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Timber Harvest and Progressive Deformation of Slopes in Southwestern Oregon

D. N. SWANSTON, Principal Geologist
USDA Forest Service, Pacific Northwest Research Station, Box 020909, Juneau, AK 99802

G. W. LIENKAEMPER, Geologist
R. C. MERSEREAU, Forestry Technician
A. B. LEVNO, Supervisory Biologist
USDA Forest Service, Pacific Northwest Research Station, 3200 Jefferson Way, Corvallis, OR 97331

ABSTRACT

The effects of timber harvest operations on progressive deformation of slopes were measured and studied in the Baker Creek Watershed, southwestern Oregon. Four inclinometer access tubes were installed in and adjacent to a well-defined earthflow and monitored over a 10-yr period during which prelogging, harvesting, and postlogging deformation occurred. Prior to logging, ground displacement rates responded to long-term (50-yr) precipitation trends. Following logging, substantial short-term increases in ground displacement rates occurred within the earthflow. Within three years after harvesting, displacement rates returned to prelogging levels.

INTRODUCTION

Soil creep, slumping, and large-scale earthflows are major contributors to erosion of deeply weathered bedrock and overburden underlying the mountainous terrain of southwestern Oregon. Singly and combined, these processes cause a progressive deformation of the hillslope surface and a net downslope displacement of geologic materials.

Creep is the most widespread of these processes and is present to varying degrees on all slopes. The amount of slope displacement caused by creep and the influence of creep on other mass wasting processes is a function of parent material type, depth of weathering, and the amount of water present. Creep changes the distribution of shear stresses on or in the slope. In local areas where shear stresses are large enough, slumps and earthflows develop and enlarge as a result of progressive failure. A progressive failure may begin where creep-generated stresses exceed material strength, resulting in accelerated displacement. This displacement spreads outward in a chain reaction as stresses in the surrounding material reach critical levels.

Slumps and earthflows in southwestern Oregon are intimately related. Simple slumping takes place as rotational movement of a finite block of material along a broad concave failure surface. Earthflows usually occur where slump blocks slip downslope and are broken up and transported either by a flow mechanism or by a complex mixture of translational and rotational displacement within or above a definable zone of shear. The characteristics of the re-

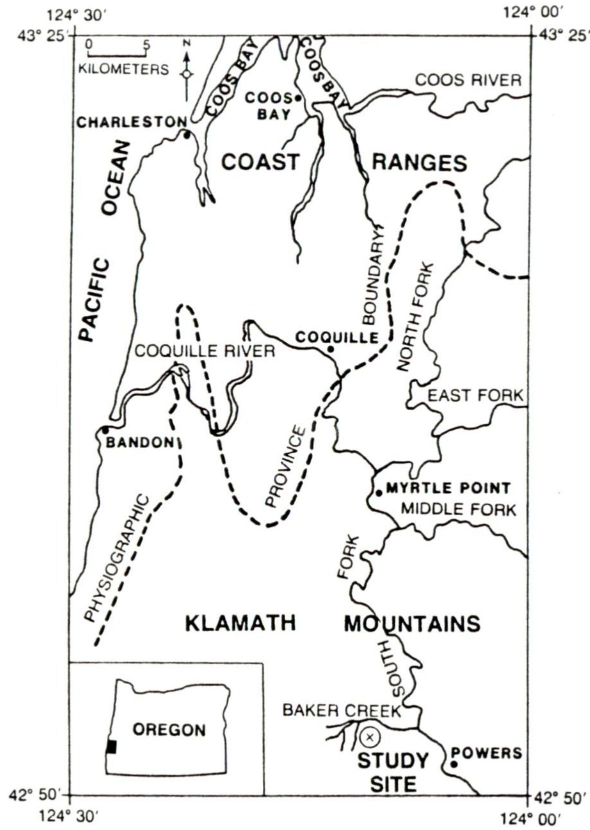

Figure 1. Baker Creek in relation to the Coquille River and to physiographic features southeast of Coos Bay, Oregon. The heavy dashed line marks the approximate boundary between the Oregon Coast Ranges and the Klamath Mountains.

sulting complex, mass-movement terrains along the west side of the Cascade Range and in the Coast Ranges of Oregon have been described by Swanston and Swanson (1976), Swanson and Swanston (1977), and Swanston and others (1983).

Earthflows disrupt 10 to 30 percent of the terrain in southwestern Oregon. These complex mass-movement features range from less than 1 ha (2.5 acres) to several square kilometers (slightly less than a square mile) and a from a few meters (less than 7 ft) to several tens of meters (more than 70 ft) deep. Commonly, a depression is formed by a slump and a headwall scarp develops at the top of the earthflow. The zone of earthflow movement extends downslope from the slump; the lower end typically extends into and is incised by streams. Debris from the earthflow is transferred to the stream channel by lateral erosion of the continually encroaching mass and by secondary processes, such as small-scale slumping, debris avalanching, gullying, and surface erosion. Such mass wasting activities constitute a significant long-term sediment source to streams in the region.

OBJECTIVE OF STUDY

In mountainous areas where creep, slumping, and earthflow processes are active or likely to occur, the land manager must plan timber harvesting to minimize impacts on these processes. Unfortunately, little quantitative information is available on the mechanics of deformation of the regolith or on changes that might result from forest harvest activities. Adequate knowledge of rates of movement, of changes in rate due to climatic events and logging disturbance, and of the character and duration of changes is necessary for effective assessment of site stability, of sensitivity to disturbance, and of the extent of downslope damage.

SITE CHARACTERISTICS

Location

In 1974, an area in the Baker Creek Watershed near Powers, Oregon, was selected with the help of personnel from the Bureau of Land Management, Coos Bay Forest District, to study creep and earthflow activity and to develop a first approximation of the stability hazard at the site. Baker Creek is approximately 67 km (41.6 mi) southeast of Coos Bay in the Klamath Mountains (Figure 1). Widespread, unstable landforms attest to active creep and to both slump and earthflow movement in the watershed. An extensive logging road system, constructed between 1963 and 1965, provided access for drilling and monitoring. Clearcutting had been planned far enough in advance of the study to allow for installation and stabilization of monitoring equipment and for characterization of preharvest deformation and displacement.

