Glacio-lacustrine Deposits Create Landslide Hazards at Deer Run Heights in Jeffersonville, Vermont

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Thesis:

The landslide which occurred in 1999 on Deer Run Heights in Jeffersonville, VT represents an ongoing problem with slope stability due to the over-steepened slopes, and glaciolacustrine materials that make up the slope. These soils are prone to a high rate of erosion which removes material rapidly further destabilizing the slope. Of greatest concern are periods of prolonged heavy rain and the addition of water through snowmelt which increases erosion along the ridge, on the slope, and adds to the weight of the slope which could cause another failure similar to the 1999 slide.

Abstract:

Deer Run Heights Ridge in Jeffersonville,VT is plagued by a high rate of erosion due to the glaciolacustrine material which makes up the slope. A landslide which occurred in 1999 and recent failures in close proximity to the 1999 event create concern of another landslide in this area.

The type of soil which makes up this ridge is extremely sensitive to water. Any high water event like a prolonged rain storm or the spring melt not only increases the rate of erosion, but can possibly trigger another landslide.

Currently the top of the ridge is being monitored with rebar stakes to determine the rate of cutback along the top of the ridge. The average rate of cutback along the entire ridge was determined to be about 0.62 meters per year. Certain areas along the ridge are stable while those with stakes are actively losing ground at various rates.

There are three places along this ridge that should be closely monitored for further activity: the area right behind the Farara residence, 324 Deer Run Heights, Jeffersonville, VT, along the 1999 slide, and along stakes 13-19 where a large gully is forming within sight of the Cambridge Elementary school. The historic landslide scars that become visible while walking along the ridge create further incentive for accurately mapping and monitoring the ridge. These historic mass wasting events provide solid evidence that another similar event may occur, and further study is necessary to protect the lives and property of the people living on top of the ridge, as well as those living at the bottom. This ridge is also a great opportunity to study the causes of mass wasting events and how to remediate the situation to prevent, or at least delay further failures

Description of Deer Run Heights:

The area of concern is Deer Run Heights which is located in Jeffersonville, VT. The first monitoring stake is located in the south-western corner of the McCuin yard, which is the property neighboring the Farara residence. The other 18 stakes are placed along the ridge heading south for about 400 meters from the first stake (See Appendix 1 and 2 for stake descriptions and locations). The stakes are used to measure the rate of cutback along the ridge.

The soil consists of alternating layers of clays, silts, and fine sands and these sediments become progressively coarser further up the slope. This area is very steep at about a 25 to 50% slope and the soil is prone to high rates of erosion according to the Lamoille County Soil Survey (Babcock, 1981).

Materials and Methods:

Figure 2. Measuring Cutback

The rate of cutback is monitored by using rebar stakes as a reference points and measuring directly in front of the stake to the edge of the ridge, and approximately 30° to either side (Figure 2). Measurements were taken at each stake along the ridge, and a compass and measuring tape were utilized. The iron rebar were placed at various intervals along the ridge and were only placed along the parts of the ridge where unstable soils were visually apparent. There are 18 stakes and the three measurements are taken at each stake except stake 13 and 18 where only two were taken. Stake number 19 was not used because it was only recently rediscovered in a patch high grass.

Results:

Most of the measurements show only a small amount of change and the average rate of cutback for the period between 23-Aug-2006 and 20-Apr-2007 (241 days) is 1.71 mm/d (millimeters per day) which amounts to 0.62 m/y (meters per year). In some areas change was more rapid. A large section near stake number 12 has broken away recently which accounts for the 2.7 meters loss of land. Stake 15 on Table 1 indicates a gain in land. This discrepancy could be the result of faulty measurements.

