Hazard Evaluation at the Jeffersonville Landslide Site

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Landslide Definition

• “The downslope movement of soil, rock and organic materials under the influence of gravity and also the landform that results from such a movement” (The Landslide Handbook, USGS Circular 1325, p. 4).

Outline

1. Introduction
2. Geologic background
3. History of landslides at site
4. Ongoing studies at site
5. Conclusions
# Types of Slope Movements

<table>
<thead>
<tr>
<th>Type of Movement</th>
<th>Type of Material</th>
<th>Bedrock</th>
<th>Engineering Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falls</td>
<td>Rock fall</td>
<td>Debris fall</td>
<td>Earth fall</td>
</tr>
<tr>
<td>Topples</td>
<td>Rock topple</td>
<td>Debris topple</td>
<td>Earth topple</td>
</tr>
<tr>
<td>Slides</td>
<td>Rock slide</td>
<td>Debris slide</td>
<td>Earth slide</td>
</tr>
<tr>
<td>Spreads</td>
<td>Rock spread</td>
<td>Debris spread</td>
<td>Earth spread</td>
</tr>
<tr>
<td>Flows</td>
<td></td>
<td>Debris flow</td>
<td>Earth flow</td>
</tr>
<tr>
<td>Complex</td>
<td>Combinations of two or more types of movement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creep</td>
<td>Several types</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Landslide types at Jeffersonville shown in bold.

Modified from Varnes (1978).
At the 1999 landslide the slope is about 46 meters (151 feet) high with an overall angle of 34°.
Cross Section A-A’, Jeffersonville, VT.

- **Unit ‘A’**: fluvial sand and gravel
- **Unit ‘B’**: thick fine sand-to-clayey silt varves
- **Unit ‘C’**: thin silt, silty clay, and clay varves
- **Unit ‘D’**: dense sand-to-silt-matrix till

Distance from western end of cross section (meters)

Vertical exaggeration = 2
<table>
<thead>
<tr>
<th>Environment of Deposition</th>
<th>Materials</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream Terrace (&lt;10,000 years BP)</td>
<td>Sand and gravel</td>
<td>A</td>
</tr>
<tr>
<td>Lake Vermont</td>
<td>Fort Ann Stage</td>
<td>Sand-silt varves</td>
</tr>
<tr>
<td></td>
<td>Coveville Stage</td>
<td>Silt-clay varves</td>
</tr>
<tr>
<td>Lake Mansfield</td>
<td></td>
<td>Silt-clay varves</td>
</tr>
<tr>
<td>Subglacial (&gt;13,600 years BP)</td>
<td></td>
<td>Till</td>
</tr>
</tbody>
</table>
Upper fluvial sand and gravel (Unit A) at Cross Section A-A’). Photo by G. Springston, 5/19/2011.
At the 2006 landslide looking up at top of slide. This is Unit B, which consists of 1.5 -2.5 ft thick layers of fine sand separated by thin silty clay layers (i.e. thick varves).
Close-up of one thick varve in upper section of 2006 slide. Note undercut portion at base of sandy layer (at level of trowel).
Stiff, varved lacustrine deposit (Unit C) at site of 2011 landslide. Very fine sand and clayey silt are brown and silty clay is grey. Trowel for scale. Photo by G. Springston, 5/19/2011.
Photo taken in about 1911. 

Photo by Harold Thomas from collection of Stub Wells, Jeffersonville.
Aerial photo taken August 1, 1942. Landslide scar is circled.
Jeffersonville Landslide, May, 1954

Photos by Harold Thomas from collection of Stub Wells, Jeffersonville.
Aerial photo taken in the spring of 1962. The 1954 landslide is circled.
Site map showing landslides and cross-section location.
Jeffersonville landslide after the April 18, 1999 slide

Note house on top at edge of landslide. Mosaic of photos taken on April 20, 1999 by Jon Kim, Vermont Geological Survey.
House perched at top of Jeffersonville landslide, 1999.
View of the 1999 landslide deposit looking southeast. Vermont Landscape Change Program photo LS21623_000 used courtesy of Paul Bierman, University of Vermont.
Landslide deposit pushed up against house at southwest corner of 1999 landslide. Vermont Landscape Change Program photo LS21615_000 used courtesy of Paul Bierman, University of Vermont.
Cut in silt and clay of the 1999 landslide deposit. Vermont Landscape Change Program photo LS21616_000 used courtesy of Paul Bierman, University of Vermont.
Looking east across river at 1999 landslide with house at top. Note prominent dark-grey bench on lower part of slope. Rip-rap has been placed at the toe of the slope on the far bank of the river. Vermont Landscape Change Program photo LS21620_000 used courtesy of Paul Bierman, University of Vermont.
Looking east across Brewster River at 1999 slide on right, future site of 2011 slide in center, and area of 2006 slide in wooded section on left.
Borings, gauges, and cross-section locations.
Examining a section of laminated fine sand and silt in the split spoon sampler, Jeffersonville.