Climate

The climate in the Baker Creek watershed is mediterranean. Actual climatic variability within the watershed is unknown. The only available body of climatological data is the daily record of precipitation and temperature that has been kept continuously since 1931 at Powers. The mean monthly temperature and precipitation for Powers for 1973–84 (the period of this study) are shown in Figure 2. The mean maximum temperature in July ranges from 17 to 18°C (62.6 to 64.4°F) and the mean minimum temperature in January ranges from 6 to 7°C (42.8 to 44.6°F). The mean annual precipitation at Powers

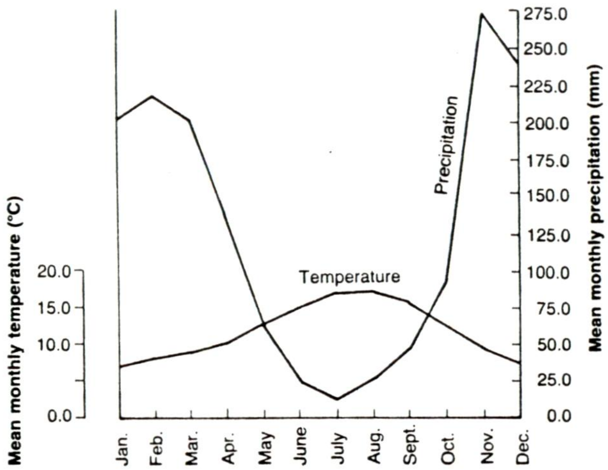

Figure 2. Mean monthly temperature and precipitation at Powers, Oregon, from 1973 to 1984.

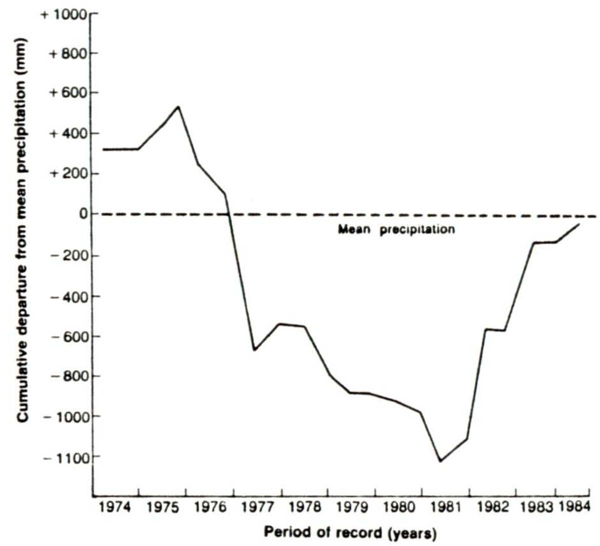

Figure 3. Historical record of semiannual rainfall at Powers, Oregon, for 1974 to 1984 reported as cumulative departures from the mean. Means were computed monthly over the common interval 1931–84. Semiannual intervals corresponded to borehole inclinometer surveys.

is 1,573 mm (61.9 in.). The seasonal distribution of precipitation includes a winter rainfall maximum and a pronounced summer drought. Maximum mean monthly precipitation ranges from 228 to 280 mm (9.0 to 11.0 in.) from November through March with the peak in November. An analysis of historical records for rainfall at Powers indicated a pronounced decrease in annual rainfall for most of the study period. From 1974 to 1980, the record was characterized by annual means consistently lower than the long-term mean. From 1981 to 1984, annual means exceeded the long-term mean (Figure 3). Lowest annual rainfall occurred from 1976 to 1979; precipitation for each year averaged 30 percent below normal. Greatest precipitation occurred during 1982–83 and exceeded the annual mean by 23 percent.

Vegetation

Moderately productive soils, moderate temperatures, and seasonally abundant moisture support a mixed cover of dense forest and prairie vegetation. Mineral soil is exposed under natural conditions only where vegetation cover is disrupted by mass movement activity or by lateral stream erosion. Douglas-fir (*Pseudotsuga menziesii*) and its common associate, grand fir (*Abies grandis*), dominate the overstory vegetation; lesser amounts of western red cedar (*Thuja plicata*) and red alder (*Alnus rubra*) occur at disturbed sites.

Geology and Soils

The lithologies and structural properties of the rocks underlying the Baker Creek Watershed make those rocks highly susceptible to chemical decomposition and erosion by mass wasting processes. The entire basin is underlain by highly sheared greywacke sandstones and siltstones of the Otter Point Formation of late Jurassic to early Cretaceous age (Beaulieu and Hughes, 1975). Largely unmetamorphosed siltstones and sandstones underlie the upper part of the watershed where drill sites were located. Bedrock outcrops are few because of the nearly continuous mantle of colluvium, deep residual soil, and saprolite produced by soil mass movement and by mechanical and chemical weathering. The depth of this regolith is variable, ranging from less than 0.1 m (3.9 in.) on ridge tops to more than 10 m (32.3 ft) within earthflows and on mid to lower slope sites undergoing creep.

The soils in the Baker Creek drainage basin are mostly stony loams and stony-clay loams of the Etelka and Whobrey Series. These are typically deep, somewhat well to somewhat poorly drained loams and silty loams that developed in colluvium and residuum derived from weathered siltstones and sandstones (Huddleston, 1979). Underlying saprolites are rich in silt-sized particles and montmorillonite clay and typically extend to depths of 3 to 5 m (9.7 to 16.1 ft). Near the interface with unweathered rock, the saprolites commonly display alternating thin layers of slightly altered and deeply decomposed and leached parent materials. The decomposed and leached zones are usually associ-

