SIX RIVERS NATIONAL FOREST

Burned Area Emergency Response

MAD RIVER COMPLEX
GEOLOGIC RISK AND HAZARD ASSESSMENT

Prepared by: Fred Levitan, BAER Team Geologist
October 9, 2015

OBJECTIVES

An interdisciplinary assessment of post-fire conditions was conducted within the National Forest areas of the Mad River and Humboldt Lightning Complex fires, with the objective of: 1) identifying post-fire changed watershed conditions within the burned area; 2) identifying key values at risk on National Forest System lands: 3) assessing any threats resulting from direct and indirect effects of changed conditions that present an unacceptable risk to those values; and 4) prescribing treatments where appropriate to reduce the risk to those key values to acceptable levels.

This report summarizes the findings of a geologic investigation conducted as part of this Burned Area Emergency Response (BAER) assessment, which consisted of field examination of fire effects to sensitive landforms, as well as modeling and analysis of geologic processes with the potential to respond to fire effects and impact values at risk. The assessment was conducted over the period of August 29 through September 6, 2015, and included ground-based investigation, aerial reconnaissance, and GIS modeling of landscape, geologic and climatic parameters to provide estimates of geologic instability and potential effects to human life, safety, property, and natural and cultural resources.

BURNED AREA CHARACTERIZATION

The fires of the Mad River and Humboldt Lightning Complexes were caused by lightning storms on July 30-31, 2015, and burned until contained in late August and early September, 2015. In general, the most intense burning occurred during the first few days of the fires, largely on ridgetops, with lower fire intensities occurring as the fires spread downslope, with some exceptions of later active burning periods. Fire spread from the crest of South Fork Mountain (Pickett Fire), Mad River Ridge (Gobbler Fire), and the Lassics (Lassic Fire) in the Mad River Complex Fires, as well as from the Pine Mountain (Pine Fire) and Dobbyn Creek (Bluford Fire) areas in the Humboldt Lightning Complex. The fires as they spread affected watersheds including the South Fork Trinity River, the Mad River and Ruth Lake, and the Van Duzen River and many tributary streams. The Pickett Fire burned portions of both the Six Rivers and Shasta-Trinity National Forests and adjacent private lands; the other fires in the complexes were restricted to the Six Rivers National Forest and adjacent private lands.

The burned area includes bedrock of a variety of lithologies of the Coast Range geologic and geomorphic province of northern California, dominantly Franciscan assemblage rocks west of the crest of South Fork Mountain, and the South Fork Mountain Schist on its eastern slope. All of these formations are susceptible to slope instability, with a variety of dormant and active deep-seated and shallow landslide features present. The Franciscan formation is pervasively sheared and stratigraphically incoherent; with basic lithologies of sandstone and argillaceous materials predominating. The South Fork Mountain Schist is highly foliated quartz mica schist, with structure dipping parallel to the eastern slope of the mountain, supporting ubiquitous deep-seated landslide complexes and perched groundwater. The schist is the tectonic sole of the Farallon Plate that was subducted and sutured to North America in an accretionary event that began in the late Jurassic; the Franciscan represents the subduction complex associated with that event

(Dumitru et al, 2010). The Lassics area is a unique geologic area representing an outlier of the Coast Range ophiolite associated with the Great Valley Formation, the bulk of which is located in the easternmost Coast Ranges and westernmost Sacramento Valley (McLaughlin et al, 2000). The Lassics contain numerous outcrops of ultramafic rocks of the ophiolite sequence, and support unique and rare plant communities adapted to harsh serpentine environments.

The unstable geomorphology of the area is susceptible to accelerated slope instability, erosion and sediment delivery as a consequence of fire effects to soil and vegetation. Possible mechanisms of increased erosion and landsliding include: 1) increased surface erosion and delivery of sediment as well as increased channel scour due to increased post-fire peak flows from burned watersheds; 2) increased probability of shallow debris sliding along channels and inner gorges where toe slopes are susceptible to erosion from higher flood flows; 3) channelized debris flows from burned areas with loss of soil cover and structure, reduced root strength and increased sediment delivery to channels; and 4) reactivation of deep-seated landslides, potentially related to loss of evapotranspiration and associated elevated groundwater following tree mortality from fire (Mikulovsky et al, 2012; Levitan 2014). Landsliding and increased sediment delivery can present direct threats to stationary values at risk from impact and destabilization, as well as indirect effects to values such as water quality for aquatic organisms, drinking water, and other defined beneficial uses.

