A century of urban landslides:
The legacy and consequences of altering our landscapes

Isabella B. Bennett, Paul R. Bierman, Christopher T. Halsted

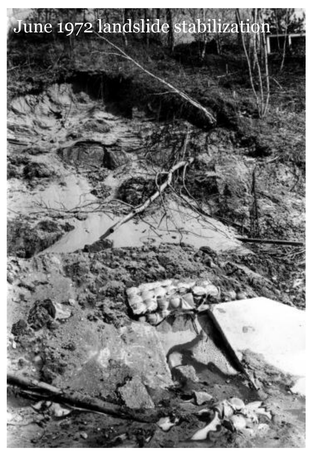
Rubenstein School of Environment and Natural Resources, University of Vermont, 81 Carrigan Drive, Burlington Vermont, 05405, USA

Gund Institute for Environment, University of Vermont, 210 Colchester Ave, Burlington Vermont, 05405, USA

Introduction

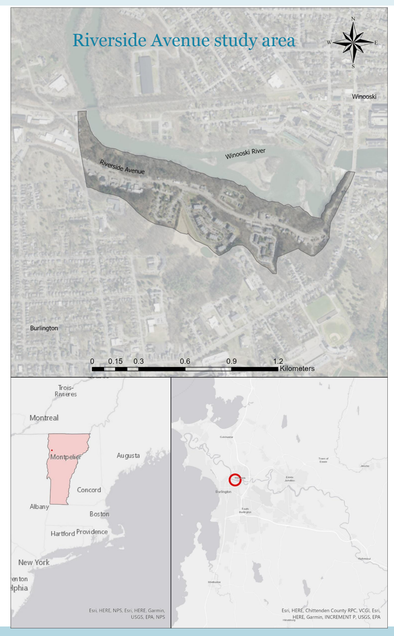
Landslides are caused by a combination of factors, including failure prone geologic materials, steep topography, human-induced land use change, and intense and/or long duration precipitation events that raise groundwater tables. In regions shaped by glaciation like New England, glacial sediment type and distribution can contribute significantly to landslide vulnerability. Glacial outwash deposits, especially those dominated by sand, lack cohesion. Along river valleys, the already unstable nature of these materials is exacerbated by river incision and resulting slope oversteepening and destabilization.

Human actions play a significant role in determining landslide vulnerability. While landslides are naturally occurring geomorphic phenomena in undisturbed environments, the alteration of natural systems can exacerbate land instability, resulting in more frequent and intense landslides. We use an interdisciplinary approach to examine the spatial distribution, timing, and cause of landslides affecting buildings and roads along the top of a steep, urban riverbank in northern Vermont.