Stake Number	8/23/2006	10/22/2016	4/20/2007	Avg cutback over 241 days (m)	mm/d
1	3.63	3.58	3.55	0.08	0.35
2	4.80	4.13	4.67	0.13	0.55
3	6.23	6.18	6.20	0.03	0.14
4	11.28	11.27	11.17	0.12	0.48
5	7.48	7.30	7.18	0.30	1.24
6	4.93	4.87	4.80	0.13	0.55
7	6.14	5.98	6.02	0.12	0.51
8	6.40	5.38	5.10	1.30	5.39
9	4.77	4.78	4.57	0.20	0.83
11	3.72		2.93	0.79	3.28
12	6.75		4.72	2.03	8.44
13	3.58		3.53	0.05	0.21
14	3.67		3.60	0.07	0.28
15	3.61		3.67	-0.06	-0.24
16	3.60		3.46	0.14	0.57
17	3.54		3.30	0.24	1.00
18	3.08		1.75	1.33	5.50
				Avg cutback along ridge	1.71

Table 1. Rate of cutback along ridge

Sometimes it was hard to gauge how far to lean out over severely undercut soils near the edge of a steep drop-off which is why the final rate for each stake is an average of the three measurements, or in the case of 13 and 18, two.

Only a few sections of the ridge are currently active, and it is on these sites that rebar stakes were placed to monitor the rate of cutback. Other areas along the ridge are currently stable. Measurements were taken after prolonged precipitation events since there seems to be such a clear correlation between water, sediment loss, and slope failure. Stake number 10 and 19 are not listed because of trouble locating these stakes; therefore no measurements were taken at those locations.

Observations:

One of the problems encountered while measuring the amount of cut back on the ridge was that there didn't seem to be any change in the measurements. Visually the loss of sediment was noted in the amount of material found down slope and the increase in undercutting as seen in Figure 3. The roots of trees and grass keep the cutback of the ridge line at a minimum by holding the soils together while the slope fails below. This kept the measurements from changing a great deal although the loss of sediment was visually apparent.

Figure 3. Undercutting of Soil Horizons

This illustrates the importance of vegetation in keeping a slope stable. However, once the support of the trees and other vegetation is sufficiently compromised, it will fail. This pattern will continue until the slope reaches a lower angle of repose and stabilizes (Montgomery, 2006). According to Mr. McCuin and Mr. Farara, who are the owners of the two adjacent properties threatened by slope failure, Figure 3 is the top scarp of a gully formed as a result of a water hose left on in 2003 (Springston, 2006). This gully is the northern border of a small scale mass wasting event which occurred sometime in late June to early July of 2006.

Walking south along the ridge to the edge of the Farara property this slide becomes visible approximately five meters down slope when looking west. This landslide occurred after a period of above normal rainfall and is described by George Springston as a complex rotational earth-slump flow using the Cruden and Varnes classification (Springston, 2006). This slide has continued to widen since it was first examined.

Figure 4. McCuin and Farara slides

The 2003 McCuin slide is visible on the left of Figure 4, and the 2006 Farara slide on the right. In between is a new rotational slump. The scarp at the top of this slump shows about 0.5 meters of displacement down slope, and it will continue to move because of the steep nature of the slope and the fine clays, silts and fine sands which are present in this area.

This graph, created using weather data from the Johnson State College weather station, shows a five year average of precipitation. During most of 2006 precipitation was close to average for the year. However, May and June 2006 shows precipitation far above normal for these months. The exact timing of the slide is uncertain because Mr. Farara was on vacation at the time it occurred but there does seem to be lag between water entering the system and failure illustrated by the 1999 slide which occurred after a prolonged dry spell (Wright, 1999).

