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An Investigation of Rock Fall and Pore Water Pressure using LiDAR in Highway 63 Rock Cuts

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by

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16. Abstract

The purpose of this research work is compare LIDAR scanning measurements of rock fall with the natural changes in groundwater level to determining the effect of water pressures (levels) on rock fall. To collect the information of rock cut volume change, we chose two rock cuts in highway 63, measured the rock fall, and installed and measured water pressure in piezometers.

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0. Introduction

Rock fall is a geological problem in the entire world. In USA, is numerous rock falls happen every year, especially in highway rock cuts. These rock falls could result in property damage, injury and even death. So, it would be useful to be able to protect rock falls and take appropriate action. But normally the prediction work is difficult, because the limitation of geological technology. Here at Missouri University of Science and Technology we have used LIDAR 3D scanning technology to measure rock falls. Simultaneously we have monitored freeze/thaw cycles, rainfall, and seismic activity from a nearby quarry as the possible influencing factors on rock fall on Highway 63 north of Rolla.

In this research program, we mainly focus on the relationship between the rainfall, water pressure, seismic activity, thermal/freeze-thaw cycling with the rock raveling. In this specific project we add the concept of water pressure in the ground by installing and measuring water levels in standpipe piezometers. The long-term objectives are to develop a conceptual model and predictive capability for raveling of rock slopes, ultimately developing 3-D numerical models.

1. Project Purpose

The purpose of this research work is compare LIDAR scanning measurements of rock fall with the natural changes in groundwater level to determining the effect of water pressures (levels) on rock fall. To collect the information of rock cut volume change, we chose two rock cuts in highway 63, measured the rock fall, and installed and measured water pressure in piezometers.

2. Site locations

Two rock cuts were selected for this work along Highway 63 just north of Rolla (Figure 1). Site 1 (Figure 2) was located on a problematic rock cut that traverses across a filled sinkhole. This rock cut is constantly raveling and the ditches below this rock cut have been cleared of debris many times. Site 2 (Figure 3) was located just outside of a local operational quarry, where the seismic effects of blasting would contribute to rock fall. This location was chosen because there was evidence of both rock fall and groundwater leakage.