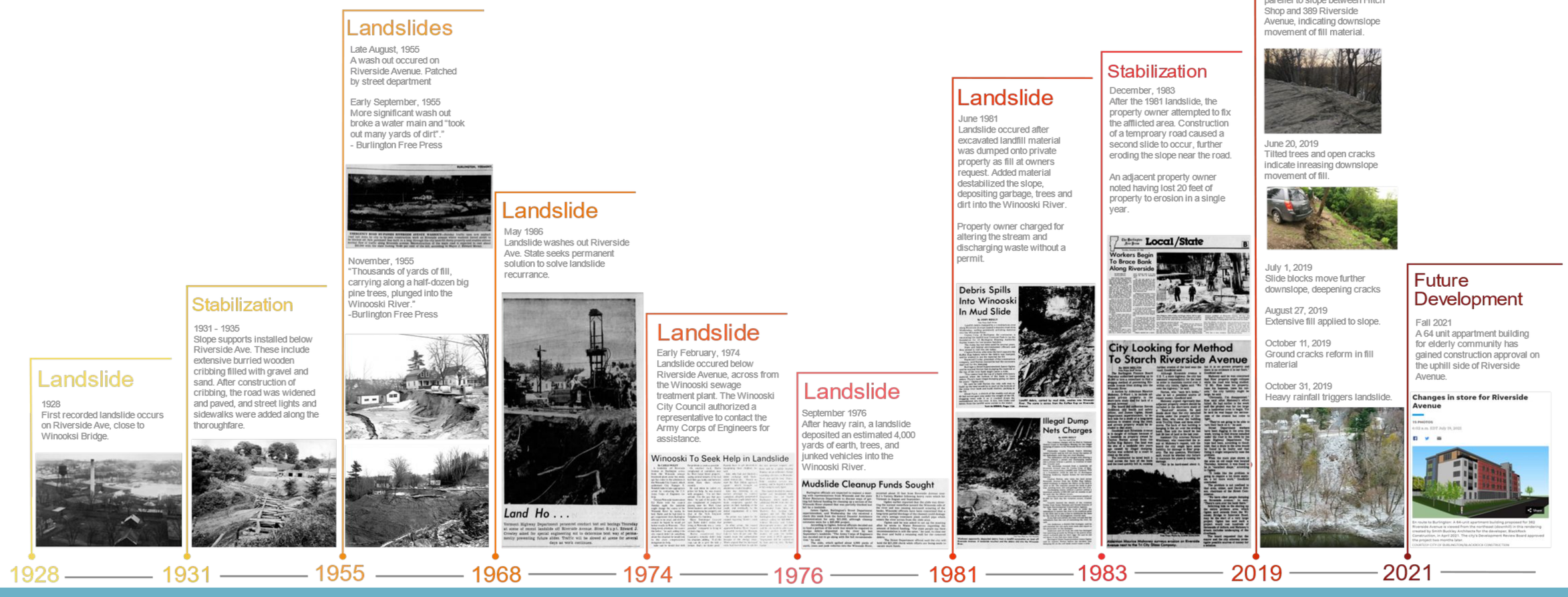

June 1972 landslide stabilization

Background

Once the land of the Abenaki Native Americans, European settlers began to colonize Vermont in the 1700s, clearing land for timber, agriculture and construction. The cities of Burlington and Winooski were constructed along prominent bodies of water; Lake Champlain and the Winooski River. Today, these cities are connected by a heavily trafficked two-lane road; Riverside Avenue. True to its name, Riverside Avenue runs parallel to the Winooski river, about 20-30 meters above the steeply incised river. As recently as the 1920s, this slope was forested and undeveloped along the then dirt road. As the cities on either side of this roadway grew, the road was expanded and development sprung up on both sides. The combination of deforestation and impermeable surfaces on an already steep slope proved problematic, and a century of intermittent slope failures began.



Timeline of landslide events and stabilization efforts



Methods

We compiled maps from the Library of Congress and the University of Vermont (UWM) Howe Library Special Collections, air and ground photographs from the UVM Landscape Change Program and Howe Library Special Collections, and local newspaper clippings from the Burlington Free Press spanning more than 100 years. We corroborated newspaper events with photos and maps through time to chronicle slope failure events. We then calculated slope stability for a translational slide on a planar failure surface using the infinite slab approximation force balance model. Finally, we conducted spatial analysis using drone video footage of the most recent landslide, which can be seen in this local news coverage:

https://www.wcax.com/content/news/WCAX-Investigates-Properties-in-peril-564760921.html

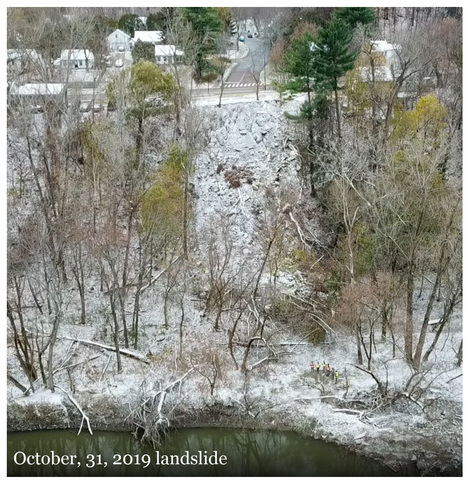

November,1955 landslide

Results

- We found evidence of 9+ landslides along Riverside Avenue over the past century in local newspaper archives
- Light Detection and Ranging (LiDAR) imagery of the slope show at least as many landslide scarps
- Newspaper articles most often list a significant rainstorm and/or illegal dumping as the landslide trigger
- The infinite slab model indicates that the 2019 slope conditions were liable to failure with low to moderate saturation
- While saturation is the tipping point of most slides, the underlying causes of instability here include oversteepening of low cohesion glacial sediments and fill material, garbage dumping on the slope, and lack of robust root systems
- Attempts to stabilize areas of the slope have had some success, but the majority of the slope remains unstable

Conclusions

- The slope below Riverside Avenue has been unstable for at least 100 years, largely as a result of human interference
- Climate change is projected to increase the frequency and intensity of precipitation events in Vermont, increasing the likelihood of future slope failures along this thoroughfare
- New construction should not be zoned above this slope, because it poses a significant safety risk to those currently living in area and the intended inhabitants of the new apartment complex


October, 31, 2019 landslide

Ongoing research

- Continued observation of the slope area for new signs of failure such as tension cracks and slab detachment
- Using spatial context clues from newspaper articles and historic photos to match historic slides to scarps visible on LiDAR imagery of the slope
- Estimating volume of mobilized material in large landslides


Early October, 2019

Acknowledgements

The authors would like to thank Jarlath O'Neil-Dunne, Adam Zylka and the UVM Geospatial Analysis Laboratory for drone footage contributions, Thomas Visser and the UVM Historic Preservation Program for historic records contributions, Kestrel Owens for historic map compilation, and the UVM Geomorphology students of fall 2020 for in-class contributions: Skylar Alger, Julia Bailey-Wells, Luc Burnier, Jason Drebber, Remy Farrell, Ben Gaucherin, Adam Gellman, Mark Hehlen, Lauren Hurst, Harrison Hurwitz, Liviya Kovacevic, Freddy Larson, Grant Long, Derek Marquis, Emily Mischler, Ryan Mistur, Anne Morrison, Emma Robinson, Ryan Sauer, Elijah Schreiber, Katelyn Silvia, Shayla Triantafillou, Brenda Waters. Finally, thank you for your interest in this virtual poster!