To: Rich Tatro, Shauna Clifford, Vermont Agency of Transportation

From: Larry Becker, Vermont State Geologist and George Springston, Research Associate, Norwich University

Subject: Landslide in Hardwick, Vermont

Date: 1/8/2004

On November 6, 2003 we received a report from Tom Eliassen, Transportation Geologist for the Agency of Transportation, notifying us of a landslide in Hardwick on the south side of Vermont Route 15, approximately 500 feet southeast of the intersection with Glenside Avenue (Figures 1a and 1b). The slide is on the opposite side of Route 15 from the motel. The upper limits of the slide are on the Holmes and Wiggins properties. We visited the site on November 10 and participated in a site review arranged by your office on November 21.

Site Description

The following observations are based on our site visits at the dates mentioned above and a review of the available topographic and geologic maps, aerial photos, and orthophotos. On our November 10 visit we observed that the slide is located on a wooded slope above Route 15. Many of the trees on parts of this slope outside the present landslide have curving trunks, indicating at least some previous down-slope movement has occurred. The slope appears to be a former cut-bank formed by the Lamoille River, which presently is located to the north of the motel. The area of sliding is about 150 feet wide, about 105 feet high, and has an overall slope angle of 28 degrees. A general view of the slide from below is shown in Figure 2. Using the landslide classification of Cruden and Varnes (1996) this is an active, complex landslide consisting of several rotational earth slumps and a central earth flow. This flow can be seen in Figures 2 and 3. Figure 4 shows sediment from this flow washing into a catch basin on the south side of Route 15 opposite the motel. From our observations at the slide, along Glenside Avenue, and in the stream valley to the northeast, there does not appear to be bedrock near the surface. The surficial geologic material at the site is shown as glacial till on the manuscript surficial geologic map of the Hardwick 15 minute quadrangle by Paul MacClintock (1963, in Vermont

Geological Survey files). Our field observations confirm that most of the slope is underlain by glacial till containing angular pebbles, cobbles, and boulders in a silt-rich matrix. The materials are best exposed on the fracture surfaces and are described further below.

Fresh fracture surfaces are exposed at three locations:

1. The lowest of the three failures is partway up the wooded slope. The top of this fracture is about 57 feet above the highway. This is the section of the slide that is being monitored by VAOT with a system of stakes and strings (Figures 5 and 6). This failure is in glacial till. The till has a silt-rich matrix with angular pebbles, and cobbles. The material we observed had a loose to medium density. Glacial boulders up to several feet in diameter are scattered sparsely throughout the woods. Although a few may have been dumped over the edge from above as part of artificial fill activities, most of the boulders on the slope appear to be from the underlying glacial till.
2. A second failure surface is located at the base of the concrete foundation wall at the back of the Wiggins house (Figure 7). The base of the wall is approximately 81 feet above Route 15. Movement on this fracture surface has removed material from the north (downhill) side of the Wiggins foundation. This failure is partly in glacial till and partly in what appears to be artificial fill. At the closest point, the fracture is about 50 feet from the north side of Glenside Avenue. Near the top of the slope at the Holmes residence there is sandy artificial fill that has settled, leaving a prominent steep scarp approximately 3 feet high (Figures 8-11). The top of the scarp is about 105 feet above Route 15. The scarp extends westward onto natural ground and there cuts into approximately 1.5 feet of sand over till. This sand appears to be a natural deposit of lake sand. The scarp drops in elevation as it extends northwest towards the Wiggins house and trends directly toward a propane tank on the southeast side of the house.

Site History

1962--Detailed 1:6000 aerial photos of the site taken in May of 1962 were examined using a stereoscope. These show what appears to be a steep scarp on the northwest side of the Holmes residence with open, brushy land below. The area contains some light-colored spots that may be some of the boulders or may be pieces of debris that have been dumped over the edge. This brushy area extends westward behind the Wiggins house and a garage located on the east side of the house. The open area extends about 75 to 100 feet behind the buildings. The remainder of the slope is wooded. A barn that has since been removed is visible on the present Holmes property.

1974--Aerial photos taken in 1974 at 1:20,000 scale show less detail but the brushy area below the houses can still be seen. Some trees are visible behind the Wiggins house. A very steep drop-off is visible about a third of the way from the barn on the Holmes property to Route 15. This may represent a landslide scarp.

1998--No signs of active sliding are seen on orthophotos produced from 1998 aerial photos (Figure 1b). The orthophotos are not sharp enough to tell whether or not there are signs of failure at the top. However, the lower part of the slide is entirely wooded, so there does not appear to be any landslide large enough to disrupt the tree canopy.