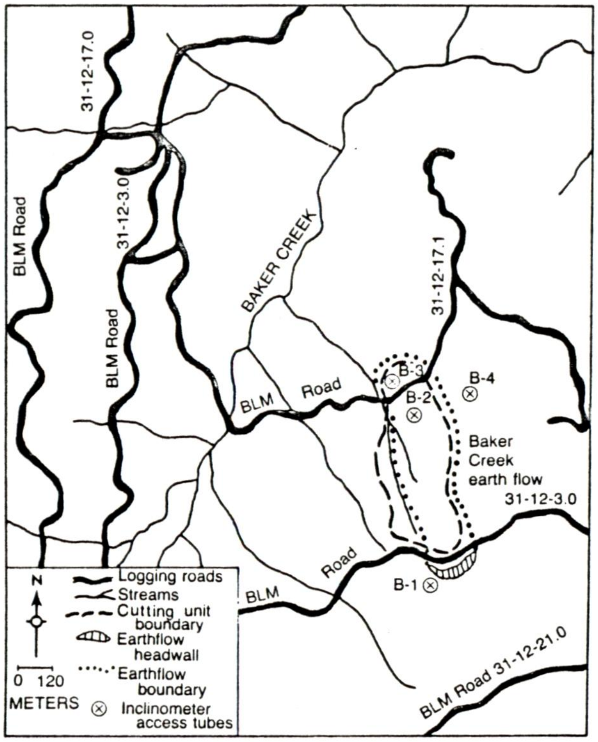

Figure 4. Upper Baker Creek watershed and locations on inclinometer access tubes in relation to earthflow and cutting unit boundaries.

ated with subsurface water movement and constitute potential zones of weakness along which failures can develop.

METHODS

Site Selection and Preparation

Displacement resulting from progressive slope deformation was studied in the Baker Creek basin by installing four inclinometer access tubes. These tubes were located within and adjacent to a well-defined earthflow within the boundaries of the planned Baker Creek timber sale (Figure 4). Logging boundaries had been marked, but actual felling and yarding were not scheduled for 2 to 3 yrs after the 1974 starting date of the study, which allowed sufficient time for measuring and characterizing prelogging rates of creep and earthflow activity. Access tubes provided a way to place an inclinometer within the regolith and measure the differences in rate of displacement and mode of deformation by location within and around the earthflow.

Inclinometer access tube B-1 was installed above the headwall area of the earthflow. This location was outside the planned cutting unit boundary and outside the zone where landforms and disrupted vegetation indicated active movement. Inclinometer access tube B-2 was installed at a midslope location well within the planned cutting unit; the site was approximately 600 m (1,935.5 ft) downslope of tube B-1 and within the active earthflow zone in a shallow, poorly drained depression. Inclinometer access tube B-3 was also installed within the cutting unit in a toe-slope position approximately 120 m (393.7 ft) downslope of tube B-2. The site was on hummocky ground adjacent to an intermittent channel believed to define the lateral margin of the earthflow. Inclinometer access tube B-4 was installed east of tube B-2 and outside the cutting boundary; this tube was on a low ridge outside the boundary of the active earthflow.

Access Tube Installation

Inclinometer access tubes were installed in 130 mm (5.1 in.) diameter boreholes drilled by a truck-mounted auger. The bottoms of the tubes were anchored below the regolith in stable bedrock. The depth of the access holes and the character of the regolith and bedrock were determined indirectly during the drilling operation by conducting penetration tests at 1-m (3.2-ft) intervals and recording resistance to penetration and changes in composition of the boring samples with depth. "Bedrock" was defined as material with a penetration resistance exceeding 60 blows per 30.48 cm (12.0 in.) of penetration in a standard penetration test (each blow is a constant energy increment of 63.56 kg (141.2 lb) being dropped a distance of 76.2 cm (30.0 in.) to drive a standard split-spoon sampler). Once bedrock was reached, the hole was drilled an additional meter (3.2 ft), and the access tube was installed. The annular space between the tube and the wall of the borehole was backfilled with pea-gravel to provide maximum stable continuity between the tube and the surrounding materials. Composition and penetration resistance encountered in each borehole were plotted for later comparison with deformation profiles.

Stability of the bottoms of the tubes was important for proper interpretation of the data. If the bottom of a tube is stable, a three-dimensional coordinate system can be defined within which the deformation of the access tube can be plotted. Subsequent surveys of all the inclinometer access tubes showed only minor changes in inclination of the bottom 0.3 m (12.0 in.) during the study. The tubes were therefore assumed to be sufficiently stable for analytic purposes.

The inclinometer access tubes were made of polyvinyl chloride (PVC) with a 76.2-mm (3.0-in.) inside diameter. Four grooves were milled longitudinally inside the tube at 90-degree intervals. A mechanical pendulum with electronic readout, fixed in a rigid carriage riding in the grooves, was passed down the tube to measure changes in inclination (this is a commercial inclinometer device; tubes and instrumentation were manufactured by Slope Indicator Company, Seattle, Washington; the use of this and other equipment does not imply endorsement or approval by the U.S. Department of Agriculture, Forest Service). Differences in inclination between successive readings were used to calculate displacement. The orientation of the readings, and thus of the relative displacement in two principal planes, was governed by the grooves inside the casing; it was therefore essential that the grooves be oriented as accurately as possible. The four grooves were referenced to cardinal compass points (north, east, south, and west) and, as far as was feasible, tubes were installed with this orientation. The azimuth of the planes, as defined by groove pairs, was measured with a Brunton compass to obtain true bearings. All subsequent data sets at each hole were oriented using that azimuth.

Monitoring Program

Because the Baker Creek Watershed is in a region of relatively heavy winter rainfall and pronounced summer drought, each access tube was surveyed for changes in inclination semiannually—in the late spring after fall and winter storms and in early fall after the summer dry period. Seasonal variation in standing water in each tube was also monitored during the study. These semiannual readings were begun in November 1974 and continued through spring 1984. This 10-yr monitoring period bridged prelogging (1974–76), harvesting (1976), and postlogging (1977–84) deformation at the Baker Creek site. The resulting data was used to analyze the effects of seasonal and annual rainfall, regolith structure, and timber felling and yarding on variations in horizontal and vertical movement with depth within and adjacent to the earthflow.

DATA ANALYSIS

Standing water was present in the access tubes throughout the study. The water level at all sites fluctuated within a narrow range between the surface and a depth of 1.5 m (4.8 ft). Water levels tended to be at or near the surface at the end of the winter rainy period; however, no significant relation between season and water height was indicated by the available data. It is unlikely that this standing water represented year-round maintenance of saturated conditions within the entire profile. Only local zones within the saprolite exhibited excessive moisture during the drilling operations. The water in the access tubes was probably the result of ground water flowing in from one or more of these water-bearing horizons.

