saves multiple files for each of its projects as illustrated in Figure A-9.

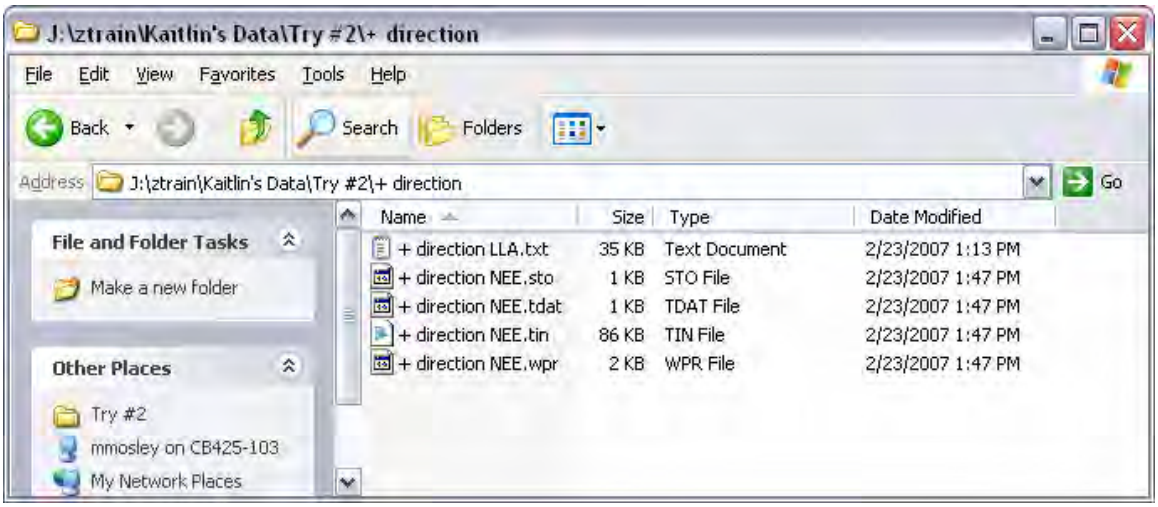
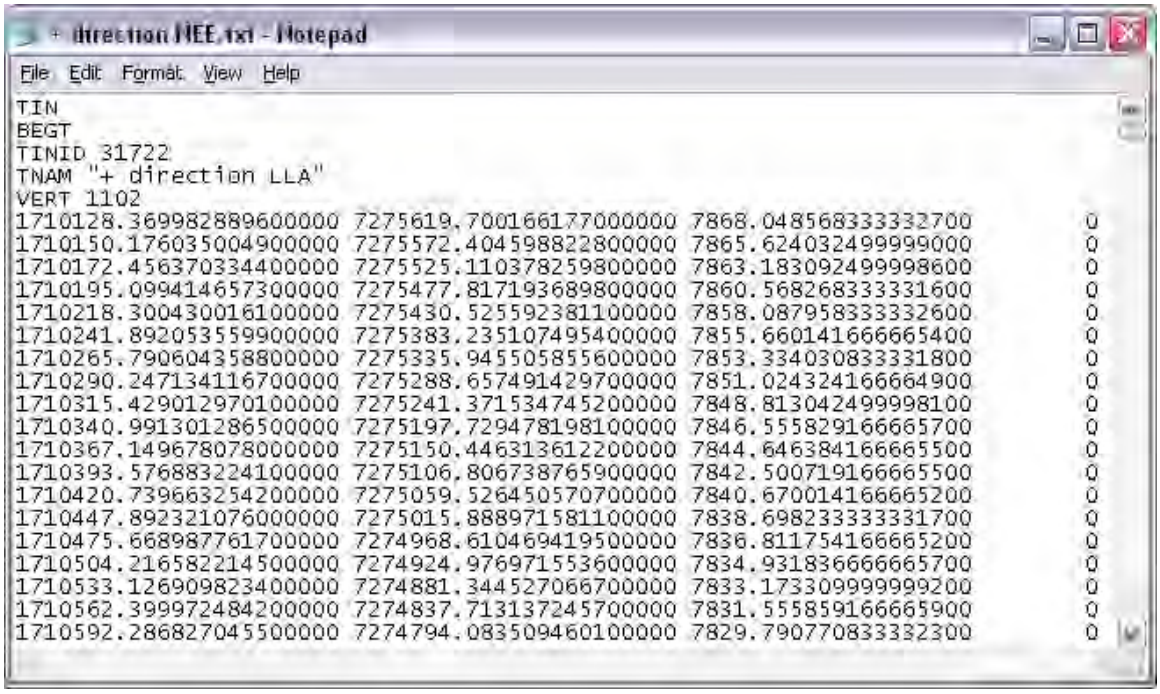


Figure A-9: List of Files Created by WMS

Locate the file that was just saved with the suffix .tin. (All of the other extra files can be disregarded to simplify things.) The .tin file is in text format. Right click the .tin

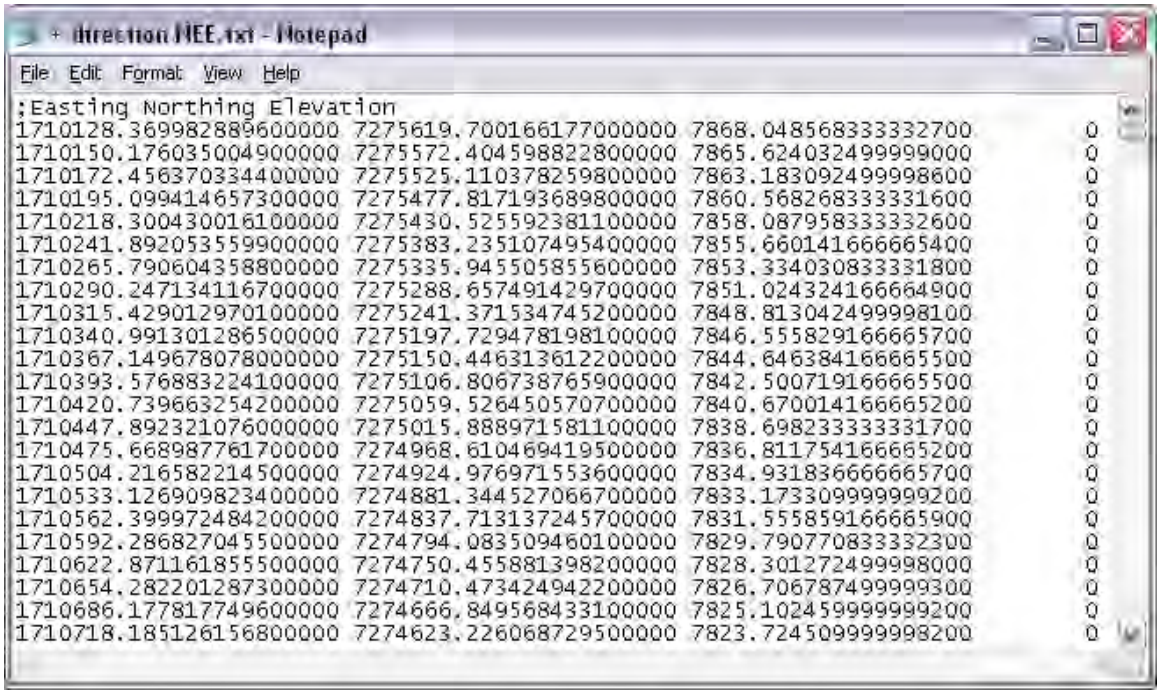
file and rename the file as a .txt, then open the file using a text editor such as Note Pad or Word Pad. The content of the file should look like Figure A-10 below.



```
+ direction NEE.txt - Notepad
File  Edit  Format  View  Help
TIN
BEGT
TINID 31722
TNAM "+ direction LLA"
VERT 1102
1710128.369982889600000 7275619.700166177000000 7868.048568333332700        0
1710150.176035004900000 7275572.404598822800000 7865.624032499999000        0
1710172.456370334400000 7275525.110378259800000 7863.183092499998600        0
1710195.099414657300000 7275477.817193689800000 7860.568268333331600        0
1710218.300430016100000 7275430.525592381100000 7858.087958333332600        0
1710241.892053559900000 7275383.235107495400000 7855.660141666665400        0
1710265.790604358800000 7275335.945505855600000 7853.334030833331800        0
1710290.247134116700000 7275288.657491429700000 7851.024324166664900        0
1710315.429012970100000 7275241.371534745200000 7848.813042499998100        0
1710340.991301286500000 7275197.729478198100000 7846.555829166665700        0
1710367.149678078000000 7275150.446313612200000 7844.646384166665500        0
1710393.576883224100000 7275106.806738765900000 7842.500719166665500        0
1710420.739663254200000 7275059.526450570700000 7840.670014166665200        0
1710447.892321076000000 7275015.888971581100000 7838.698233333331700        0
1710475.668987761700000 7274968.610469419500000 7836.811754166665200        0
1710504.216582214500000 7274924.976971553600000 7834.931836666665700        0
1710533.126909823400000 7274881.344527066700000 7833.173309999999200        0
1710562.399972484200000 7274837.713137245700000 7831.555859166665900        0
1710592.286827045500000 7274794.083509460100000 7829.790770833332300        0
```

Figure A-10: Screenshot of the Text File Containing Converted Data

Delete the extra information at the top and bottom of the text file and re-label the top as Easting, Northing, and Elevation, respectively, as shown in Figure A-11. This is the format required for an ASCII (text) file to be read by InRoads.



