U.S. GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR
Open-File Report 2006-1397; Sheet 1 of 2

Introduction

The Scenic Drive landslide in La Honda, San Mateo County, California (Figure 1) began movement during the El Niño winter of 1997-98 (Jayko and others, 1998). Recurrent motion occurred during the mild El Niño winter of 2004-05 (Wells and others, 2005) and again during the winter of 2005-06. This report documents the changing geometry and motion of the Scenic Drive landslide in 2005-2006. The landslide is a complex rotational and translational earth and weak rock slump with localized slow earthflow behavior (Varnes, 1978). Because we have digital mapping in successive years, we can document changes and persistent features that we interpret to reflect underlying structural control of the landslide. We have also compared the displacement history to near-real time rainfall history for the continuously recording La Honda rain gauge LAH (Figure 1) for the period October 2004-November 2006.

Figure 1. Location map of La Honda, California. 2006 landslide in red; 2005 landslide in green.

2005-06 Monitoring Program

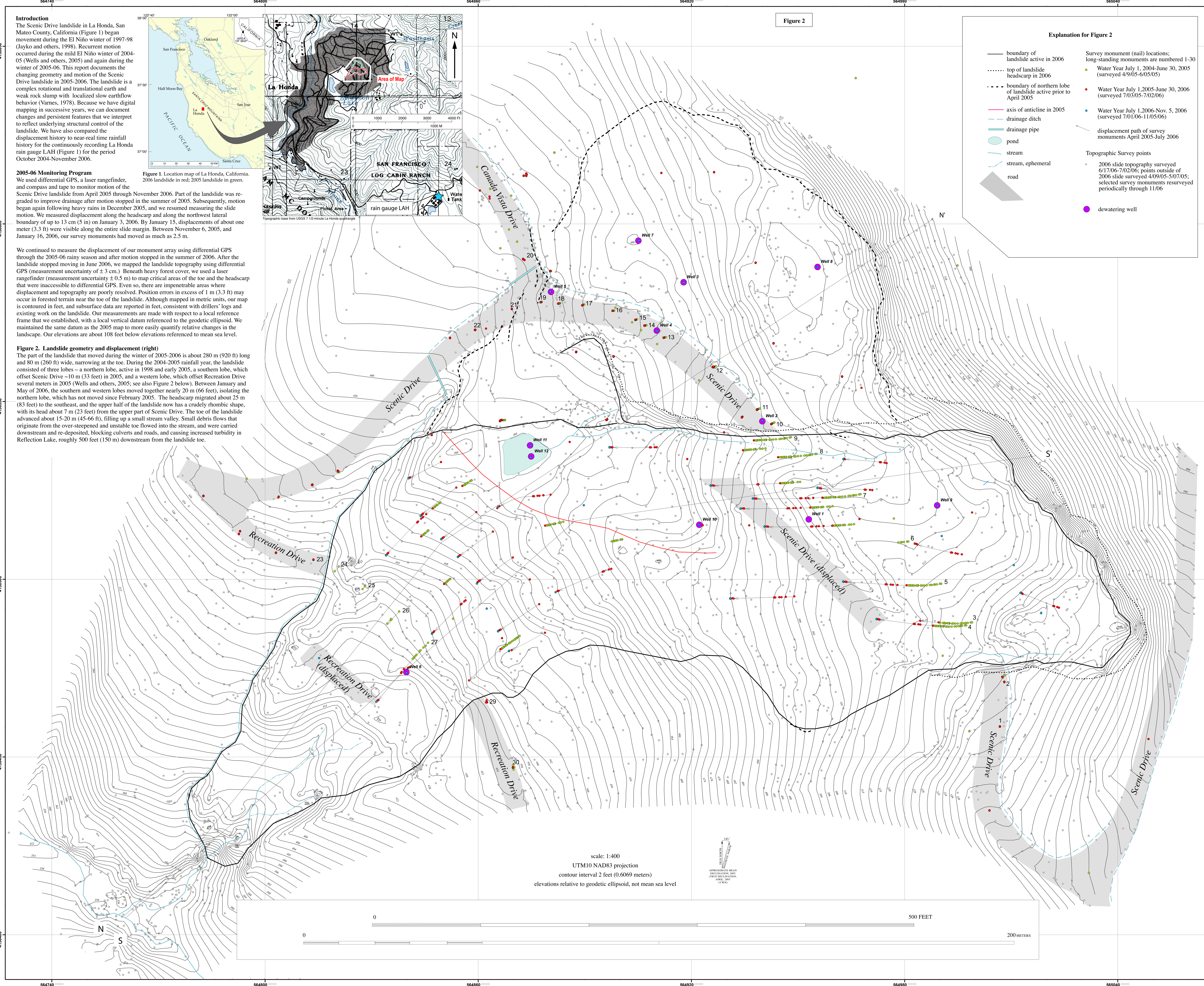
We used differential GPS, a laser rangefinder, and compass and tape to monitor motion of the Scenic Drive landslide from April 2005 through November 2006. Part of the landslide was re-graded to improve drainage after motion stopped in the summer of 2005. Subsequently, motion began again following heavy rains in December 2005, and we resumed measuring the slide motion. We measured displacement along the headscarp and along the northwest lateral boundary of up to 13 cm (5 in) on January 3, 2006. By January 15, displacements of about one meter (3.3 ft) were visible along the entire slide margin. Between November 6, 2005, and January 16, 2006, our survey monuments had moved as much as 2.5 m.