The inclination of access tubes was measured at 0.5-m (19.4-in.) intervals starting at the bottom of the hole. To estimate the configuration of the tubes, it was necessary to approximate the centerline of the casing by a series of casing vectors oriented point to tail from the bottom of the casing to the surface. The bottom-most vector was 0.25 m (9.7 in.) long. All successive vectors were 0.5 m (19.4 in.). The number of vectors corresponded to the number of measurement intervals, and vector orientations were described by inclination (zenith angle) and by resulting coordinates in the north and east planes (azimuth). Position vectors were defined by adding the casing vector coordinates cumulatively, proceeding up the hole; the cumulating coordinates determined the actual position of the measurement point in three-dimensional space. Subsequent surveys provided the necessary data for vertical profile plots showing distance and direction of movement between successive surveys throughout the depth of the hole. The computer analysis methodology and plotting programs used to display these data were developed by R. B. Thomas and R. R. Ziemer of the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Arcata, California.

Variability in direction and distance of movement between successive surveys at each depth interval was occasionally large. This is illustrated by the dashed surface movement vectors in Figure 5. Variability was due to several factors. Large displacements downslope are primarily the result of 1) changing characteristics of deformation of the regolith in response to changing water content, and 2) differential adjustment of individual blocks within the moving regolith. Small, random displacements laterally and upslope are largely a response to differential movement of the inclinometer tube within the drilled hole.

To construct the vertical profile of movement and compare profile changes over time, cumulative position vector coordinates were projected into a single plane with an azimuth approximating the dominant movement direction. This plane was designated as the "plane of maximum movement" (PMM). An

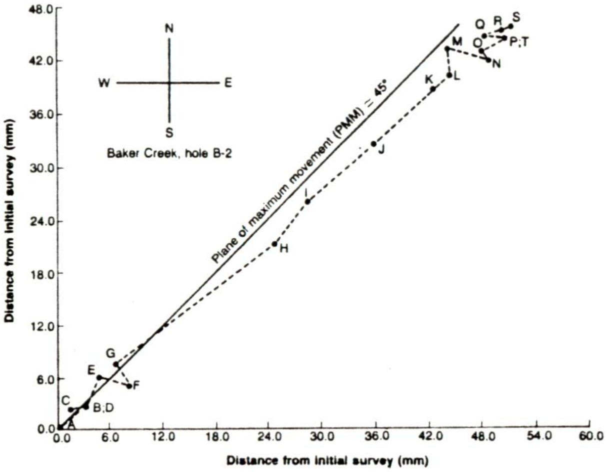

Figure 5. Plot of surface displacement vectors (dashed line) for the establishment of the plane of maximum movement (PMM), hole B-2. Letter designations correspond to survey intervals.

approximate PMM for each hole was determined graphically from the general direction of a plot of surface movement over the total period of monitoring. Figure 5 illustrates the establishment of the PMM for hole B-2 in the middle of the earthflow. Once the profiles were plotted in the plane of maximum movement, displacement configuration with depth and the location of zones of shear or accelerated deformation were defined. Annual and seasonal displacement and rates of movement at the surface were obtained by calculation and graphic scaling from the profiles. Displacement and rates were then regressed against annual and seasonal precipitation and against cumulative departures from mean precipitation to determine relations that might exist between movement and prevailing climate conditions.

RESULTS AND DISCUSSION

Movement Configuration and Displacement

Swanston (1981) describes three major types of profile configurations indicative of accelerated movement in the mantle. Creep-dominated terrain generally exhibits either a progressive deformation (shear strain) profile, with displacement increasing toward the surface, or an extension-flow profile, with pronounced axial strain taking place over a broad zone at some depth below the surface. The former configuration indicates stresses great enough to cause deformation but not great enough to cause failure. The latter indicates increased strain and possible incipient failure developing within the profile. Active slump and earthflow sites consistently exhibit a block-gliding profile with primary movement taking place above a well-defined failure zone.

Inclinometer access tubes B-1 and B-4, both located outside the boundaries of the active earthflow, exhibited characteristic creep profile configurations. Access tube B-1 (Figure 6), located near the ridge top and above the headwall of the slump-earthflow, displayed progressive (increasing) deformation toward the surface over a depth of approximately 3 m (9.7 ft). Greatest displacement occurred within 0.8 m (2.6 ft) of the surface. Total surface displacement exceeded 60 mm (2.4 in.) over the 10-yr period, 1974–84, with 63 percent of the total cumulative movement (38 mm or 1.5 in.) occurring in a major surge during winter 1981. By the spring of 1982, displacement had returned to pre-surge levels. This displacement surge occurred at the beginning of a general increase in precipitation in the region. It also occurred immediately following shelterwood cutting on the slope above the earthflow. The short duration of the displacement surge, and physical damage observed at the top of the inclinometer tube during the spring, 1982 instrument reading, suggest that the surge was predominantly the result of heavy machinery working near the tube. Access tube B-4, located on the low ridge east of the earthflow (Figure 7), displayed only minor movement during the study period, although both progressive and extension-flow deformation characteristics were indicated within the profile. Only about 6 mm (0.24 in.) of cumulative surface displacement was recorded over the 9-yr period, 1975–84. Movement of this magnitude is probably not within the ability of the measuring system to accurately define. Nevertheless, the profile configuration and general movement trends indicate an incipient zone of extended deformation beginning at a depth of about 1.6 m (5.2 ft) with axial strain and extension flow developing toward the surface. Minor accelerated downslope movement (approximately 4 mm or 0.16 in.) indicated within this profile during the summer and fall of 1978 suggested incipient failure at the interface between bedrock and saprolite.