direction NEE.txt - Notepad

File Edit Format View Help

```
;Easting Northing Elevation
1710128.369982889600000 7275619.700166177000000 7868.048568333332700 0
1710150.176035004900000 7275572.404598822800000 7865.624032499999000 0
1710172.456370334400000 7275525.110378259800000 7863.183092499998600 0
1710195.099414657300000 7275477.817193689800000 7860.568268333331600 0
1710218.300430016100000 7275430.525592381100000 7858.087958333332600 0
1710241.892053559900000 7275383.235107495400000 7855.660141666665400 0
1710265.790604358800000 7275335.945505855600000 7853.334030833331800 0
1710290.247134116700000 7275288.657491429700000 7851.024324166664900 0
1710315.429012970100000 7275241.371534745200000 7848.813042499998100 0
1710340.991301286500000 7275197.729478198100000 7846.555829166665700 0
1710367.149678078000000 7275150.446313612200000 7844.646384166665500 0
1710393.576883224100000 7275106.806738765900000 7842.500719166665500 0
1710420.739663254200000 7275059.526450570700000 7840.670014166665200 0
1710447.892321076000000 7275015.888971581100000 7838.698233333331700 0
1710475.668987761700000 7274968.610469419500000 7836.811754166665200 0
1710504.216582214500000 7274924.976971553600000 7834.931836666665700 0
1710533.126909823400000 7274881.344527066700000 7833.173309999999200 0
1710562.399972484200000 7274837.713137245700000 7831.555859166665900 0
1710592.286827045500000 7274794.083509460100000 7829.790770833332300 0
1710622.871161855500000 7274750.455881398200000 7828.301272499998000 0
1710654.282201287300000 7274710.473424942200000 7826.706787499999300 0
1710686.177817749600000 7274666.849568433100000 7825.102459999999200 0
1710718.185126156800000 7274623.226068729500000 7823.724509999998200 0
```

Figure A-11: Screenshot of the Converted Data after Modification

A.1.2 Import Data Info Using an ACSII File

InRoads 2004 Edition (v.08.07), which was available at the time this manual was developed, on the CAEDM network in the College of Engineering and Technology of BYU was used in this study. Hence, the menu selections presented in this section may differ from the latest version available to the user. Also, due to the peculiar setup of the CAEDM system, some of the instructions discussed below apply only to the InRoads software on CAEDM network. The user of this manual should pay attention to the steps required for the work and consult an InRoads expert of the UDOT main or region office for specific menu sequences that are required to perform the tasks described below when a different version of InRoads is used. The survey data in text format created by WMS are now imported to InRoads. Follow the menu selections presented below.

The FILE>IMPORT>SURFACE menu selection brings up the Import Surface window. It has multiple tabs. Since survey data is imported in text format, select the ASCII tab. Enter the data as shown in Figure A-12. Repeat this procedure for all other needed sets of data. The data should be in the correct location on the surface of the earth;

therefore, the drawing can be compared with a map such as Google® maps to verify its location.

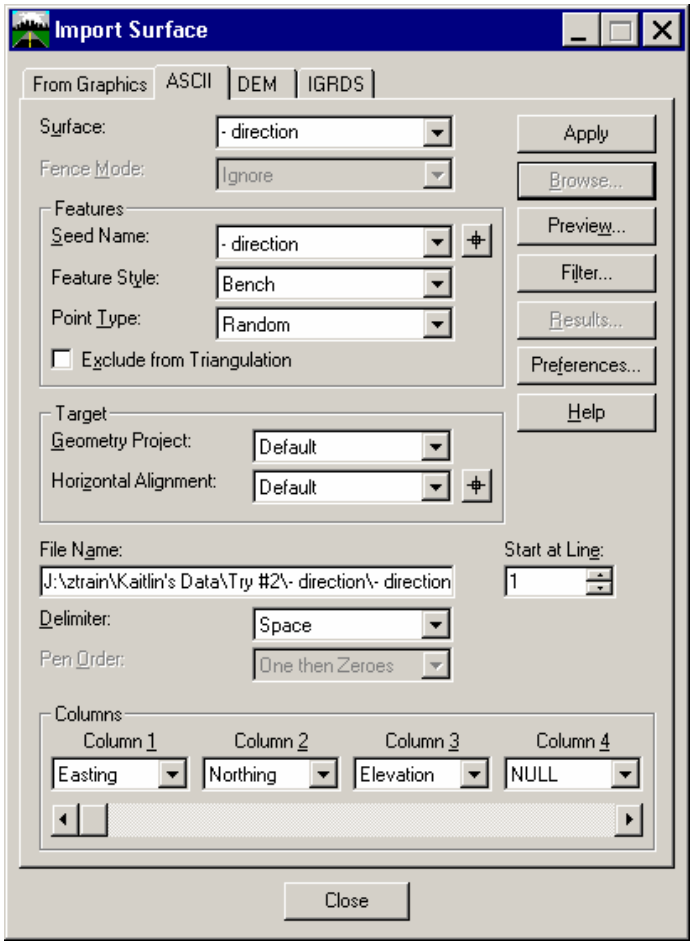


Figure A-12: Screenshot of the Window of Importing Points in InRoad

A.2 Notes on InRoads

Please note that the following descriptions related to computer drive names are all related to the CAEDM system of BYU. When these steps are implemented in a different system, computer drive names are different.

Since InRoads is used through the Citrix server of the CAEDM network, each time the program is opened, the Preferences have to be changed from the default o:/ server to a local file on your j:/ drive. The Preferences can be changed by toggling the PRFERENCES Tab and right clicking and selecting OPEN. (This modification is peculiar to InRoads on the CAEDM system and the user of this manual is recommended

to get assistance from InRoads specialists available to him/her to know how to deal with the driver selections.)

There are always two Preference files. The first is a just an .ini file and the second is a wysiwyg.ini. See Figure A-13 to find where these Preference files are listed. Open both of these files to maintain proper preferences. If it is desired to change any of the preferences in the Preference files, the user can do so at anytime. The preferences can be saved and used in the next session of Inroads.

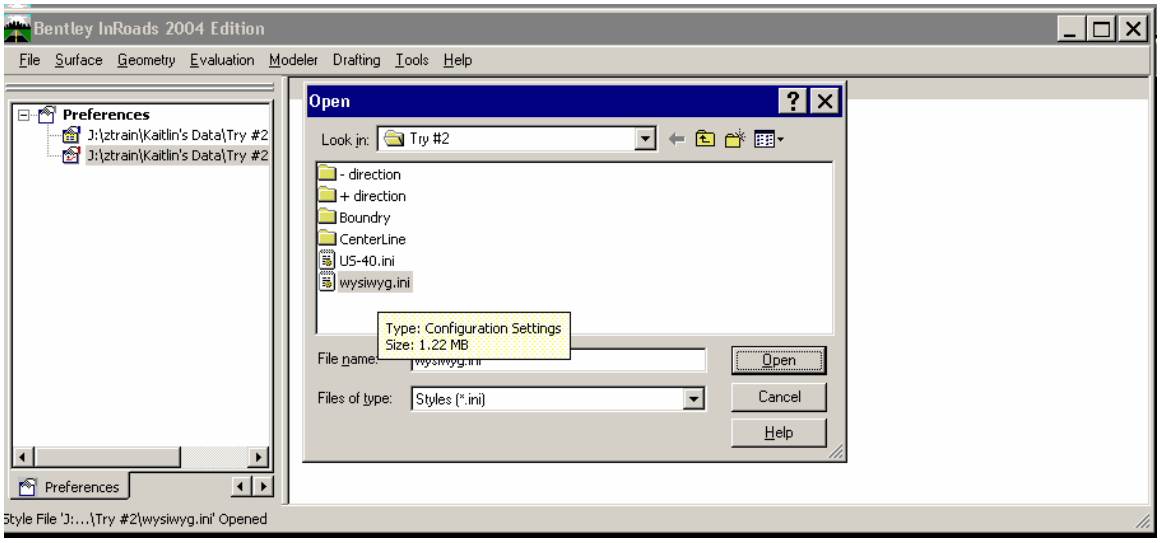


Figure A-13: Screenshot Showing the Preference Files

A.3 Laying Out Centerline Horizontal Alignment

Clear the drawing space and make a new level that will be used for the tangents of the Horizontal Alignment. Change the color to whatever is desired and make sure that the Level color thickness and type are all set to "By level." These buttons can be found at the top of the main drawing window in Microstation. Once the survey points are imported, the point data are presented in the InRoads drawing area as shown in Figure A-14. Note that the points of the two directions appear to be a single "line"; however, as the drawing area is zoomed in, the two "lines" appear.