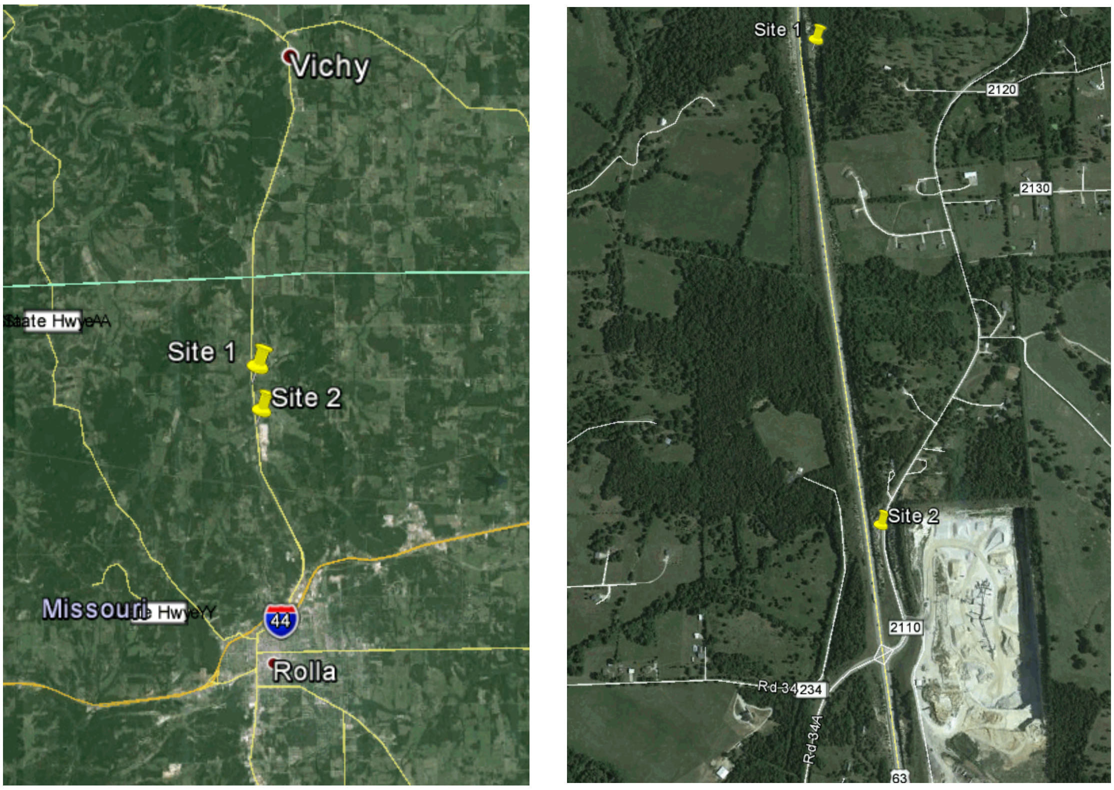

Figure 1: Location of the rock cut test site, just north of Rolla MO USA on State Highway 63. Images taken from Google Earth.

Figure 2: Site 1. This is a filled sinkhole that requires ongoing maintenance.

Figure 3: Site 2. Note the black stains on the rock indicating water flow.

3. Site preparation (drilling)

In preparation for data collection, standpipe piezometers needed to be installed at each location. MODOT (Missouri Department of Transportation) graciously provided drilling and installation services.

Figure 4 shows the drilling work. On site one, 3 holes were to depths of 22, 45, and 70 feet. On site 3 holes were drilled to depths of 14 and 25'. Details are given in table 1. Although not necessary, drilling in the rock was conducted using a coring bit and double tube core barrel. Figure 5 shows some of the core in the core boxes. Rudimentary core logs can be found in Appendix 1.

Figure 4: Core drilling on site 2.

Figure 5: Core drilling on site 1.

Table 1: Boreholes Information

Drill Position and Bore Hole Number	Depth of Bore Hole (‘)	Stick Up	Borehole Bottom (m)
Site 2, BH 1	22 ft.	0.61 m	7.10 m
Site 2, BH 2	70 ft.	0.61 m	21.70 m
Site 2, BH 3	45 ft.	0.62 m	13.10 m
Site 1, BH 4	14 ft.	0.57 m	4.77 m
Site 1, BH 5	25 ft.	0.55 m	8.20 m

Figure 5: The rock core from Site 1.

4. Site preparation (installing piezometers)

In each hole, 1” PVC piezometers were installed (Figure 6) with 3” screened sections packed with pea gravel. The rest of the hole was backfilled with cement grout.

Figure 6: Piezometer installation.

Figure 7: Making water level measurements.

5. Water Level Measurements

Water level measurements are made simply with a water level tape (Figure 7). Table 2 shows the water level in the piezometers. Table 2 shows the water level over the period of time of the study. In Table 3, we can find that the Boreholes 3, 4 and 5 are dry in most of time, and the variation in boreholes 1 and 2 is very small. Figures 8 and 9 show the water level as a function of time.

Table 2: Water Level in the piezometers

Date	Underground water level in Boreholes (meters)				
	No.1	No.2	No.3	No.4	No.5
Bottom of BH	***7.10***	***21.70***	***13.10***	***4.77***	***8.20***
12/04/2013	6.62	19.48	Dry	4.77	8.13
12/09/2013	6.65	19.48	Dry	4.77	Dry
12/112013	6.65	19.56	Dry	4.77	Dry
12/16/2013	6.67	Dry	Dry	Dry	Dry
12/22/2013	6.69	19.49	Dry	Dry	Dry
01/12/2014	6.77	19.29	Dry	Dry	8.17
01/22/2014	6.67	19.30	Dry	Dry	8.15
02/02/2014	6.67	19.29	Dry	Dry	8.17
02/10/2014	6.87	19.46	Dry	Dry	Dry
02/20/2014	6.87	19.46	Dry	Dry	Dry
03/01/2014	6.92	19.46	13.10	Dry	Dry
03/10/2014	6.96	19.44	13.10	Dry	Dry
03/20/2014	7.06	19.41	Dry	Dry	Dry
04/02/2014	Dry	19.50	Dry	Dry	Dry
04/10/2014	Dry	19.48	Dry	Dry	8.20

