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Geo 4/593 Fall 2016

Final Project Abstract

Analyzing Terrain for High-Speed Train Route Suitability

Abstract

Finding a suitable route for a high-speed rail line considers several factors to determine the most economically feasible, efficient, and environmentally sensitive course possible. Not the least of these is the area of terrain analysis to ascertain slope characteristics of possible route locations. Because of the number of potential routes, the varying terrain profiles, and the distances involved, it is necessary to establish a process using a computerized digital terrain analysis format, such as GIS, to identify prospective problems areas quickly and efficiently, as well as to recommend the most appropriate solutions to these problems.

Using a prospective DEM quadrangle, a possible route was created between two destinations. After establishing a vertical profile of the route to help identify problems areas and splitting the route into smaller sections to aid in the analysis, surface information was added to the sections to provide distance, elevation, and slope data. A spatial join was then employed to determine the slope relationship between each section and its neighbors based on a variety of different search radii. Summary statistics was used to tabulate these results and joined to each route segment to provide an assessment of their overall slope characteristics.

The result of the analysis was only a partial step towards the ultimate goal of comprehensive terrain analysis. The issue of determining the slope characteristics of each segment and how this relates to its neighbors to ascertain the most appropriate course of action was left unfulfilled, and would require further analysis. Most likely, a new tool would have to be created, in which the script would be to take into account the slope characteristics of each segment, those of the two neighboring segments, and place said segment into a category based upon all of the possible slope permutations.

Key words: High-speed rail, route, slope, GIS, DEM, spatial join

Analyzing Terrain for High-Speed Train Route Suitability

Michael Brehm
Portland State University
Geography 493 (Digital Terrain Analysis)
December 5, 2016

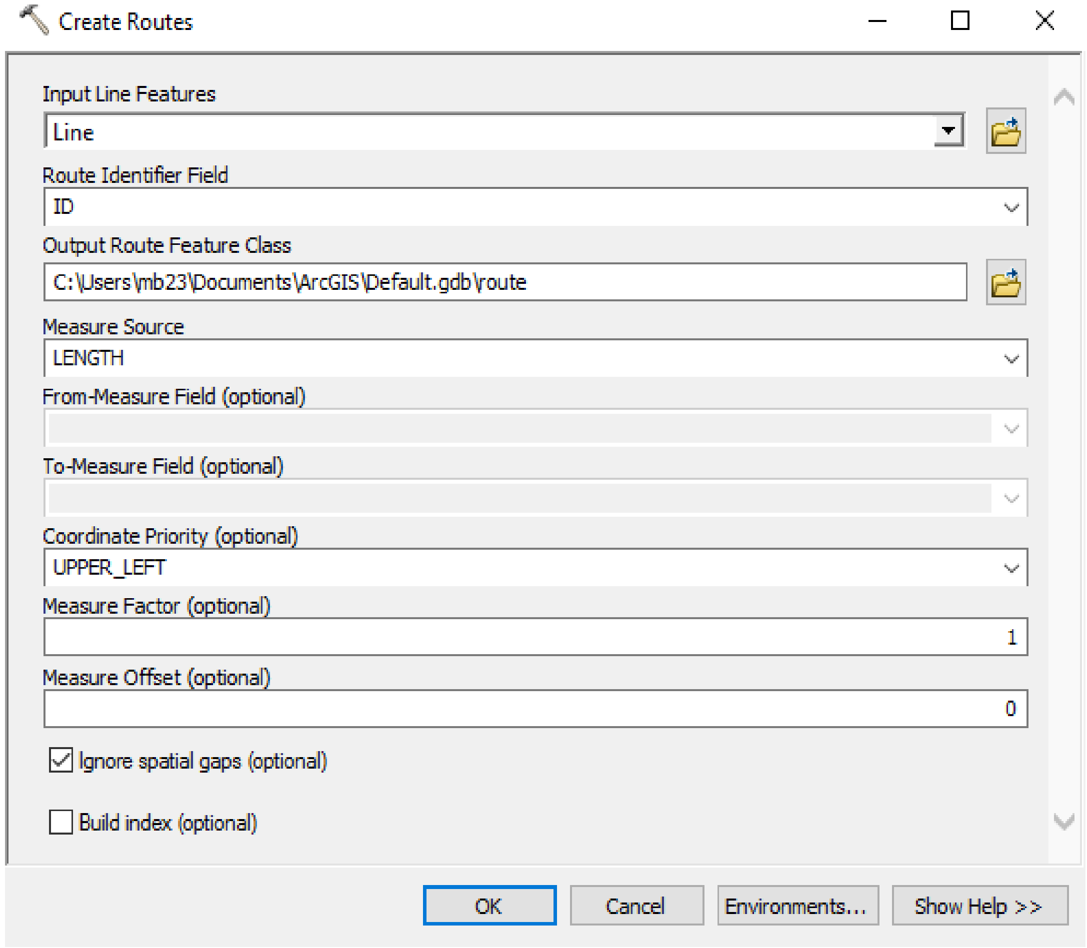
Project Goal

Use the various tools of digital terrain analysis in GIS to examine a proposed direct high-speed train route from Portland to Bend, based upon slope gradient specifications. Gradient specifications used are from the Engineering Criteria prepared for the California High-Speed Rail Authority. The ultimate objective is to develop a process for dividing route segments into potential terrain modification categories (Excavation, Bridge, Tunnel, or Re-Route).

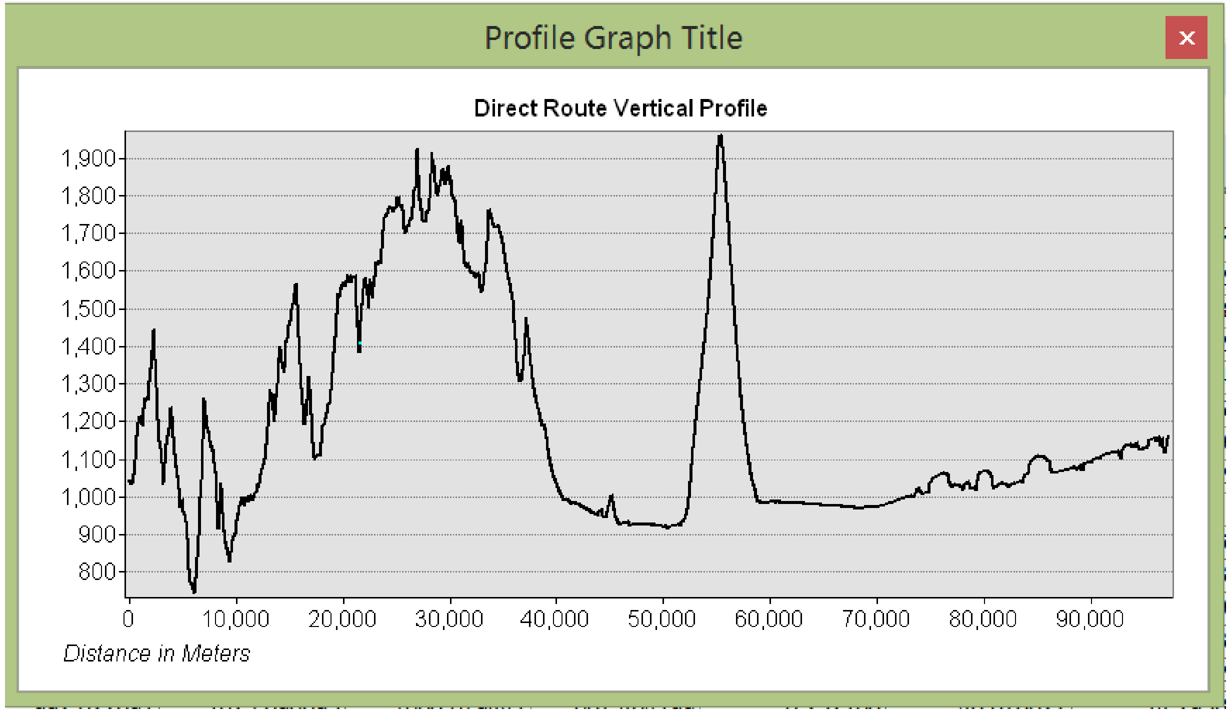
Summary of Engineering Design Parameters