G. Springston
Photo 1796, 7/20/2009
Cross Section A-A’, Jeffersonville, VT.

- **Unit A**: Fluvial sand and gravel
- **Unit B**: Thick fine sand-to-clayey silt varves
- **Unit C**: Thin silt, silty clay, and clay varves
- **Unit D**: Dense sand-to-silt-matrix till

Distance from western end of cross section (meters)

Vertical exaggeration = 2
### Engineering characteristics of materials in Boring B1 at Jeffersonville, VT.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Units</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average SPT N_{field}</td>
<td>36</td>
<td>23</td>
<td>16</td>
<td>&gt;100</td>
</tr>
<tr>
<td>USCS Group Symbol</td>
<td>SP-SM</td>
<td>SM</td>
<td>CL</td>
<td>SC-SM</td>
</tr>
<tr>
<td>Soil Classification</td>
<td>Poorly graded SAND with silt and gravel</td>
<td>Silty SAND w/ sandy lean clay lenses</td>
<td>Lean CLAY with silty lenses</td>
<td>Silty clayey SAND with gravel</td>
</tr>
<tr>
<td>Unit Weight (kN/m³)</td>
<td>20</td>
<td>18</td>
<td>17.5</td>
<td>21</td>
</tr>
<tr>
<td>Cohesion (kPa)</td>
<td>0</td>
<td>0</td>
<td>62</td>
<td>200</td>
</tr>
<tr>
<td>Effective Angle of Internal Friction (deg.)</td>
<td>40°</td>
<td>31°</td>
<td>30°</td>
<td>40°</td>
</tr>
<tr>
<td>Hydraulic Conductivity (m/s)</td>
<td>1.5x10^{-4}</td>
<td>3x10^{-5}</td>
<td>2x10^{-7}</td>
<td>7x10^{-8}</td>
</tr>
</tbody>
</table>

**SPT N_{field} and W (%)**

- **Unit A**
- **Unit B**
- **Unit C**
- **Unit D**

**Graph:**
- Depth in meters
- SPT N_{field}
- W %

**Legend:**
- SPT N_{field}
- W %
Precipitation and water levels at Jeffersonville from May of 2011 to May of 2012.

Monitoring well MW1: red
Monitoring well MW2: green
Gauge on upper stream: dark blue
Rain gauge (hourly): grey

Some Causes of Landslides in Vermont

- Stream erosion resulting in oversteepening of the base of a slope.
- Heavy rainfall or snowmelt causing saturation of soil and increase in pore pressure.
- Adding excess load onto slopes, such as by dumping of fill onto a slope.
- Excavation of base of slope, resulting in oversteepening.
- Reduction in strength of materials due to physical and chemical weathering of soil.
Possible Causes of 1999 Jeffersonville Landslides

- Both stream erosion and increased pore pressure may have played roles in the 1999 landslides.
- Rainfall appears to have been below average in spring of 1999, but heavy rains occurred in the summer of 1998. It’s possible that water from the 1998 rains moved slowly through the fine-grained silts and clays, leading to slope failure in April of 1999 (Bierman and others, 1999).
- Another possibility is that the water infiltrated slowly from the upper stream.
- Toe erosion may have occurred during the heavy rains of the previous summer and may have contributed to the first slope failure in 1999 (April 11).
- The landslides of April 18 and July 4, 1999 broke out on top of the dark grey bench in the slope rather than at the toe of the slope, indicating that increased pore pressure was the cause rather than toe erosion (Bierman and others, 1999).
Preliminary Conclusions

- Landslides at the site go back more than a century.
- The 1954 and the 1999 landslides crossed the river, with the 1999 landslides involving over 27,000 cubic meters (35,300 cubic yards) of material and extending ~125 meters (400 feet) beyond the west bank of the river.
- Area of greatest concern appears to be north of 1999 slide.
- Area of secondary concern is south of 1999 slide and above the school.
- Heavy or extended rains or heavy snowmelt would make slope failures more likely.
- Any future toe erosion by the river would make slope failures more likely.
- Slope failures can occur long after the driving event and can be expected to extend across the river, placing the Village at risk.
- Although no earlier events are known to have dammed the river to a dangerous extent, this is a concern and would place the Village at risk of flooding.
Further Information

General:


Jeffersonville Landslide:


Acknowledgements

- Jon Kim, Vermont Geological Survey.
- Dave Severance, (Village of Jeffersonville)
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  - Johnson State College students who have conducted research projects at the site include Adam Banks, Michaela Forsberg, Sam Hellman, Christine Languerand, Ed Robbins, Amanda Wells, and Nathaniel Weiss.