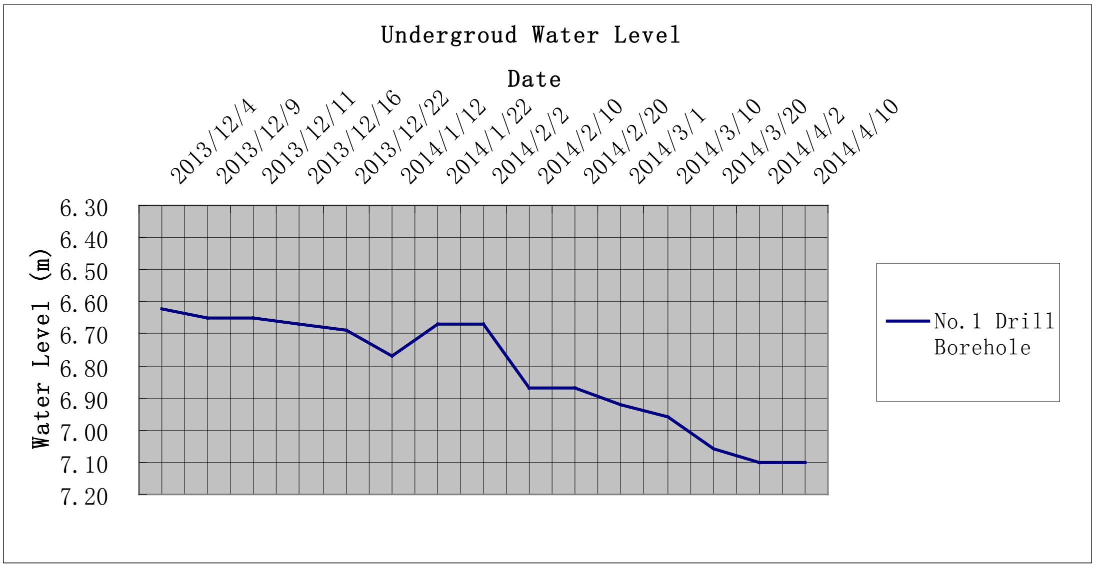

Figure 8: Underground water level in Borehole 1.

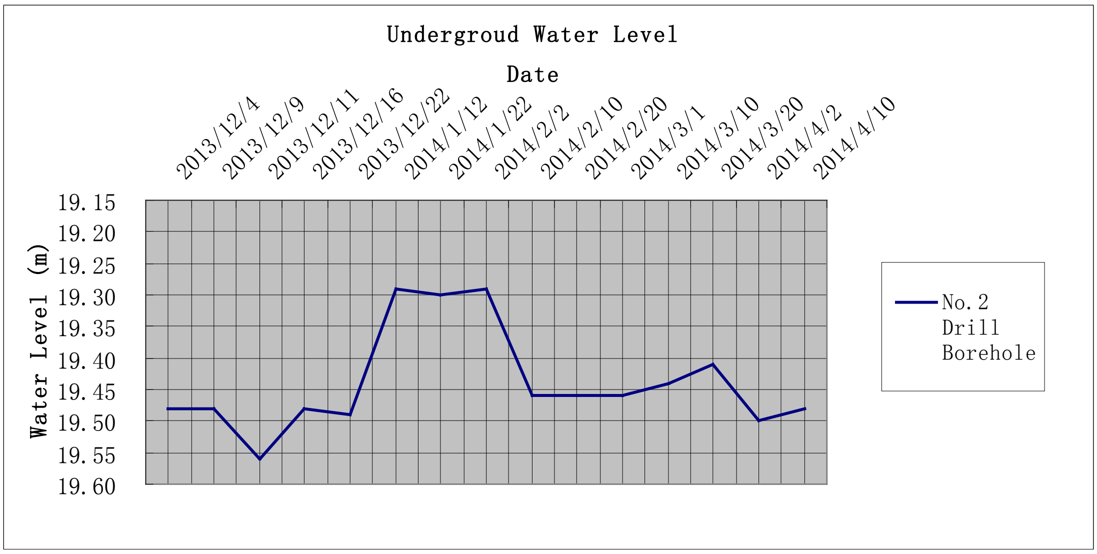

Figure 8: Underground water level in Borehole 2.

6. Rainfall and Temperature Measurements

Rainfall and temperature measurements were taken (Tables 3, 4; Figures 9, 10, 11).