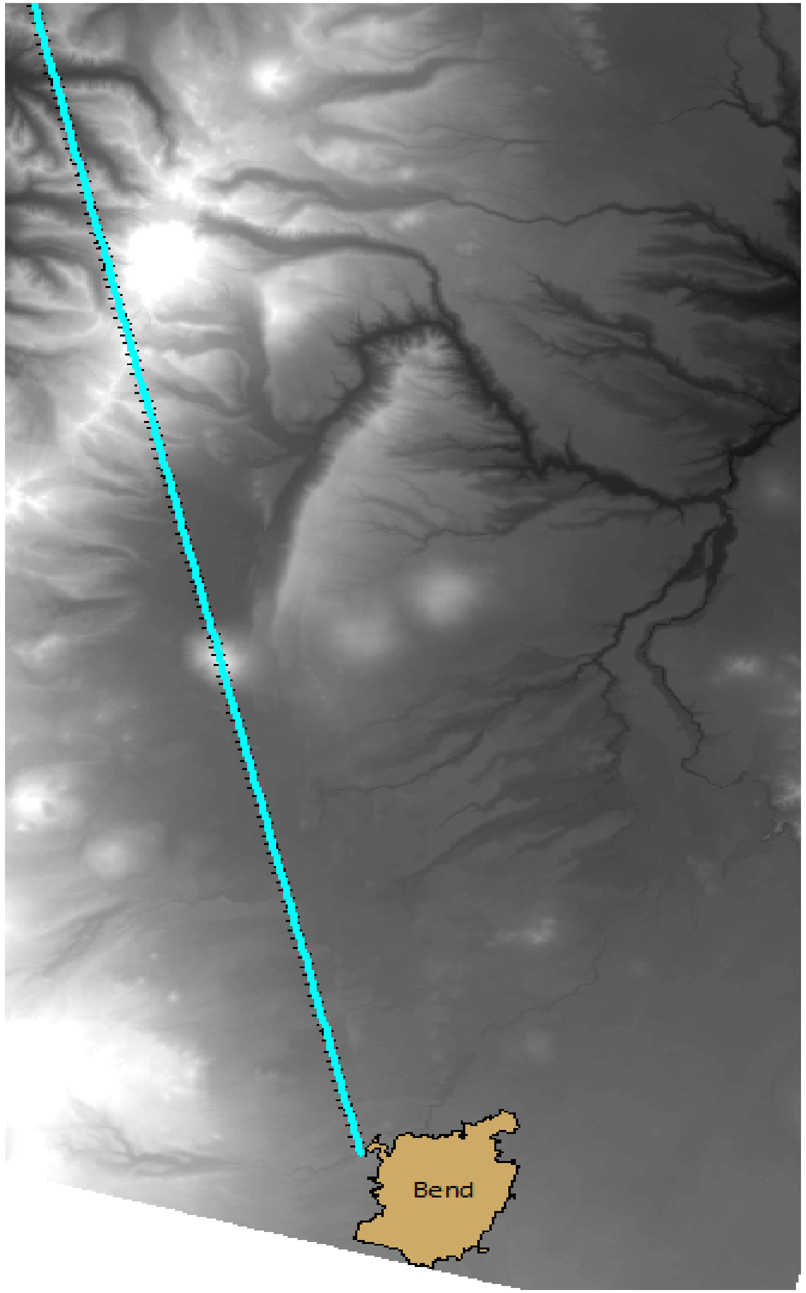
Parameter	Very High-Speed
Double Track	Full
Power Source	Electric
Grade Separations	Full
Potential for Shared Use	Yes
Corridor Width ❑ **Desirable** ❑ **Minimum**	 100 ft (30.4 m) 50 ft (15.2 m)
Top Speed	220 mph (350 km/h)
Average Speed	125-155 mph (200-250 km/h)
Acceleration	0.4-1.3 mph/s[3] (0.6-2.1 km/h/s[4])
Deceleration	1.2 mph/s (1.9 km/h/s)
Minimum Horizontal Radius	500-650 ft (150-200 m)
Minimum Horizontal Radius (At top speed)	15,600 ft @ 220 mph (4,750 m @ 350 km/h)
Superelevation ❑ **Actual (Ea)** ❑ **Unbalanced (Eu)**	 7 in (180 mm) 5 in (125 mm)
Grades ❑ **Desirable Maximum** (sustained grade) ❑ **Absolute Maximum** (limited length)	 3.5% 5.0%
Minimum Vertical Radius Crest Curve (at top speed)	157,500 ft @ 220 mph (48,000 m @ 350 km/h)
Minimum Vertical Radius Sag Curve (at top speed)	105,000 ft @ 220 mph (32,000 m @ 350 km/h)
Horizontal Clearance (Centerline of track to face of fixed object)	10 ft 4 in @ 220 mph (3.1 m @ 350 km/h)
Vertical Clearance (Top of rail to face of fixed object)	21 ft (6.4 m)
Track Centerline Spacing	15 ft 8 in @ 220 mph (4.7 m @ 350 km/h)

Create a Route:

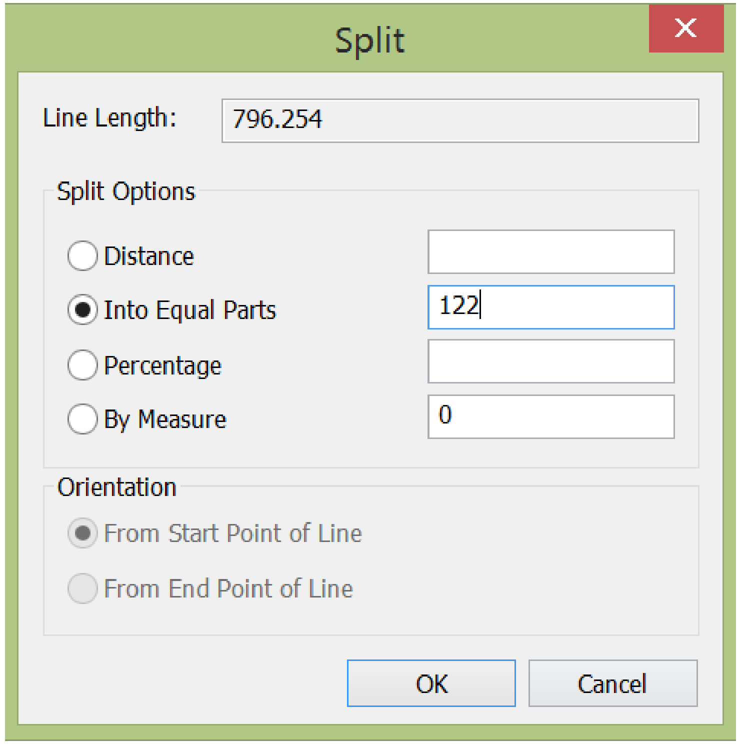


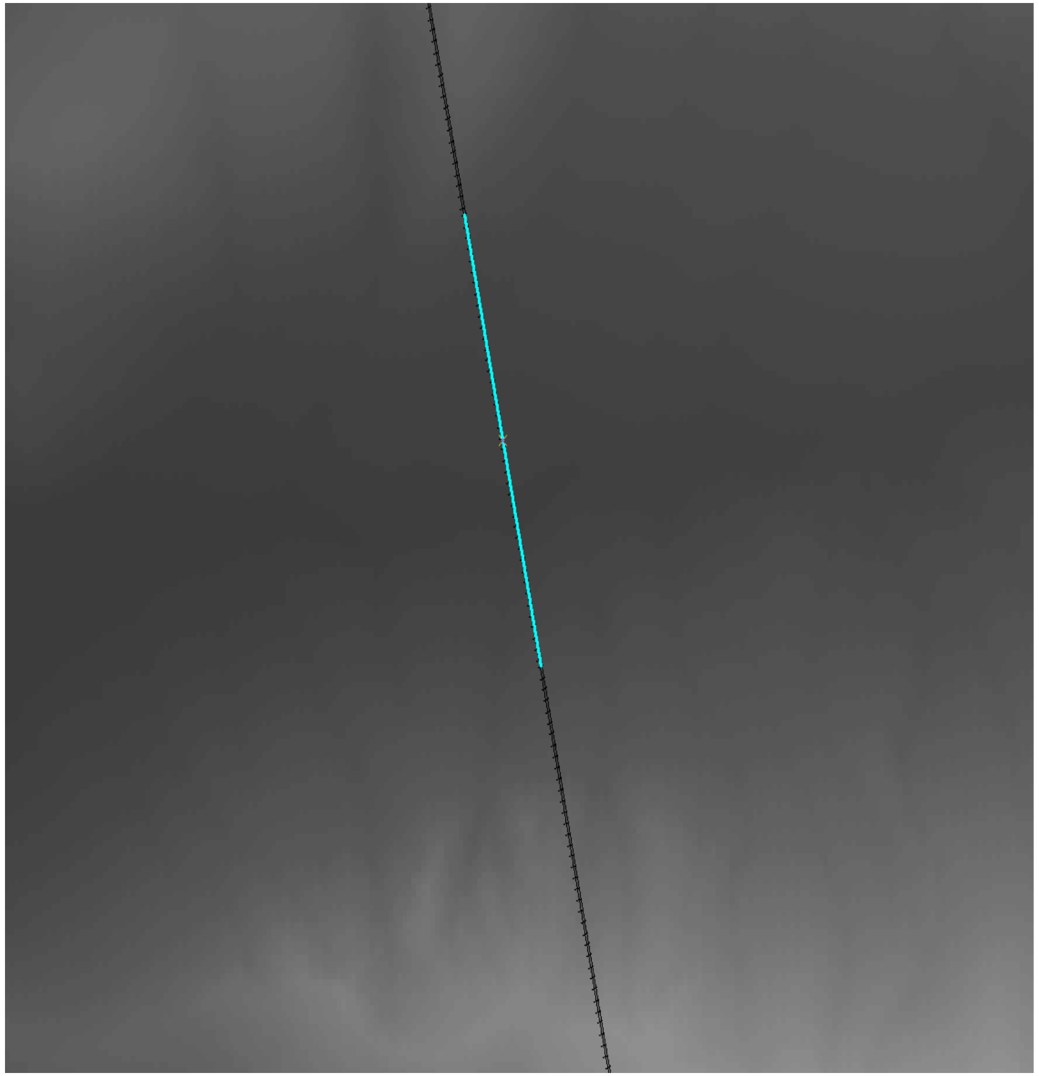
Create Vertical Profile:





