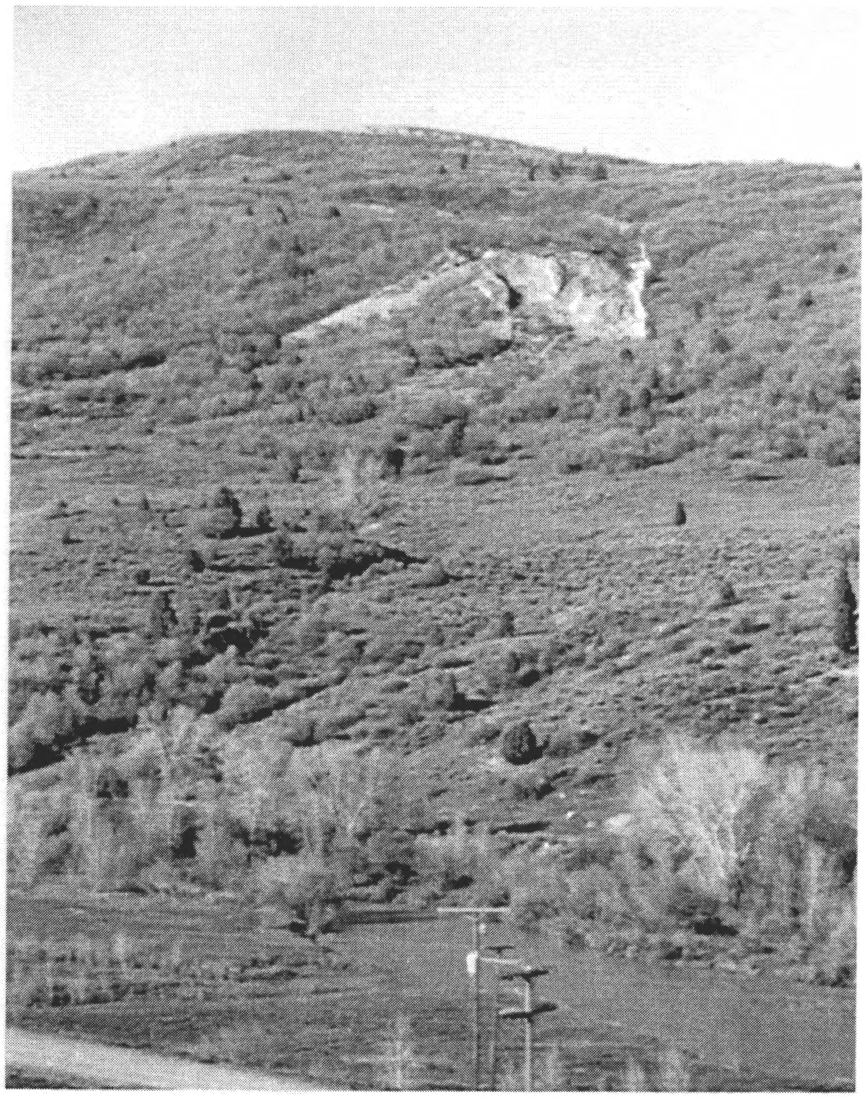
RECONNAISSANCE OF THE SHURTZ LAKE LANDSLIDE, UTAH COUNTY, UTAH

by
F.X. Ashland
Utah Geological Survey



REPORT OF INVESTIGATION 234 July 1997
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ABSTRACT

The Shurtz Lake landslide is the largest slide to become active in Utah during the spring snowmelt of 1997. It is located on a northeast-facing slope directly south of the confluence of Diamond Fork and the Spanish Fork River. Landslide movement began on Tuesday, May 6, 1997, and disrupted power transmission on two sets of high-voltage power lines as transmission poles were displaced and tilted by the slide. The landslide is a composite slide, and consists of four areas with distinct landslide features. Two separate earth-flow areas exist on the right and left flanks in the lower part of the landslide that bound a relatively intact area in the center of the slide. The heads of the earth flows coincide with an abrupt change in slope about 500 feet above the original toe of the slide. Below the earth flows, contractional landslide-deformation features are common and consist of a series of downslope-directed, shallow thrusts where topsoil and underlying soil are thrust over the pre-existing ground surface. Topsoil is folded at the leading edge of the thrusts. Upslope of the earth flows the landslide consists of slumped and extended terrain similar to that in a lateral spread. The crown of the slide, last observed on May 19, was about 1,500 feet upslope and south of the heads of the earth flows. During the month of May, the area of landslide activity enlarged as new landslide features appeared downslope. However, the rate of movement slowed throughout the same period. Continued movement of the landslide could divert or dam the Spanish Fork River and thus the landslide warrants monitoring to warn of imminent rapid movement, or to document the slide's continued slow movement or return to dormancy.

INTRODUCTION

On May 7, 1997, the Utah Geological Survey (UGS) began a reconnaissance investigation of a large, active, composite landslide near Shurtz Lake, Utah County, Utah. The landslide is on a northeast-facing slope directly south of the confluence of Diamond Fork and the Spanish Fork River, in section 20, T. 9 S., R. 4 E., Salt Lake Base Line and Meridian (figure 1). The landslide (figure 2) was brought to my attention by Scott Burton of Utah Power & Light (UP&L). According to Mr. Burton, the landslide movement began on Tuesday, May 6, 1997, and disrupted power transmission on two sets of high-voltage power lines that cross the slide (figure 3). As a result of ground movement, four transmission poles were displaced and tilted. Tilting and downslope movement of the upslope set of poles was so severe that transmission was discontinued and the power lines abandoned. The purpose of the investigation was to document the occurrence and to assess whether the landslide posed any short-term public safety concerns or had long-term hazard implications. This report presents observations of landslide features and activity made during visits on May 7, 9, 19, and 30, 1997, where I was accompanied, on separate occasions, by UGS geologists Barry Solomon and Gary Christenson, and U.S. Geological Survey (USGS) geologist Rex Baum. During this entire period the landslide was active and new features, described in detail below, continued to appear.