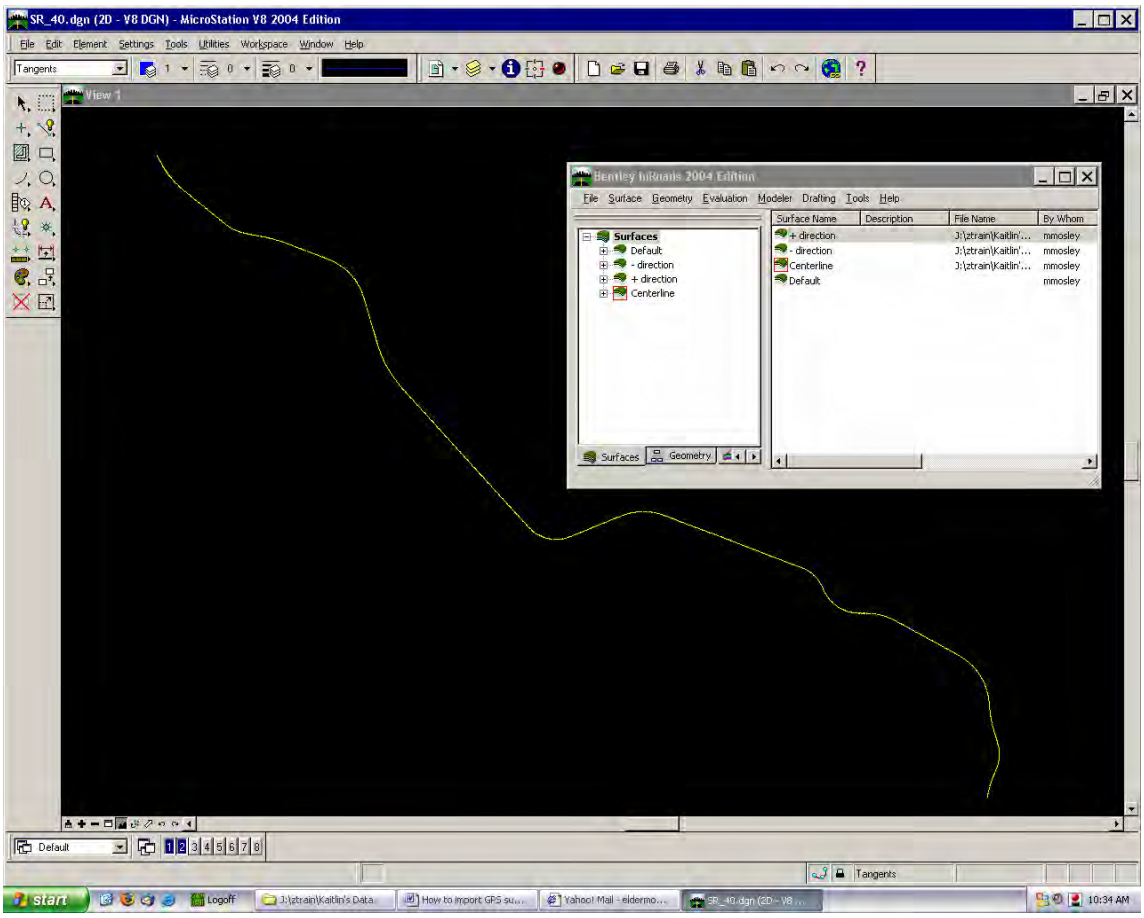


Figure A-14: Screenshot of the Plotted Survey Points in InRoads

Draw in tangents for a guide using the line function to prepare for drawing a horizontal alignment, as shown in Figure A-15. Note that a good trick for Microstation is to click both right and left buttons at once to snap to a desired location.

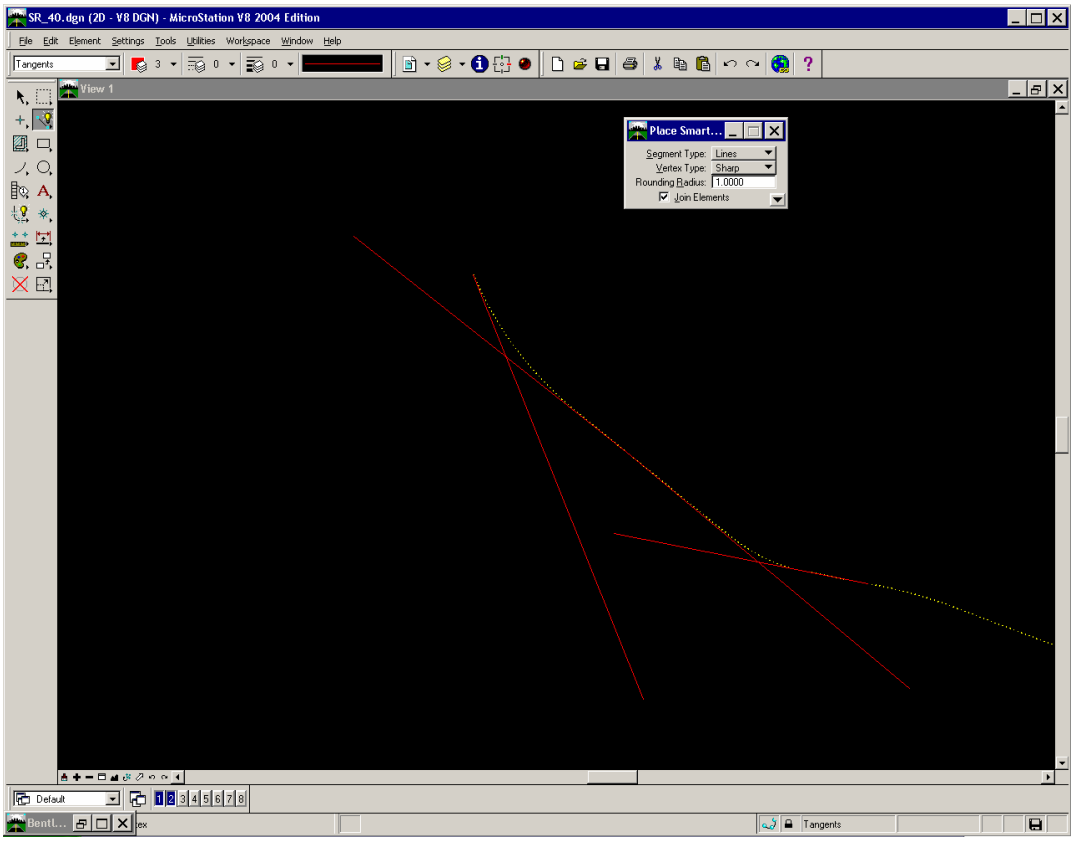


Figure A-15: Screenshot of Tangents in InRoads

Where these tangents intersect is called the Point of Intersection (PI). Continue to place tangents along the lengths of the curves until each curve has point of intersection.

Next, under the Inroads Menu select the TOOL>CUSTOMIZE sequence, which opens the Customize window as shown in Figure A-14. Check the box of Horizontal Curve Set and close the Customize window. After this action, a tool bar containing command icons of the Horizontal Curve Set method of laying down horizontal alignments shows up right below the InRoads Main Menu as shown in Figure A-16.

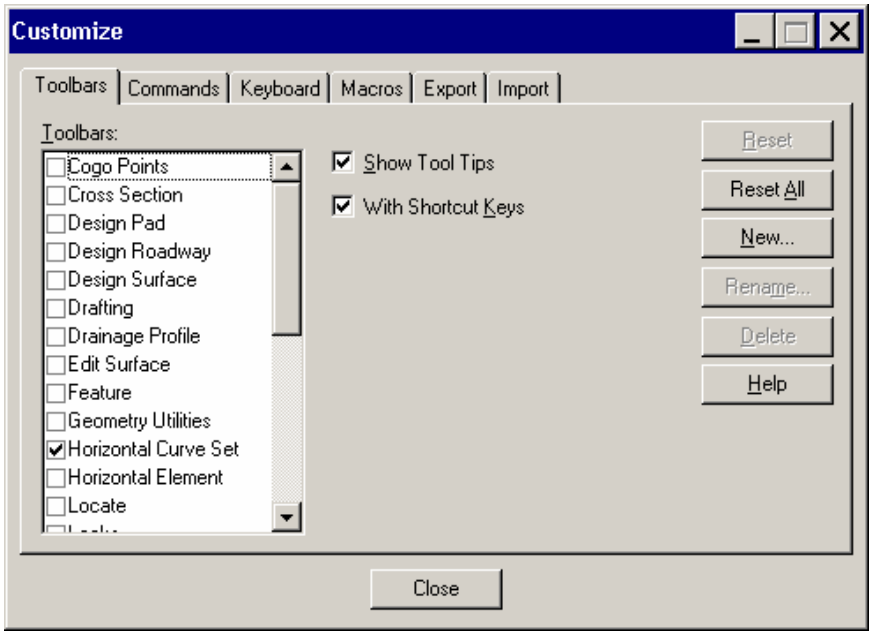


Figure A-16: Screenshot of the Customize Window

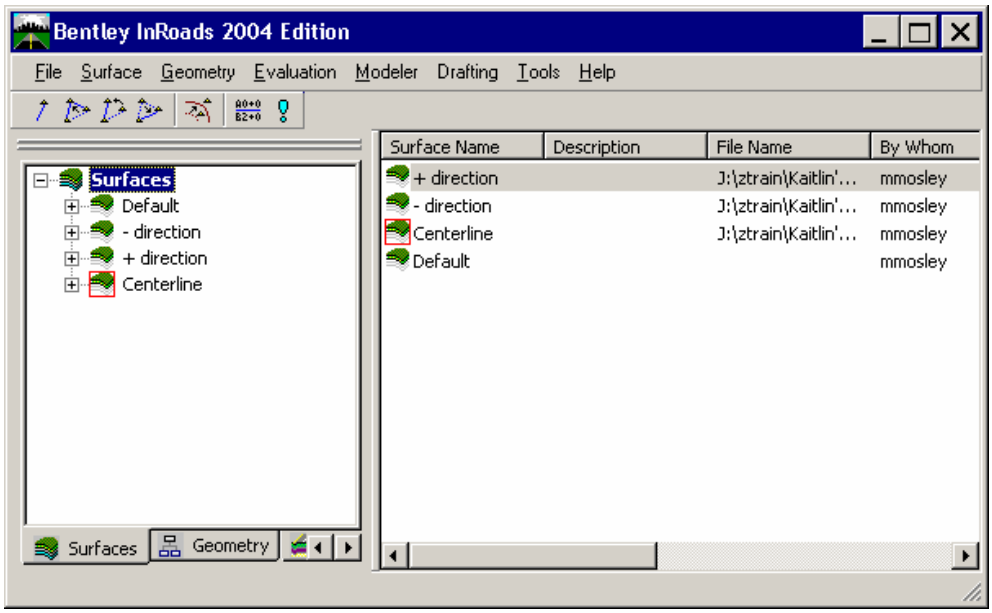


Figure A-17: Screenshot of the InRoads Main Window Showing the Horizontal Curve Tool Bar

Toggle over to the Geometry tab in InRoads. Right click over the main Geometry tree and click new. Add a new Project and call it whatever the road is that you are working on. Click the Apply button, then, without closing out of the new window, use the drop down menu under type and select Horizontal Alignment as shown in Figure A-18.