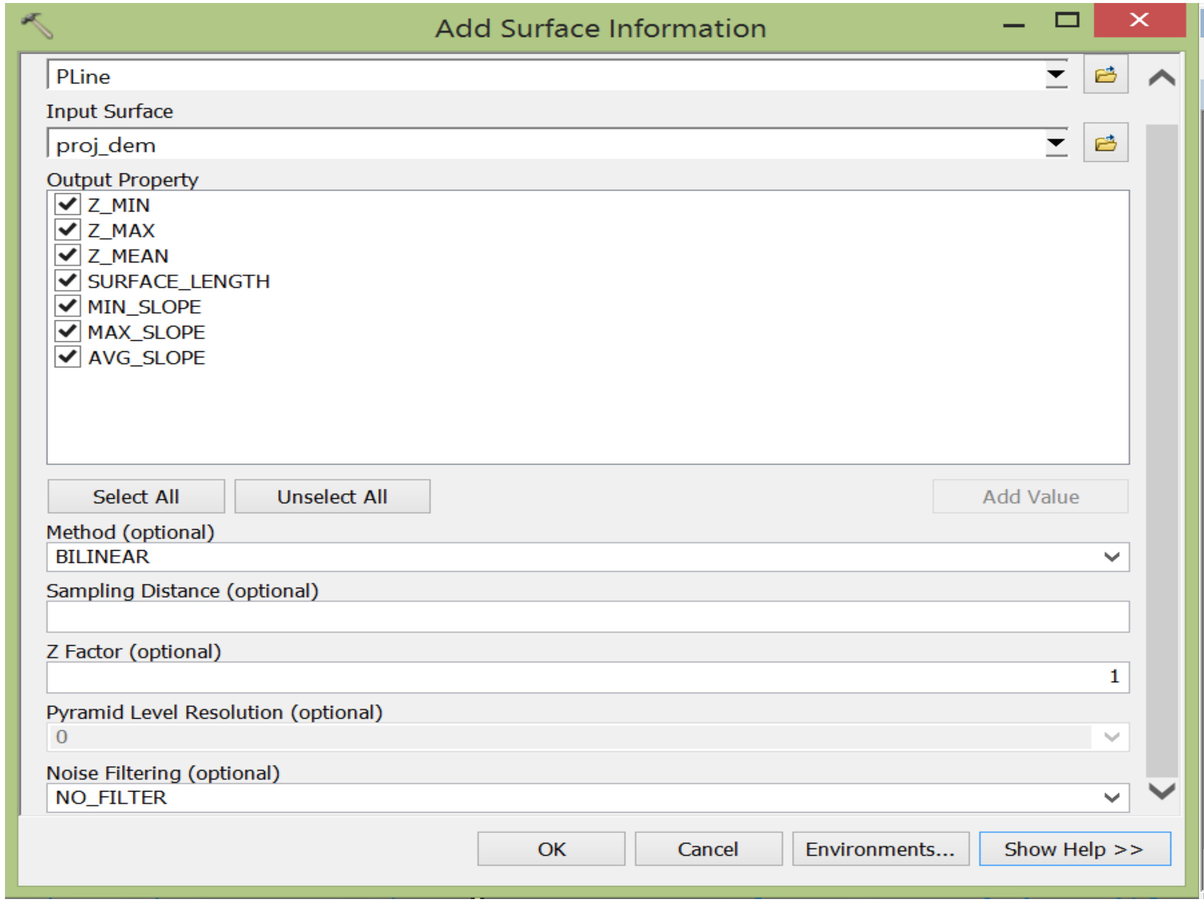
Split Line into Segments:

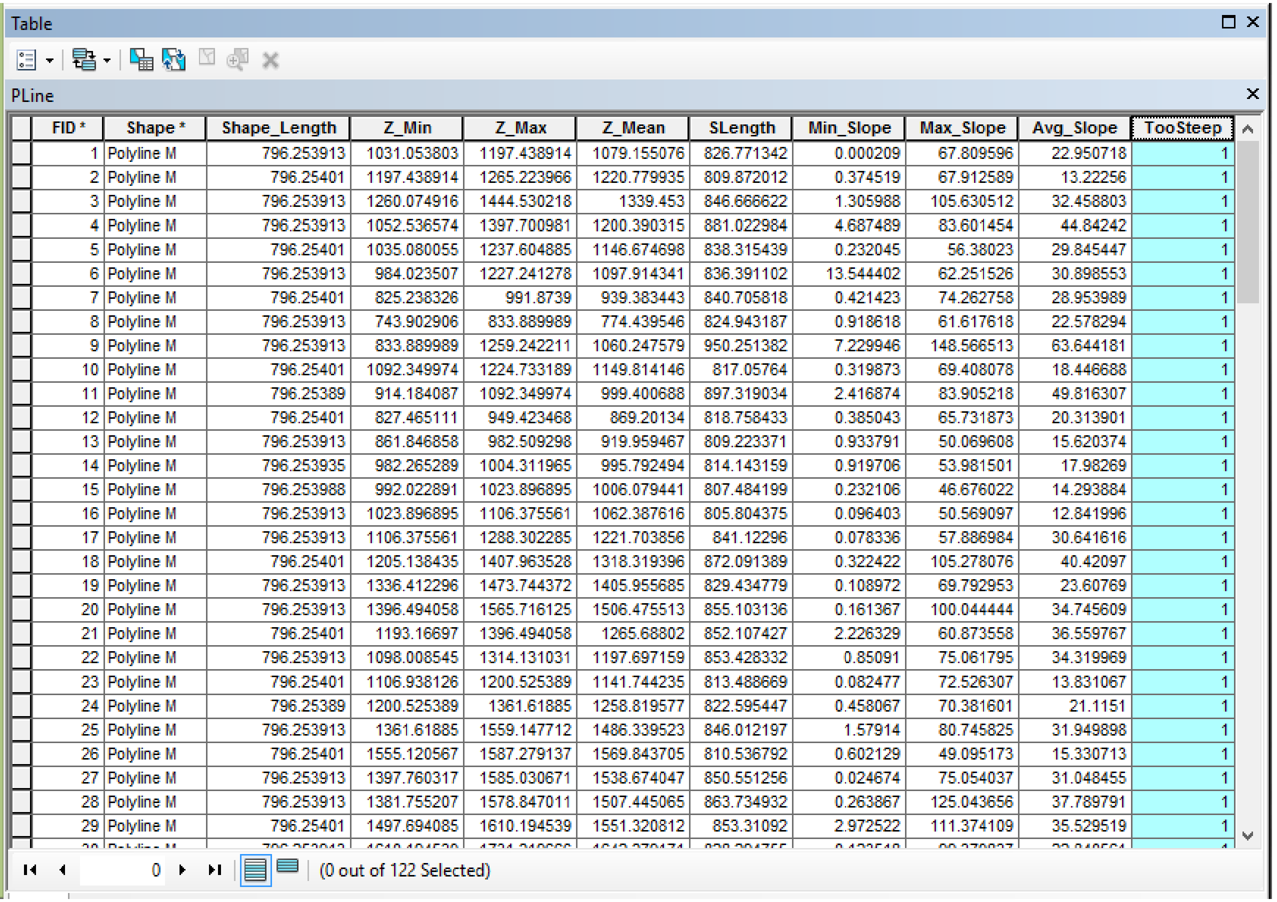




<u>Add Surface Information:</u>

Populates attribute table with new fields of spatial information derived from an input surface