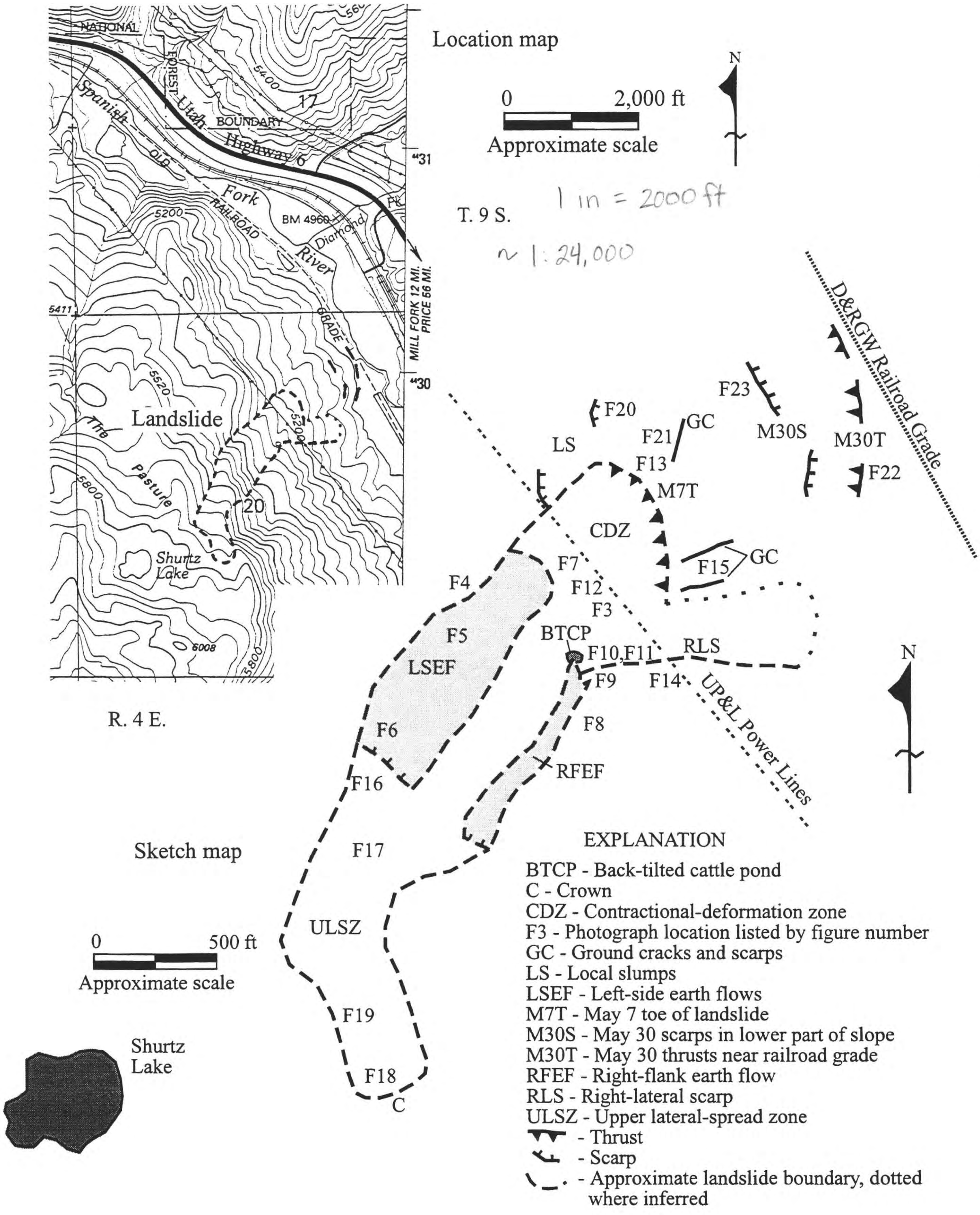

Figure 1. Location map of Shurtz Lake landslide and sketch map of major deformation features.

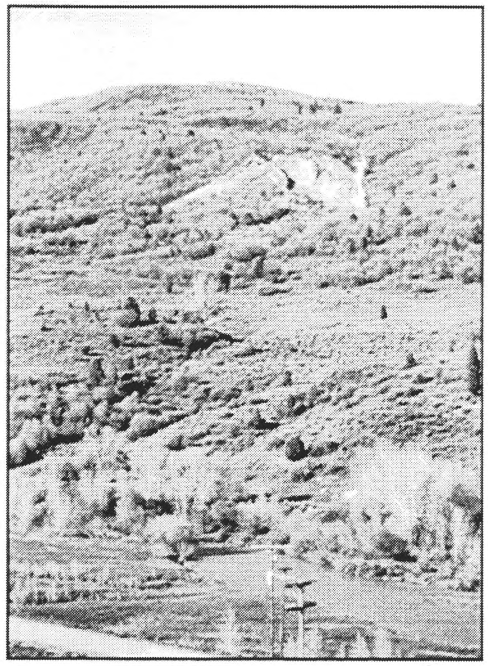

Figure 2. The Shurtz Lake landslide on May 9, 1997. View is to the south from Utah Highway 6. Spanish Fork River is visible in bottom of photograph.

Figure 3. Transmission pole tilted by landslide movement. Pole is one of two in upslope set of Utah Power & Light (UP&L) transmission poles on landslide. Downslope movement caused one of three powerlines to be severed from pole. Powerlines were subsequently abandoned by UP&L.

PHYSIOGRAPHY AND GEOLOGY

The landslide occurred on a northeast-facing slope southwest of the Spanish Fork River south of its confluence with Diamond Fork. The slope is characterized by a series of benches having different origins; however, all the benches appear to be gently inclined to the southwest and thus back-tilted. The lowest bench was mapped by Witkind and Page (1983) as a possible late Pleistocene Lake Bonneville feature. The bench is at roughly elevation 5,100 feet and about 100 feet above the modern Spanish Fork River flood plain. The probable Bonneville bench is present east of the landslide but is obscured or absent due to post-Bonneville landsliding directly downslope and north of the slide. Upslope, to the south and west of the landslide, is another bench known as The Pasture (figure 1). It consists of a broad, relatively flat, grassy meadow that slopes gently to the northwest. Farther upslope of The Pasture is another flat bench of limited extent on which Shurtz Lake sits. Another bench, at an intermediate elevation between the Lake Bonneville bench and The Pasture bench, exists northwest of the landslide. The benched topography of this slope is distinct from the more uniformly steep-sloping mountains to the north and west, and may indicate that landsliding is a more active process in this benched area. Between the benches, slopes are relatively steep. The lower part of the Shurtz Lake landslide is on one of these steeply sloping areas directly above the jeep road that accesses the UP&L power lines.

Several unnamed drainages cross the mountain slope and delineate the boundaries of the Shurtz Lake and prehistorical landslides. The most prominent of the drainages coincides with the left flank of the Shurtz Lake landslide. Downslope of the landslide the drainage flows to the north and northeast into a retention pond formed upslope and behind the abandoned Denver and Rio Grande Western (D&RGW) railroad grade on the Spanish Fork River flood plain. A muddy alluvial fan has formed in the retention pond, partly filling it. The left-flank drainage was completely buried by the landslide, but gullying of the landslide deposits began immediately, and flow existed in the drainage downslope of the landslide at the time of my first visit on May 7. In the upper part of the landslide, the left-flank drainage forms a deeply incised gully, with a depth of over 50 feet locally. Upslope of the landslide, the drainage is relatively shallow, typically incised less than 5 feet. The drainage originates from seeps and springs in a grassy upland area south of the crown of the landslide.

Two other drainages, farther to the southeast, are present downslope of and partly coincide with the May 7 landslide boundary. An unnamed flowing drainage near the centerline of the landslide becomes increasingly incised a few hundred feet downslope of the power-line access road. The central drainage generally flows northeast into a second retention pond behind the abandoned D&RGW railroad grade. A third shallow drainage, that was dry during most of May, exists along the right flank of the landslide and merges with a more prominent drainage to the southeast that eventually flows into the east end of the same retention pond as the central drainage.