Table 3: Temperature and Precipitation

Date	Average Temperature (°C)	Precipitation (mm）
12/4/2013	10	0
12/9/2013	-5	0
12/11/2013	-6	0
12/16/2013	6	0
12/22/2013	-3	20.83
1/12/2014	7	0
1/22/2014	-4	0
2/2/2014	0	1.78
2/10/2014	-11	0
2/20/2014	12	7.37
3/1/2014	1	2.03
3/10/2014	14	0
3/20/2014	8	0
4/2/2014	12	5.84
4/10/2014	19	0

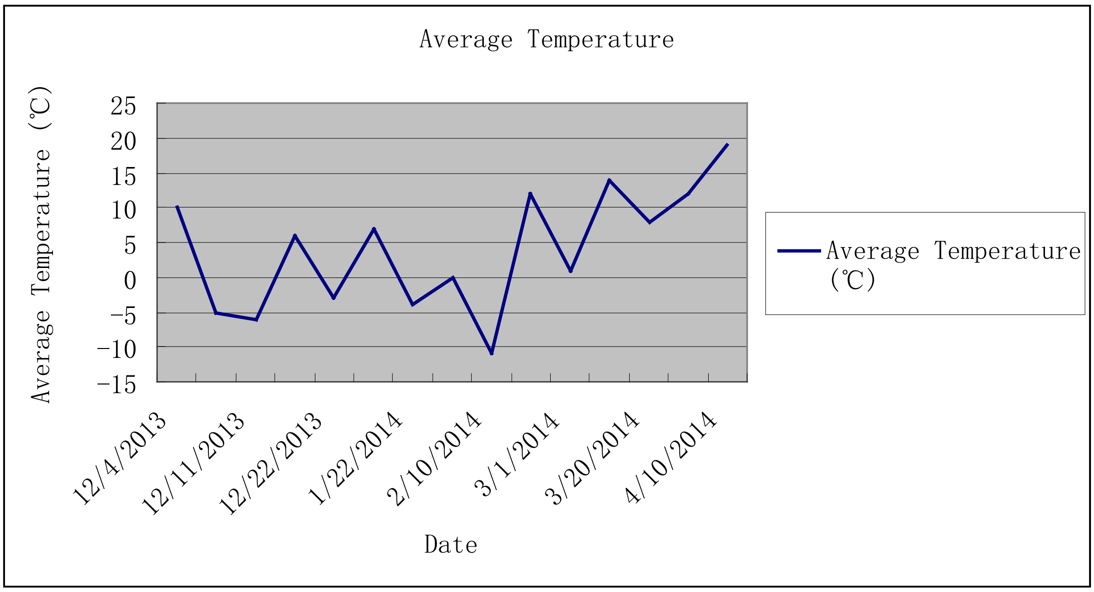

Figure 9: Average Temperature

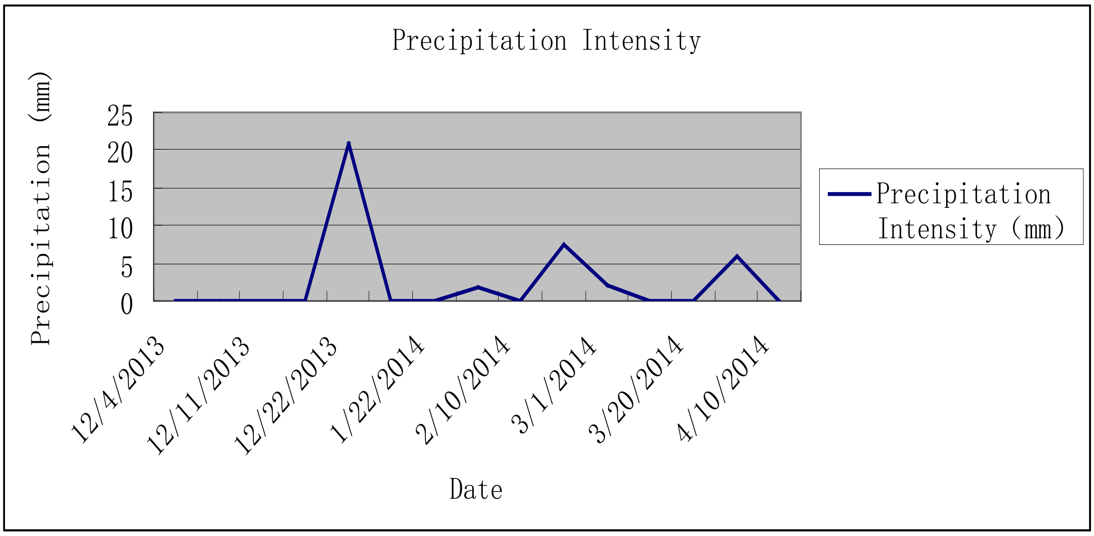

Figure 10: Precipitation Intensity

Table 4: Temperature cycles above and below Freezing

Date	**Number of Freeze-Thaw Cycles Since Last Measurement**
12/4/2013	3
12/9/2013	2
12/11/2013	10
12/16/2013	9
12/22/2013	10
1/12/2014	24
1/22/2014	16
2/2/2014	15
2/10/2014	2
2/20/2014	15
3/1/2014	13
3/10/2014	11