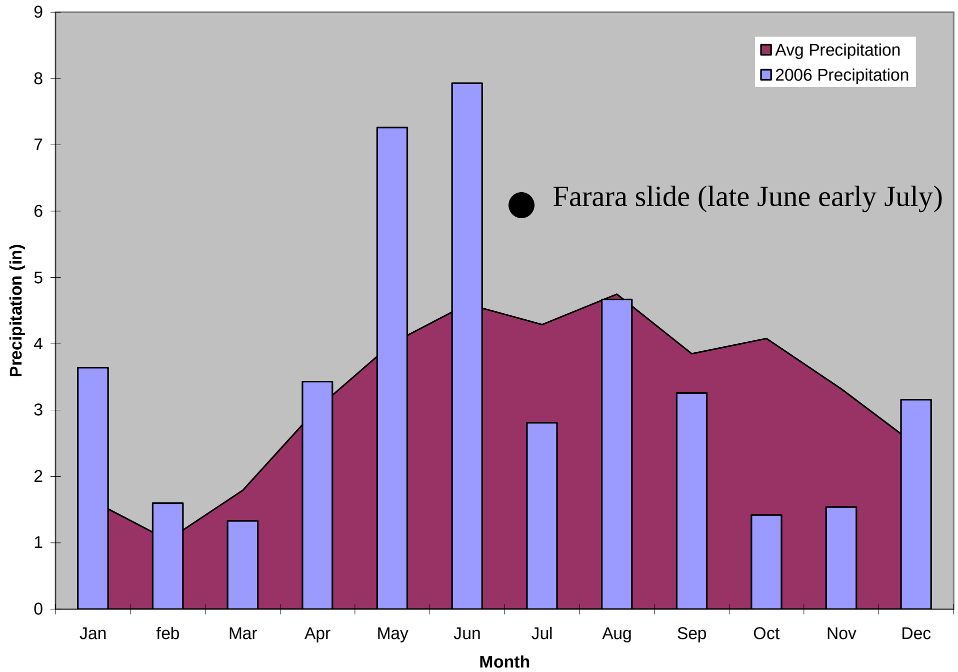


Figure 5. Above Avg. Precipitaiton Summer, 2006 (JSC, 2007)

Currently this area is plagued by many small scale slides; prior to the 1999 slide similar small-scale recurring slides were observed (Wright, 1999). These small scale slides may have a similar effect in further destabilizing the slope, much like a road cut can sometimes destabilize a slope by removing material from down slope. As the base of support is removed the weight of the overlying hill could overcome the frictional forces which keep this slope at a tentative equilibrium (Sidle and Ochiai, 2006). Loss of support due to high rates of erosion and small scale landslides, sensitivity to water, and the presence of a perched water table (Wright, 1999) may make this area the location of the next large landslide.

Further down slope, the rotational slide turns into an earth-flow which is a type of mass wasting caused by water which mobilizes the soil on a hillside (Baskerville, Lee, and Ratte, 1993). After the early spring nor-easter which lashed Vermont with torrential rain, high winds and heavy wet snow, two large debris fans were noticed at the toe of the slope not far from the Brewster River (Sutkoski, 2007; Figure 6).