Table

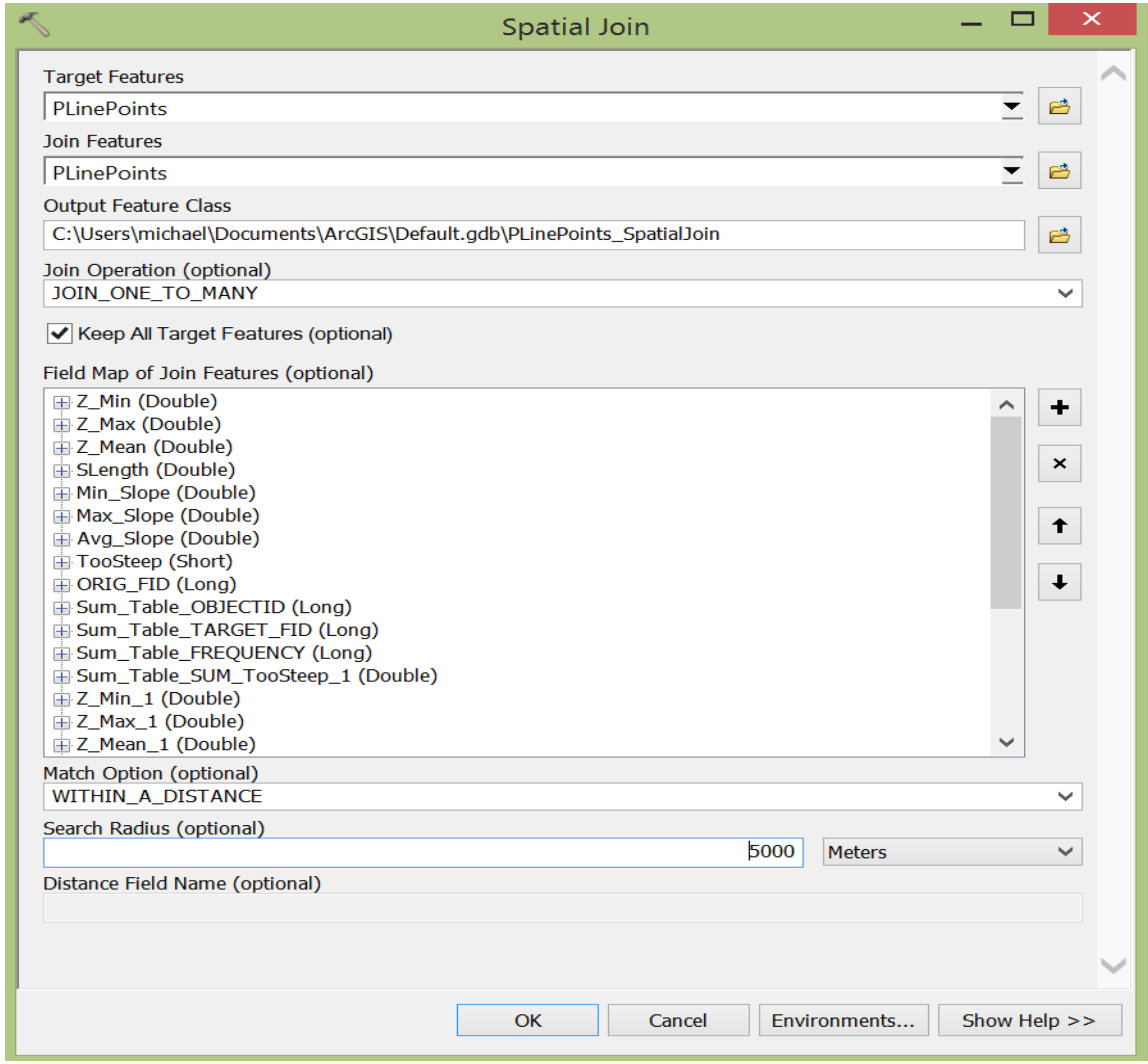
PLine

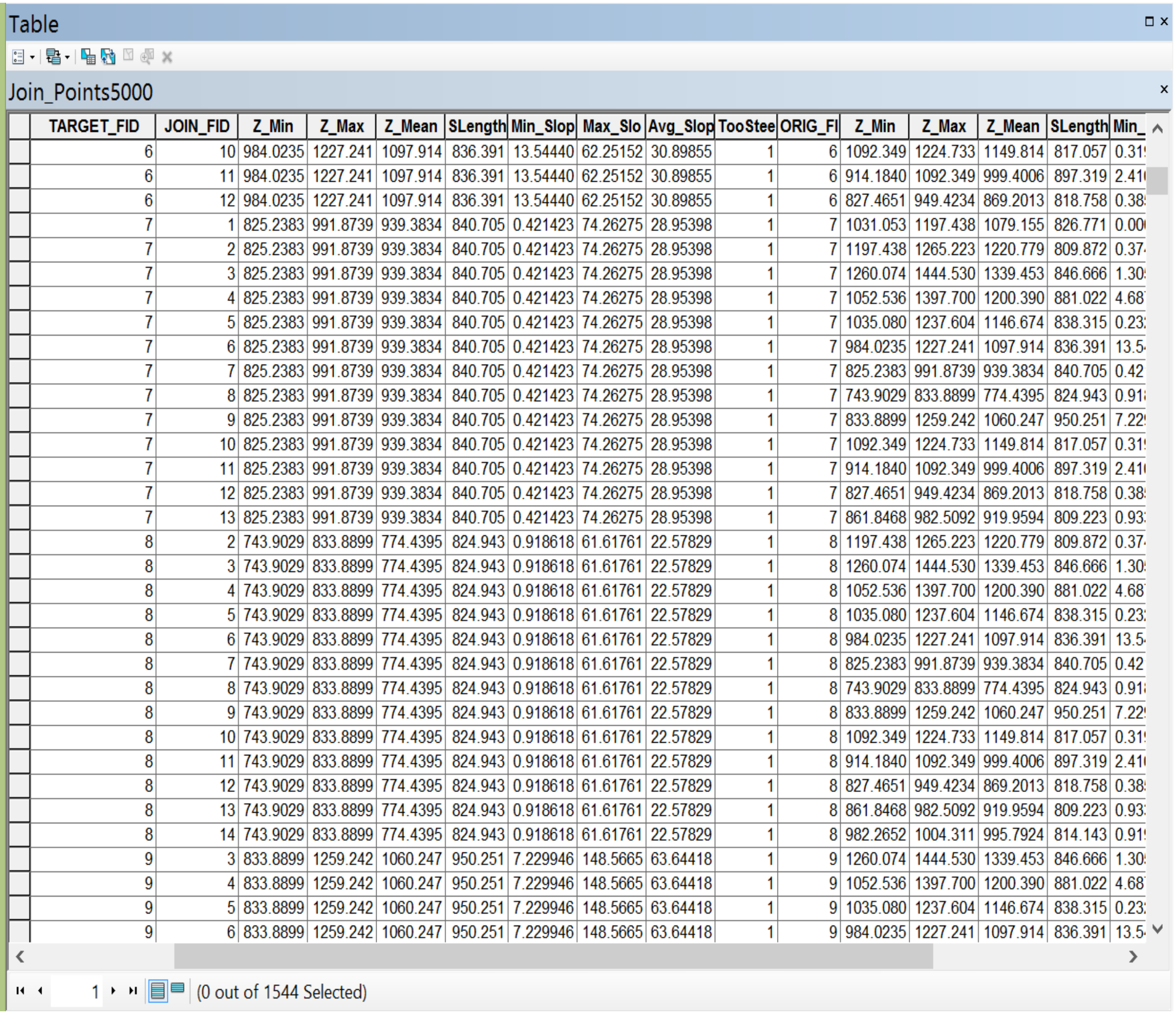
FID *	Shape *	Shape_Length	Z_Min	Z_Max	Z_Mean	SLength	Min_Slope	Max_Slope	Avg_Slope	TooSteep
1	Polyline M	796.253913	1031.053803	1197.438914	1079.155076	826.771342	0.000209	67.809596	22.950718	1
2	Polyline M	796.25401	1197.438914	1265.223966	1220.779935	809.872012	0.374519	67.912589	13.22256	1
3	Polyline M	796.253913	1260.074916	1444.530218	1339.453	846.666622	1.305988	105.630512	32.458803	1
4	Polyline M	796.253913	1052.536574	1397.700981	1200.390315	881.022984	4.687489	83.601454	44.84242	1
5	Polyline M	796.25401	1035.080055	1237.604885	1146.674698	838.315439	0.232045	56.38023	29.845447	1
6	Polyline M	796.253913	984.023507	1227.241278	1097.914341	836.391102	13.544402	62.251526	30.898553	1
7	Polyline M	796.25401	825.238326	991.8739	939.383443	840.705818	0.421423	74.262758	28.953989	1
8	Polyline M	796.253913	743.902906	833.889989	774.439546	824.943187	0.918618	61.617618	22.578294	1
9	Polyline M	796.253913	833.889989	1259.242211	1060.247579	950.251382	7.229946	148.566513	63.644181	1
10	Polyline M	796.25401	1092.349974	1224.733189	1149.814146	817.05764	0.319873	69.408078	18.446688	1
11	Polyline M	796.25389	914.184087	1092.349974	999.400688	897.319034	2.416874	83.905218	49.816307	1
12	Polyline M	796.25401	827.465111	949.423468	869.20134	818.758433	0.385043	65.731873	20.313901	1
13	Polyline M	796.253913	861.846858	982.509298	919.959467	809.223371	0.933791	50.069608	15.620374	1
14	Polyline M	796.253935	982.265289	1004.311965	995.792494	814.143159	0.919706	53.981501	17.98269	1
15	Polyline M	796.253988	992.022891	1023.896895	1006.079441	807.484199	0.232106	46.676022	14.293884	1
16	Polyline M	796.253913	1023.896895	1106.375561	1062.387616	805.804375	0.096403	50.569097	12.841996	1
17	Polyline M	796.253913	1106.375561	1288.302285	1221.703856	841.12296	0.078336	57.886984	30.641616	1
18	Polyline M	796.25401	1205.138435	1407.963528	1318.319396	872.091389	0.322422	105.278076	40.42097	1
19	Polyline M	796.253913	1336.412296	1473.744372	1405.955685	829.434779	0.108972	69.792953	23.60769	1
20	Polyline M	796.253913	1396.494058	1565.716125	1506.475513	855.103136	0.161367	100.044444	34.745609	1
21	Polyline M	796.25401	1193.16697	1396.494058	1265.68802	852.107427	2.226329	60.873558	36.559767	1
22	Polyline M	796.253913	1098.008545	1314.131031	1197.697159	853.428332	0.85091	75.061795	34.319969	1
23	Polyline M	796.25401	1106.938126	1200.525389	1141.744235	813.488669	0.082477	72.526307	13.831067	1
24	Polyline M	796.25389	1200.525389	1361.61885	1258.819577	822.595447	0.458067	70.381601	21.1151	1
25	Polyline M	796.253913	1361.61885	1559.147712	1486.339523	846.012197	1.57914	80.745825	31.949898	1
26	Polyline M	796.25401	1555.120567	1587.279137	1569.843705	810.536792	0.602129	49.095173	15.330713	1
27	Polyline M	796.253913	1397.760317	1585.030671	1538.674047	850.551256	0.024674	75.054037	31.048455	1
28	Polyline M	796.253913	1381.755207	1578.847011	1507.445065	863.734932	0.263867	125.043656	37.789791	1
29	Polyline M	796.25401	1497.694085	1610.194539	1551.320812	853.31092	2.972522	111.374109	35.529519	1