Fill in the Name and Description entries. Now you have a memory area to put your alignment data.

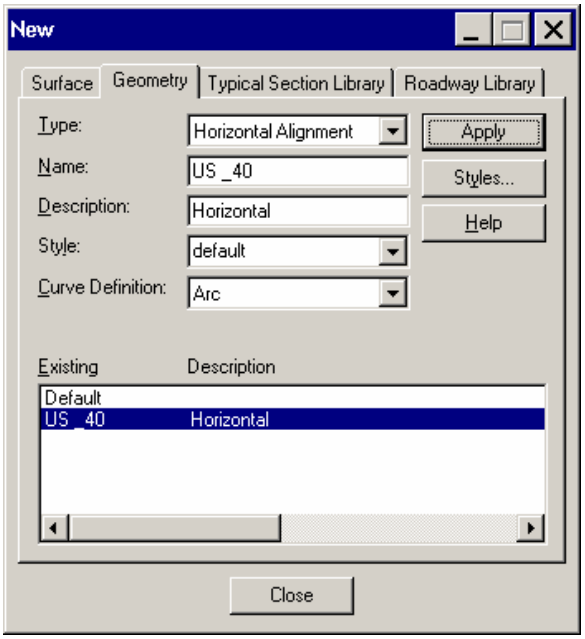


Figure A-18: Screenshot of Geometry Setup Window

When using InRoads, be sure to save your drawing. InRoads does not save anything that you have worked up to this point unless the user explicitly save the work. After this action is taken, there should be horizontal alignment below the Geometry Project. In the screen shot shown in Figure A-19, a place holder for the alignments for the "US_40" study section was created.

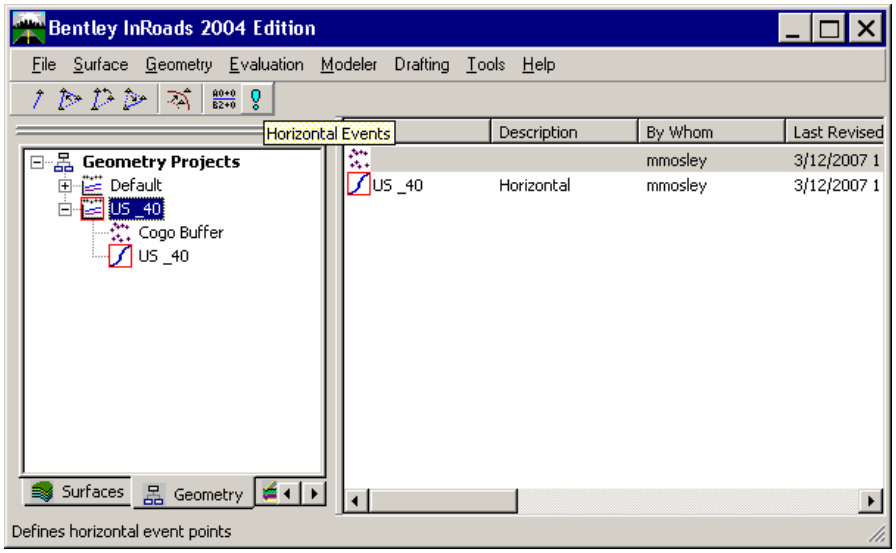


Figure A-19: Screenshot of the Geometry Projects Window

Select the Insert PI function from the Horizontal Curve Set tool bar to place PI all along the alignment. Place the PI starting at the end of the alignment and then place at each intersection that was drawn using the tangents. The user may want to bring up the Button Bar in Microstation to help snap to the intersections of the tangent lines. This button bar is found by right clicking on the light blue connected balls on the bottom right of the Microstation main screen. Then the intersection snap command will be available when it is needed. Be sure to left click after selecting the PI location to confirm to both Microstation and Inroads what you want to do. Figure A-20 shows the task of inserting PIs.

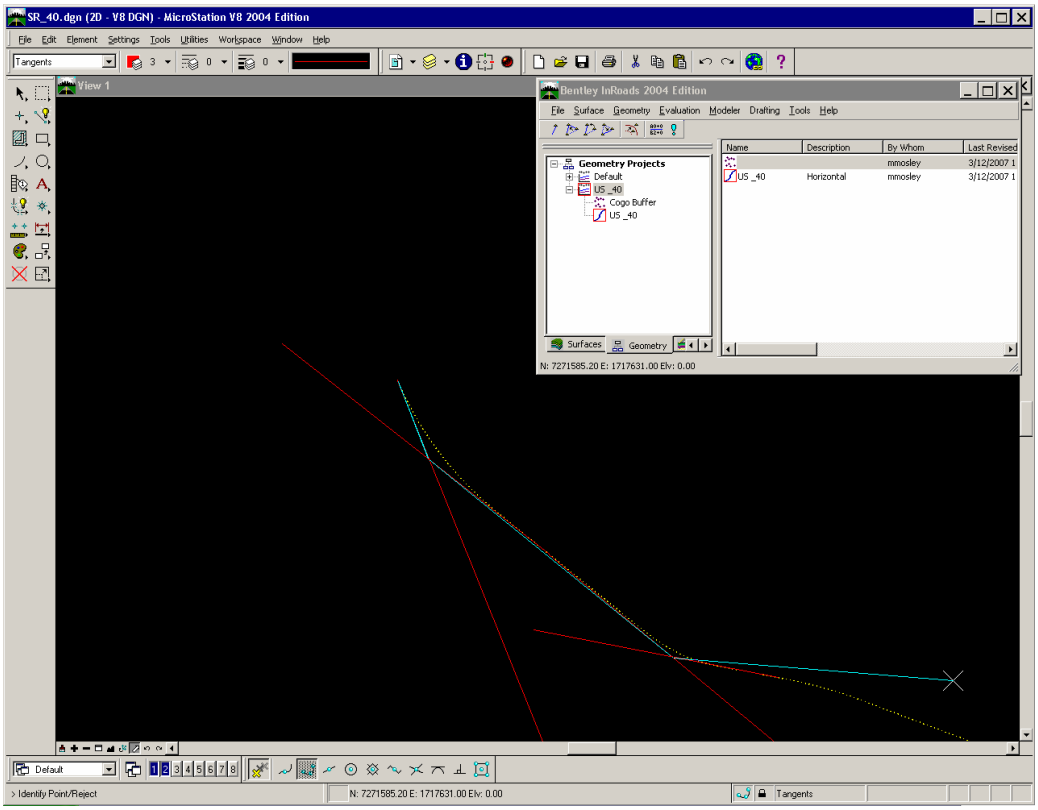


Figure A-20: Screenshot Showing the Task of Inserting PI's

Next, view both outer sides of the road way by viewing the surface. The user needs to triangulate to place a surface between the GPS data of the east and west directions. Refer to Section A.4 of this Appendix to find out how to triangulate between the two sets of survey points (for the two directions of the highway). Figure A-21 shows the triangulated surface between the two lines that indicate the data points of the two directions of the highway.

