Characterizing the Spatial Variability of Saturated Hydraulic Conductivity in Historic Landslides to Determine Thresholds for Instability at Sedgwick Ranch, Ca.

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Steepland areas commonly experience storms that can cause sudden shallow landslides, threatening communities. In general, shallow landslides are interrelated with the generation of positive pore-fluid pressures caused by heavy rainfall and hydraulic discontinuities (figure 1). In order to determine the triggering mechanisms and thresholds for landsliding, it is necessary to understand what rainfalls lead to soil water pressures that drive failure. With funding by the Earth Research Institute (ERI) was able to visit three historic landslide sites at Sedgwick Ranch, Ca. that occurred during the El Nino of 1997-98, and used falling head tests in the soil column and bedrock at the base of landslides to estimate near saturated hydraulic conductivity ($K_{sat}$). Soil samples were collected to determine grain size fraction, bulk density, and water retentions curves. It was found that a low conductivity layer is correlative with the failure plane at the soil-bedrock interface and was the primary cause of all three shallow landslides. Infiltration data also indicate that $K_{sat}$ has a strong dependence on soil horizon (figure 2). $K_{sat}$ values at failure planes ranged from 4 to 33 mm/hr, whereas overlying soils of the A and B/Bt horizons often had higher infiltration rates, ranging from 37 to 138 mm/hr and 24 to 127 mm/hr, respectively. The low-conductivity layer at the base of the soil column was hypothesized to be formed by a reduction in grain size and a decrease in pore space due to compaction. However, measurements of grain size distributions and bulk densities do not provide conclusive evidence that this is the case. Infiltration measurements, soil properties, and hill slope parameters collected over the summer provide substantial information to perform a stability analysis. In this analysis, infiltration in the vadose zone will be modeled to estimate the depth of the wetting front and the timing of the pore-fluid pressure response that caused failure. Based on this analysis, a rainfall-rate threshold for debris flow initiation may be estimated in order to forecast landslide-causing storms for this area. This study suggests that the patterns and spatial variability in hydraulic
Conductivities of landslide prone soils are important factors that should be considered when analyzing or predicting slope stability with mathematical modeling.

**Conclusions**

1. Shallow landslides at Sedgwick Ranch, Ca failed from the buildup of pore fluid pressure at the soil-bedrock interface.

2. $K_{sat}$ has a strong dependence on soil horizon.

3. $K_{sat}$ values at failure planes ranged from 4 to 33 mm/hr and suggest that rainfall exceeding these rates need to be sustained for several hours to initiate debris flow activity.

4. Causes for the formation of the failure plane are inconclusive.

**Questions to be answered with future work**

1. Are surface, subsurface, and failure plane infiltration rates constrained well enough to use a simple model for unsaturated zone flow to predict the timing that a temporary perched water table will form?

2. Are other landslide causing characteristics constrained well enough to predict the timing of shallow landsliding?

3. What soil-water pressures are generated at the failure plane during intense rainfall?

![Figure 1. Conceptual figure portraying the failure mechanism for shallow landslides at Sedgwick Reserve. Intense rainfall and a hydraulic discontinuity at the soil-bedrock surface facilitates the formation of a perched water table, which causes a loss in frictional strength and subsequent failure.](image-url)
Figure 2. Histogram showing the distribution and frequency of infiltration measurements in the A horizon, B horizon, and Failure Plane. Note that the failure plane and A horizon measurements show no overlap, and that there are significant differences in kurtosis and skewness between the failure plane, A horizon, and B horizon.