0 (0 out of 122 Selected)

Spatial Join:

Joins attributes from one feature to another based on their spatial relationship





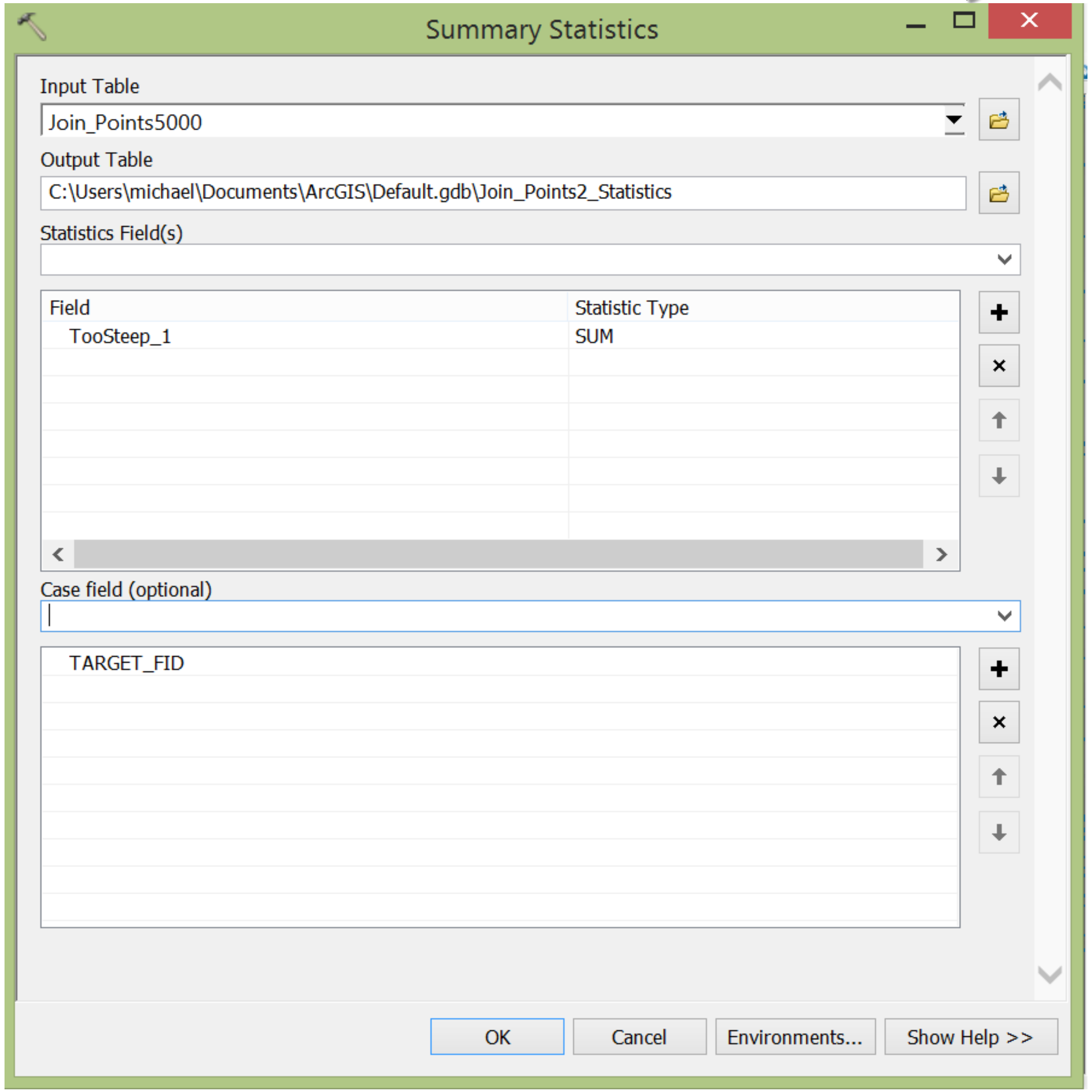
Table

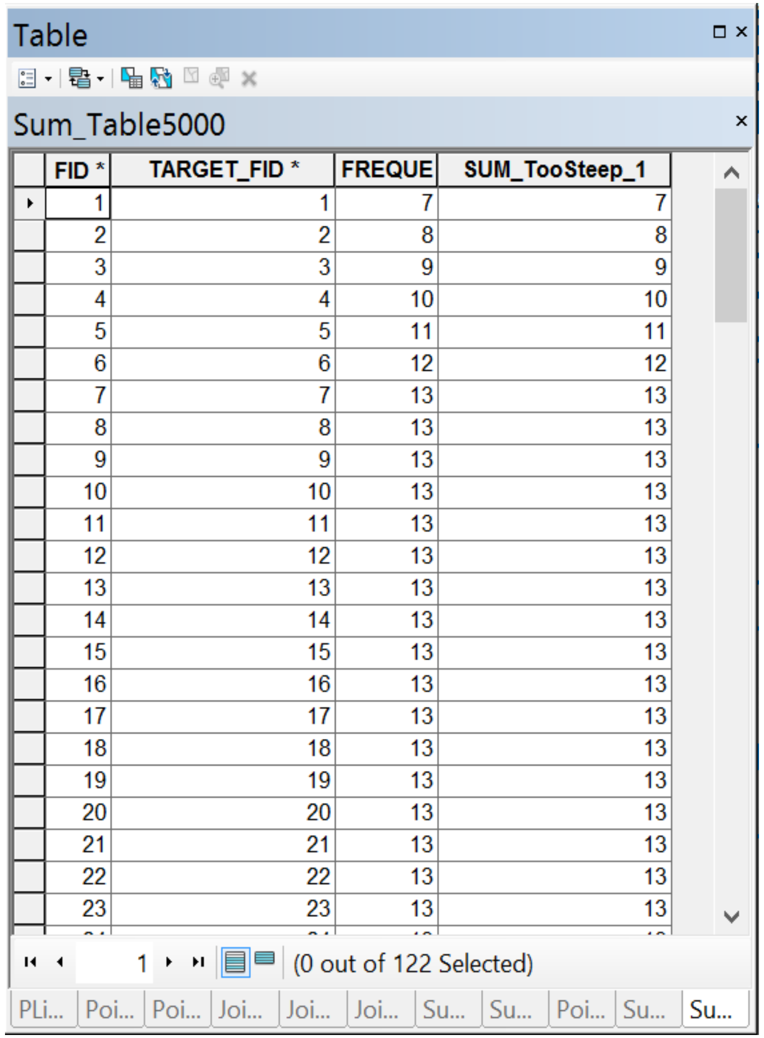
Join_Points5000

TARGET_FID	JOIN_FID	Z_Min	Z_Max	Z_Mean	SLength	Min_Slop	Max_Slo	Avg_Slop	TooStee	ORIG_FI	Z_Min	Z_Max	Z_Mean	SLength	Min_
6	10	984.0235	1227.241	1097.914	836.391	13.54440	62.25152	30.89855	1	6	1092.349	1224.733	1149.814	817.057	0.31
6	11	984.0235	1227.241	1097.914	836.391	13.54440	62.25152	30.89855	1	6	914.1840	1092.349	999.4006	897.319	2.41
6	12	984.0235	1227.241	1097.914	836.391	13.54440	62.25152	30.89855	1	6	827.4651	949.4234	869.2013	818.758	0.38
7	1	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	1031.053	1197.438	1079.155	826.771	0.00
7	2	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	1197.438	1265.223	1220.779	809.872	0.37
7	3	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	1260.074	1444.530	1339.453	846.666	1.30
7	4	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	1052.536	1397.700	1200.390	881.022	4.68
7	5	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	1035.080	1237.604	1146.674	838.315	0.23
7	6	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	984.0235	1227.241	1097.914	836.391	13.5
7	7	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	825.2383	991.8739	939.3834	840.705	0.42
7	8	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	743.9029	833.8899	774.4395	824.943	0.91
7	9	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	833.8899	1259.242	1060.247	950.251	7.22
7	10	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	1092.349	1224.733	1149.814	817.057	0.31
7	11	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	914.1840	1092.349	999.4006	897.319	2.41
7	12	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	827.4651	949.4234	869.2013	818.758	0.38
7	13	825.2383	991.8739	939.3834	840.705	0.421423	74.26275	28.95398	1	7	861.8468	982.5092	919.9594	809.223	0.93
8	2	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	1197.438	1265.223	1220.779	809.872	0.37
8	3	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	1260.074	1444.530	1339.453	846.666	1.30
8	4	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	1052.536	1397.700	1200.390	881.022	4.68
8	5	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	1035.080	1237.604	1146.674	838.315	0.23
8	6	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	984.0235	1227.241	1097.914	836.391	13.5
8	7	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	825.2383	991.8739	939.3834	840.705	0.42
8	8	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	743.9029	833.8899	774.4395	824.943	0.91
8	9	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	833.8899	1259.242	1060.247	950.251	7.22
8	10	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	1092.349	1224.733	1149.814	817.057	0.31
8	11	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	914.1840	1092.349	999.4006	897.319	2.41
8	12	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	827.4651	949.4234	869.2013	818.758	0.38
8	13	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	861.8468	982.5092	919.9594	809.223	0.93
8	14	743.9029	833.8899	774.4395	824.943	0.918618	61.61761	22.57829	1	8	982.2652	1004.311	995.7924	814.143	0.91
9	3	833.8899	1259.242	1060.247	950.251	7.229946	148.5665	63.64418	1	9	1260.074	1444.530	1339.453	846.666	1.30
9	4	833.8899	1259.242	1060.247	950.251	7.229946	148.5665	63.64418	1	9	1052.536	1397.700	1200.390	881.022	4.68
9	5	833.8899	1259.242	1060.247	950.251	7.229946	148.5665	63.64418	1	9	1035.080	1237.604	1146.674	838.315	0.23
9	6	833.8899	1259.242	1060.247	950.251	7.229946	148.5665	63.64418	1	9	984.0235	1227.241	1097.914	836.391	13.5

1 (0 out of 1544 Selected)