Recent History:
November 5, 2003--Site visit by C. Benda, T. Eliassen. Photos taken.

November 7--Site visit by Shauna Clifford and placement of two lines of grade stakes running about east-west midway up the slope. The lines were several feet apart when placed. A string was stretched over each line from stakes from the more stable ends to provide reference lines. Photos taken.

November 10--Site visit by G. Springston and L. Becker. Geologic reconnaissance. Some of stakes observed to have moved downhill from their original positions. Photos taken.

November 21--Site meeting. Further movement of monitoring stakes has occurred since November 10. Stakes that were originally on the upper line have now moved below the lower line. Photos taken by T. Eliassen. After the site meeting, we talked with Mr. Holmes, who stated that they had been adding fill in their back yard for "20 years" in response to continued subsidence.

Triggering of the Slide
Some of the possible causes for landslides include high ground water levels from rainfall or snowmelt, diversion of stormwater onto a slope, artificial loading of a slope, removal of material from the base, or vibrations such as traffic, machinery, or earthquakes. Also, some earth materials are simply weaker than others, leading to increased likelihood of failure on a steep slope. Given the reports we have received that the recent movements on the slope came soon after heavy rains, it seems likely that this was the final trigger for the recent movements. However, loading of the top of slide due to placement of artificial fill (sand) may have contributed to the unstable situation. Rapid snowmelt commonly results in high ground water levels and may well be a cause of some of the earlier movements on the slope. We did not observe any signs of stormwater being diverted onto any part of the slide, so that does not appear to be a cause. We are unable to evaluate the effect of vibrations.

Hazards Posed by the Slide
It is likely that future heavy rains and/or snowmelt will lead to renewed movement on parts of the slide.

Highway Impacts:
The position of this active slide above Route 15 warrants concern. Even a fairly small landslide could result in material entering the right-of-way. We do not know the depth to which the failure surfaces penetrate and we do not know the strength of the underlying

material. Therefore we cannot say whether there will be a massive, deep-seated failure that sends hundreds of cubic yards of soil and trees down onto and across the highway or only one or more small, shallow failures that cause a few tree topples and send a few cubic yards of sediment down to the catch basin. However, we do know, from our observations of other landslides, that the toe of a slide can extend far beyond the base of the slope. Therefore, a careful geotechnical analysis of the site is needed.

Even if a large slide did not block the road, it is likely that it would result in a large quantity of sediment washing into the catch basin on the south side of Route 15. If this were to clog, the sediment might then wash across the highway.

Landowner Impacts:
The hazard posed by the slide to the houses at the top is difficult to evaluate. The proximity of the scarps to the foundations of the Holmes and Wiggins houses is a cause for concern. The next house west of the Wiggins house (#17) is not currently effected by the slides but it is possible that future movement could threaten this house as well. Certainly no additional artificial fill should be placed within or near the area of sliding, as this would be likely to cause additional movement. Likewise, there should be no diversion of stormwater onto the slide. Beyond this, we cannot say whether or not there will be continued movement along the failure surfaces or if new failures will form outside of the existing ones. We recommend that the owners should consult with qualified engineers as to the stability of their foundations.

This hazard analysis is necessarily limited and general. Partly, this is due to poor exposures of the surficial materials at the site but it is also due to the fact that we are not qualified to undertake a quantitative engineering analysis to determine the slope stability. Detailed soil borings and an analysis by a qualified geotechnical engineer are needed for this next level of detail.

Further Work
Given that there is the possibility of further movement on the existing fractures and development of new ones, and the possibility of earthslides that could enter the highway right-of-way, we recommend that VAOT make arrangements for establishing a network of precisely surveyed monitoring points over at least the lower portion of the slide and that these points be measured periodically to see if movement were accelerating. If measurements were frequent enough, this could help warn of impending sliding. It would also be helpful to survey the extent of the failure surfaces in detail in order to be able to identify new ones and extensions of old ones.

Summary
In summary, we believe that heavy rains and/or snowmelt will lead to renewed movement on this slide and that it therefore does constitute a hazard that may affect Route 15. Whether it will cause damage to the houses at the top of the slope is more difficult to say, but the proximity of the existing scarps to the houses is a cause of concern. Because of

this, we recommend that there should be no placement of artificial fill within the existing landslide and the owners should consult with qualified engineers as to the stability of their foundations. VAOT should monitor the slide and consider taking steps to prevent a slide from entering the right-of-way.