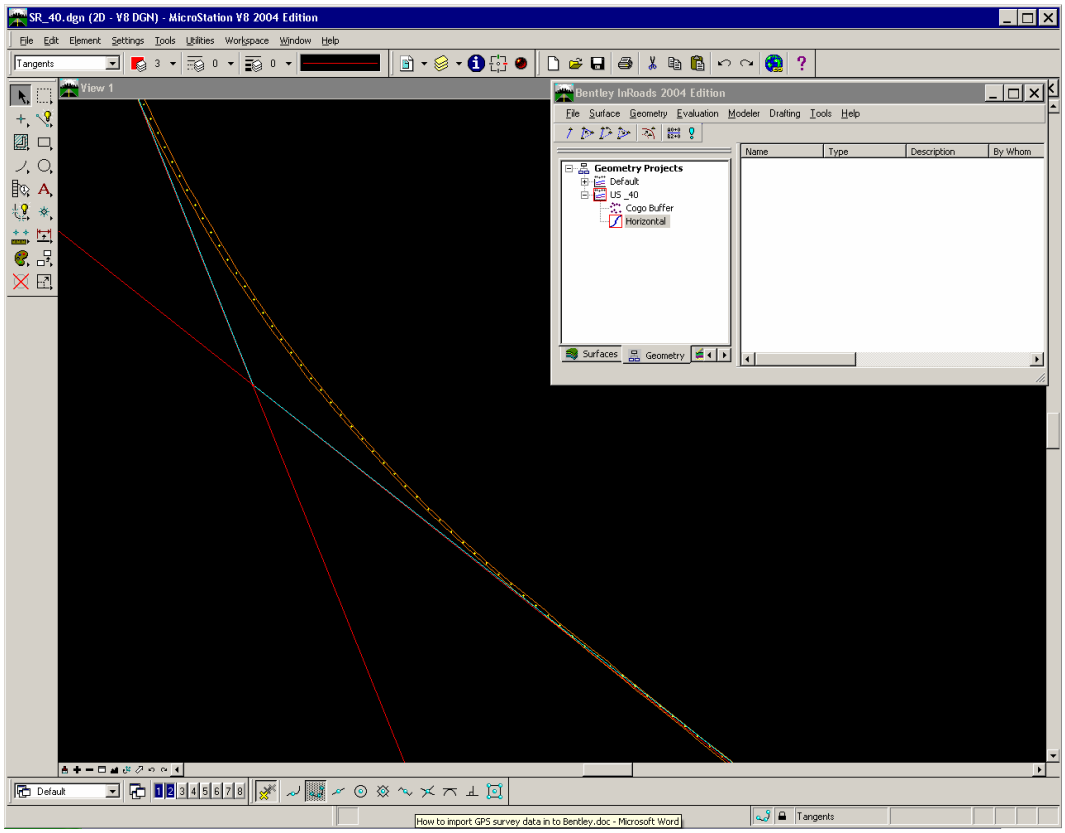


Figure A-21: Screenshot of the Triangulated Surface

Use the Define Horizontal Curve Set window (illustrated in Figure A-22) to adjust the radius of the curve to fit the curve in between the two lines, which were created by using the survey data converted from the GPS data in the previous step. Figure A-23 shows a curve that are fitted between the two tangents. If the Horizontal alignment is placed outside the GPS data on each side it will not show up on the Profile because it does not pass through a triangulated surface.

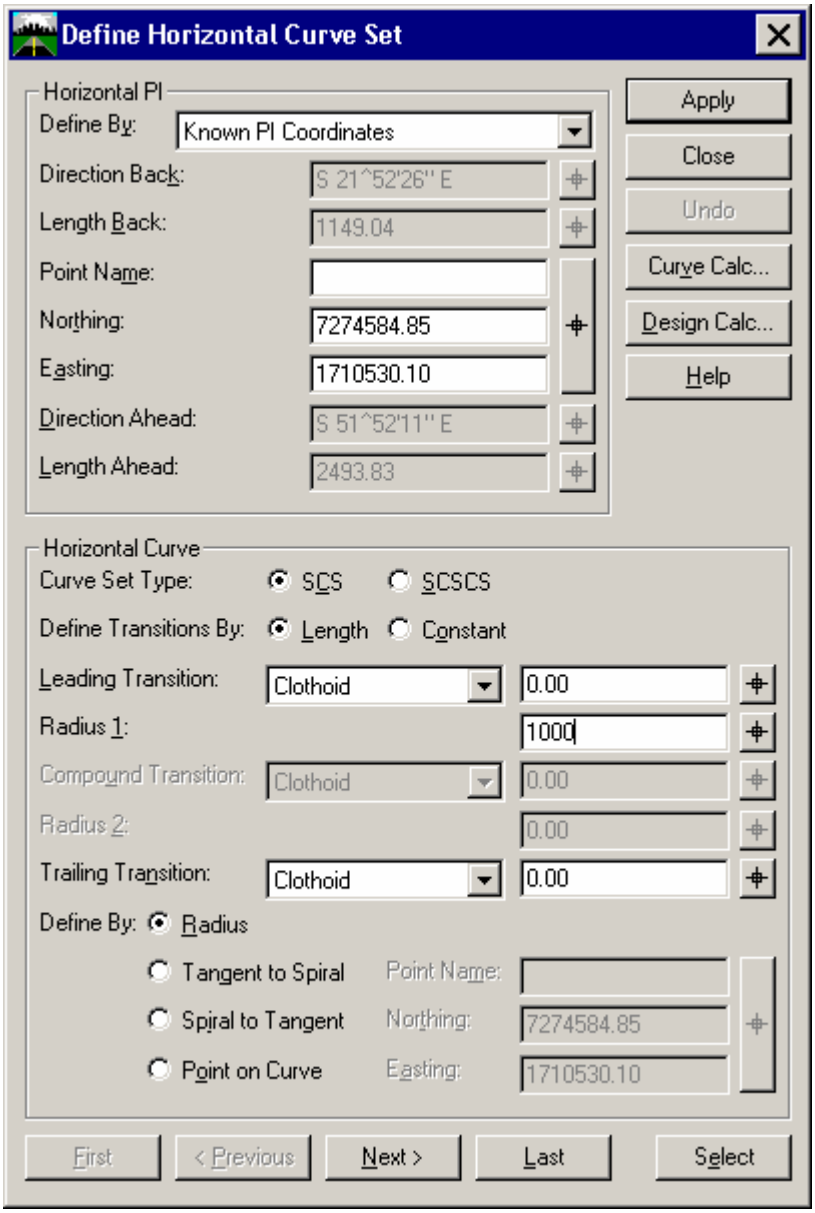


Figure A-22: Screenshot of the Horizontal Curve Setting Window

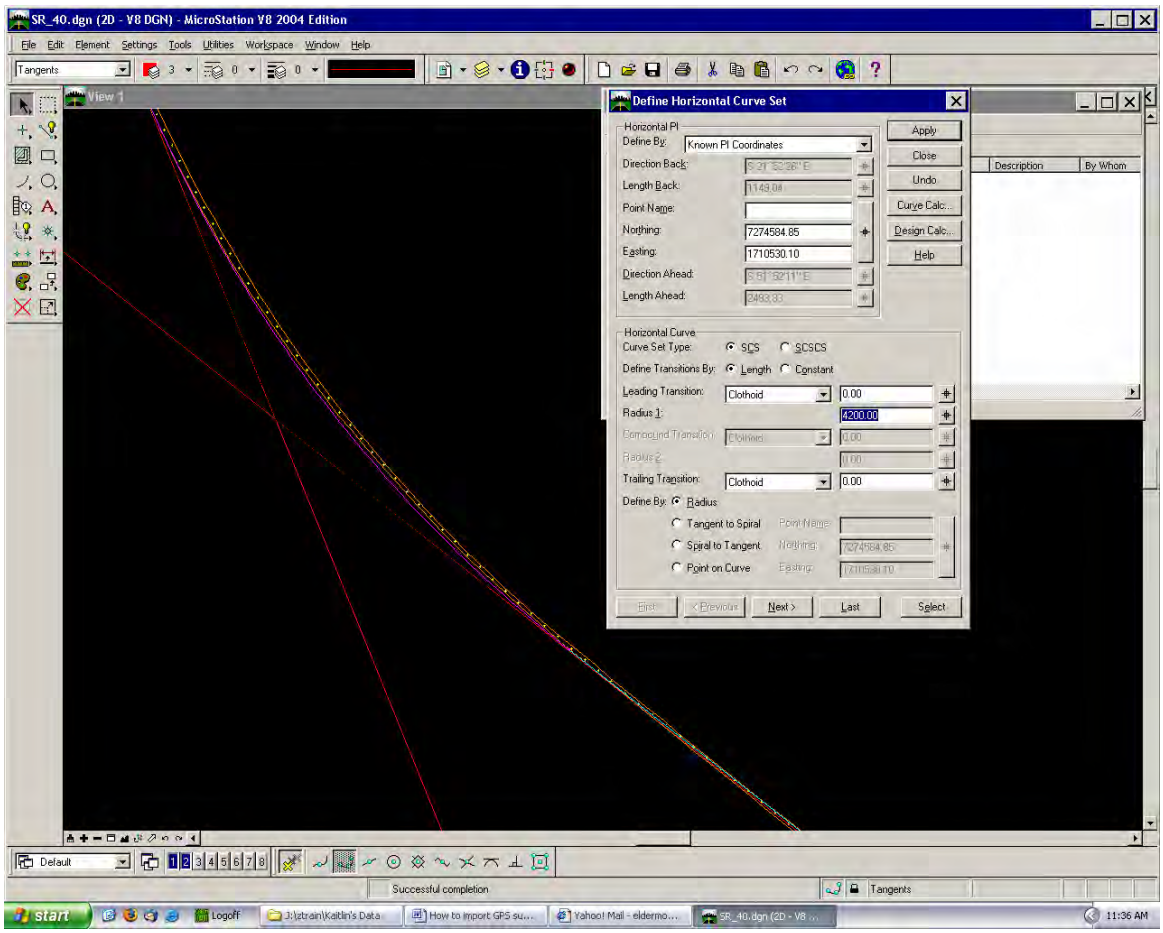


Figure A-23: Screenshot of a Horizontal Curve

Adjust the radius until the curve fits between the two boundaries. If the curve does not fit with any given radius, adjust the PI location by using the Move PI button. Adjust the radius and the Move PI function until the curve falls right in between the boundaries as shown in Figure A-24. The boundary lines were created by the survey point data for the + direction and the - direction.