Summary Statistics





FID *	TARGET_FID *	FREQUE	SUM_TooSteep_1
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3	3	9	9
4	4	10	10
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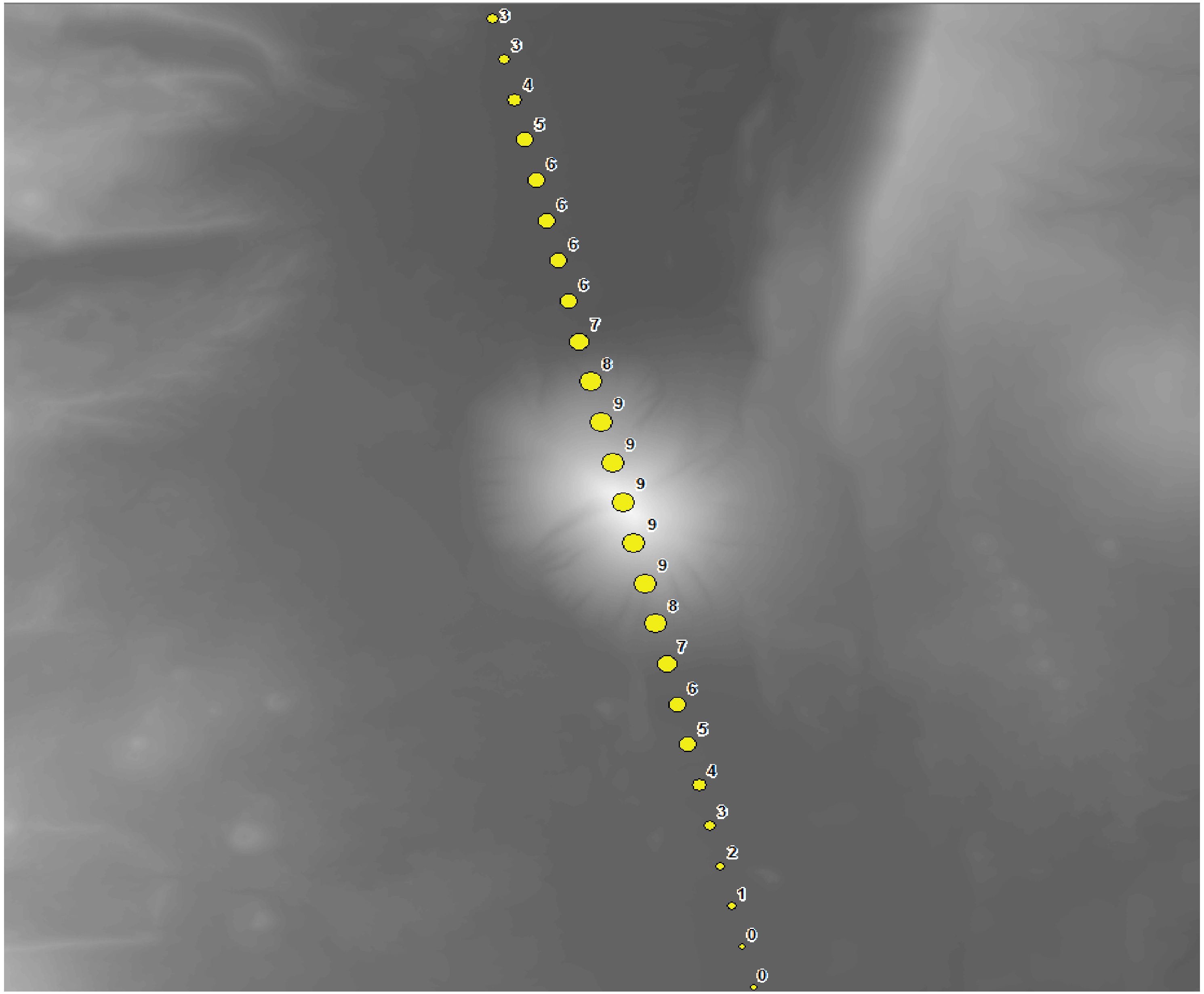
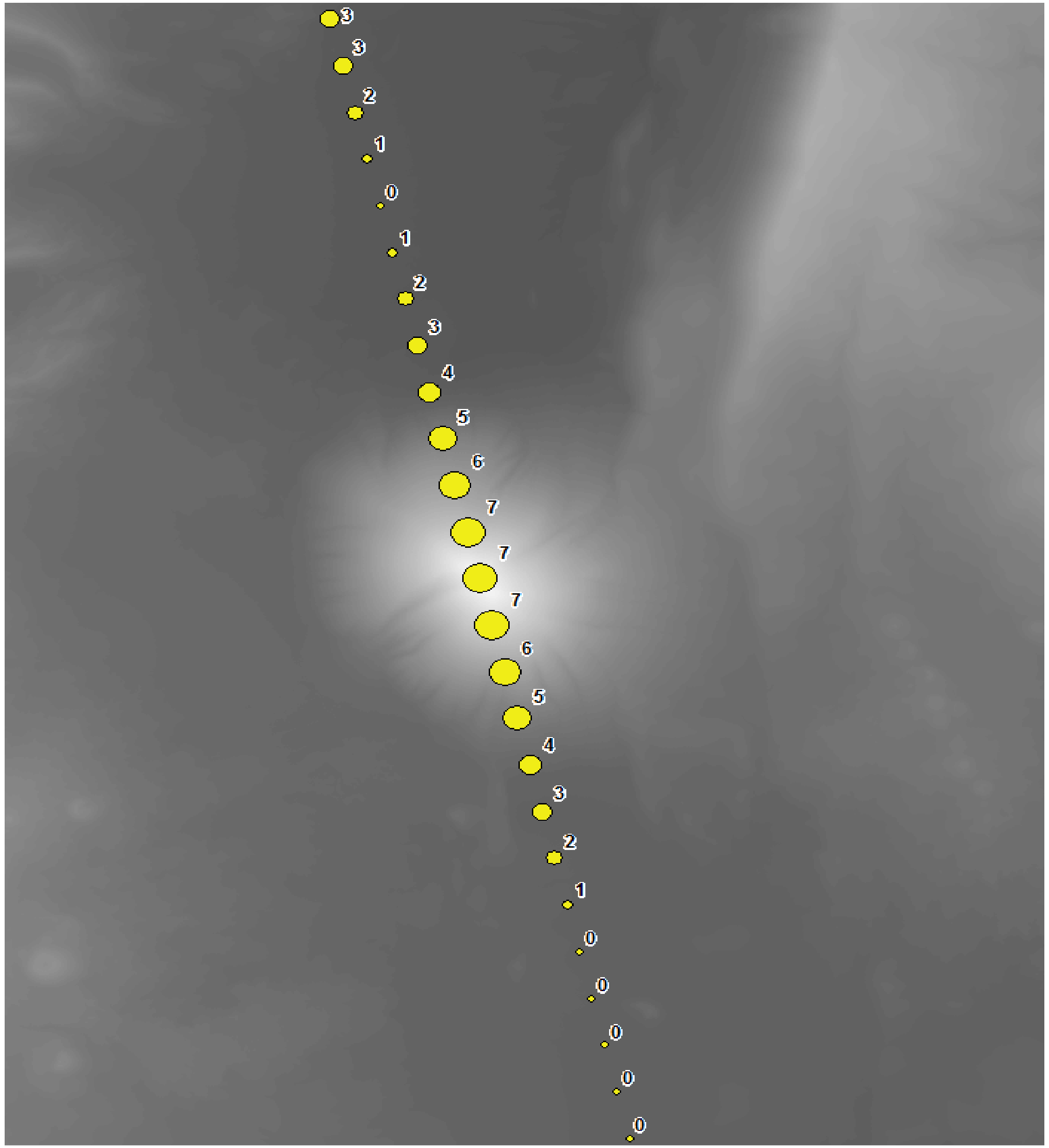