Inclinometer access tubes B-2 and B-3, both located within the boundaries of the earthflow, exhibited finite failure profiles. Access tube B-2 (Figure 8), located on a slump block in the lower half of the active zone, displayed block-glide deformation characteristics with uniform movement occurring above a shear zone ranging from 3.2 to 3.7 m (10.3 to 11.9 ft) deep. Total displacement at the surface exceeded 68 mm (2.7 in.) over the 10 yrs from 1974

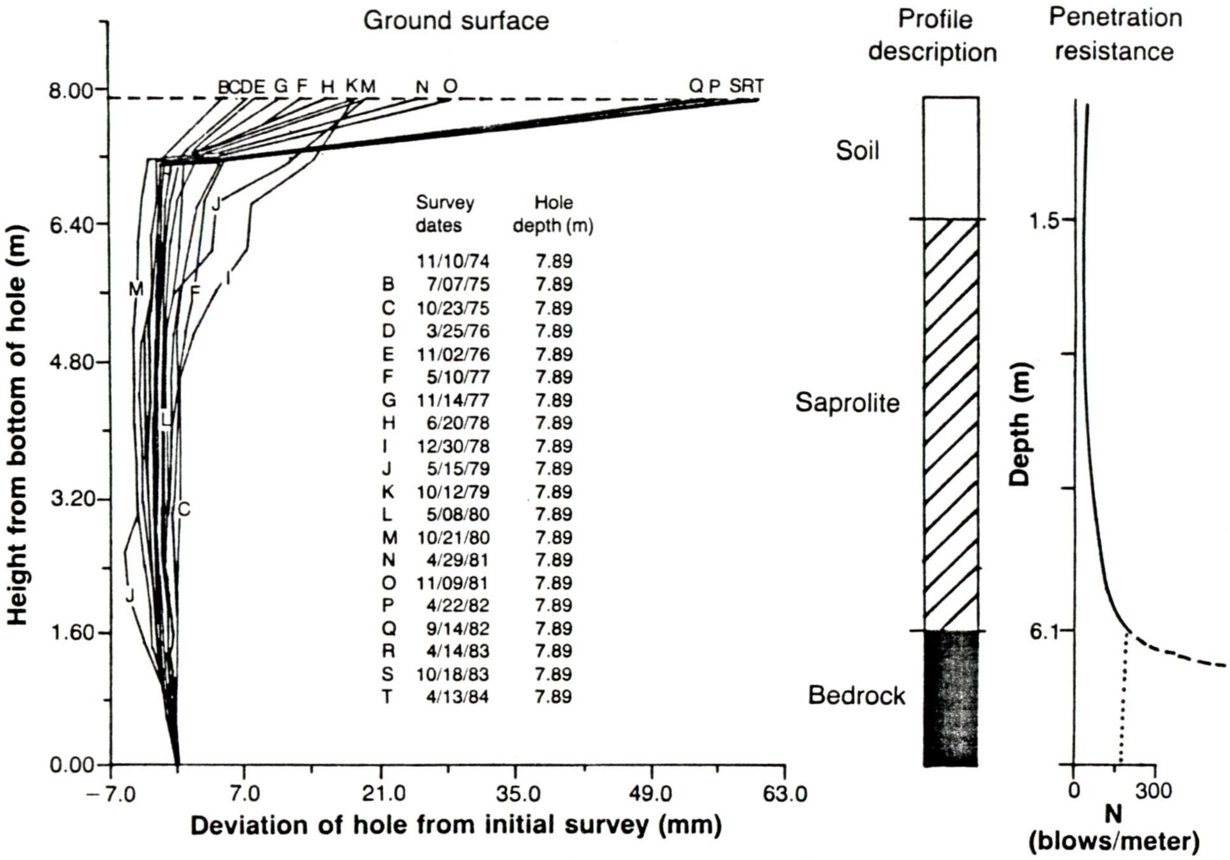

Figure 6. Plot of casing deformation over the 10-yr period, 1974–84, for hole B-1, which was above the earthflow headwall and outside the original cutting unit. The profile description is based on split-spoon samples and changes in density obtained during installation of the access tube. Density is reported as penetration resistance (N) in blows per meter. Bedrock is defined as material with a penetration resistance in excess of 180 blows per meter.

to 1984 with 70 percent of the total cumulative movement (41 mm or 1.6 in.) occurring during the 2 yrs from winter 1977 to winter 1979. Access tube B-3 (Figure 9), near the toe of the earthflow, displayed block-glide deformation characteristics with uniform movement occurring above a shear zone that ranged from 5.2 to 5.6 m (16.8 to 18.1 ft) deep. Displacement was substantially less than that recorded at access tube B-2, with movement totaling about 16.5 mm (0.7 in.) at the surface over the 10 yrs. Of this displacement, 75 percent (12 mm or 0.5 in.) resulted from a surge during summer, fall, and early winter 1978. As in access tube B-4, this accelerated displacement extended to within 0.6 m (1.9 ft) of the bottom of the hole where incipient failure may be occurring at the bedrock-saprolite interface.

A comparison of cumulative displacements over time for all four sites (Figure 10) clearly displayed an acceleration in earthflow movement in 1978 and 1979 (access tubes B-2 and B-3). A very minor acceleration in surface movement that occurred at about the same time was also evident along the east side of the earthflow in access tube B-4. Creep in the regolith above the headwall of the earthflow (access tube B-1) continued at a fairly constant rate (3.3 mm/yr or 0.13 in./yr) throughout the period. The sharp increase in displacement at the surface in this hole in 1981 is probably the direct result of mechanical disturbance of the tube during logging.

Effects of Precipitation

Two surveys a year were made at each site to determine any effects of seasonal precipitation on movement. Work elsewhere in the Cascade and Coast Ranges of Oregon and northern California (Swanston, 1981; Swanston et al., 1983) suggests that both displacement amount and movement rate are sensitive to seasonal and annual precipitation. Linear regression of both displacement and rate