The Quaternary geology of the landslide area has not been mapped in detail. Witkind and Page (1983) included this area in their mapping of the 1983 Thistle landslide but did not show any Quaternary deposits except for the possible Lake Bonneville beach deposits capping the bench described above, and flood-plain alluvium along the Spanish Fork River. Their mapping shows that slope soils are underlain by the Triassic Ankareh Formation, mostly east of the landslide, and the

Upper Cretaceous-Paleocene North Horn Formation. My reconnaissance indicated that these formations do not crop out in the vicinity of the landslide, but blocks and boulders of conglomerate and limestone (North Horn Formation) occur as float in slope materials. Harty (1992) indicates the majority of the slope consists of undifferentiated landslide and colluvial deposits and identifies several historical landslides of a variety of sizes in the area. Exposures of landslide deposits consist mostly of fine-grained sand, silt, and clay, with trace amounts of gravel and rare boulders and cobbles of rock types in the North Horn Formation.

My preliminary reconnaissance, and observations by other UGS geologists, suggest the recent landslide movement is, as of May 30, confined within the limits of prehistorical landslide deposits. Field observations in combination with review of aerial photographs (1983, 1:15,000 scale) indicate lobate hummocky deposits, likely of landslide origin, occupy most of the area downslope of the Shurtz Lake landslide. The youngest of these deposits appears to overlie the Lake Bonneville bench on the southeast side and overlap onto older landslide deposits directly downslope. The toe of the youngest prehistorical landslide deposits forms a steep slope above the bench several hundred feet downslope of the toe of the Shurtz Lake landslide. Farther downslope is a flatter lobate deposit, likely related to an older landslide event. The tip of the older landslide deposit abuts the D&RGW railroad grade on the Spanish Fork River flood plain, indicating that prehistorical landsliding has involved the entire lower part of the slope and may have been partially removed by the Spanish Fork River. The prehistorical landslide deposits appear to be bound on the northwest by the left-flank drainage (as viewed in the direction of movement or downslope); however, other prehistorical landslide deposits are inferred to exist northwest of the drainage. Unfortunately, aerial photographs available at the time of this report were inadequate to precisely delineate boundaries of landslide deposits northwest of the drainage. Upslope of the prehistorical deposits, scalloped source areas are clearly identifiable. The head of the youngest prehistorical landslide appears to coincide with the break in slope upslope of the power-line access road and the head of recent earth flows, described in more detail below. Additional prehistorical landslide features are visible above this break in slope. Other nearby prehistorical landslides are visible on the aerial photographs, including one abutting the right flank of the Shurtz Lake landslide. The southeastern two drainages described above coincide with boundaries of a smaller landslide-deposit lobe inferred to be contemporaneous with the youngest prehistorical landslide deposits.

PHYSICAL CHARACTERISTICS

The 1997 Shurtz Lake landslide is a composite slide (classification after Cruden and Varnes, 1996), and consists of four areas with distinct landslide features. Two separate earth-flow areas exist on the right and left flanks in the lower part of the landslide that bound a relatively intact area in the center of the slide. The heads of the earth flows coincide with an abrupt change in slope about 1,500 feet upslope of the original May 7 toe of the slide. Below the earth flows, contractional (the horizontal distance between two points becomes less) landslide-deformation features are common and consist of a series of downslope-directed, shallow thrusts where topsoil and underlying soil are thrust over the pre-existing ground surface. Topsoil is folded at the leading edge of the thrusts. Upslope of the earth flows the landslide consists of slumped and extended terrain similar to that in a lateral spread. The crown of the slide, last observed on May 19, was about 1,500 feet upslope and south of the heads of the earth flows.

My preliminary estimates of the landslide dimensions, on May 7, were that the slide was about 2,900 feet long at its centerline, and, on average, about 600 feet wide, thus covering an area of about 190,000 square yards. These estimates are not based on actual field measurements and are, at best, approximate. If the slip surface is, on average, 60 feet below the ground surface, then the volume of the landslide, on May 7, was about 3.9 million cubic yards or about one-seventh the volume of the 1983 Thistle landslide (Schuster, 1996). The width of the landslide along the power-line access road is about 800 feet. The slide narrows upslope, particularly at the break in slope, and continues to narrow toward the crown of the slide. In addition, the landslide also makes a slight southward deflection at the break in slope so that, in plan view, it is concave to the southeast.

Earth Flows

The earth flows are the most prominent features in the landslide and are visible from Utah Highway 6. Earth-flow deposits are generally fine grained and consist mostly of silty clay and clayey fine sand. As early as May 7, the deposits had a firm dry crust that supported an individual's weight. The left-flank earth flow is about 500 feet long and is bounded on the northwest (left) side by an earth-flow levee (figure 4) that ranges from several to tens of feet high. The levee has steeply sloping sides and the inside-facing side is sheared smooth, slickensided, and nearly vertical locally. The slickensided inside slope of the opposite (southeast) side levee was clearly visible from the top of the left-side levee (figure 5). Slickenlines, which trace the direction of movement of the earth flow, parallel the original ground surface. The main scarp of the left-flank earth flow is over 50 feet high (figure 6). The left-flank earth flow completely disrupted and filled the left-flank gully along its entire length. On May 7, water was flowing inside the earth flow near the left-side levee. In several locations, flow was blocked and ponded by irregularities in the earth-flow deposits.

The majority of the left-flank earth-flow deposits came to rest upslope of the power-line access road. The earth flows deformed, or "bulldozed", shallow soils and vegetation in their path into large fractured mounds (figure 7). This deformation also caused, or at least accompanied, thrusting of topsoil and shallow underlying soils onto downslope materials. Two of the UP&L poles are located in the zone of deformation downslope of the left-flank earth flow. A small finger of the left-flank earth flow continued about a hundred feet downslope below the road along a pre-existing drainage. A second earth flow abuts the left-flank earth flow. An elliptical ridge defines the boundary between the upper parts of the two earth flows. Downslope the two earth flows merge and their common boundary is difficult to delineate.

A third earth flow exists along the right flank of the landslide (figure 8). Its head is about the same elevation as that of the left-side earth flows but the right-flank earth flow appears to be slightly longer. Lateral levees similar to those bounding the left-flank earth flow exist on both sides of the upper part of the right-flank earth flow. Near the top of the earth flow, the partially exposed slip surface is curviplanar and irregular. The earth-flow deposits bifurcate, with the main body of the earth flow bending to the north with its tip in a cattle pond which was completely drained by May 9. Loose pond-bottom vegetation was displaced around the tip of the earth flow in the pond,

Figure 4. Lateral levee along northwestern edge of left-flank earth flow. Levee is about 10 to 15 feet high.

Figure 5. Left-side earth flows. View is to the east from on top of left-flank lateral levee. Inside of opposite earth-flow levee shows ground-parallel slickenlines indicating direction of flow.