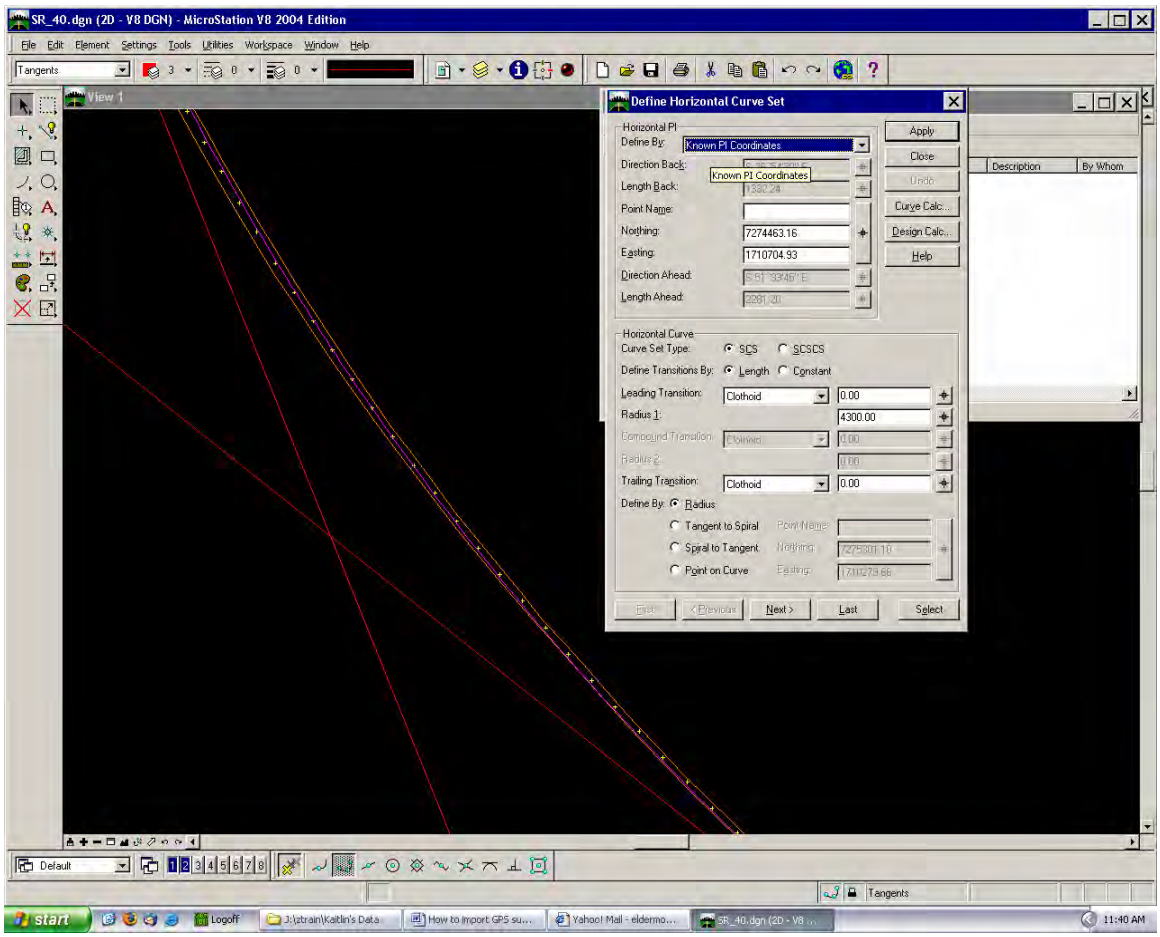


Figure A-24: Screenshot of Inserting PI Station

The finished horizontal alignment can be viewed by right clicking on the alignment in InRoads and selecting Review. The information of the alignment is shown. The user can then save the information as a text file to be used in other software programs such as IHSDM.

A.4 Triangulating Surface

When triangulating among the data points in the two directions, that is, two outer boundaries, under the SURFACE>TRIANGULATE SURFACE option, make sure that the lengths of the triangle do not exceed the triangular distance across the roadway. In order for this to work, the outer boundary coordinates need to be in one .txt file so that the triangles are formed correctly. Copy and paste all of the coordinates from one of the

sides of the road into the other and then SAVE AS and import this surface into the project.

The ends of this surface should be connected by one line as shown in Figure A-25. Now this surface can be triangulated. Select the SURFACE>TIANGULATE SURFACE menu sequence and get the Triangulate Surface window.

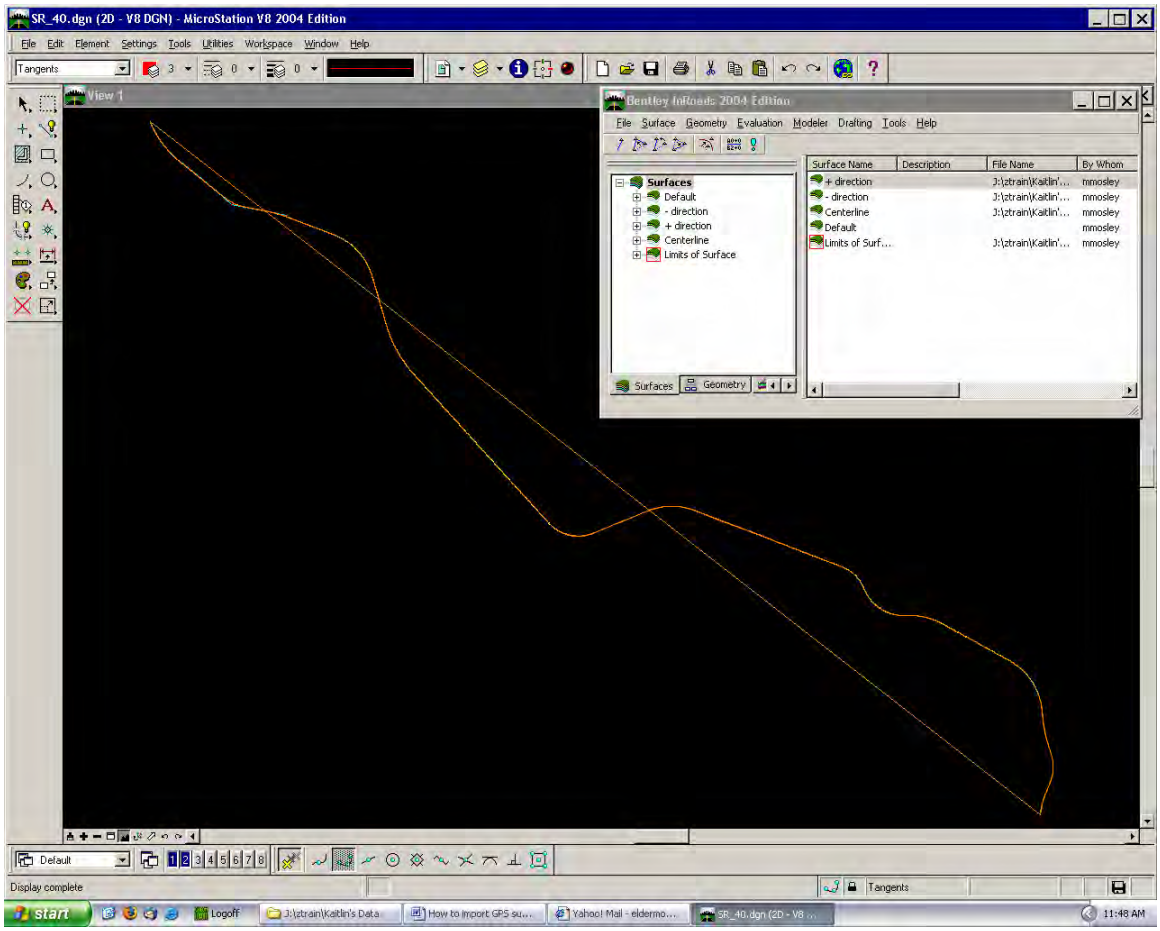


Figure A-25: Screenshot of the Triangulated Surface

Make sure that the maximum length is no longer than across the road, roughly 200-300 feet. Also make sure the View Triangles check box is selected as shown in the screenshot in Figure A-26.

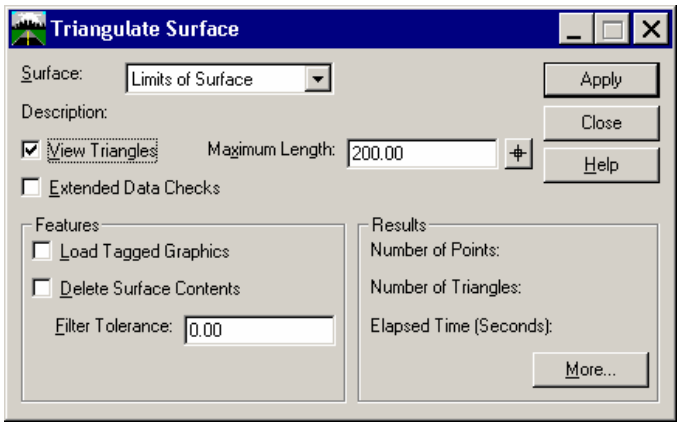


Figure A-26: Screenshot of the Triangulate Surface Setup Window

A.5 Laying Out Centerline Profile

Once the centerline horizontal alignment is completed, the profile associated with the horizontal alignment is laid out. Use the EVALUATION>PROFILE>CREATE PROFILE menu sequence to create a profile. Figure A-27 shows the Create Profile window of InRoads. Go through each of the tabs to become familiar with what goes into a profile. On the Features tab, make sure that the crossover data is selected just in case there are any holes, or "gaps," caused by the horizontal alignment that went outside the boundary lines, in the profile.