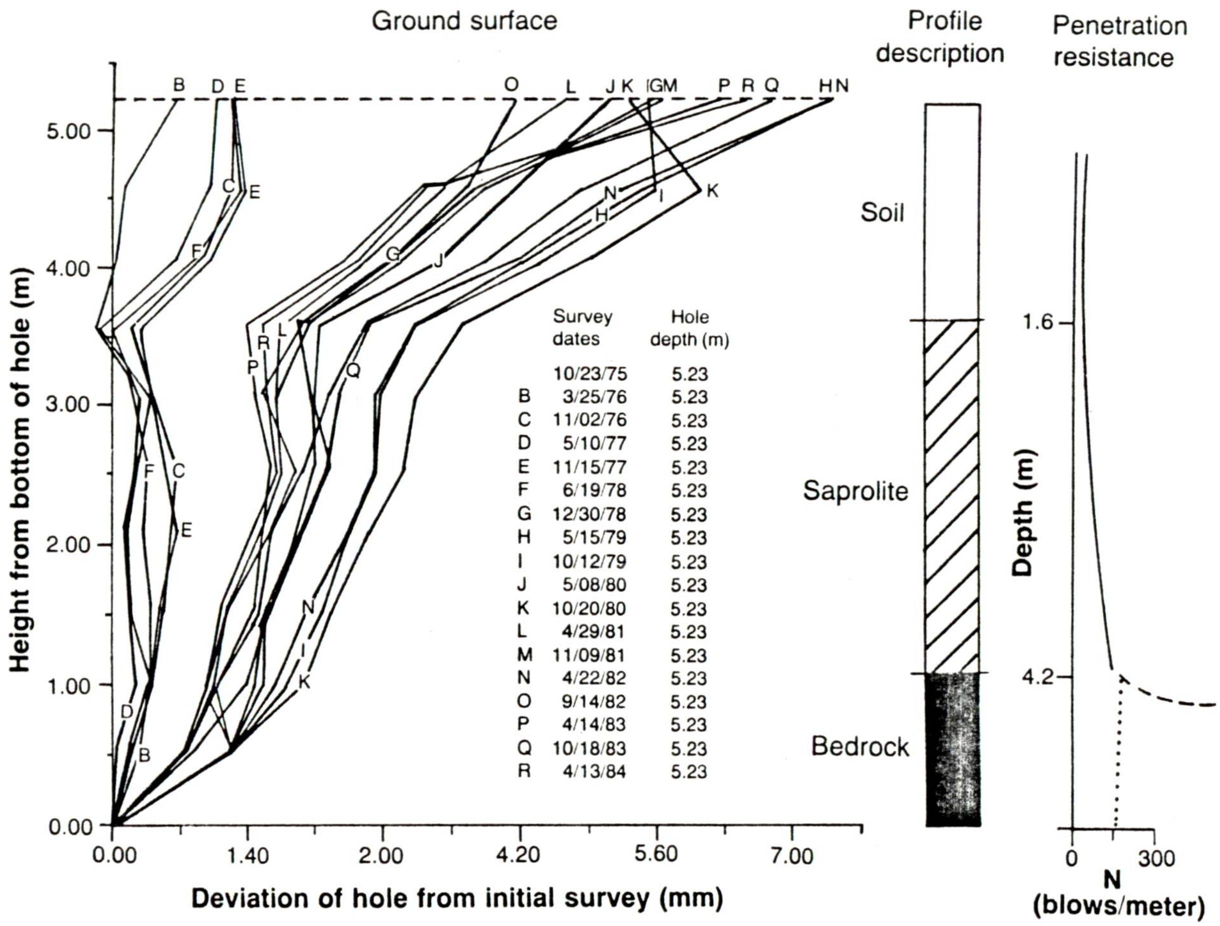

Figure 7. Plot of casing deformation over the 9-yr period, 1975–84, for hole B-4, which was east of the active earthflow boundary and outside the cutting unit. The profile description is based on split-spoon samples and changes in density obtained during installation of the access tube. Density is reported as penetration resistance (N) in blows per meter. Bedrock is defined as material having a penetration resistance in excess of 180 blows per meter.

against seasonal and annual rainfall for each access tube, however, showed no significant correlations between these variables, which suggested that movement was progressing independently of short-term precipitation (seasonal and annual) and might have been responding to long-term variations in soil-water content in the regolith. A plot of cumulative departures from mean annual precipitation and displacement at each access tube during the study period supported this suggestion (Figure 11). Access tube B-1, outside the immediate influence of the earthflow and generally unaffected by harvest disturbance, showed a direct correlation between declining long-term rainfall and declining displacement. A linear regression of these cumulative departures at access tube B-1 yielded an equation of the form:

$$Y = 0.41 + 0.01X \qquad \text{Eq. 1}$$

where Y was displacement in millimeters or inches and X was precipitation in millimeters or inches. The coefficient of determination was 0.70 with a standard deviation about the regression of 4.6. Access tubes B-2, B-3, and B-4, within or immediately adjacent to the earthflow, also displayed slight declines in displacement with long-term precipitation through 1977. From 1978 to 1980, a substantial increase in displacement occurred, however, in access tubes B-2 and B-3 despite a continuing below-average rainfall. The regolith materials at these sites were clearly responding to destabilizing forces that had accelerated earthflow activity despite below-average, area-wide moisture availability.

Response to Harvesting

Accelerated movement of the earthflow feature at Baker Creek appeared to be directly related to harvesting activities in the upper portion of the watershed. The surface area of the earthflow was clearcut, and felling and yarding occurred in fall and