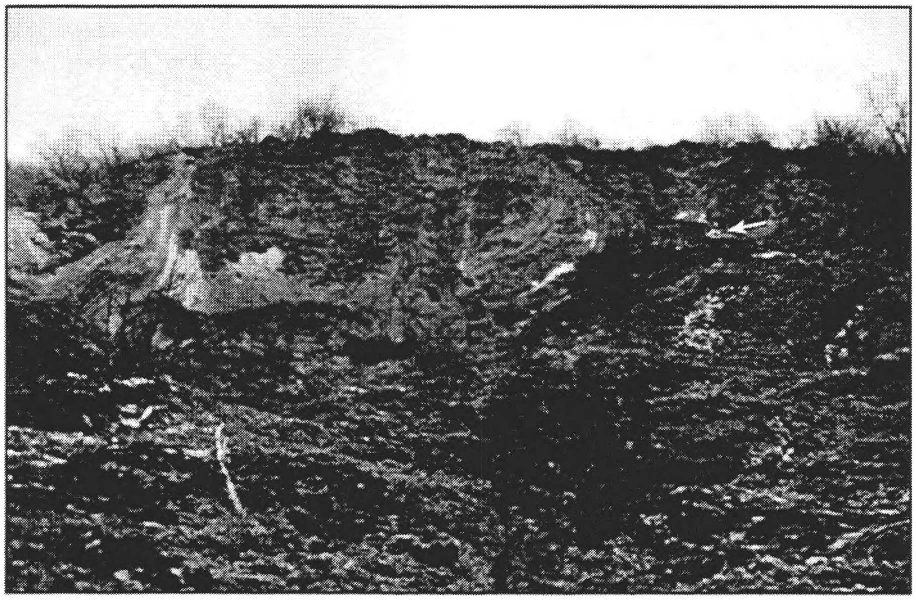

Figure 6. Main scarp of left-flank earth flow. Scarp height exceeds 50 feet. Note geologist (arrow) for scale.

Figure 7. Deformed soil and vegetation downslope of left-side earth flows. Earth-flow deposits are directly upslope of trees near top of photograph. Note intense ground cracking and steep downslope tilt of leading edge of deformed materials. Note also tilt of power-line access road (center left) and transmission pole (upper right).

indicating the earth flow reached the pond when water was still present. Subsequent ground tilting and cracking likely caused the pond to drain rapidly. A secondary earth-flow finger extends about 50 feet downslope from the northeastern edge of the main body of the earth flow (figure 9). Although the right-flank earth-flow deposits had a dry, firm crust on May 9 and later visits, ground water continued to flow from the base of the northeast edge of the earth flow as sheet flow downslope across an area about 70 to 100 feet wide to the power-line access road several hundred feet below. The sheet flow increased between May 19 and May 30, possibly as a result of heavy precipitation on May 24 and 25. Like the left-side earth flows, the earth-flow deposits on the right-flank came to rest upslope of the power-line access road and deformed downslope shallow soils and vegetation.

Contractional Deformation Features

Downslope of the earth flows, landslide features consist of mostly contractional deformation features, including folds and thrusts. As described briefly above, shallow soils and vegetation directly downslope of the tips of the earth-flow deposits were deformed. Directly downslope of the right-flank earth flow, the ground surface is heaved upward about 24 inches and back-tilted. A roughly vertical soil face is exposed with nearly horizontal slickenlines indicating initially the block of soil moved downslope and parallel to the ground surface (figure 10). The ground directly downslope of the heaved block is displaced downslope. The leading edge of the displaced soils is steeply tilted downslope and intensely cracked (figure 11). The soils are likely thrust downslope over the original ground surface. Similar landslide features occur beneath the left-side earth flows (figure 12). Several seeps and ponds exist at the base of the deformed soils.

Downslope of the deformed soils, contractional features consist of a series of mostly downslope-directed thrusts (figure 13) involving topsoil and shallow soils. Through May 19, several stacked thrust sheets existed between the downslope edge of the deformed deposits below the earth flows and the toe of the landslide. The downslope set of UP&L transmission poles are founded in soils that were thrust downslope. Downslope displacement of the northwesternmost of these poles is directly related to the thrusting, and was estimated on May 9 to be about 38 feet. In addition, vertical uplift in the vicinity of the poles ranged from 6 to 8 feet (Scott Burton, UP&L, verbal communication, May 9, 1997). Heights of individual thrust-sheet fronts ranged from several inches to several feet. Topsoil at the leading edge of the thrust sheets is commonly folded. Fold axes trend generally parallel to the leading edge of the thrust sheets and perpendicular to the direction of thrusting. A few upslope- and side-directed thrusts exist between and slightly downslope of the deformed deposits below the earth flows.

Contractional landslide features extend downslope of the main stacked thrust sheets on the right flank of the landslide. On May 9, I observed that the right-lateral scarp crossed the power-line access road and extended about 500 feet below the road. The ground surface was heaved upward several inches on the landslide (northwest) side of the scarp (figure 14). Downslope movement was likely on the order of several inches. The scarp generally bounds the right side of the smaller lobe of prehistorical landslide deposits described above and extends to the toe of the deposits. Offset of the ground surface decreases downslope. A diagonal traverse on May 19 from the intersection of the right-lateral scarp and the power-line access road to the centerline of the landslide indicated

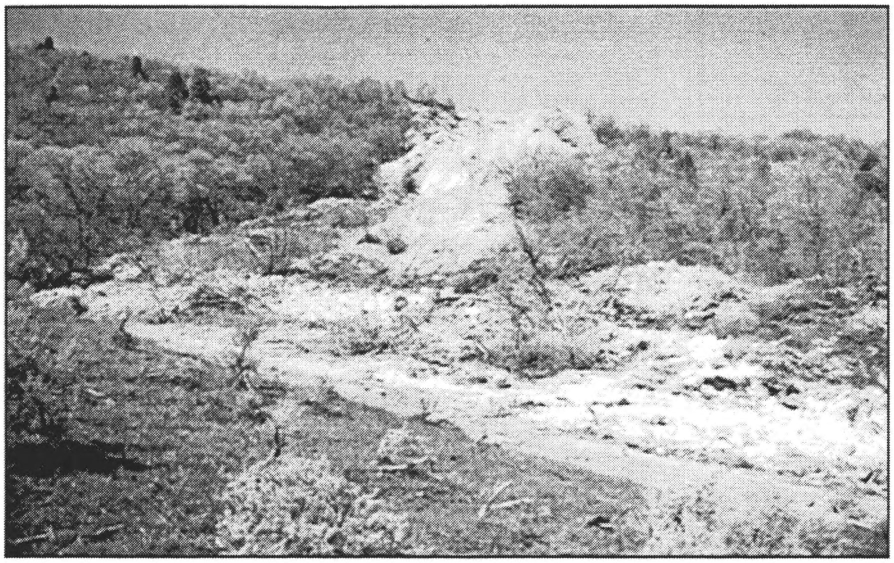

Figure 8. Right-flank earth flow. View is to south-southwest from near the toe of the deposits.

Figure 9. Small finger extending northeast from main body of right-flank earth flow. View is to south-southwest. Water continued to drain from base of earth flow on May 30, 1997.