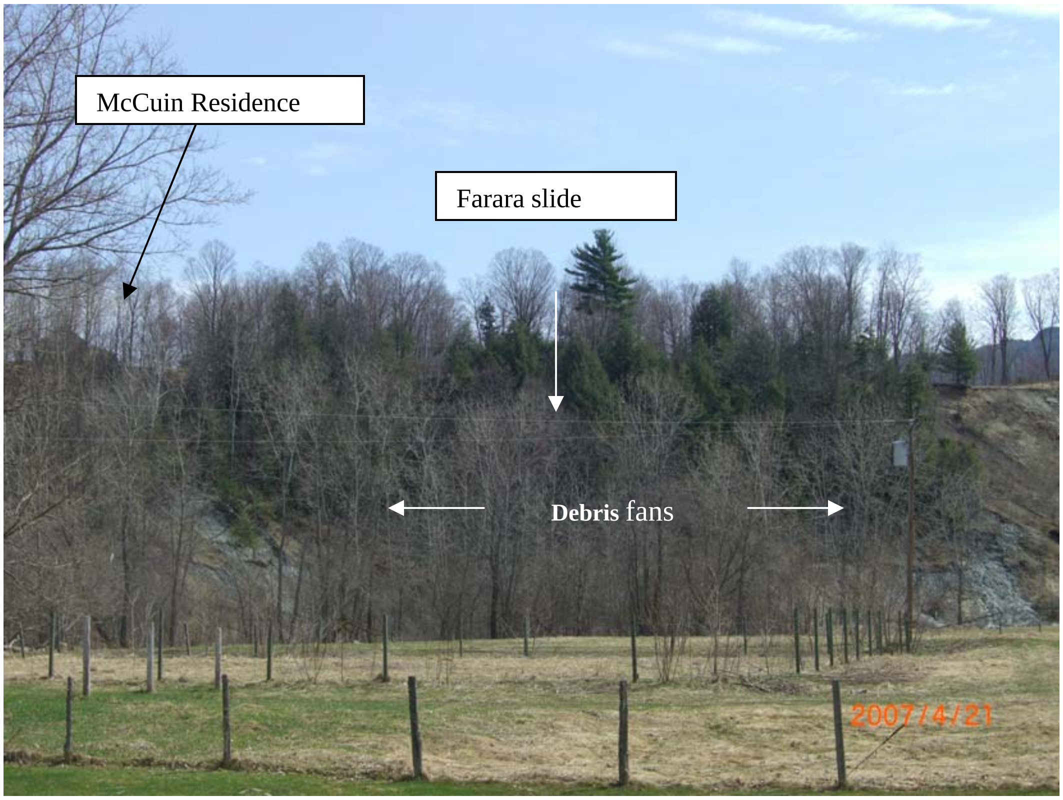


Figure 6. Deer Run Heights

Earth flows on the toe of a slope have been associated with rotational slumps, and water was observed piping from between layers of fine sand and silt, a good indication of the wet conditions (Baskerville and Ohlmacher, 1988). These debris fans become more noticeable every time it rains because of this soils tendency to flow.

Walking south along the ridge past the 1999 slide to stakes 11 and 12 there is a gully with recent ground loss. Sometime during the spring melt a cohesive parcel of soil, approximately five meters long, 3.5 meters wide and about 0.5 meters thick broke away from the edge taking two large trees along with it. Movement was only a few meters because the gully is shallow, and the slope levels out not far from the scarp. This area is in a field and does not threaten property or lives should it fail catastrophically, unlike the area shown in Figure 4 which could possibly cause damage to the McCuin and Farara residences, as well as damage to the village of Jeffersonville.

Further south is another gully which is actively eroding. This area is very steep and water was observed seeping from between layers of soil in a similar fashion as near the Farara slide.

Figure 7. Gully with Cambridge Elementary School visible in the Distance

This gully is large, about 36 paces or 55 meters long across the top and it narrows near the bottom. Rate of cutback is rapid in this area, and measurements must be taken carefully because of severe undercutting of soil horizons at the top of the scarp. This site should be carefully monitored because of the danger it poses to the elementary school which is clearly visible from the top of the hill.

The 1999 slide material was extremely mobile and threatened residents 150 meters away from the slide (Wright, 1999). The extreme mobility of the 1999 slide may be a good indication of how far material may flow should this area fail, and this distance may be great enough to put the school, which is approximately 120 meters away from the ridge, in harms way.

Continued Work:

Monitoring the rate of cutback along the ridge needs to be continued along with other methods to monitor the movement of soils along this ridge. On the 17th of December, two piezometers were installed at this site to measure pore water pressure. The piezometer consists of black iron piping which is pounded into the ground with a sledgehammer. A bolt is placed into the end of the pipe which is driven into the soil to prevent soil from being forced into the pipe as it is pounded into the ground. Each pipe section has a diameter of 1.5 inches and a length of ten feet. Pipe sections are held together with a 1.5 inch merchant coupling.

The first piezometer was placed in the north-west corner of the Farara property about ten feet from the edge of the ridge. Unfortunately the pipe failed at about 17 feet after the second pipe was attached, and new pipe must be placed in this area using the original hole to expedite the insertion of the pipe.

Another piezometer was placed over the ridge near the place where Dr. George Springston is standing in Figure 4, just visible from behind the tree on top of the slide scarp. Only one section of ten foot pipe was used. Both piezometers were marked using colorful tape.

Plans to bore holes for coaxial cable are in effect. The coaxial cable can be used to measure the amount of movement at depth. A total mapping station can be useful to map the rate of movement more accurately than just measuring the amount of cutback with a compass and a measuring tape.