3/20/2014	12
4/2/2014	14
4/10/2014	4

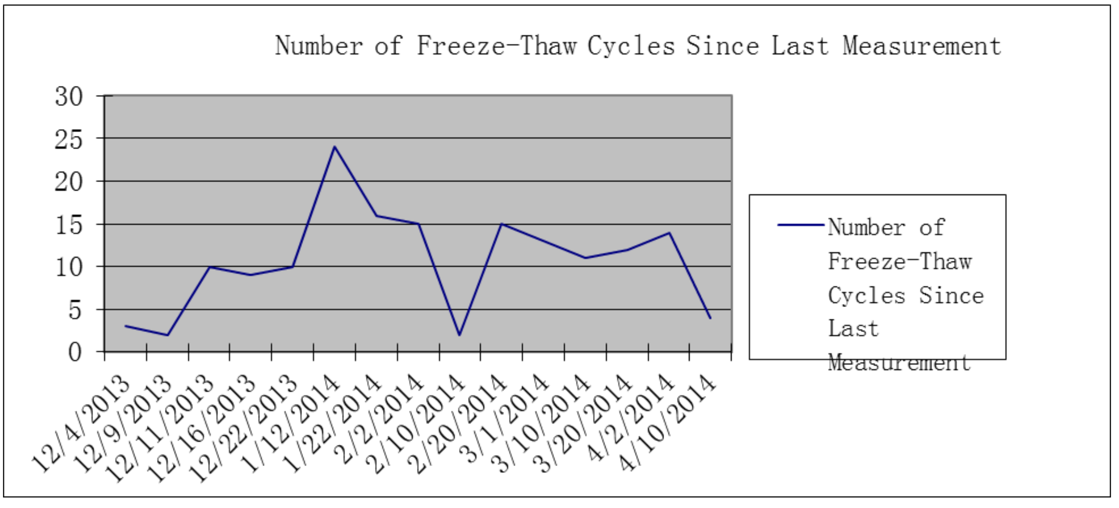

Figure 11: Temperature cycling above and below freezing.

Figure 12: LIDAR scanning, site 1.

7. LIDAR Scanning, Example Results

LIDAR scanning was done using a Faro Focus 3D scanner (Figure 12). From 12/4/13 to 4/10/14, both sites were scanned 15 times. Scanning could only be done on days where the temperature was at least 5 degrees C. The face had to be scanned in sections to increase the resolution to 4 mm. Then registration was needed to join the separate scans.

Figure 13 shows the results of a completed scan of the entire cut. Figure 14 shows the results of a completed scan of 2/22/14, right hand side of the cut, cropped to the active face.