VALUES AT RISK AND THREATS

During the BAER assessment, a number of critical values at risk from a variety of post-fire effects were identified. The values identified and the additional analysis performed to identify the level of threat, if any, and any proposed treatments focused on the Mad River Complex Fires - critical BAER values were negligible for the Pine and Bluford Fires and no further assessment was done for those fires.

The following table from the Forest Service Manual defines the critical BAER values for assessment:

CRITICAL VALUES (FSM 2523.1, exhibit 1)
HUMAN LIFE AND SAFETY
Human life and safety on National Forest System (NFS) lands.
PROPERTY
Buildings, water systems, utility systems, road and trail prisms, dams, wells or other significant investments on NFS lands.
NATURAL RESOURCES
Water used for municipal, domestic, hydropower, or agricultural supply or waters with special Federal or State designations on NFS lands.
Soil productivity and hydrologic function on NFS lands.
Critical habitat or suitable occupied habitat for federally listed threatened or endangered terrestrial, aquatic animal, or plant species on NFS lands.
Native or naturalized communities on NFS lands where invasive species or noxious

weeds are absent or present in only minor amounts.
CULTURAL AND HERITAGE RESOURCES
Cultural resources which are listed on or potentially eligible for the National Register of Historic Places, Traditional Cultural Properties, or Indian Sacred Sites on NFS lands.

A number of locations and resources were identified as potentially susceptible to impacts from geologic processes that might be accelerated post-fire. These are discussed in detail in the Burned Area Report (2500-8) and in the various resource specialist reports. A synopsis of some of the major values at risk (VAR) is presented below, and discussed with respect to the potential for geologic impacts in the following sections. Non-Forest resources where the burden for hazard mitigation is on State, municipal, private or other Federal entities are marked with an asterisk (*) - these are not considered critical BAER values. Surface erosion, flooding, loss of control of water and sediment delivery are addressed separately in the soils, hydrology and other resource reports.

VAR	Location and Description	Nature of Geologic Threat
Human Life and Safety	Visitors and residents at the Forest Glen rental cabin, Fir Cove & Bailey Canyon Campgrounds. Residences and occupied structures in Choptoy Creek, Pickett Creek, Sheriff's Cove and Rutledge Opening.* Travelers on roads and at stream crossings downstream of high hazard drainages.	Debris flow
	Highway 36 east of South Fork Mountain summit and west of Forest Glen*.	Rockfall
Property	Ruth Reservoir - Humboldt Bay Municipal Water District (HBMWD) facility and public water supply*.	Sedimentation and reservoir fill from debris flows
	Forest roads and bridges; culverts and other road/stream crossings. Specified in Engineering report and 2500-8.	Debris flow
	Fir and Bailey Cove campground facilities and water supplies.	Debris flow
	Forest Glen rental cabin.	Debris flow
	State and County roads and bridges*.	Debris flow
	Ruth Lake hydropower facility - HBMWD	Sedimentation
	Non-FS campgrounds, businesses, homes, and water systems (Sheriff's Cove, Journey's End, Ruth Lake CSD, Rutledge Opening and other private residences)	Debris flow
Natural	Water quality	Debris flow &

Resources		sedimentation
	Aquatic habitat	Debris flow & sedimentation

** = Non-FS values - Responsibility for emergency protection falls to the landowner or administrating agency.*

RESOURCE ASSESSMENT

The threat from accelerated geologic processes was evaluated using a number of qualitative and quantitative methods. Data sources include the Six Rivers and Shasta-Trinity National Forest geology, geomorphology and active landslide inventories, and other geographic, soil property and climatic layers used as model inputs, as well as the soil burn severity classification developed by the BAER team. A distributed debris flow model developed (Cannon et al 2010) and run by the USGS was used to help evaluate the risk of post-fire debris flows. The model, as well as other results of GIS analysis, is described below. Finally, field observations were used to validate the model results as well as define some risks that were not explicitly addressed by modeling.

As described above, hillslope instability is widespread throughout the burned area, with styles ranging from deep-seated landslides with chronic or episodic movement, to shallow rapid failures such as inner gorge and toe zones debris sliding, and debris flows and debris torrents released in response to high intensity or long duration precipitation events. Most slope failures initiate or accelerate during prolonged winter wet periods, although occasional high intensity convective storms also can also trigger landslides.

