

Ferguson Rock Slide Monitoring Plan

The Ferguson Rock Slide is a reactivation of an existing landslide. It is reasonable to assume that changes in movement rates and deposition of slide material may occur for the near future. This could impact California Highway 140 and the Merced River with significant consequences to the public safety of travelers and local residents. Consequently, it is prudent to institute a monitoring program.

Monitoring Goal 1: *To provide information on movement of the Ferguson Rock Slide so there is sufficient time to initiate appropriate emergency response actions in a safe and orderly manner.*

During the initial response to the rock slide movement in May and June 2006, a disaster response plan was developed (<http://www.fs.fed.us/r5/sierra/conditions/slide/response-plan.pdf>). This response plan coordinates the actions of the Mariposa County Sheriff, Forest Service and other agencies with responsibilities for public safety and emergency response. Specific actions under this response plan will require knowing if the rock slide is about to or is moving rapidly and the nature of any deposition in the river. This information would be needed in “real-time”. In other words, the monitoring would need to display what is happening at the time it happens. This is necessary because there is limited time available for affected publics to be notified and emergency agencies to be deployed in order to limit threats to public safety. Possible actions could include increased on-site observation, evacuating people living near the rock slide and closing downstream water district intakes.

Monitoring Goal 2: *To provide for safe use of California Highway 140 in the vicinity of the Ferguson Rockslide.*

This monitoring goal is necessary because increased rockfall activity below the toe of the Ferguson rockslide could pose a threat to vehicles using the detoured highway section or cause damage to the temporary bridges. Rockfall activity could increase due to precipitation impact to the existing oversteepened slope, freeze-thaw action in the spring or slow advancement of the Ferguson Rockslide. Caltrans and the California Highway Patrol are the agencies with the statutory authority to decide that road use restrictions or closure should be imposed. Data generated from the overall monitoring program to achieve monitoring goal #1 will be helpful to these agencies in fulfilling monitoring goal #2. Caltrans operates specific monitoring sensors to generate data for achieving monitoring goal #2.

Monitoring Program

There are a number of basic assumptions for ensuring that the monitoring carried out at the Ferguson Rock Slide achieves the monitoring goal. Some of these assumptions are general in nature:

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- To the extent possible, monitoring must be in real time. Sensors must provide data that does not require interpretation that adds significant time between collection and availability to users.
- Real-time monitoring data must be transmitted from the site so that it can be viewed remotely at designated locations.
- Data collected should support assessment of whether there is increasing or decreasing threat from the rock slide so that appropriate levels of response can be initiated.
- It is desirable to have some redundancy in the collection of critical data to avoid having a system failure that creates a “blackout” of information.
- Real-time monitoring data must be collected continuously 24-hours a day/7 days a week. However, other monitoring device intervals will be dependant on sensors and how they are arrayed.
- It is anticipated that monitoring will be necessary through the next two winters (rainy periods), i.e., winter 2006-2007 and winter 2007-2008.

Monitoring Changes in Movement and Impact to Flow in the Merced River

GPS Units: The primary device for monitoring movement in real-time will be three (3) GPS units with individual housings. Due to their appearance, they are often referred to as “spider” units. The USGS has developed and tested these devices for comparable monitoring needs at other locations. Each GPS unit is placed on a discrete block within the rock slide mass based on geologic evaluation of the most critical ones to future movement. As of October 2006, two units were sited near the lower end of the rockslide mass and the third neared the headscarp. Power to the units is supplied by batteries. A fourth GPS base unit located off the rock slide near Savage’s Trading Post provides a reference for determining movement rate and direction for the three on-site units. The reference GPS unit is solar powered.

Geophones: A secondary component placed in the same individual housing is a geophone. These devices are sensitive to high-frequency ground vibrations. Different frequency bands can be sampled as frequently as every second. Increasing or rapid movement of the landslide would generate significant ground vibration that would be detected. This provides an additional redundant means for detecting rapid movement on the rock slide. One geophone is co-located with each of the three “spider” units on the Ferguson Rockslide.

The GPS devices and geophones communicate via telemetry through radio and serial to Ethernet connections at the Yosemite National Park facilities in El Portal. The signal is relayed through a repeater sited on Trumbull Peak. The data is automatically processed by a USGS computer to produce graphs from these sensors. GPS solutions will be computed at specified intervals, typically every 30 or 60 minutes. Threshold values will be set for the different amplitudes on the geophones. When these values are exceeded, an alert transmitted to indicate that significant movement is taking place. All processed information is uploaded to a USGS web server for remote access through a password-protected system.