Table 6: The Volume Change of Rock Cut

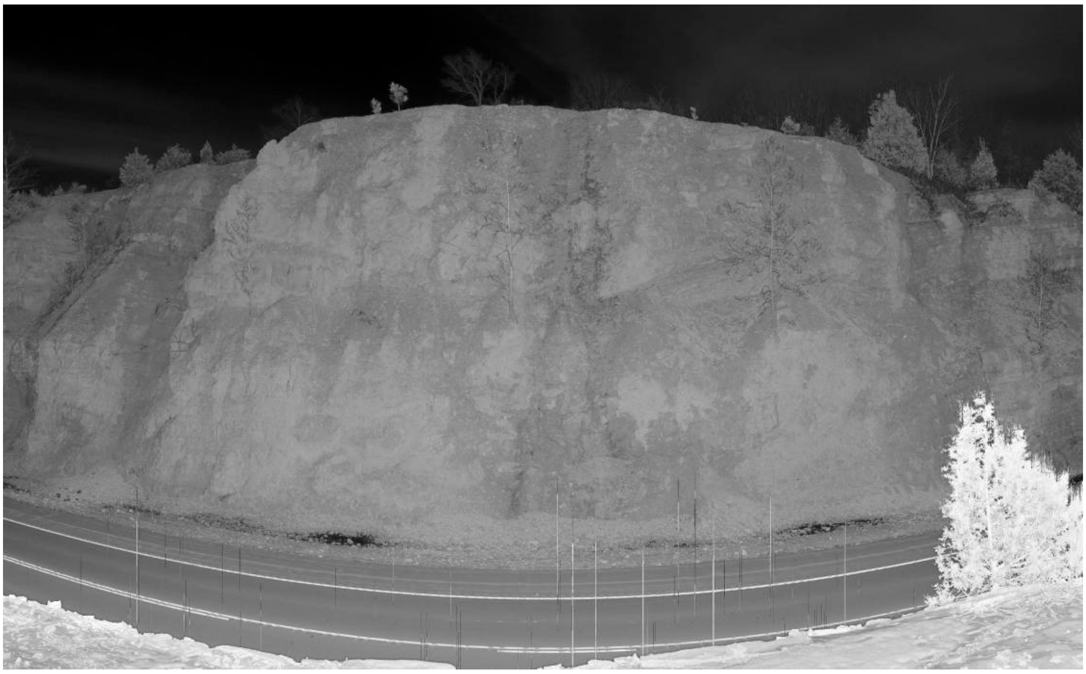

Figure 13: Scanning result. Vertical lines show when the scanner intercepted cars speeding done the highway. These are easily edited out.

Figure 14: Scanning result of the right hand side of the cut, cropped to the active face.

Figure 15 shows the raw results of the change detection algorithm, which nominally shows lost material in blue, gained material in red, and no change in green. The algorithm also has a vegetation removal aspect, however in Figure 15, the tree of Figure 14 (right hand true) is physically missing because it has either fallen down or been removed by the Missouri Department of Transportation personnel.

Figure 16 shows the final results of the change detection algorithm. Most of the fallen rock (blue) is as a result of the fallen/removed tree. Gained material (red) is typically the result of rock material that has fallen from higher up and has been left on the slope.

The statistics from this analysis show a lost rock volume of 8275.48 liters, and a gained rock volume of 2874.36 liters for a net loss of 5401.12 liters.