Deep-seated landslides, particularly earthflows, are a dominant landslide type on the Franciscan formation areas west of the crest of South Fork Mountain. They are also common on the eastern slopes of the mountain in the South Fork Mountain Schist, although the failure style there tends more to block slides and other deep-seated complexes rather than earthflows. The toe zones of all of these slides tend to be the most active portion of the features, although slow or incremental movement often occupies significant portions of hillslopes, and head scarp areas can be actively unstable, with headward extension of landslides into previously stable ground a possible consequence of fire effects. Toe zones are often susceptible to debris slides or debris flows, especially where oversteepened by road cuts or stream channels. Where deep-seated landslides have burned, changes in soil properties, root strength and groundwater elevation can initiate or reactivate movement. Significant portions of the burned area occupy landslide terrain, and increased slope instability is expected in many areas of high and moderate burn severity. Landforms of particular concern are toe zones of deep-seated landslides and inner gorges. Where tributary inner gorges exit from headwall areas burned at high severity, or cross mid- to lower slope areas with active toe zones, debris flow processes can be accelerated. Some areas of concern based on geomorphology are described below in addition to the results of the debris flow modeling.

The USGS debris flow model was run by the USGS Landslide Hazards Program after they were provided with a final soil burn severity layer derived from the remotely sensed burned area reflectance classification (BARC) data. It is calibrated and best applied in the intermountain West. Results from the very different climate and vegetation of northern California may not

represent debris flow probabilities as accurately as for the calibration area. In particular, the following conditions differ markedly from the model design conditions:

- The model design precipitation event is a one-hour convective storm - these types of events are less typical for this region compared to the intermountain area. Longer duration storms of lower intensity generate most debris flows in northern California, often from road/stream crossings or timber harvest units.

- The model does not address the loss of root strength or reduced evapotranspiration from tree mortality.

- It does not address flash flooding (increased peak flows) or predict debris flow runout.

- Large woody debris, which creates channel roughness and may impede debris flows of moderate energy, is much more common in northern California channels as compared to the intermountain West.

Despite these caveats, the model is used in this assessment to describe the risk of debris flow generation, bearing in mind the factors that may affect model interpretations. A design storm of 25-year magnitude is used for this analysis - this exceeds the recurrence interval of the typical BAER design storm of ten years or less, but may help balance some of the mitigating factors listed above. It is also consistent with model results displayed by USGS for a nearby 2015 fire - the Saddle Fire north of Hyampom.

The model outputs include probabilities, volume estimates, and a combined hazard rating for defined drainage basins and for individual channel segments. For this analysis, the basin probabilities for debris flow occurrence are examined, and the risk categories, based on the model output probabilities, are defined according to the BAER risk assessment matrix categories for probability of damage or loss (see table below in the Assessment of Values at Risk).

Initial observations in the field and from aerial reconnaissance indicated a number of drainages and hillslopes that appeared to have enhanced risk of slope failure and debris flow generation post-fire. Descriptions of the sites, field and model results, and conclusions regarding the level of risk are listed below. The model results are displayed in Plate 1 (filed as a separate document).

Glen Creek - The headwaters, immediately downslope on the east side of Pickett Peak, burned at high severity (Photo 1). Landslide inventory indicates a debris torrent gutted the channel in the 1964 flood. There is debris flow evidence in the upper channel, including accumulated colluvial deposits, and oriented schist boulders from a past (prehistoric?) event (Photo 2). The channel downslope of Road 1S04 is densely vegetated with abundant large woody debris present, which is likely to impede any but a very high energy flow. Debris flow deposits are evident in the channel banks near the mouth at Forest Glen. The debris flow model describes an unlikely probability of a debris flow for the main channel of Glen Creek at less than 1%. Based on field evidence, this estimate may be low. **Conclusion:** The probability of debris flow remains **Unlikely**, but may exceed the model prediction.

Fir Cove - The model produces the most elevated probability of debris flow occurrence in this basin, at 19.4%. This is a short, straight drainage with a high proportion of moderate and some high burn severity, so this is plausible. **Conclusion:** Debris flow probability is **Possible**.