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Water Level Monitors: With assistance from the California Department of Water Resources (DWR), two water level recorders were installed in the Merced River upstream and downstream from the immediate vicinity of the Ferguson Rock Slide. One water level station is located by the south abutment of the downstream temporary bridge for California Highway 140. The other is at the south abutment of the upstream temporary bridge. These devices are designed to provide continuous information on the height of water above a pressure sensor by bubbling gas through a column of water. However, the devices do not record discharge of the river at those locations. The relative water levels between these locations should rise and fall in a similar pattern. Any rapid increase in water level at the upstream site coupled with decrease at the downstream site will indicate a restriction of flow or blockage by material representing significant, rapid deposition due to movement of the Ferguson Rockslide.

The two water level recorders are coupled with data loggers that transmit via the GOES satellite for downloading to a link with the DWR. The California Department of Water Resources will host the reported data on its internet site, California Data Exchange Center (CDEC).

Seismograph: While current movement of the Ferguson Rock Slide was triggered by recent precipitation levels, ground shaking from earthquakes as well as precipitation may affect future movement. An existing network of U.S. Geological Survey seismographs exist and are accessible via the Internet for California-Nevada seismic activity. However, the nearest station in this network is at Mariposa, CA. This limits the ability to reliably estimate ground motion from regional earthquakes at the Ferguson Rock Slide. A seismograph is being installed at the Yosemite National Park administrative facility near El Portal, CA. This location is dictated by availability of telephone lines for transmitting the recorded ground motion to the U.S. Geological Survey and an adequate location for supporting the instrument. This additional sensor will enhance resolution for any shake maps generated for nearby seismic events. Shake maps are currently available on the internet through <http://www.cisn.org/shakemap.html>. This information can also be reached through the U.S. Geological Survey website <http://www.usgs.gov>. Individuals or organization can subscribe at no cost to automatically receive shake maps for earthquakes as they occur in California.

Field Observers: Initial monitoring of the Ferguson Rock Slide was carried out by field observers on the road near the rock slide and at an observation post across the Merced River. Observation was limited to the daylight hours. From the observer posts, the toe of the rock slide and the apron of rock debris extending into the river could be seen. This was largely a qualitative monitoring that the rock slide was moving faster or slower based on visual observations of the feature and the number of rockfall events hour. These observers were withdrawn once the rockfall activity dramatically diminished. However, it is a component that could be re-instituted during periods of increased movement detected by other monitoring measures.

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Additionally, Caltrans contracted for a geologist to collect observational data for 8-hour periods during construction of the temporary detour. This was one of the monitoring components for worker safety during construction. It included estimating the volume of rockfall material moved down on the rocky deposit each day as well as the frequency of rockfall events. Photographs were taken from a designated observation point to provide a visual record of change in the appearance of the rockfall deposit in relation to the river, bridges, and Incline Road. Caltrans will have this record to compare to any future observation sets generated due to changes in the activity of the Ferguson Rockslide.

Caltrans-operated Slope Stability Radar: This is a real-time monitoring device that uses repetitive radar measurements from a fixed point to determine movement on the target slope. Over a 10-minute period, the mobile radar unit scans the toe of the rock slide and the apron of debris extending down the face of the slope and into the Merced River. With a precision of millimeters, it compares repetitive sweeps across this area to detect rates of movement. The results of successive sweeps can be displayed as different colored areas to distinguish slope areas that are now closer or farther from the unit in a real time display. This represents where material is being displaced or accumulating from the toe of the Ferguson Rockslide and on the apron of rock debris extending into the river. It is also possible to set threshold values for movement that triggers an automatic alert.

Initially the slope stability radar (SSR) was placed across the Merced River from the rock fall deposit as a component of the monitoring program to protect Caltrans and its contractor during construction of the California Highway 140 detour. As part of Caltrans traffic safety monitoring for the detoured section of California Highway 140, the SSR unit was moved to a platform set in the hillside upslope from the road in October 2006.

Caltrans-surveyed Monuments: Nearly twenty-five monuments consisting of Carsonite posts or similar durable material have been placed at various points on the Ferguson Rockslide by Caltrans geologists. A permanent survey station is established on the opposite slope from the rockslide at a point upslope from the temporary California Highway 140 bypass. Caltrans surveyors used traditional survey methods to establish the initial position of each monument (survey point). The monuments are surveyed on a monthly basis to determine if they have moved relative to their initial position. The direction and monthly rate of movement can be determined for any point where a change is measured. While not providing real-time monitoring data, the surveyed monument data can be compared to the GPS unit data near them. This increases the reliability of estimations for how extensive movement detected in real-time is within any nearby part of the rockslide.