Once the Apply button is pressed, the profile is drawn as shown Figure A-28 (see the top side of the drawing window for a white rectangular area). The rectangular grey area is the profile created. The starting point of the profile, that is the base point which is used to draw a profile, can be placed anywhere in the drawing. Make sure that the profile will not overlap with the horizontal alignment. The extra lines in the Profile can be deleted to make a cleaner drawing as shown in Figure A-29.

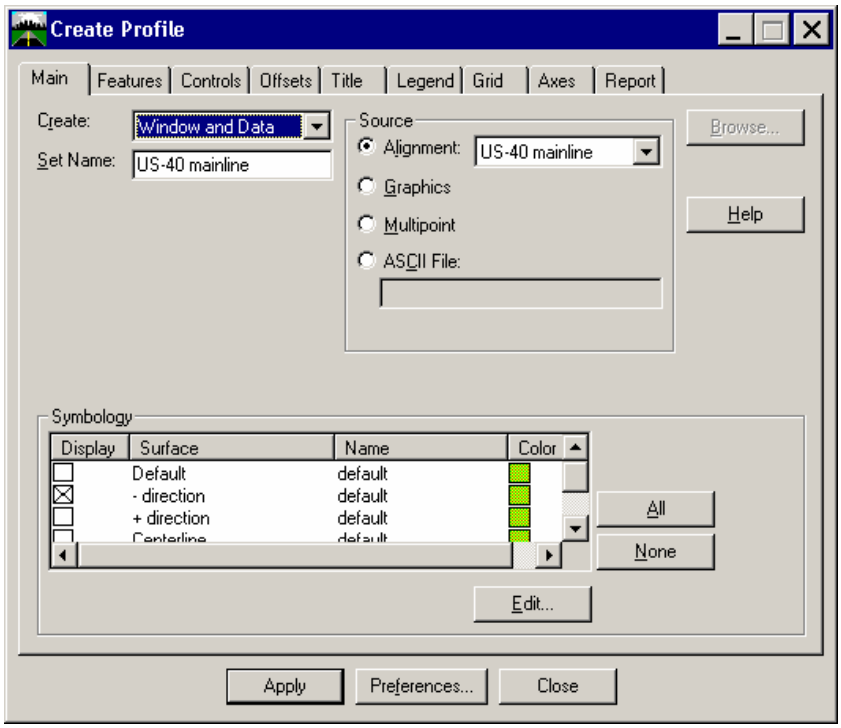


Figure A-27: Screenshot of the Create Profile Window

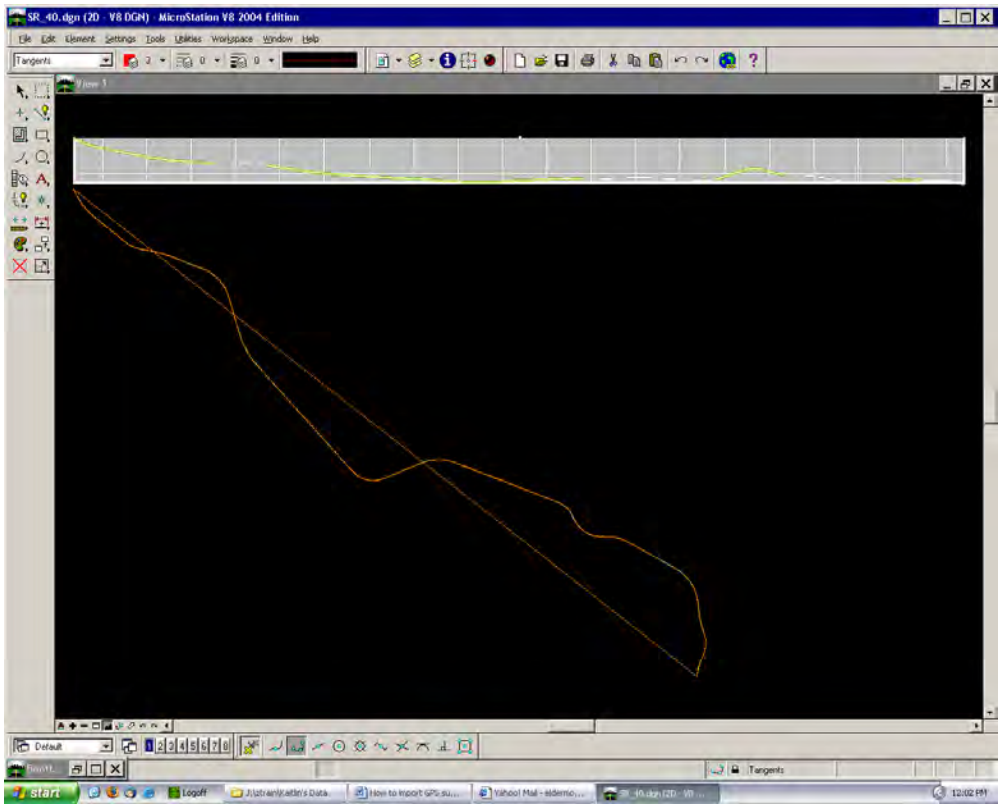


Figure A-28: Screenshot of the Created Profile

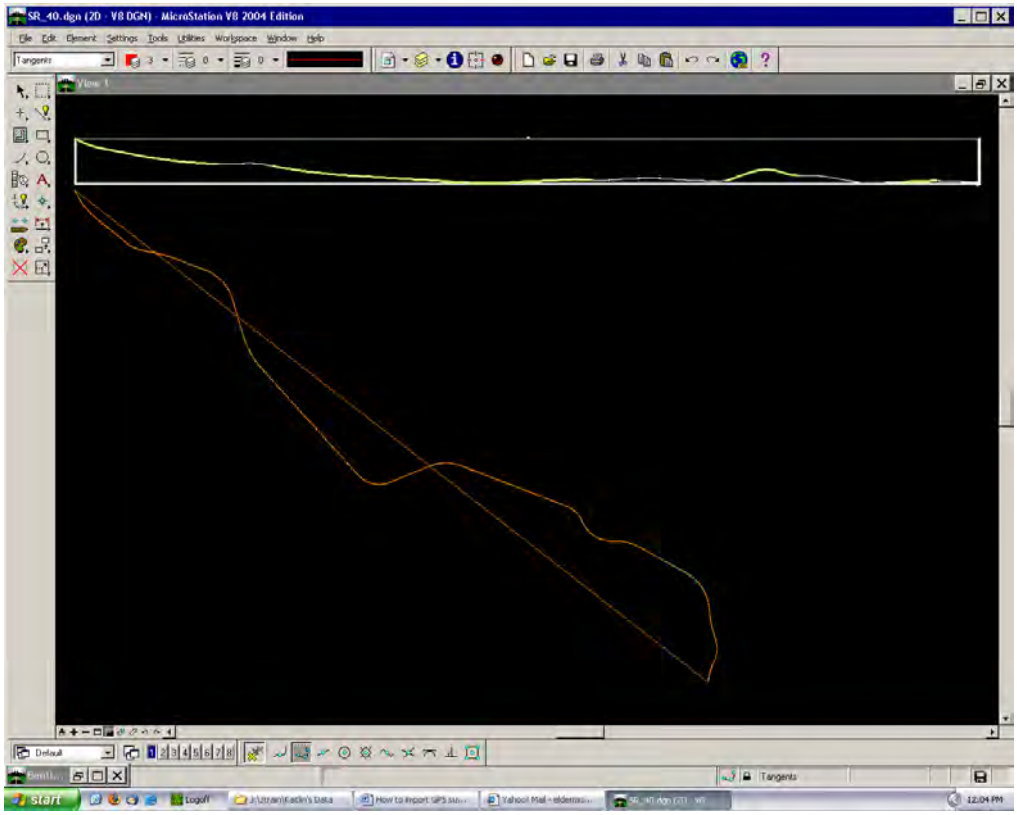


Figure A-29: Screenshot of Edited Profile Window

A.6 Laying Out Centerline Vertical Alignment

The vertical alignment can be laid out in the manner similar to the way that the horizontal alignment was done. Draw tangents using the profile as a guide. If needed, a second profile can be produced with greater exaggeration of the slopes, such as 50 to 1, so as to help draw the tangents and place the vertical points of intersection (VPI). Bring up the Vertical Curve Tool Bar under the Customize Menu to make it easier to draw vertical alignments. Figure A-30 shows the Geometry Project window where vertical alignments created by the user will appear.