Bailey Canyon - The model indicates that debris flow generation is **Unlikely,** at 3.5% probability. Based on the simple basin morphometry and relative absence of high and moderate burn severity, this conclusion is supported. **Conclusion:** Debris flow probability is **Unlikely**.

Choptoy Creek - Unlikely at 2.74%. Despite considerable high burn severity and **Possible** to **Likely** debris flow predictions for upper basin channels, gentler and more vegetated lower slopes should reduce energy and prevent delivery to the basin outlet. **Conclusion:** Debris flow probability is at the basin outlet is **Unlikely**, but debris flows that affect upper basin channels are **Possible** to **Likely**.

Pickett Creek - Unlikely at 3.12%. Similar to Choptoy Creek. A debris flow may originate high in the watershed, but is not likely to reach the basin outlet. However, upper basin channels are rated as **Possible** to **Likely**, and debris flows may affect the main channel in the basin as far downslope as Road 2S27. **Conclusion:** Debris flow probability is at the basin outlet is **Unlikely**, but debris flows that affect upper basin channels are **Possible** to **Likely**.

Sheriff's Cove - Possible at 13.9%. Vegetation may impede channelized flows, but the model indicates channel debris flow possibilities as far downstream as Ruth Lake. **Conclusion:** Debris flow probability is at the basin outlet is **Possible.**

Journey's End - The basin probability of debris flow is rated as **Unlikely**, but near the high end of that range at 8.04%. The unnamed drainage above the resort accumulates flow from a number of headwater channels in high and moderate burn severity areas. The model indicates **Possible** debris flows in the channels in the immediate vicinity of the resort. Considerable length of very low to unburned area in and near the lower channel may help reduce this chance. **Conclusion:** Debris flow probability at the basin outlet is **Possible.**

Rutledge Opening - Unlikely at 2.15%. Black Lassic Creek flows near the community in Rutledge Opening, and there is at least one structure very near the channel. Gentler unburned slopes in the lower watershed should impede debris flow deposition at the basin outlet where the structures are located. However, some upper basin channels in steep headwater areas that burned at high severity do have ratings of **Possible** to **Likely**. **Conclusion:** Debris flow probability at the basin outlet is **Unlikely**, but debris flows that affect upper basin channels are **Possible** to **Likely**.

Devil's Backbone - Waggit Spring - Unlikely at 6.75%. While rated unlikely for debris flows at a basin scale, this watershed on the west slope of Mad River Ridge (an unnamed stream tributary to the Van Duzen River) has very steep headwater slopes with convergent ephemeral drainages that resemble the classic model of colluviation (dry ravel) and subsequent debris flows from sediment-laden channels (see Photo 3). The headwater channels and lower-gradient mainstem channel in this watershed are rated as **Possible** debris flow channels by the model, and this assessment appears justified by field evidence. Any debris flow would probably deposit in the lower-gradient mainstem channel - there is a large aggraded area at the confluence of two tributaries upstream of Van Duzen Road and the river that is likely the result of past floods and

debris flows that follow this pattern. **Conclusion:** Debris flow probability at the basin outlet is **Unlikely**, but debris flows that affect upper basin channels are **Possible** to **Likely**.

Mule Slide - Road 1S11 - West Fork Van Duzen River - Unlikely to Possible - Two basins in West Fork Van Duzen River HUC7 watershed on the east slope of the Lassics exhibit high slope instability. The northern basin (Freezeout Creek) contains a large landslide named the Mule Slide, which is a naturally occurring debris slide basin in highly sheared meta-argillite of the Franciscan Yolla Bolly terrane (Photo 4). Upper margins of this slide in the right lateral portions of the scarp, south of the junction of 1S07 and 1S11, burned at high severity, and a series of nested scarps that experienced high tree mortality may reactivate as a consequence of fire effects (Photo 5). The basin containing the Mule Slide was rated **Unlikely** to experience debris flows, although a number of headwater channels, including one draining the slide, were rated as **Possible to Likely** to experience debris flows. The drainage basin south of Mule Ridge and Road 1S11 (W. Fork Van Duzen) was given a **Possible** rating, based on more area of high burn severity. **Conclusion:** Debris flow probability at the basin outlet is **Unlikely** to **Possible**, and debris flows that affect upper basin channels are **Possible** to **Likely**. There is an increased risk of headward extension of the Mule Slide on its right-lateral scarp from fire effects.