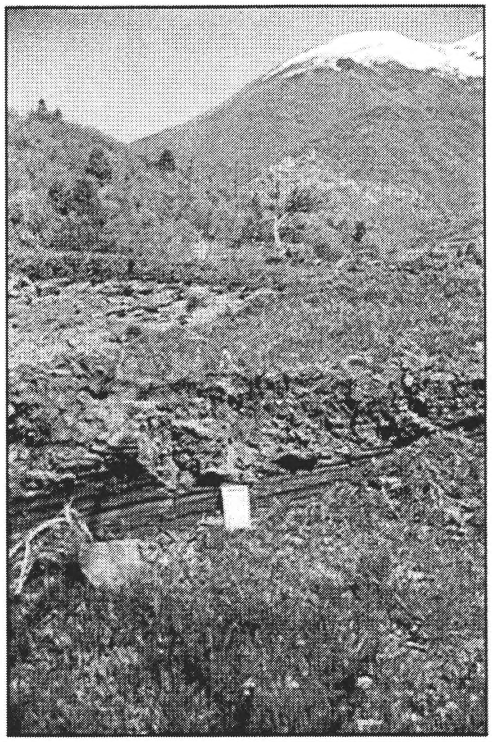

Figure 10. Ground deformation directly downslope of right-flank earth flow. View is to northwest. Ground has heaved upward about 24 inches. Note nearly horizontal slickenlines behind field book indicating earliest movement of heaved block was downslope parallel to ground surface. Dry cattle pond behind scarp was drained as ground tilted and cracked. Field book is 7-1/2 inches high.

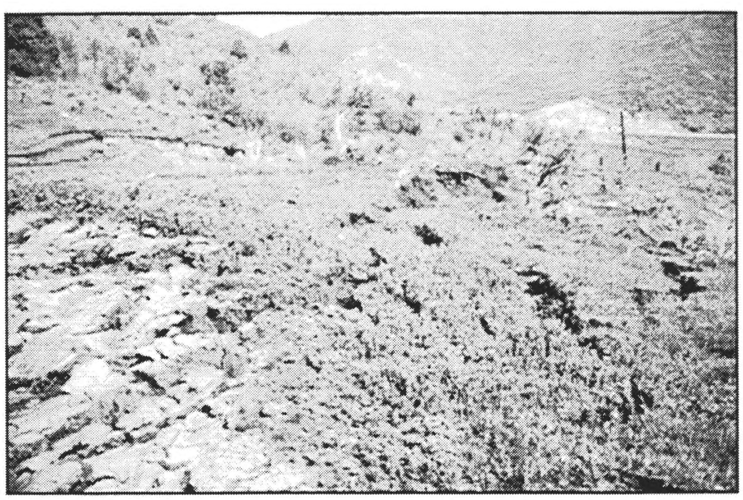

Figure 11. Ground deformation directly downslope of drained cattle pond. View is to northwest. Ground to right of cattle pond was displaced by upslope earth-flow deposits and coherent slide blocks (see figure 10). Intense ground cracking likely contributed to rapid draining of cattle pond.

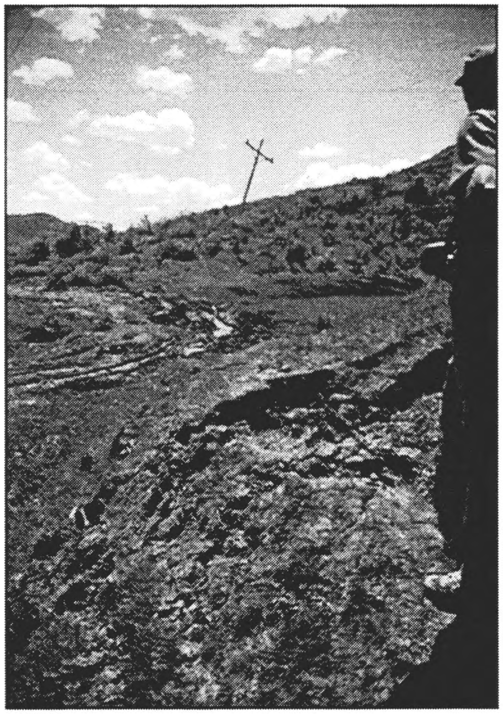

Figure 12. Ground tilting and cracking downslope of left-side earth flows. View is to southeast. Power-line access road (below geologist's foot) was tilted to nearly vertical between May 6 and 9, 1997. Transmission pole shown in figure 3 is visible in distance.

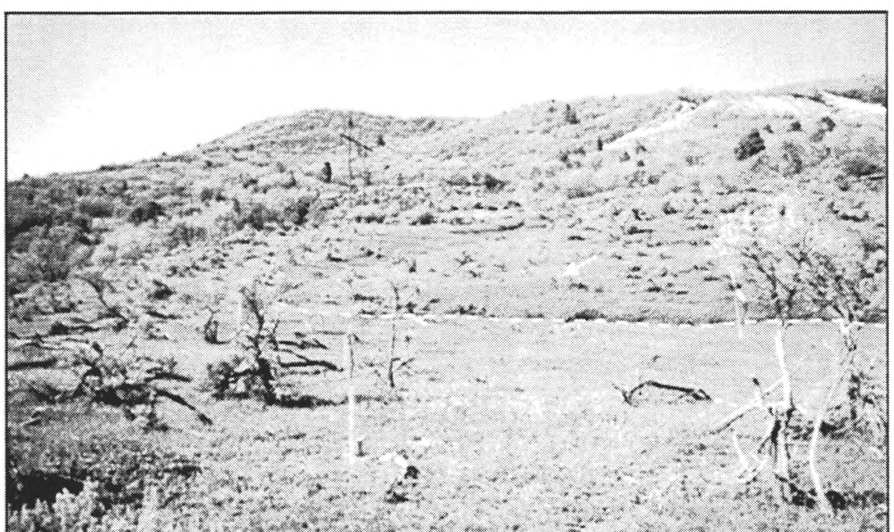

Figure 13. Thrusting at toe of landslide on May 7, 1997. Stake in foreground is on original ground surface downslope of slide. Stake in distance (arrow) is near tip of slide on lowest thrust sheet. Dashed line indicates lowest thrust. View is to the south.

additional longitudinal right-lateral shear cracks or shears. Along a left-stepping set of right-lateral shears thrusting occurs in the zone between the shear crack tips (figure 15).

Radial and longitudinal shears, ground cracks, and scarps exist in all the thrust sheets indicating local shearing and extension perpendicular to the downslope-directed thrusting and folding. Offsets along scarps are generally on the order of several inches. Prior to and including May 19, these types of cracks were not observed downslope of the May 7 toe of the landslide.

Slumping and Lateral-Spread Features

Upslope of the crown of the earth flows is a large area of slumping and extensional deformation that extends for about 1,500 feet upslope to the south. Along the left-flank drainage, slumping into the deeply incised gully (figure 16) continues for about 1,500 feet above the head of the left-flank earth flow. Downdropped slump blocks are visible on both sides of the gully. The landslide is about 600 to 700 feet wide directly above the earth flows but narrows toward the head. This area consists of relatively coherent soil blocks separated by ground cracks or scarps (figure 17), suggesting lateral spreading as the dominant style of ground deformation. Visual estimates of an offset tree line on the right flank of the upper part of the slide suggest a combination of downslope movement and extension on the order of 30 to 50 feet. The main scarp (figure 18) of the landslide ranges between about 10 and 40 feet high and is about 200 to 300 feet across. The head of the landslide is in a relatively gently sloping area where the average slope is less than 20 percent and local slopes are considerably flatter. The crown of the landslide, last observed on May 19, is about 200 feet upslope and south of where the left-flank drainage enters the slide area from the southwest. At the point of intersection of the drainage and the landslide, the drainage is generally incised less than 5 feet. Water was flowing in the drainage and into the left side of the landslide throughout the month of May (figure 19).