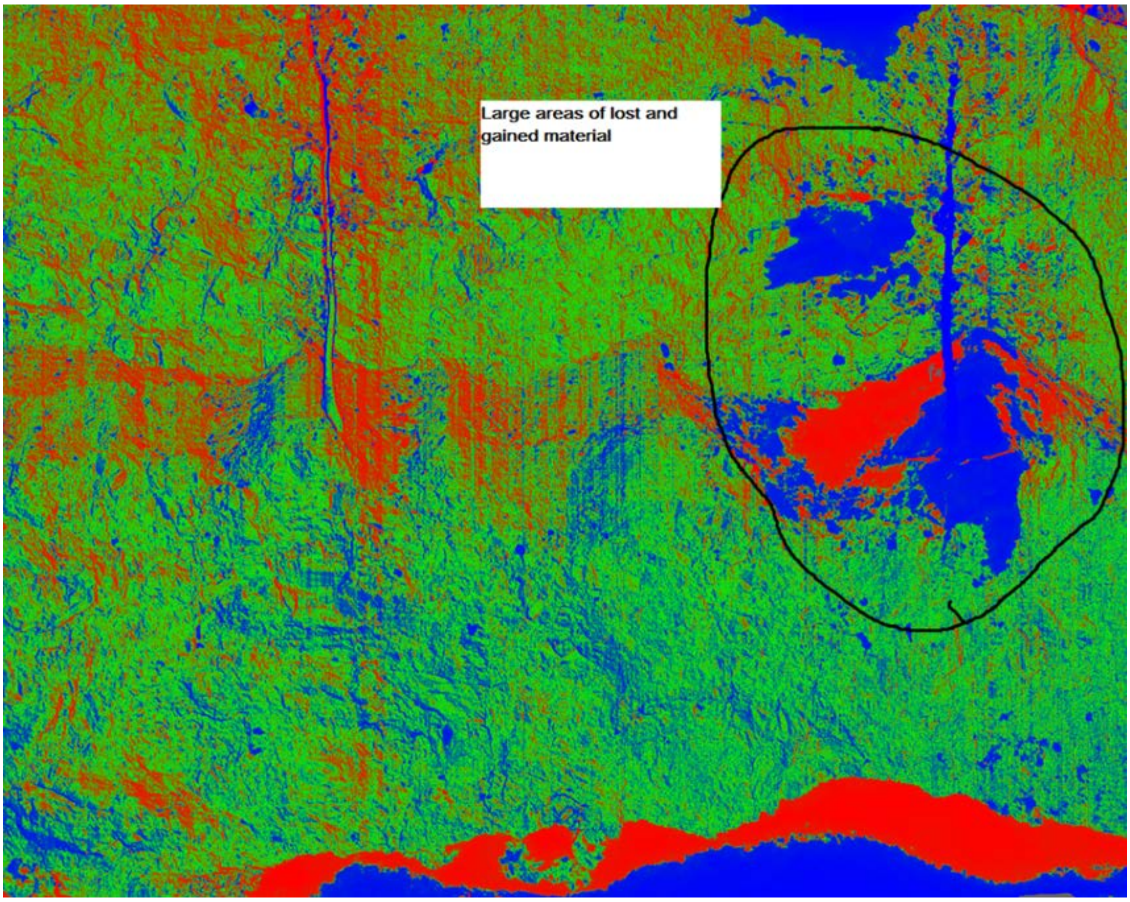

Figure 15: Initial results of change detection algorithm. Gained material is shown in red, and lost material is shown in blue. Note that tree in Figure 14 has been removed. The bottom of the image shows fallen rock.