Conclusion:

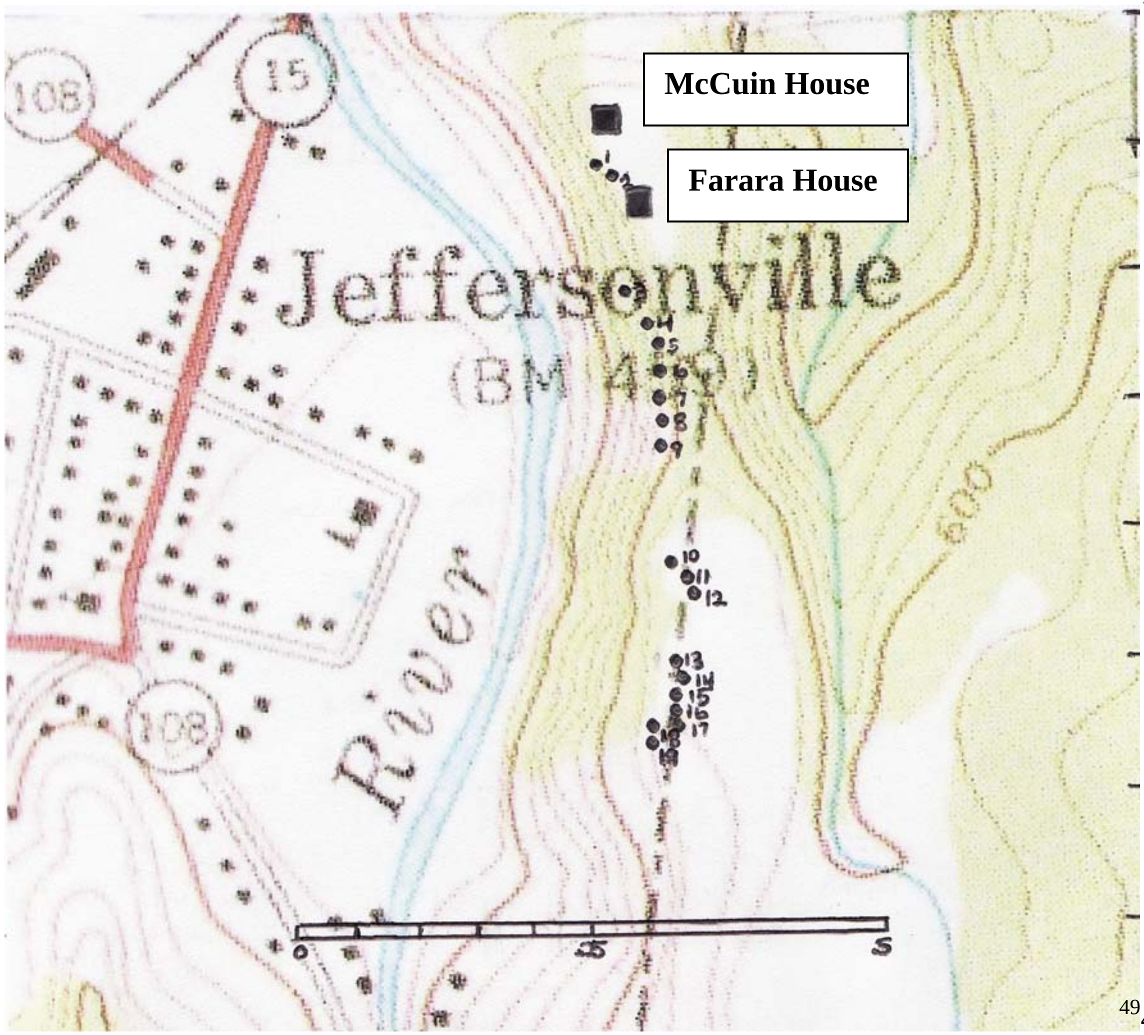
Increase in pore water pressure has been noticed at glaciolacustrine sites similar to what is seen in Jeffersonville during high water events (i.e. prolonged heavy rain and spring snow melt). Pore water pressure can increase between the layers of silt and fine sand which decreases the amount of friction along this plane causing the mass to slide by reducing the effective normal stress and triggers failure of the slope (Baskerville, Lee, and Ratte, 1993).

Landslide hazards in Vermont abound because of this state's glacial history (Baskerville, 1993). The topography of this state also created the perfect conditions for the formation of ice dams which result in the types of deposits seen in Jeffersonville (Wright, 1999). However, landslides are naturally occurring phenomena, and the best way to prevent a problem is to examine an area before construction begins.