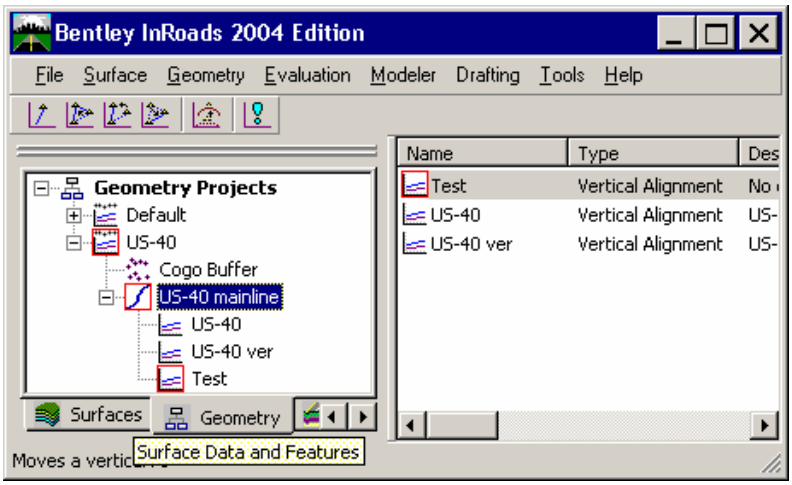


Figure A-30: Screenshot of the Geometry Projects

To place these VPIs, follow the instructions that are presented in the bottom of the Mircostation information bar. Click on the location of each of the VPI as marked by the tangents. Always make sure that the left button is used to confirm these locations. Define the vertical curve using the length of the vertical curve and place it as close as possible to the existing profile. Go through each curve on the alignment. Figure A-31 shows the Define Vertical Curve Set window that will help the user create a vertical curve with a given vertical curve length.

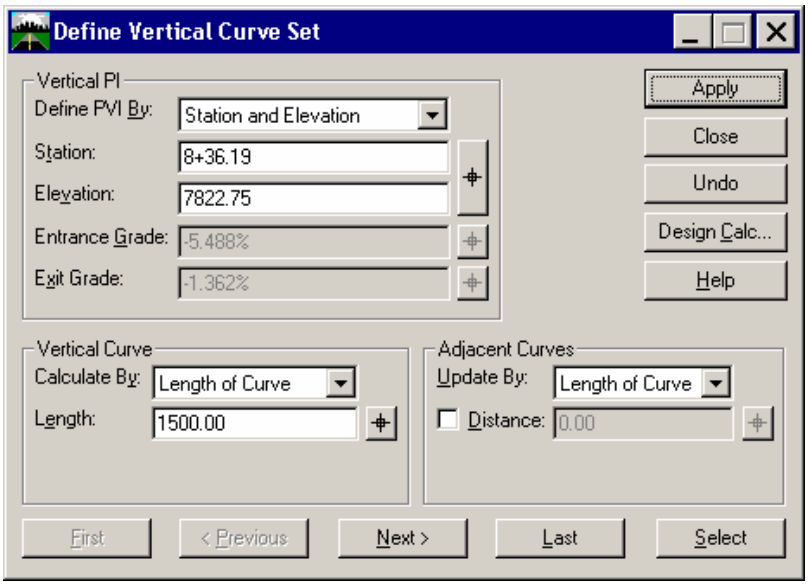


Figure A-31: Screenshot of the Define Vertical Curve Set Window

Data for the vertical curves can also be viewed by right clicking on the specific curve in Inroads and selecting the Review option. Figure A-32 shows the result of selecting the Review option. This window presents data of all the vertical curves created by the user. Save the file as a .txt for use in other programs like IHSDM.

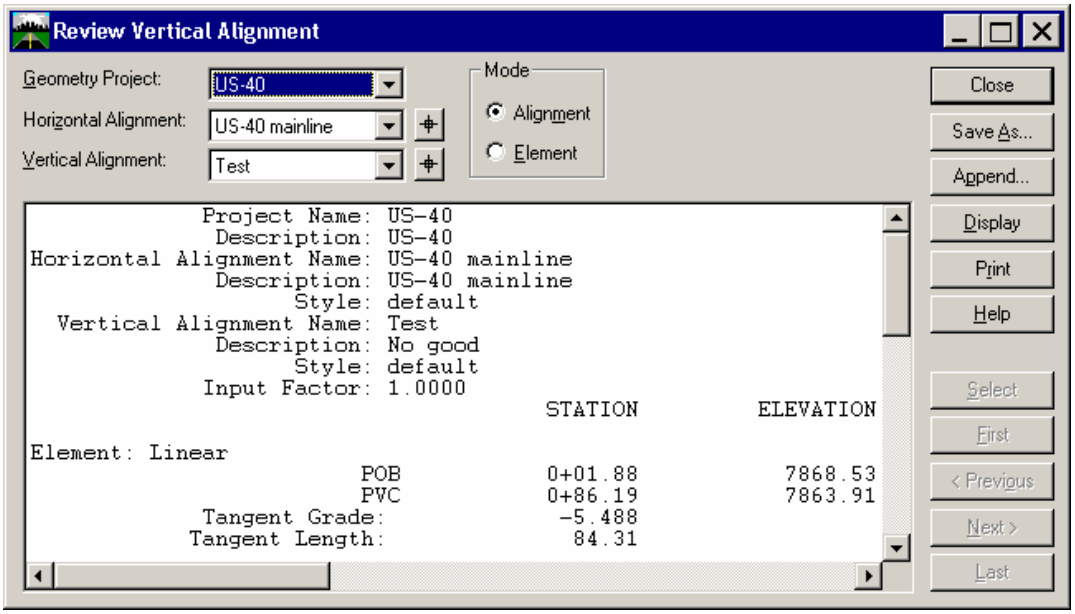


Figure A-32: Screenshot of Reviewing Vertical Alignment Window

A.7 Stationing

The stationing feature is found under the Geometry Menu Select functions that are desired to be shown in drawing. In the View Stationing window, enter all necessary selections. Some of the leaders and minor stationing can be unchecked to simplify the information. Figure A-33 shows a screenshot of the View Stationing window. An illustration of the final view of the stationing on the horizontal alignment is shown in Figure A-34.

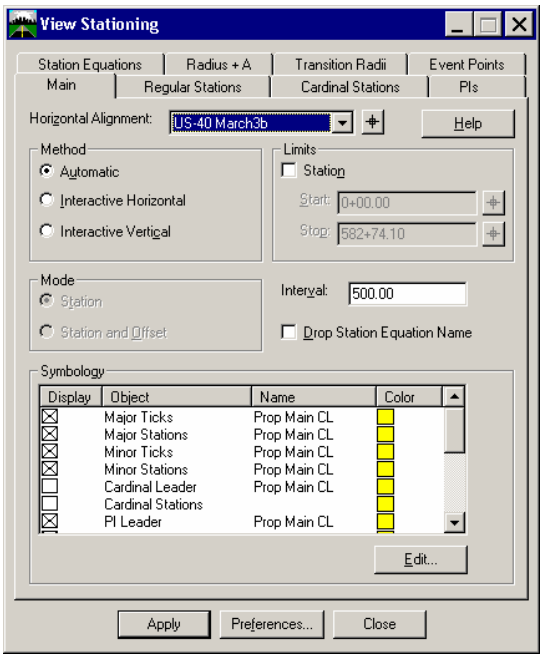


Figure A-33: Screenshot of the View Stationing Window

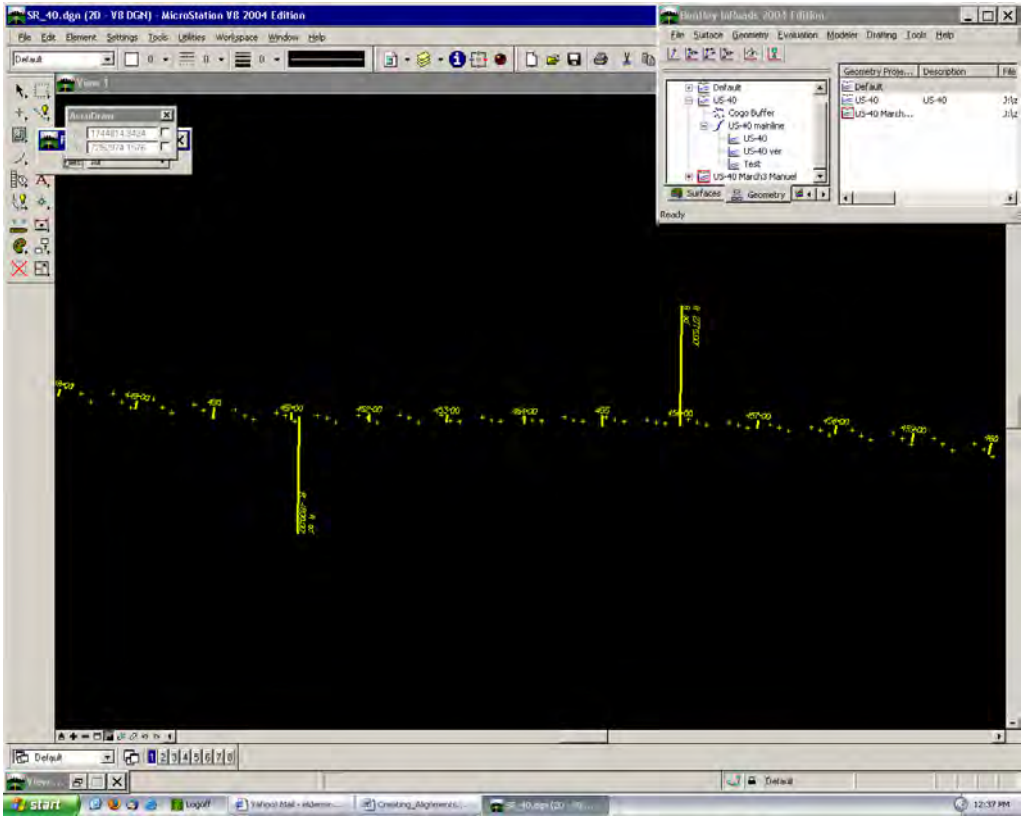


Figure A-34: Screenshot of a Completed Stationing