I observed additional evidence of slumping into the left-flank drainage along most of the left flank of the Shurtz Lake landslide. Adjacent to the left-flank earth flow, the toes of these slumps were buried by the northwestern earth-flow levee. Slumping (figure 20) and debris sliding in the steep slopes of the left-flank gully also occurred downslope below the toe of the landslide.

Deformation Features Downslope of the May 7 Landslide Toe

On May 30, I observed landslide-deformation features downslope of the original toe of the Shurtz Lake landslide. These features extend downslope to the toe of the prehistorical landslide deposits and were as close as 70 feet to the Spanish Fork River. Movement of the prehistorical landslide deposits may have been caused by a combination of factors including increased loading from the toe deposits of the May 6 landslide and heavy precipitation over the Memorial Day weekend (May 24-26).

I observed ground cracks (figure 21) and minor scarps over 200 feet downslope and northeast of the May 7 toe of the landslide. Cracks and scarps along the slopes of the central drainage could be followed for several hundred feet downslope and across the foot of the youngest of the

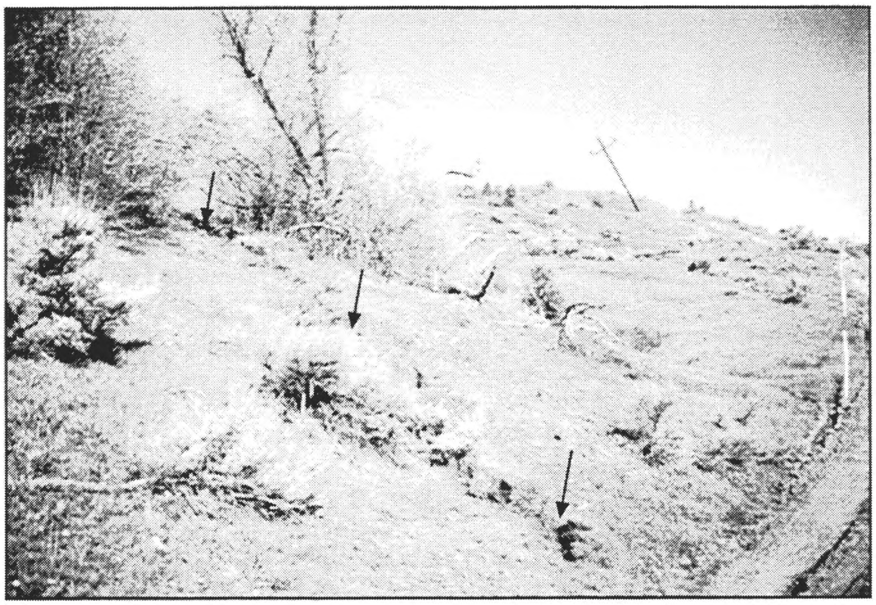

Figure 14. Right-lateral scarp (arrows) upslope of power-line access road. The ground surface on north side of scarp is heaved upward several inches. Note tilt of transmission pole. View is to the west-northwest.

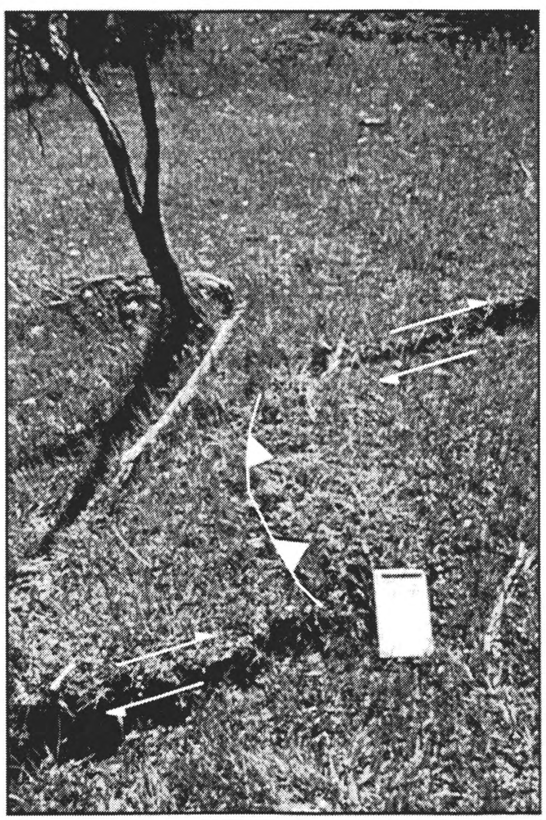

Figure 15. Thrusting between left-stepping en echelon right-lateral shear cracks. Topsoil to right of thrust has moved toward left over original ground surface.

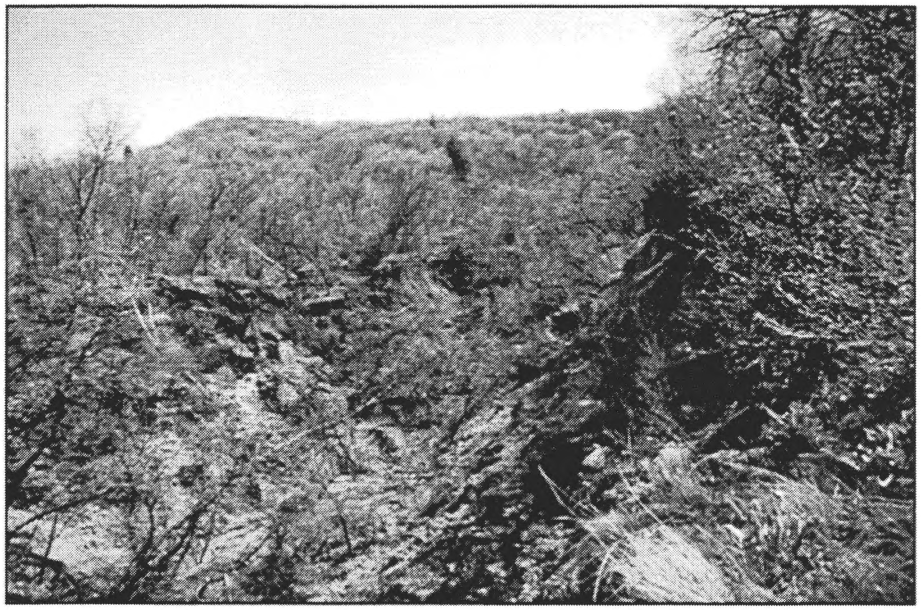

Figure 16. Slumping along the left-flank gully upslope of the crown of the left-flank earth flow. View is to the south.