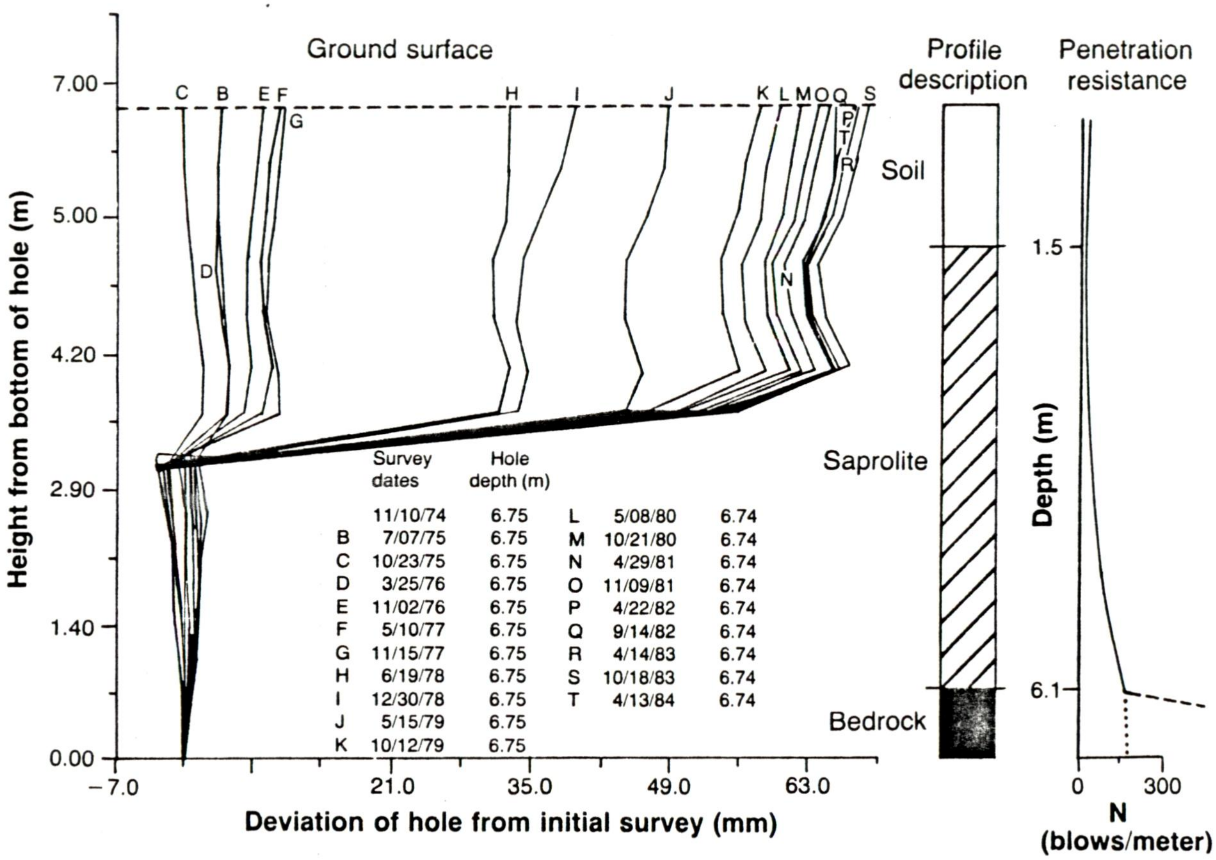

Figure 8. Plot of casing deformation over the 10-yr period, 1974–84, for hole B-2, which was in the middle portion of the earthflow and well within the cutting unit. The profile description is based on split-spoon samples and changes in density obtained during installation of the access tube. Density is reported as penetration resistance (N) in blows per meter. Bedrock is defined as material with a penetration resistance in excess of 180 blows per meter.

winter 1976. An increase in displacement rate was measured in the lower half of the earthflow at access tube B-2 during winter 1977. This surge occurred one year after clearcut felling and tractor yarding in an area that exhibited declining prelogging displacement and below-average annual precipitation. The accelerated displacement in access tube B-2, was detected 120 m (393.7 ft) downslope in access tube B-3, at the toe of the earthflow, by summer 1978. The semistable hillslope east of the earthflow (access tube B-4) also displayed a slight increase in displacement rate during summer 1978. This increase may have been in response to increasing stresses in the regolith as the result of movement in the earthflow. Accelerated movement at access tube B-2 continued through summer 1979, after which the displacement rate returned to prelogging levels. Accelerated movement at the earthflow toe (access tube B-3) continued for only a single season, and by the spring of 1979, displacement rates had returned to prelogging levels. The short-lived nature of the surge was probably the result of the generally dry conditions and the small regolith blocks involved in the accelerated displacement; the result was rapid redistribution and balancing of stresses in the earthflow mass.

Although the combined operations of timber felling and yarding were strongly implicated as the cause of the increased activity, it was not possible to specify the actual mechanism of destabilization based on existing evidence. Some speculation is possible, however. It is highly unlikely that the movement was the direct result of the loss of anchoring and reinforcing effects of roots. It takes more than one year for root strength to deteriorate sufficiently to affect stability. Also, root systems occupy only a small percentage of the total sliding mass, generally the near-surface zone, and where they do occur, they have already been disrupted by movement. Finally, roots do not generally extend to the depths where failure takes place in an earthflow. The dominant effect of timber removal is probably the immediate