Appendix 1

#	Orig. #	GPS	Error	Description of site	Direction to next monitoring stake	Paces	Meters
1	1	0672500' 4945873	±6	South west corner lawn of yellow house. Leaning tree in close proximity of rebar			
2	2	0672510' 4945856	±11	Middle patch of trees. Tree marked by yellow tape. Large pine at edge with exposed roots from undercutting.	Walk 6.5 paces at 160° from stake 1.	6.5	9.88
3	3	0672538' 4945766	±8	Middle of pine trees. Rebar placed 8/23/06.	Walk approximately 30 paces through yard heading 160°	30	45.6
4	3.5	0672557' 4945749	±7	By a rock. Pine tree visible when facing 147° (Rebar placed 8/23/06).	17 paces at 128°	17	25.84
5	4.5	0672562' 4945734	±10	Small tree with brown bark marked. Surrounded by thorn bushes (Rebar placed 8/23/06).	10.5 paces heading 150°	10.5	15.96
6	4	0672564' 4945704	±8	Brambles and milkweed. Face 272° at stake can see green warehouse.	9.5 paces at 164°.	9.5	14.44
7	5	0672561' 4945697	±7	Tree is marked. In between an oak and evergreen.	15.5 paces at 178°	15.5	23.56
8	5.5	0672567' 4945674	±7	Between some trees. Large tree marked.	8.5 paces at 168°.	8.5	12.92
9	6	0672564' 4945650	±13	In stand of trees. stake is marked.	9 paces at 190°	9	13.68
10	N/A	N/A		stake in forest located by George. Tree marked in background.	61 paces through forest at 322° Watch out for barbed wire on large maple tree	61	92.72
11	7	0672574' 4945546	±12	Marked by wooden stake	10 paces at 167°	10	15.2
12	8	0672584' 4945539	±13	Gully developing. Some trees down. Large section of intact soil with trees has broken away.	7.5 paces at 100° marked by stake	7.5	11.4
13	9	0672572 4945487	±11	Large Gully, School visible through trees.	35.5 paces 210°. Right side of gully when facing 257°	35.5	53.96
14	10	0672575 4945481	±5	Many trees down.	5 paces at 155°	5	7.6
15	11	0672566 4945467	±6	Soils are highly eroded.	7.5 paces at165°	7.5	11.4
16	12	0672566 4945457	±5	Undercutting of upper soil horizons.	7.5 paces at 192°	7.5	11.4
17	13	0672565 4945442	±6	Clumps of soil and grass evident in gully which have broken away from edge.	7.5 paces at 181°	7.5	11.4
18	14	0672541 4945444	±14	Trees root are exposed. Will break away soon.	8 paces at 250°	8	12.16
19	N/A	0672553 4945431	±6	Hidden in tall grass, base stake	Approximatly 150° at 4.5 paces	4.5	6.84

Appendix 2



Jefferson Quadrangle Mapped by the Army Map service and published by USGS

References:

Army Map Service (1948). *Jeffersonville Quadrangle*, USGS.
Babcock, R. (1981). *Soil Survey of Lamoille County, Vermont*. National Cooperative Soil Survey, Vermont. 152.
Baskerville, Charles, Fitzhugh Lee, and Charles Ratte. (1993). *Landslide Hazard in Vermont.* Vermont Geological Survey, Vermont. 23.
Baskerville, C and Ohlmacher, G., (1988). *Some Slope-Movement Problems in Windsor County, Vermont*, 1984. Library of Congress. 26.
JSC. (2006). *Johnson State College Weather Station.*
Montgomery, C. (2006). *Environmental Geology*. McGraw Hill. New York, 540.
Sidle, R and Ochiai, H., (2006). Landslides: Processes, Predictions, and Land Use. American Geophysical Union, Washington DC. 311.
Springston, G. (2006, August 8). *Memo to Laurence Becker, Vermont State Geologist: Recent* Landslide at Jeffersonville, Vermont.
Sutkoski, M.(2007, April 17). Rutland County Hit Hard by Storm. *Burlington Free Press*. Retrieved on 30-April-2007 from http://burlingtonfreepress.com/apps/pbcs.dll/article?AID=/20070417/NEWS02/70417004.
Wright, S. (1999). *Guidebook to Field Trips in Vermont and Adjacent Regions of New Hampshire and New York.*. Stop 7: Jeffersonville Clay Bank: 1999 Landslides. UVM, Vermont. 34-49.