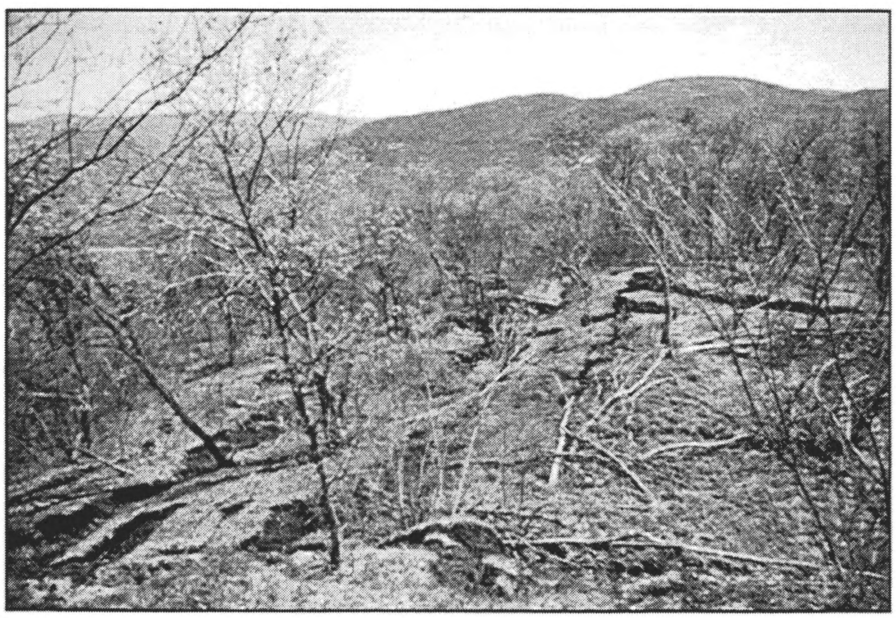

Figure 17. Ground cracks and scarps in the upper part of the landslide indicating lateral spreading. View is to the east.

Figure 18. Main scarp of landslide. Scarp height ranges from approximately 10 to 40 feet. View is to the southeast.

Figure 19. Intersection of left-flank drainage with left-flank of landslide. Geologist (upper left corner) stands next to drainage. Water flowed into slide mass thoughout the month of May. View is to the north.

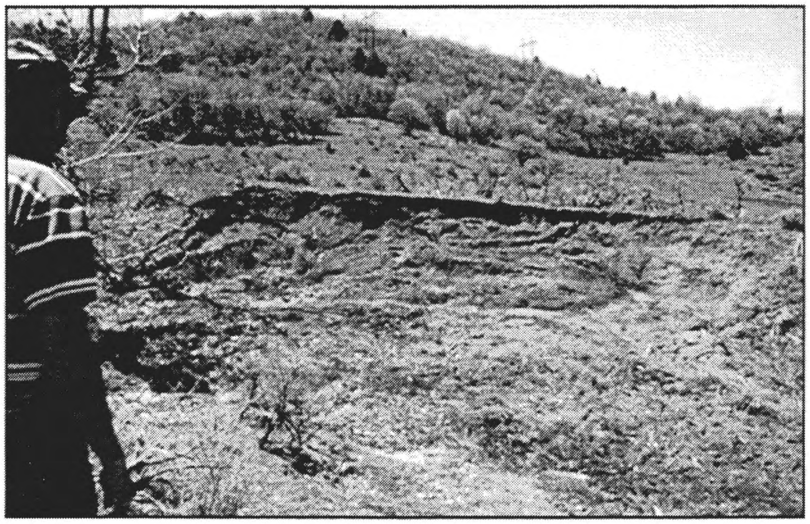

Figure 20. Local slump below the Shurtz Lake landslide in the left bank of the left-flank drainage. Slumping into gully may have been caused by rapid downcutting in early May. View is to the west.

Figure 21. Ground crack observed on May 30 over 200 feet downslope of May 7 toe of landslide. Deformation suggests distribution of landslide activity is enlarging and progressing downslope. Cracks likely formed following heavy precipitation over the Memorial Day weekend. Field book is about 7-1/2 inches long.

prehistorical landslide deposits. Additional ground cracks in these deposits were visible farther to the northwest.

Shallow thrusts (figure 22) of topsoil and shallow soil exist in several locations at the toe of the oldest prehistorical landslide deposits that abut the D&RGW railroad grade. Topsoil was generally thrust several inches to several feet downslope over the original ground surface. In one location, an old four-wheel-drive road was deformed by a thrust so that the upslope rut was moved to within a foot of the downslope rut. Seeps exist in the vicinity of most of the thrusts. Ground cracks and scarps were visible upslope of the thrusts (figure 23). These features suggested thrusting at the railroad grade level may have been caused by local slumping at the toe of the older prehistorical landslide deposits, perhaps unrelated to the May 6 landslide. However, an association of this slumping with ground cracks farther upslope suggests a cause-and-effect relationship. For instance, slumping at the toe could be caused by oversteepening of the lower part of the slope as a result of gradual deep-seated movement and increased pore pressure following the May 6 landslide and the Memorial Day weekend precipitation.

Seeps, Ponds, and Flowing Water

As indicated above, seeps and ponds are in and on the margins of the landslide. The lowest seeps exist at the base of the prehistorical landslide deposits abutting the abandoned D&RGW railroad grade. Farther upslope, seeps and wet ground occur in flat-lying areas near the base of the youngest recognized prehistorical landslide deposits. Seeps also exist at the base of deformed deposits directly below the toes of the earth flows. The water from the seeps was blocked by ground deformation in this area, forming several small ponds upslope of the power-line access road. Seepage and sheet flow at the base of the right-flank earth flow continued throughout the observation period and appeared to increase toward the end of the month following a period of heavy rain.

At least one pre-existing pond was drained and another is in jeopardy of being drained by the landsliding (figures 10 and 11). A cattle pond on the right flank of the slide was drained because of ground tilting and cracking. A second small pond is located directly downslope of the power-line access road and southeast of the northwesternmost set of transmission poles. Deformed soils directly upslope of the pond appeared to be gradually encroaching on it. In addition, longitudinal ground cracks downslope of the pond could eventually propagate upslope and drain the pond.

The two northwesternmost drainages described above flowed throughout the month of May. Flow in the left-flank drainage was initially disrupted by the left-flank earth flow but re-established itself by May 7. Water was several inches deep in the left-flank drainage below the slide. The upslope segment of the left-flank drainage discharges directly onto the landslide. The central drainage sustained a low flow in May with water depths typically an inch or so deep, but a silt line indicates higher flow levels more than a foot above the water line in the drainage that were probably contemporaneous with the first movement of the landslide. Thin deposits of clay and silt exist between the earth-flow deposits in the lower part of the landslide, further documenting an expulsion of water in the earliest stages of movement.

Figure 22. Thrusting in older landslide deposits abutting abandoned D&RGW railroad grade. Topsoil and underlying soil (on right) has been thrust over upslope rut. Field book is near tip of thrust sheet. Note wet soil and darker vegetation (arrow) directly upslope of thrust indicating seepage. View is to the south.