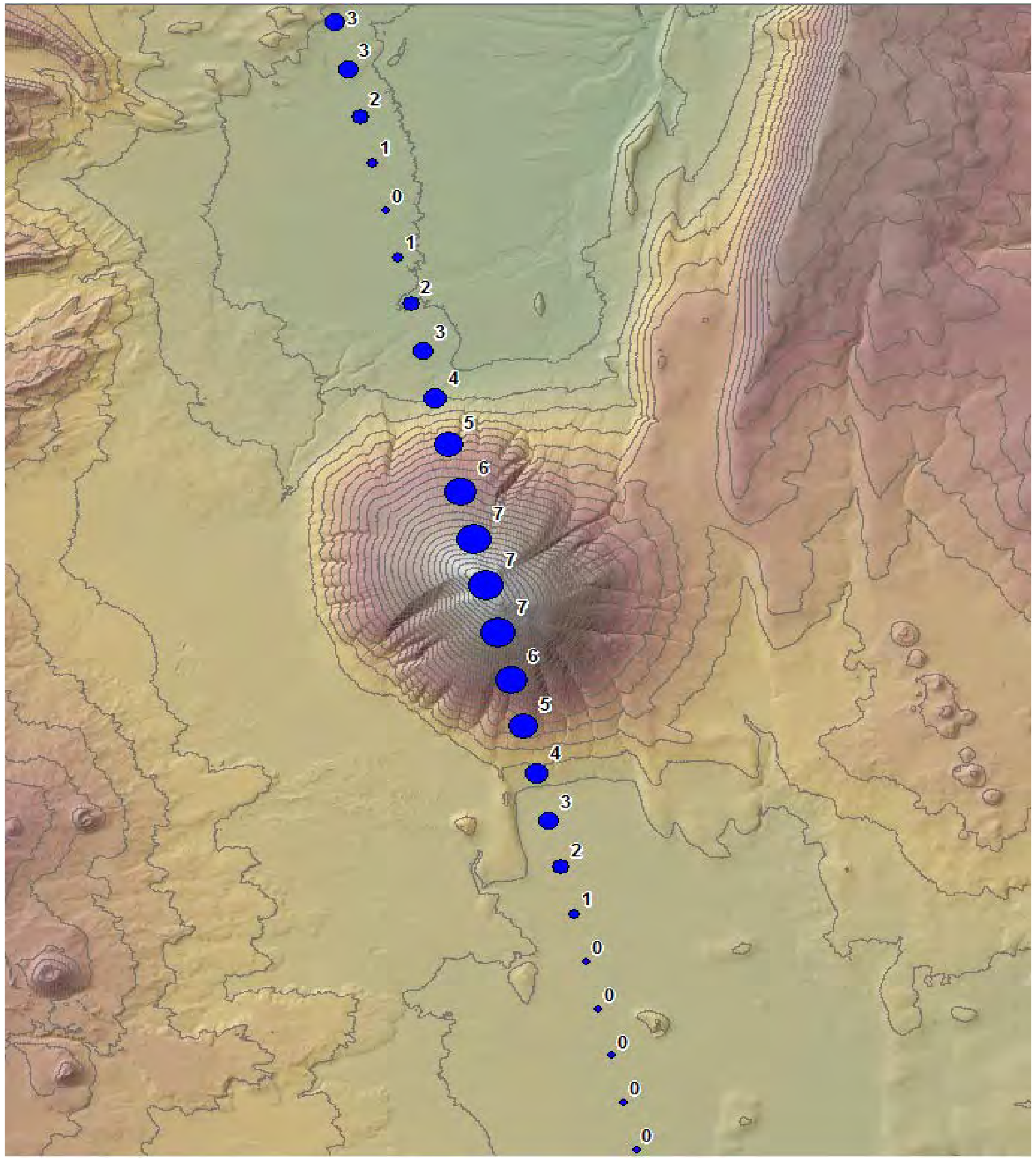
6	6	12	12
7	7	13	13
8	8	13	13
9	9	13	13
10	10	13	13
11	11	13	13
12	12	13	13
13	13	13	13
14	14	13	13
15	15	13	13
16	16	13	13
17	17	13	13
18	18	13	13
19	19	13	13
20	20	13	13
21	21	13	13
22	22	13	13
23	23	13	13