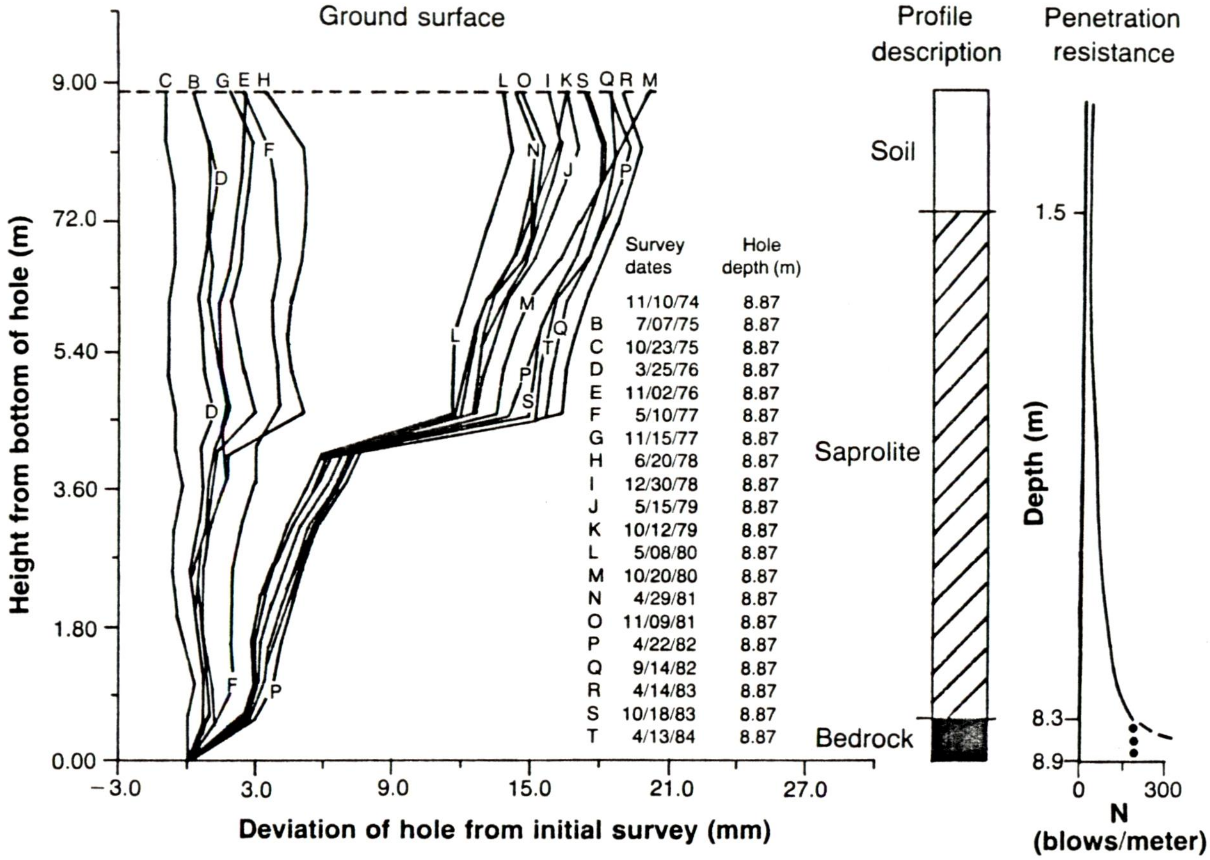

Figure 9. Plot of casing deformation over the 10-yr period, 1974–84, for hole B-3, which was in the lower portion of the earthflow and well within the cutting unit. The profile description is based on split-spoon samples and changes in density obtained during installation of the access tube. Density is reported as penetration resistance (N) in blows per meter. Bedrock is defined as material with a penetration resistance in excess of 180 blows per meter.

elimination of interception and evapotranspiration from the site. Numerous studies have clearly demonstrated a significant increase in annual water yields when forests are harvested (see summary by Hibbert, 1967). Data from high precipitation areas of the Pacific Northwest (Rothacher, 1970) indicate that the largest portion of this increased annual precipitation, approximately 80 percent, occurs during the wet October–March winter season as the result of an increasingly saturated flow from the regolith and increased surface runoff. The remaining 20 percent of the increase occurs during the dry April–September summer season as a result of increased base flow. Not only is interception less on the clearcut areas so that more precipitation reaches the ground surface, but also the retained soil moisture is much greater in the clearcuttings because of the elimination of transpirational withdrawal of stored water. Rothacher (1970) reports that as much as 150 mm (6.0 in.) more water was found at the end of the dry season in clearcuttings along the west side of the Cascade Range in Oregon. In the Baker Creek

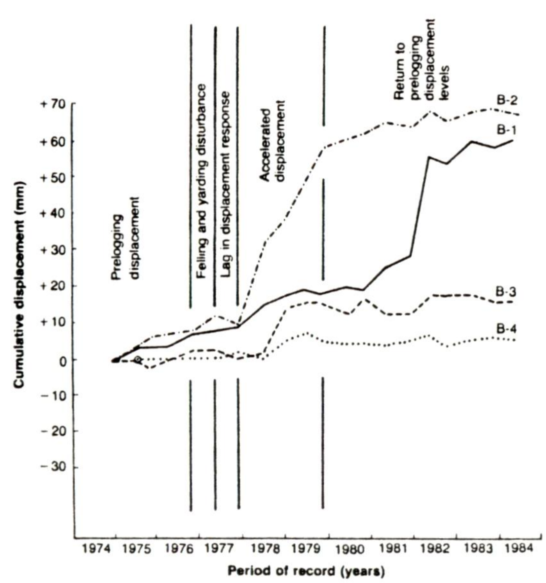

Figure 10. Cumulative surface displacement over the 10-yr period, 1974–84, for holes B-1, B-2, B-3, and B-4.

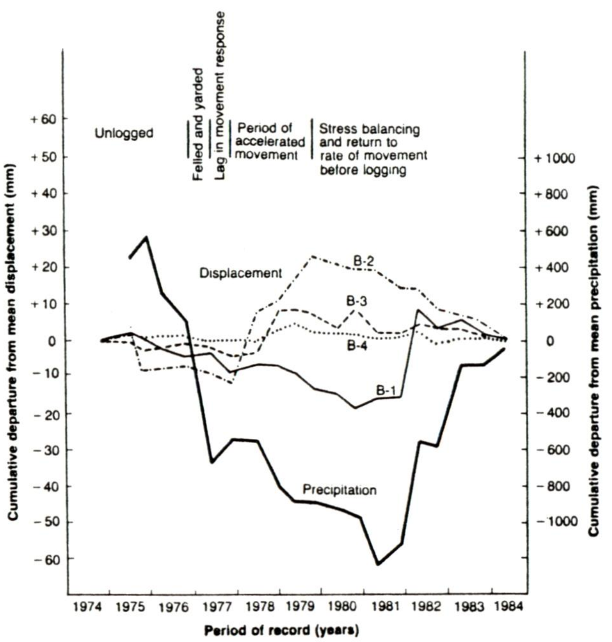

Figure 11. Historical record of seasonal movement and precipitation within the Baker Creek earthflow over the study period, 1974–84.

area, with a climatic regime similar to the west side of the Cascade Range, increased soil water content in excess of 150 mm (6.0 in.) would largely ameliorate the effect of approximately 200 mm (8.0 in.) of declining average annual precipitation over the three-year postlogging period (1977–79). Increases in the quantity of water reaching the soil coupled with the increased amount of water in the soil at the end of the dry season would result in much more rapid saturation at the beginning of the winter rainy season, active pore-water pressure development during winter storms, and maintenance of continuing high soil-water levels through several seasons. Areas of excessive soil water are also created during the yarding process from channels being created in the surface and surface water being redirected into tension cracks and sag-ponds. Where subsurface drainage is restricted because of variations in permeability and structural discontinuities, this increase in subsurface flow may result in differential saturation and increased progressive deformation of local areas on the slope. The net effect is to increase existing creep rates and reactivate quasi-stable slump blocks and earthflow features.

Management Implications

In the Klamath Mountains of southwestern Oregon, clearcutting in active creep, slumping, and earthflow terrain opens up large areas to potential increases in amounts of water in the regolith. Over time, this condition is ameliorated as new vegetation returns, but the immediate effect can be to activate marginally stable terrain. The magnitude of accelerated displacement and the time over which accelerated displacement occurs are difficult to predict for an entire region because they are largely functions of local conditions. At Baker Creek, substantial change in surface displacement of the earthflow occurred approximately one year after timber removal. An average increase of 14 percent in the annual rate of movement occurred at access tube B-2 for the two-year period, 1977–79. It took another year for this increased deformation to be reflected 120 m (393.7 ft) downslope at access tube B-3, where approximately a 7-percent increase in movement rate occurred in 1978. By the winter of 1979, three years after harvesting, all accelerated movement had ceased and movement rates had returned to prelogging levels.

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