We continued to measure the displacement of our monument array using differential GPS through the 2005-06 rainy season and after motion stopped in the summer of 2006. After the landslide stopped moving in June 2006, we mapped the landslide topography using differential GPS (measurement uncertainty of ± 3 cm.) Beneath heavy forest cover, we used a laser rangefinder (measurement uncertainty ± 0.5 m) to map critical areas of the toe and the headscarp that were inaccessible to differential GPS. Even so, there are impenetrable areas where displacement and topography are poorly resolved. Position errors in excess of 1 m (3.3 ft) may occur in forested terrain near the toe of the landslide. Although mapped in metric units, our map is contoured in feet, and subsurface data are reported in feet, consistent with drillers' logs and existing work on the landslide. Our measurements are made with respect to a local reference frame that we established, with a local vertical datum referenced to the geodetic ellipsoid. We maintained the same datum as the 2005 map to more easily quantify relative changes in the landscape. Our elevations are about 108 feet below elevations referenced to mean sea level.

Figure 2. Landslide geometry and displacement (right)

The part of the landslide that moved during the winter of 2005-2006 is about 280 m (920 ft) long and 80 m (260 ft) wide, narrowing at the toe. During the 2004-2005 rainfall year, the landslide consisted of three lobes – a northern lobe, active in 1998 and early 2005, a southern lobe, which offset Scenic Drive ~10 m (33 feet) in 2005, and a western lobe, which offset Recreation Drive several meters in 2005 (Wells and others, 2005; see also Figure 2 below). Between January and May of 2006, the southern and western lobes moved together nearly 20 m (66 feet), isolating the northern lobe, which has not moved since February 2005. The headscarp migrated about 25 m (83 feet) to the southeast, and the upper half of the landslide now has a crudely rhombic shape, with its head about 7 m (23 feet) from the upper part of Scenic Drive. The toe of the landslide advanced about 15-20 m (45-66 ft), filling up a small stream valley. Small debris flows that originate from the over-steepened and unstable toe flowed into the stream, and were carried downstream and re-deposited, blocking culverts and roads, and causing increased turbidity in Reflection Lake, roughly 500 feet (150 m) downstream from the landslide toe.