Please let us know if you have any questions. Also, please do not hesitate to contact us if you need geologic expertise to address future issues.

cc: Tom Eliassen, VAOT Transportation Geologist
Chris Benda, VAOT Soils and Foundations

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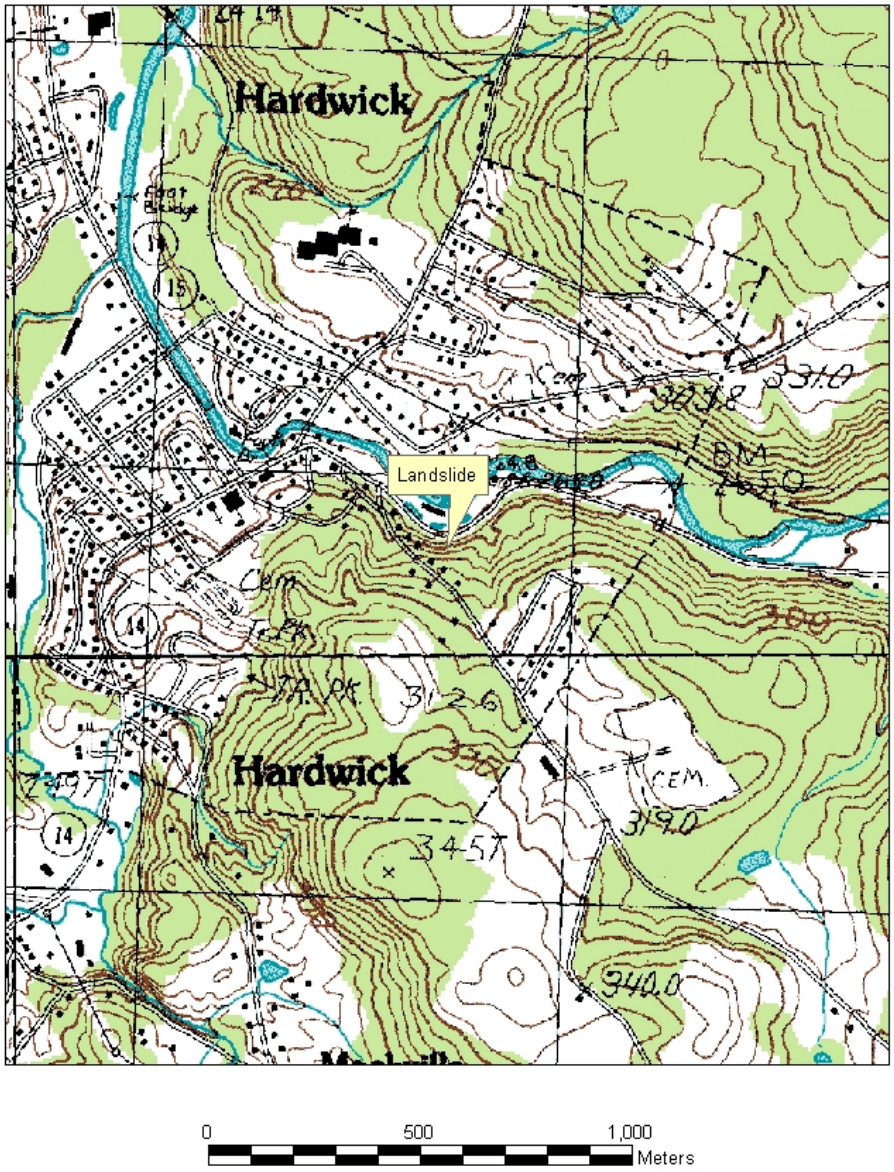

Figure 1a. Map showing location of the Hardwick landslide. From U.S. Geological Survey Caspian Lake 7.5 minute quadrangle. Contour interval 6 meters.