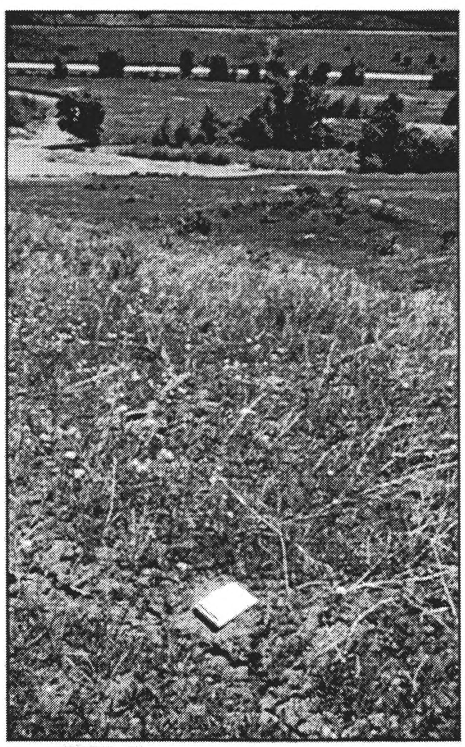

Figure 23. Scarp upslope of thrusts near abandoned D&RGW railroad grade. Note proximity of landslide deformation to Spanish Fork River (near top of photograph) on May 30, 1997. Field book is about 7-1/2 inches long. View is to the northeast.

HISTORY OF LANDSLIDING AND CAUSES OF THE MAY 6 LANDSLIDE

My review of aerial photographs indicates landsliding has been recurrent on the mountain slope on which the Shurtz Lake landslide occurred. At a minimum, the lower part of the landslide is confined within the limits of the youngest inferred prehistorical landsliding. In addition to prehistorical activity, Harty (1992) documents historical landsliding elsewhere on the mountain slope. The Shurtz Lake landslide is only about a mile north of, and shares certain geologic similarities with, the Thistle landslide, Utah's most costly landslide. These landslides and other apparent landslide features indicate the slopes are inherently unstable in this area.

No evidence exists for historical slope movement in the immediate vicinity of the Shurtz Lake landslide. The upslope UP&L power poles date back to 1923 (S. Burton, UP&L, verbal communication, May 9, 1997), and have not experienced significant movement in the last 74 years. The combination of evidence for prehistorical landsliding and the most recent movement suggests the prehistorical landslides were merely dormant (Cruden and Varnes, 1996) from at least 1923 to the present, and have not stabilized.

The May 6 Shurtz Lake landslide occurred following infiltration of seasonal snowmelt into the slope. At the time of the initial landslide movement, snow remained only at higher elevations on the mountain peaks several miles to the southwest. Most areas in northern Utah received above-average snowfall during the winter, and snowpacks were typically above average in the weeks preceding the landslide. Ground-water levels in the vicinity of the slide, therefore, were likely at or above normal seasonal highs. High ground-water levels may have coincided with seasonal peak flows in the left-flank drainage that resulted in rapid downcutting. Slumps into the left-flank gully may have been triggered by the rapid downcutting in early May.

Slumping along the left-flank gully may have caused extension across the slope, triggering movement of the landslide. The abundance of water on the flanks of the landslide associated with the drainages and high ground water may have saturated the slide deposits sufficiently to mobilize them into earth flows. Downslope movement of material on the steeply sloping lower part of the landslide may have removed support and allowed for extension and movement of the upper part of the slide as a lateral spread. However, this possible landslide sequence is unconfirmed by eyewitness accounts and is therefore speculative at best.

HAZARD POTENTIAL AND RECOMMENDATIONS

The Shurtz Lake landslide is the largest slide to become active in Utah during the spring snowmelt of 1997, and its proximity to the Spanish Fork River and the UP&L power lines warrants it being considered a potential hazard. Preliminary monitoring (S. Burton, UP&L, verbal communication, June 4, 1997) suggests that following the first landslide movement that probably occurred at a moderate to rapid rate (several feet per hour or faster) (Cruden and Varnes, 1996), subsequent movement of the slide has been slow (less than a fraction of an inch per day). On the other hand, our observations on May 30 of new landslide features downslope of the May 7 toe, suggest that the area of landslide activity has enlarged and advanced downslope since the first movement. This implies that the volume of material presently involved in movement is larger than initially estimated on May 7, but the rate of movement has slowed.

Many of the physical characteristics of the landslide increase the likelihood that the landslide will reactivate, possibly at a rapid rate of movement, in the future. These characteristics include the numerous ground cracks, seeps, ponded and flowing water on the slide, and the finer-grained and likely poorly drained nature of the landslide deposits. The development of landslide features downslope suggests that slow movement of the slide continues, but at a rate below the precision of ongoing surveying of the slide. Future, more rapid movement is possible, particularly after intense storm events and following next year's snowmelt. Open ground cracks readily allow the infiltration of water into landslide deposits, probably causing pore pressure increases and destabilization the slide. In addition, if the coherent but extended blocks in the upper part of the slide become sufficiently saturated, they may become mobilized as new earth flows. This is a significant concern given that a large percentage of the total volume of the slide, using the May 7 estimates, is upslope of the heads of the May 6 earth flows.

Regarding hazards posed by the landslide, potential scenarios related to renewed movement, listed in order from most to least likely, include:

1. additional damage or destruction of the UP&L transmission poles remaining on the slide, as a result of subsequent movement of the Shurtz Lake slide, in part or in its entirety;

2. erosion of the toe of the landslide by the Spanish Fork River as slow movement continues to expand downslope and the slide and prehistorical landslide deposits gradually encroach on the river, but at a rate at which the river can maintain its course;

3. diversion of the Spanish Fork River, as a result of moderate or rapid movement of the landslide and downslope prehistorical landslide deposits; or

4. complete blockage (damming) of the river as a result of rapid movement of the landslide and downslope prehistorical landslide deposits, with resultant downstream breakout flooding as the landslide dam is breached.

The proximity of the toe of recently reactivated prehistorical landslide deposits to the Spanish Fork River is of concern because movement need only be on the order of about 100 feet to impact the river. A secondary consequence of scenarios 3 and 4 include increased sediment load to the river with possible impact to downstream water users. Although the width of the modern flood plain suggests scenario 4 is unlikely, it is still possible. The volume of the Shurtz Lake landslide and downslope prehistorical landslide deposits is sufficient to create a dam across the entire flood plain. Scenario 4 could become likely if the landslide retrogresses (extends upslope) and drains Shurtz Lake. Such a catastrophic release may mobilize the landslide deposits into earth flows that could reach the flood plain or scour the left-flank gully and create a sedimentation problem.

Following recognition of landslide features on May 30 downslope of the May 7 toe, the UGS recommended that Utah County begin monitoring the slide on, at a minimum, a weekly basis (B.J. Solomon, written communication to Utah County Engineer Clyde Naylor, June 6, 1997). The purpose of such monitoring is to collect adequate data on continued small movements, if they occur, so that large-scale slope failure, as described in the above scenarios, can be anticipated. Despite above-average precipitation in early June, the landslide may not experience significant subsequent movement during the summer. If survey data confirm this, then surveying at a less frequent interval may be adequate until spring 1998.

I believe the periodic monitoring described above is sufficient at this time to deal with the threat posed by the Shurtz Lake landslide. However, the landslide will pose a threat for years to come, at least until data and observations indicate it has become dormant (no movement over a period of a year, but the conditions for renewed movement remain) (Cruden and Varnes, 1996). Because of the potential danger, particularly the possibility of a scenario 3 or 4 failure, monitoring should continue each spring for several years. In addition to the surveying as described above, the UGS will continue periodic reconnaissance of the slide to observe whether significant changes can be identified outside the survey area, particularly those that might indicate changes in the slide's activity, and monitor possible retrogression of the slide toward Shurtz Lake.

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