Figure 2



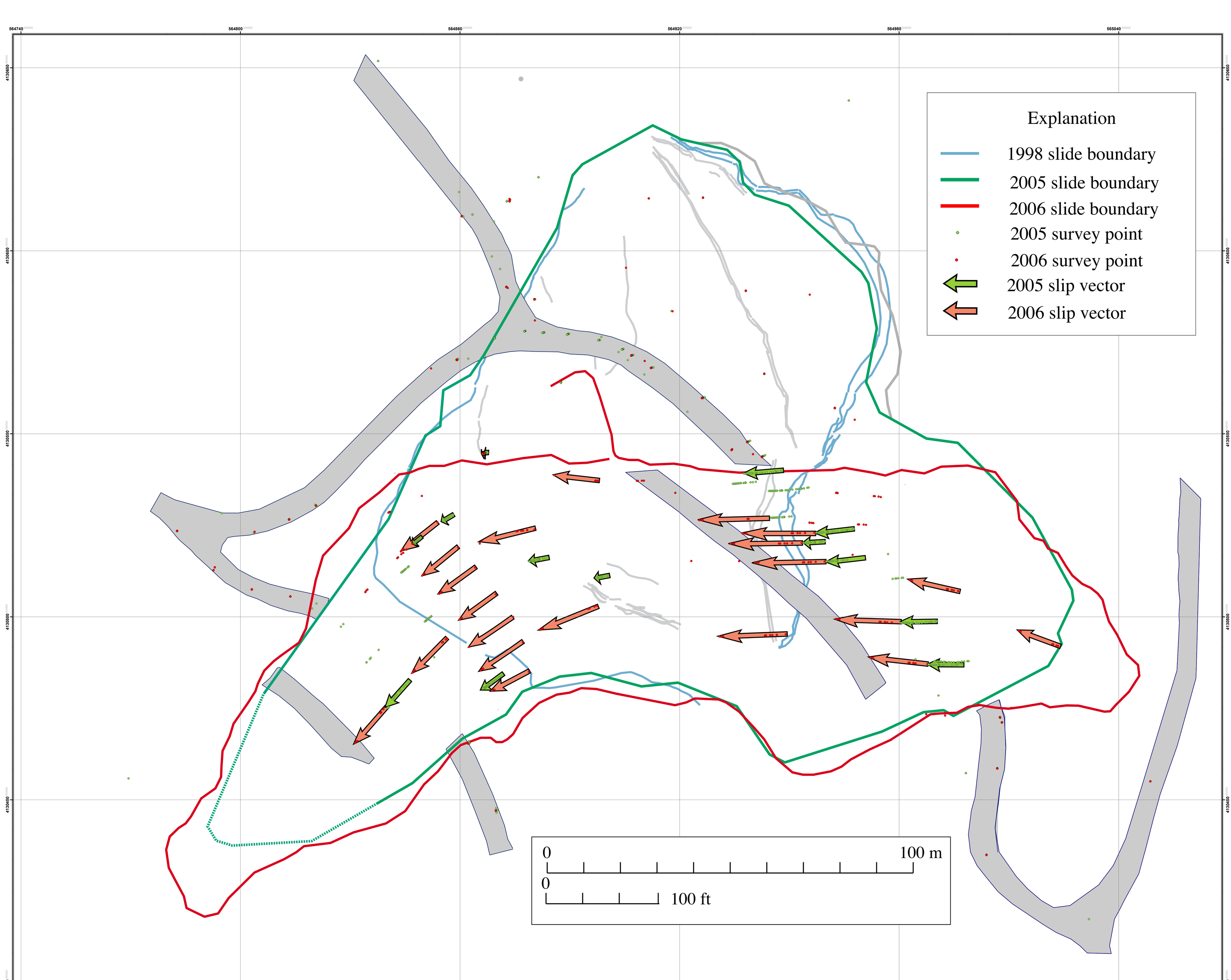


Figure 3. Landslide displacement field

Landslide motion in 2006 was dramatic, with some monuments moving as much as 19.5 m (64 feet) horizontally between January 3 and May 30 (an average of about 0.4 ft/day). Counterclockwise motion of the slide mass is pronounced, with the head moving NW, the main body moving W, and the toe moving SW. The motion suggests structural control of landslide motion, as does the rhombic shape. The NW-trending headscarp is parallel to the regional strike of bedding and faults in the underlying bedrock. A pronounced NW-trending anticlinal ridge within the body of the landslide just west of the ephemeral pond has maintained its position since 1998 (red line, Figure 2), although the landslide mass has moved about 30 m over the ridge. This suggests the landslide is moving over a buried ridge, much like a glacier advances over an icefall. The steep headscarp area of the small 1998 landslide on Recreation drive (Jayko and others, 1998) has also maintained a locally steep profile after tens of meters of slide motion.