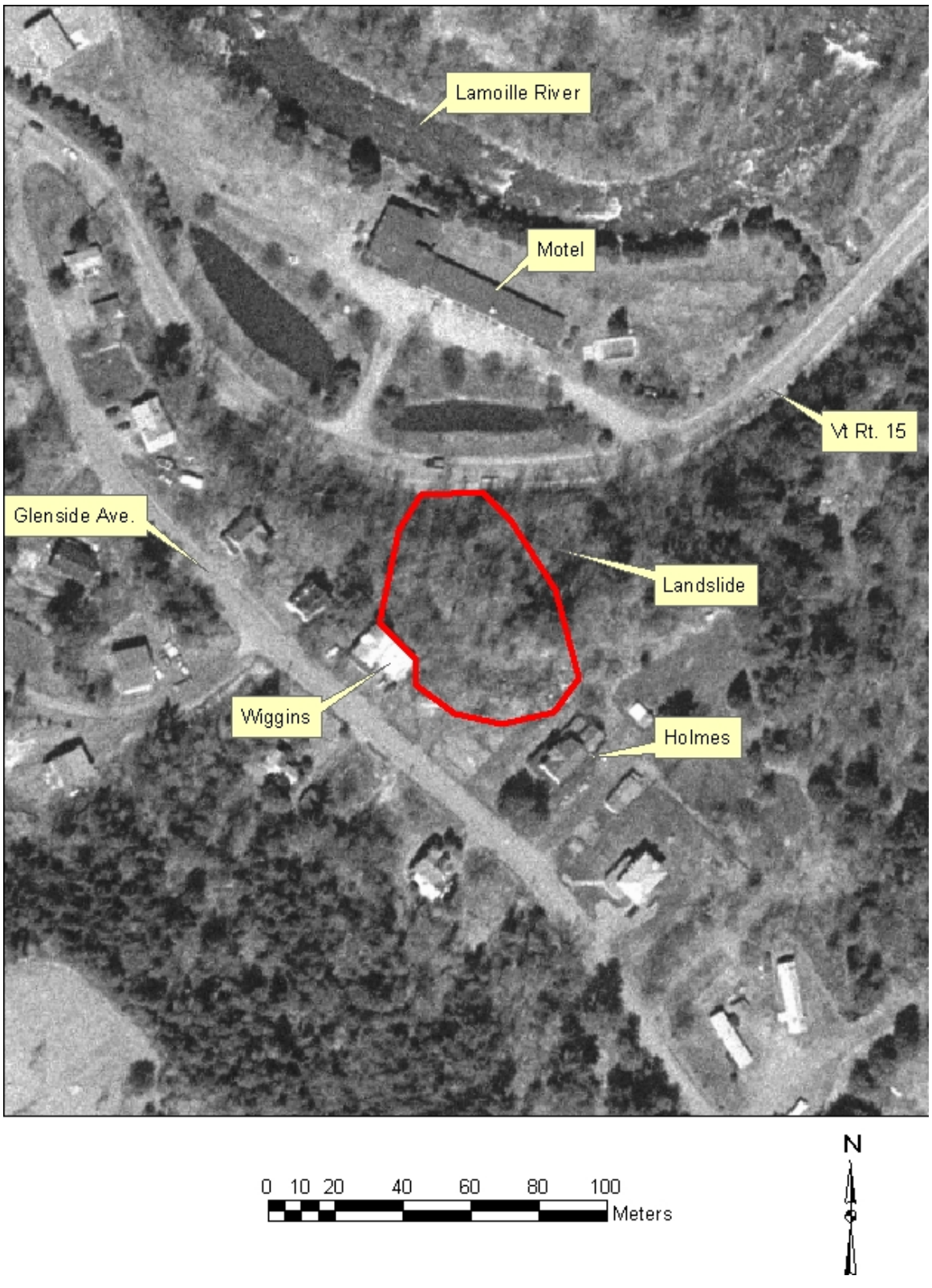

Figure 1b. 1998 orthophoto of the landslide site. The slide outline is roughly shown in red. Base from Vermont Mapping Program orthophotos 160220 and 164220.

Figure 2. Landslide viewed from below. View looking south-southeast from motel parking lot on far side of Route 15. November 10, 2003.

Figure 3. Earth flow originating in central part of slide and flowing down to culvert on east side of State Route 15. November 10, 2003.

Figure 4. View of sediment from slide washing into catch basin on south side of Route 15. Looking east. November 21, 2003. Photo by Vtrans.

Figure 5. Recent scarp formed within landslide. Photo looking northwest. VAOT reference strings are shown on left and right sides of photo. Stakes were originally under the strings and have moved downslope since they were installed. November 10, 2003.

Figure 6. Reference strings viewed from similar location as in Figure 5. Further movement of stakes has occurred since installation. November 21, 2003. Photo by VAOT.

Figure 7. Fractures in earth at lower side of foundation of Wiggins house. November 10, 2003.

Figure 8. View looking east along fracture surface in artificial fill at Holmes residence. November 10, 2003.

Figure 9. Uppermost scarp at Holmes residence. Looking northeast. November 5, 2003. Photo by VAOT.

Figure 10. Fractures in artificial fill on northwest side of Holmes residence. Photo looking east-northeast. November 10, 2003.

Figure 11. Uppermost scarp at Holmes residence. View looking southwest. November 5, 2003. Photo by VAOT.