Points with Sum Table Joined

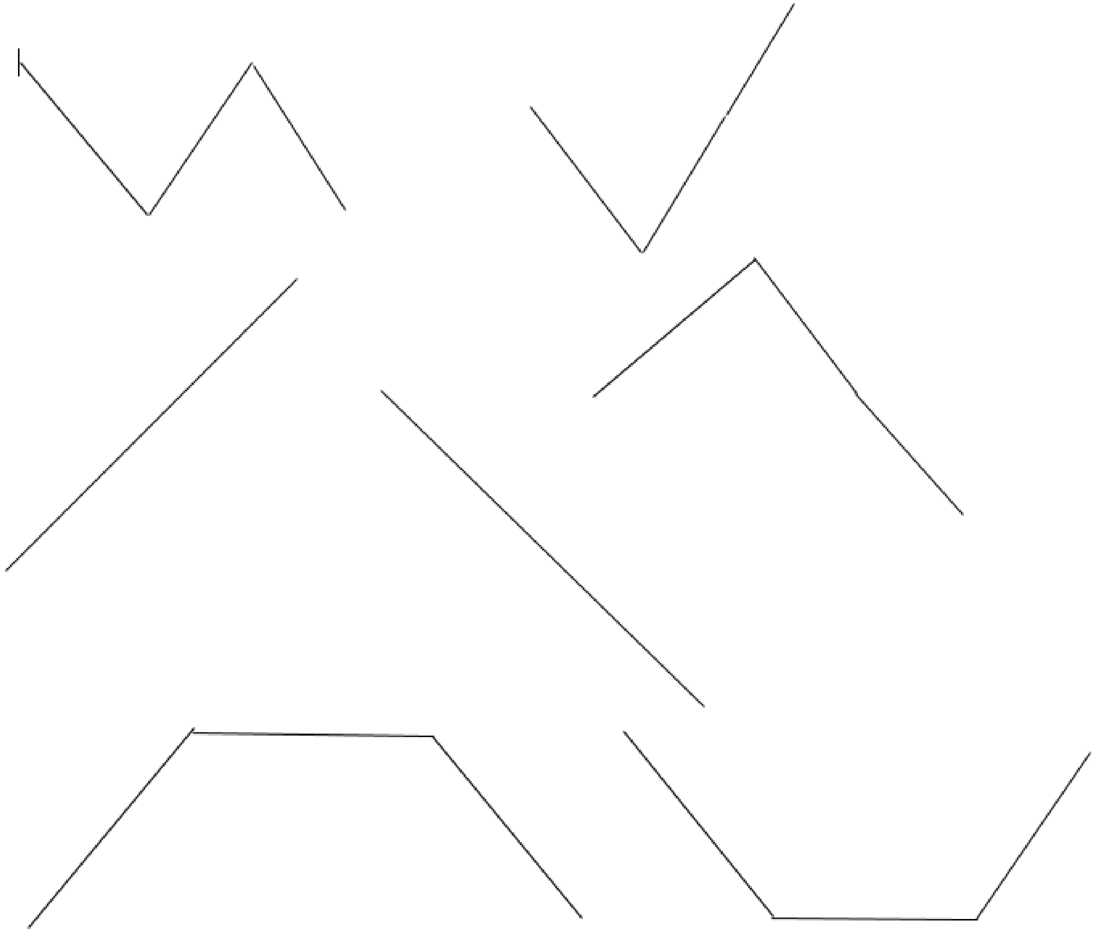


Segments with 2500m search radius





Examples of Possible Combinations



Table

Points2500

FID *	Shape *	Z_Min	Z_Max	Z_Mean	SLength	Min_Slope	Max_Slope	Avg_Slope	TooSteep
1	Point M	1031.053803	1197.438914	1079.155076	826.771342	0.000209	67.809596	22.950718	1
2	Point M	1197.438914	1265.223966	1220.779935	809.872012	0.374519	67.912589	13.22256	1
3	Point M	1260.074916	1444.530218	1339.453	846.666622	1.305988	105.630512	32.458803	1
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5	Point M	1035.080055	1237.604885	1146.674698	838.315439	0.232045	56.38023	29.845447	1
6	Point M	984.023507	1227.241278	1097.914341	836.391102	13.544402	62.251526	30.898553	1
7	Point M	825.238326	991.8739	939.383443	840.705818	0.421423	74.262758	28.953989	1
8	Point M	743.902906	833.889989	774.439546	824.943187	0.918618	61.617618	22.578294	1
9	Point M	833.889989	1259.242211	1060.247579	950.251382	7.229946	148.566513	63.644181	1
10	Point M	1092.349974	1224.733189	1149.814146	817.05764	0.319873	69.408078	18.446688	1
11	Point M	914.184087	1092.349974	999.400688	897.319034	2.416874	83.905218	49.816307	1
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14	Point M	982.265289	1004.311965	995.792494	814.143159	0.919706	53.981501	17.98269	1
15	Point M	992.022891	1023.896895	1006.079441	807.484199	0.232106	46.676022	14.293884	1
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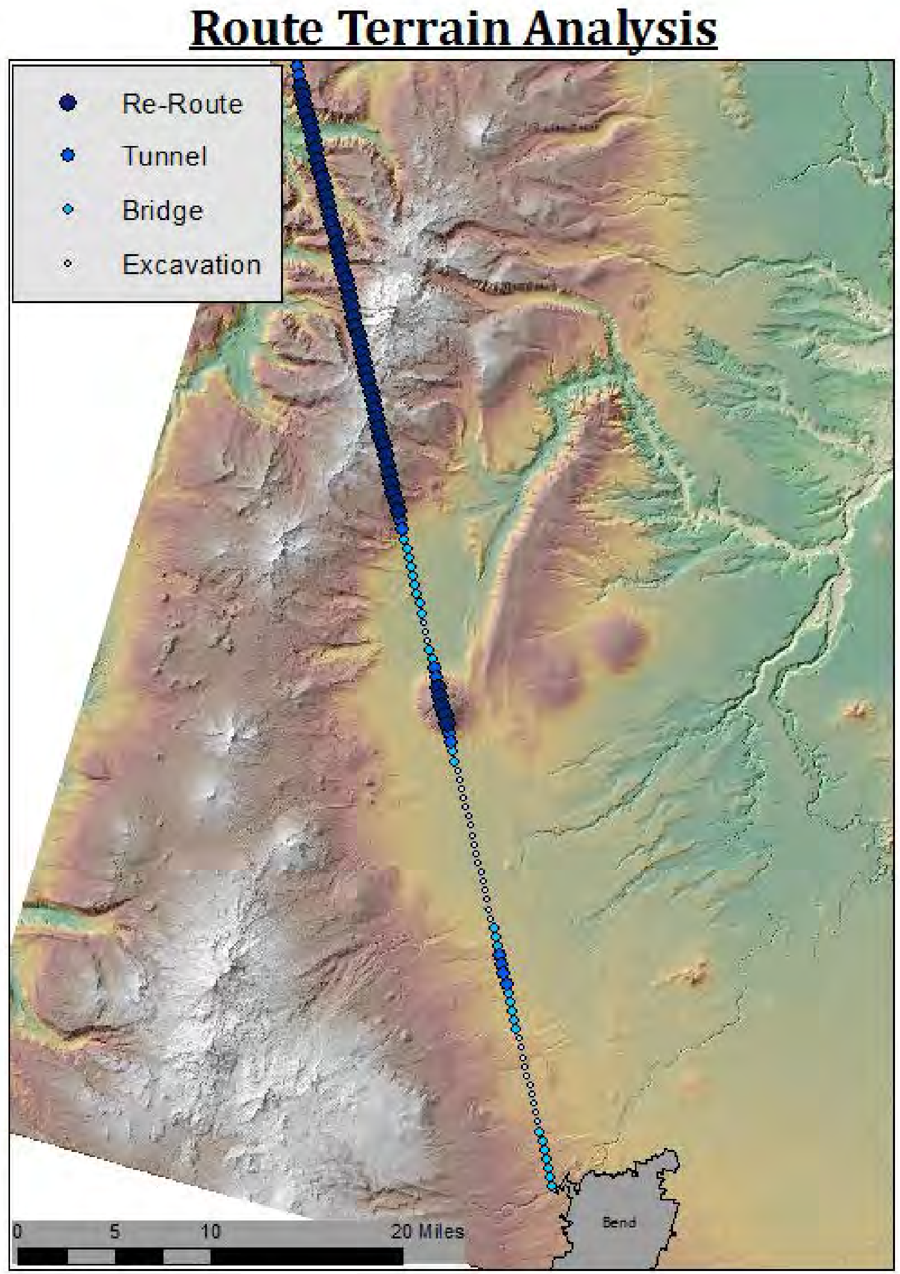
23	Point M	1106.938126	1200.525389	1141.744235	813.488669	0.082477	72.526307	13.831067	1
24	Point M	1200.525389	1361.61885	1258.819577	822.595447	0.458067	70.381601	21.1151	1
25	Point M	1361.61885	1559.147712	1486.339523	846.012197	1.57914	80.745825	31.949898	1
26	Point M	1555.120567	1587.279137	1569.843705	810.536792	0.602129	49.095173	15.330713	1
27	Point M	1397.760317	1585.030671	1538.674047	850.551256	0.024674	75.054037	31.048455	1
28	Point M	1381.755207	1578.847011	1507.445065	863.734932	0.263867	125.043656	37.789791	1

0 (0 out of 122 Selected)

Conclusions:

While the steps taken aided in the creation of a process for identifying the terrain characteristics of route segments and the most appropriate terrain/route modifications for those areas, further analysis needs to be performed in order to accurately categorize the specific characteristics and the best course of action. A newly created tool, with a script specifically written to utilize the spatial information obtained thus far based upon the parameters of the intended project, is the next logical step to simplify and automate the route terrain analysis process.



References:

--Parsons, Brinckerhoff, Quade & Douglas, Inc. "*Program Environmental Impact Report/Environmental Impact Statement: Engineering Criteria*". January, 2004. www.hsr.ca.gov/docs/programs/eir-eis/statewide_techrptEngineer_rpt.pdf

-- ESRI Resources, Help. "*Create Route*", "*Editor, Split*", "*Add Surface Information*", "*Spatial Join*", "*Summary Statistics*"