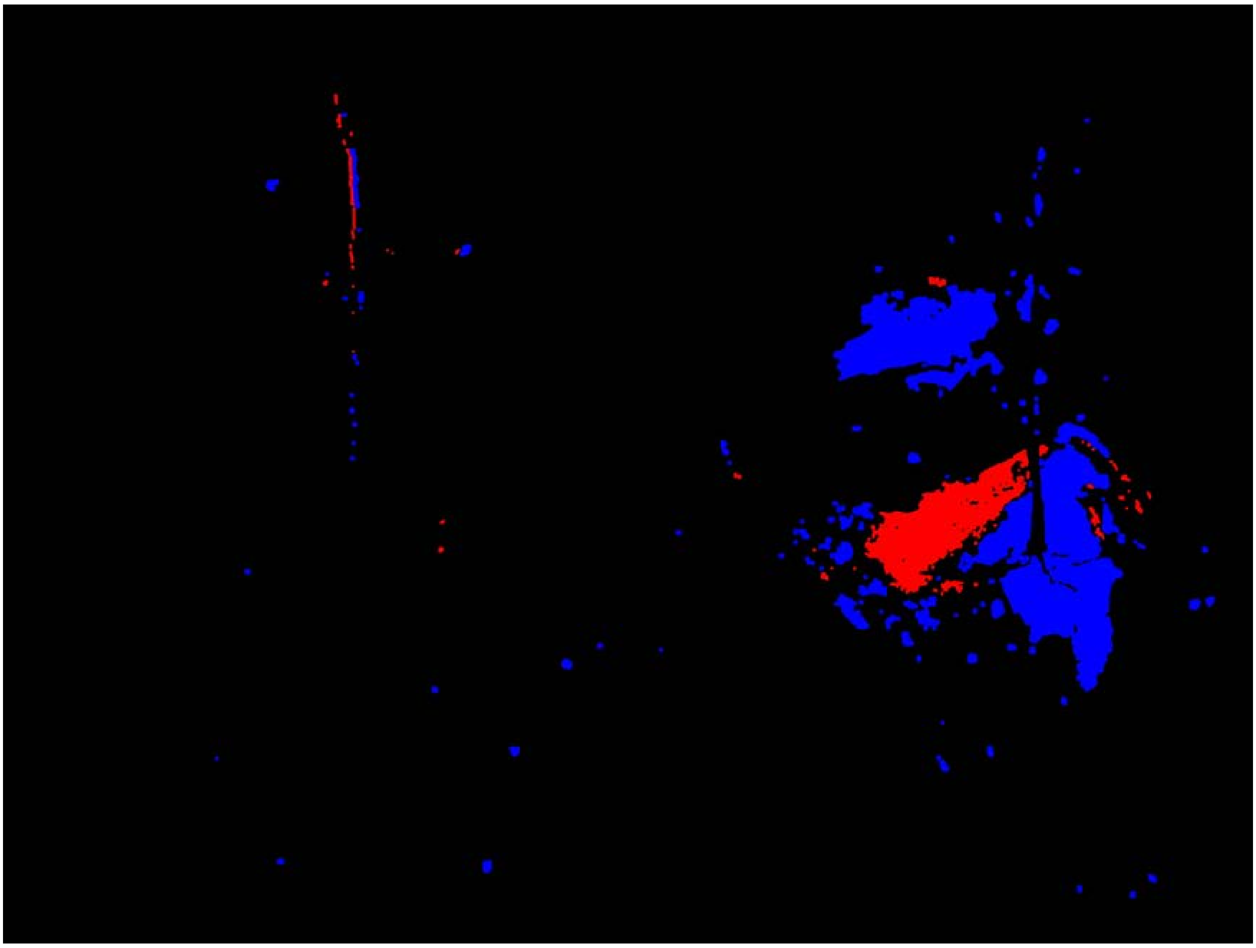

Figure 16: Final result of change detection algorithm by editing out the fallen rock at the bottom of the slope, and filtering the changes. Gained material is shown in red, and lost material is shown in blue.

8. Further Work

Although all the scanning and environmental data collection has been completed for this project, data processing (funded by other sources) is not yet complete. Once volumes lost calculations have been completed, these will be compared against water level, precipitation, and temperature cycling data.

9. Acknowledgments

The authors would like to acknowledge the National University Transportation Center and the Geological Engineering Program for funding this work.

The authors would like to also acknowledge MODOT (Missouri Department of Transportation) who graciously provided drilling and installation services.

Appendix 1: Borehole Logs

Borehole Log of Borehole R35G, Site 1

Position: Route 63 Date: 11/06/2013 Borehole Number: R35G (The 2nd of 3) Total Depth: 70.4 ft.					
Depth (ft.)	Time	Run/Rec	Core Loss ‘	RQD (%)	Log of Materials
0.4-5.4	13:55-14:05	5.0/5.0	0	46.78%	Main rock type is dolomitic. The color is from light grey to tan, highly weathered and highly fractured. There also some sandstone and clay seams. These sandstone seams and clay stone were found at depths of: 2ft, 5.5ft, 9ft, 11ft, 12.5ft, 15.4ft, 28ft, 31.5ft, 32.5ft, 33ft, 43ft, 48.5ft, 53ft, 58.5ft, 69ft.
5.4-10.4	14:09-14:18	5.0/5.0	0	21.33%	
10.4-15.4	14:21-14:30	5.0/5.0	0	22.05%	
15.4-20.4	14:34-14:46	5.0/5.0	0	74.01%	
20.4-25.4	14:50-15:00	5.0/5.0	0	67.45%	
25.4-30.4	15:04-15:12	5.0/5.0	0	45.28%	
30.4-35.4	15:17-15:24	5.0/5.0	0	58.40%	
35.4-40.4	15:29-15:36	5.0/5.0	0	64.96%	
40.4-45.4	15:40-15:49	5.0/5.0	0	28.48%	
45.4-50.4	15:52-16:00	5.0/5.0	0	40.55%	
50.4-55.4	7:59-8:08	5.0/5.0	0	69.29%	
55.4-60.4	8:15-8:21	5.0/5.0	0	58.20%	
60.4-65.4	8:26-8:35	5.0/5.0	0	68.64%	
65.4-70.4	8:41-8:51	4.6/4.6	0	55.35%	

Borehole Log of Borehole 2, Site 2

Position: Route 63 Date: 11/08/2013 Borehole Number: No.2 of 2 Total Depth: 25.0 ft.					
Depth (ft.)	Time	Run/Rec	Core Loss ‘	RQD (%)	Log of Materials
0.0-4.0	13:40-13:56	4.0/3.9	0.1	33.50%	Light grey to tan dolomite, the upper parts are heavily weathered. Highly fractured with tan sandstone seams, at depth of 6’.
4.0-6.0	14:00-14:06	2.0/2.0	0	0	
6.0-9.0	14:09-14:17	3.0/2.0	1	20.78%	
9.0-14.0	14:20-14:38	5.0/5.0	0	66.27%	
14.0-19.0	14:43-14:55	5.0/5.0	0	46.72%	
19.0-24.0	14:59-15:11	5.0/5.0	0	84.78%	
24.0-25.0	15:14-15:17	1.0/1.0	0	88.58%	