Using Monitoring Results to Achieve the Monitoring Goal

The many components of the monitoring program provide a variety of data on the activity state of the Ferguson Rock Slide and the flow of the Merced River. This information needs to be put in a framework to ensure meeting the first goal of the monitoring program:

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“To provide information on movement of the Ferguson Rock Slide so there is sufficient time to initiate appropriate emergency response actions in a safe and orderly manner.”

| Table 1. Summary of Ferguson Rockslide Alert Levels | | |
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| Alert Level | Activity | Response |
| Normal | Rockslide is dormant with no movement or only creeping movement in some parts. Rockfall occurrence has ceased or only occasionally occurs with days or weeks between events. | At least once-a-day checking of data to verify activity state is unchanged. Sensor data continues to be collected at baseline rates. |
| Advisory | Rockslide begins moving or existing creeping movement begins to accelerate. Rockfall activity becomes a daily occurrence. | Checking of real-time data is carried out by key agencies on a six hour interval. Daily evaluation of data by specialists is conducted. Field observations are taken every few days. |
| Watch | Rockslide exhibits heightened activity. Movement accelerates and/or is widespread within the rockslide mass. Rockfall activity increases to hourly occurrences every day. Accumulation of rock in the river is affecting flows. | Frequency of measurement on some sensors is increased. Checking real-time data and evaluation of data by specialists is done hourly. Field observers deployed to site. Key agencies put resources needed for response actions on stand by. |
| Warning | Significant downslope movement of all or parts of the rockslide are imminent, underway, or suspected. Rockfall activity is multiple times per hour. Significant restriction of water flow or actual blockage on the Merced River has occurred. | Key agencies initiate their response actions identified in the emergency response plan. Evacuations or other actions to protect public safety are taken. Other agency resources that may be needed are requested. |

Four alert levels are defined in Table 1 to communicate changes detected by the monitoring devices that would affect emergency response actions:

- The general state of the slide movement and any associated rockfall activity.
- The likely responses to a change in activity level.

Just as the fire danger rating uses specific wording to quickly convey the level of danger, this system uses words enhanced by color-coding to represent different alert levels. Changes in alert levels will require considerable interpretation by specialists during the coming year. The specific values obtained from various monitoring sensors that would be

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associated with changes in alert levels are not currently known. These values will need to be calibrated with actual observations during the coming rainy season. This will permit a more precise definition of what changes in the Ferguson Rockslide are associated with the different alert levels to be used during the second rainy season (winter 2007/2008).

It is expected that rockslide activity as defined by the data from the monitoring network components (GPS, geophones, etc.) will vary from week to week and month to month. This will likely respond to changing ground water conditions within the Ferguson Rock Slide over future dry and rainy seasons. The current dry season has already demonstrated a decrease in the landslide activity, particularly in rockfall occurrence per hour. This decreased activity state permit the safe construction of the two temporary bridges and improvements to the existing Incline Road necessary for detouring traffic on California Highway 140. It has also enabled traffic to be resumed on this on-way section controlled by traffic lights that alternate traffic flow every fifteen minutes. This near cessation of movement by the Ferguson Rockslide and dramatically decreased rockfall activity below the rockslide toe enabled safe installation of survey targets and GPS units for monitoring any future changes. As of mid-November 2006, measurements on existing monitors indicate the Ferguson rockslide is moving only in some parts and days or weeks pass between rockfall events. The appropriate alert level for these conditions would be "Normal" and color-coded green.

The system of alert levels should be reviewed every six months to ensure that it is communicating the necessary information to the response agencies and providing the guidance to emergency planning that is intended. This review will also provide an opportunity to evaluate whether the monitoring data parameters provisionally used to define different hazard ratings should be adjusted to improve this communication.

It is expected that after the second rainy season (winter 2007/2008) that a full scale review of the monitoring program would be carried out. This would include a decision on whether to continue the monitoring as it currently exists, scale the monitoring program back to only selected components or specific periods of likely vulnerability or dismantling the monitoring network because it is no longer needed.

Monitoring-related Studies

While catastrophic movement that would dam the Merced River is a low likelihood event, its consequences are very important for emergency response planning. The U.S. Geological Survey will conduct simulations to predict the runout and deposition of a potential catastrophic movement of the Ferguson Rock Slide. An improved understanding of a potential landslide dam through this modeling is made possible by recent, more detailed mapping of the rock slide and adjacent river canyon.

Model results will improve our estimate of the size and configuration of a landslide dam resulting from movement of the Ferguson Rock Slide. The initial estimation of upstream flooding and, later, downstream flood flows previously modeled by the U.S. Army Corps of Engineers would be re-evaluated to either confirm the earlier results or revise them.

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Such a re-evaluation will improve the information needed for any evacuation plan and related estimates of available time for undertaking emergency response actions.