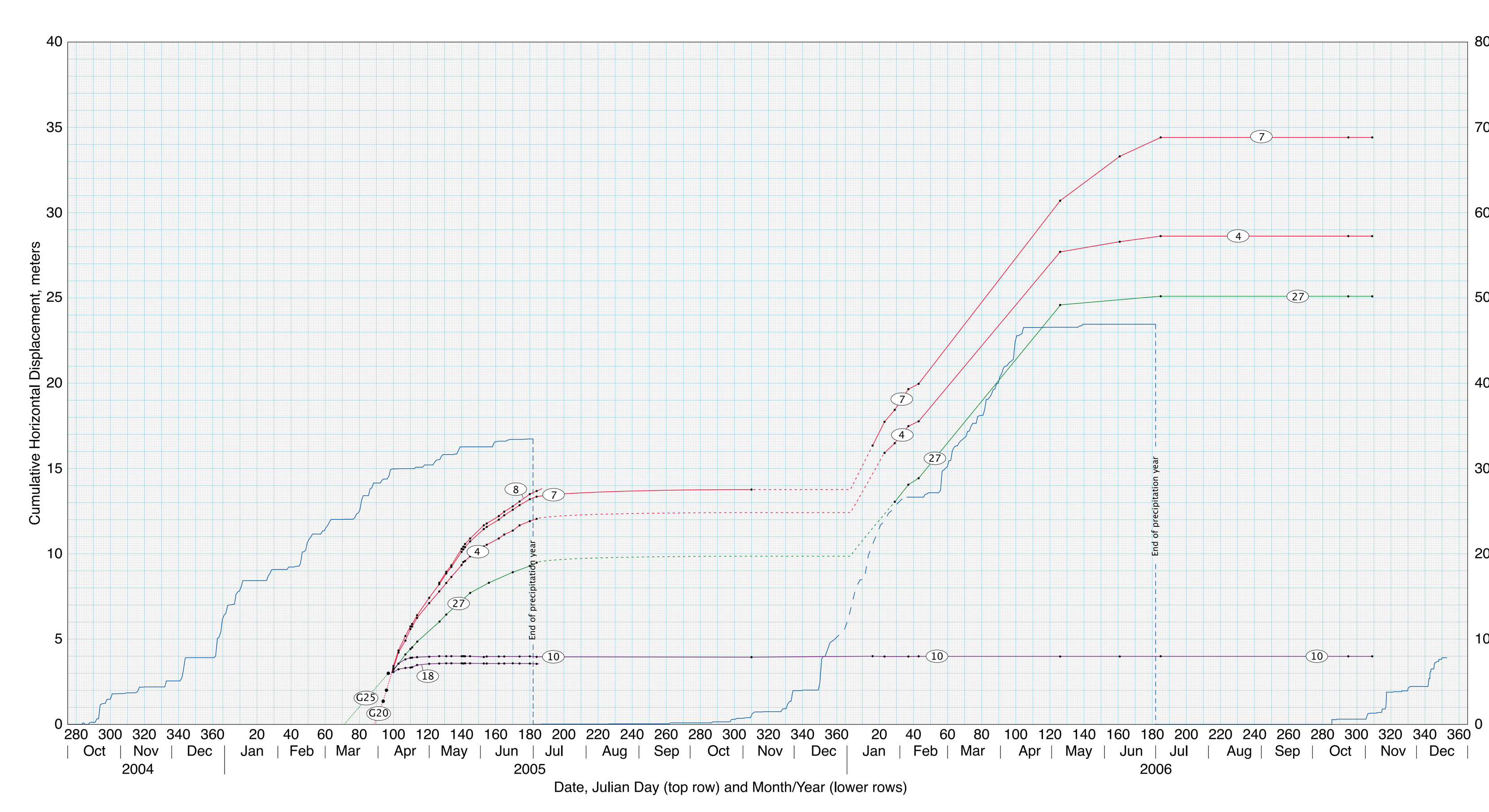


Figure 4. Landslide Motion and Rainfall

A comparison of repeated GPS measurements of selected survey monuments and rain-gauge data shows that horizontal displacement correlates well with rainfall for the period 1 October 2004 to 15 November 2006. Purple, green, and red solid and dotted lines show the motion of survey monuments in different sections of the landslide. Red and green dashed lines represent offset of fences measured using compass and tape. Start of deformation is uncertain for station G 25. Survey monuments 8, 18, and 28 were destroyed in August 2005; survey monument 4 was not measured August 2005 to 23 January 2006. Line for survey monument 7 is dotted between measurements made on 6 November 2005 and January 2006, and reflects our estimate of no displacement after 5 November 2005, until 3 January 2006, when cracks and other indications of renewed motion were first observed.

Water year cumulative rainfall (blue line) is from rain gauge LAH at Log Cabin Camp, about 1.9 km (1.2 mi) southwest of the landslide and shown in Figure 1. Rainfall plot is dashed from 1 January to 3 February 2006 during period when the rain gauge provided incomplete recordings. Rainfall during this gap is approximated using data from a rain gauge at the Christmas Tree Farm on Highway 84, about 3.6 km (2.25 mi) northwest of the landslide (Wieczorek, G.F., Reid, M.E., and Jodicke, Walter, in prep., Daily rainfall and seasonal movement of the Weeks Creek landslide, San Mateo County, California, unpublished manuscript submitted to USGS Digital Data Series). Cumulative rainfall is plotted for Water years July 1, 2004 through June 30, 2005, July 1, 2005 through June 30, 2006, and July 1, 2006 through November 5, 2006.

Landslide motion in 2005 and 2006 was episodic. Motion commonly occured in the latter part of the rainy season after significant rainfall had saturated the ground (see Jayko and others, 1998 for additional discussion). The cumulative effect of above average rainfall in 1997-98, 2004-05, and 2005-06 may have contributed to a rise in the water table and increased potential for landslide motion. Once motion had begun, the landslide appeared to respond to changes in rainfall rate. Dry intervals during the rainy season coincided with slowing of landslide motion in 2005 and 2006, for example during Julian day 30 through 46 in 2006.

Map showing Features and Displacements of the Scenic Drive Landslide, La Honda, California, During the Period March 31, 2005-November 5, 2006

by

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