Highway 36 - Not assessed in the model. Rockfall onto the road will probably continue at an accelerated rate as reduced vegetation, root strength and soil cover allow material to fall or roll downslope toward the steep slopes above the highway in the Granite Canyon area.

ASSESSMENT OF VALUES AT RISK

This assessment is based on the BAER risk assessment matrix as defined in the Forest Service Manual:

2523.1 - Exhibit 02

BAER Risk Assessment

Probability of Damage or Loss	Magnitude of Consequences		
	Major	Moderate	Minor
	RISK		
Very Likely	**Very High**	**Very High**	**Low**
Likely	**Very High**	**High**	**Low**
Possible	**High**	**Intermediate**	**Low**
Unlikely	**Intermediate**	**Low**	**Very Low**

Probability of Damage or Loss: The following descriptions provide a framework to estimate the relative probability that damage or loss would occur within 1 to 3 years (depending on the resource):

- Very likely. Nearly certain occurrence (90% - 100%))
- Likely. Likely occurrence (50% - 89%)

- Possible. Possible occurrence (10% - 49%)
- Unlikely. Unlikely occurrence (0% - 9%)

Magnitude of Consequences:

- Major. Loss of life or injury to humans; substantial property damage; irreversible damage to critical natural or cultural resources.
- Moderate. Injury or illness to humans; moderate property damage; damage to critical natural or cultural resources resulting in considerable or long term effects.
- Minor. Property damage is limited in economic value and/or to few investments; damage to critical natural or cultural resources resulting in minimal, recoverable or localized effects.

Based on the probabilities described above, the following risk categories are assigned based on the magnitude of consequences as defined for the risk assessment matrix, with description of the risk-enhancing or mitigating factors:

Site	Probability	Consequences	Risk
Glen Creek	***Unlikely***	***Moderate***	***Low***

The cabin is not occupied during the winter season when a debris flow is most likely to occur. The bridge over Glen Creek should be reinforced where the abutment riprap is failing. The domestic waterline under the bridge may be affected, but can be repaired. Therefore the consequences are likely to be moderate, and the risk is low.

Fir Cove	***Possible***	***Moderate to Major***	***Intermediate to High***

The campground is not open during the winter season when a debris flow is most likely to occur. There may be damage from overbank flows and sediment to infrastructure, but it can be repaired. There is still an intermediate to high risk to human life and safety if a storm event were to occur, most likely in the spring or late summer when the campground may be open. Proposed treatments include shoulder season closures based on forecasted weather.

Bailey Canyon	***Unlikely***	***Moderate to Major***	***Low to Intermediate***

The campground is not open during the winter season when a debris flow is most likely to occur. There is less debris flow hazard here compared to Fir Cove based on watershed characteristics and proportion of watershed area burned at high or moderate burn severity. In the unlikely event of a debris flow, there may be damage from overbank flows and sediment to infrastructure, but it can be repaired. There is still an intermediate risk to human life and safety if a storm event were to occur, most likely in the spring or late summer when the campground may be open. Proposed treatments include shoulder season closures based on forecasted weather.

Choptoy Creek ***Unlikely*** ***Moderate*** ***Low to Intermediate***

There are private residences in the vicinity, and a private road crosses channels with debris flow probabilities rated as possible. Road damage would probably consist of crossing failure that could be repaired. Ingress/egress could be temporarily compromised. Structures in the area appear to be situated at adequate distances from the channels to generally avoid threats to human life and safety. Residents should be advised of the potential risk to their life and property, though.

Pickett Creek ***Unlikely*** ***Moderate*** ***Low***

A private road crosses Pickett Creek. Consequences would be similar to Choptoy Creek; therefore the risk is low to intermediate. Road damage would probably consist of crossing failure that could be repaired. Ingress/egress could be temporarily compromised. Structures in the area appear to be situated at adequate distances from the channels to generally avoid threats to human life and safety. Residents should be advised of the potential risk to their life and property, though.

Sheriff's Cove ***Possible*** ***Moderate to major*** ***Intermediate to High***

Generally, there would be little use of and few if any boats in the marina area when debris flow chances would be the highest in the winter season. Shoulder season users might experience some risk if they are on the depositional lobe that makes up the boat ramp/parking area at the time of a high flow event. Any flow would probably pass through the road drainage structure without causing serious damage - if deposits accumulated, they could be removed. Users and the facility management should be advised of the potential risk - they may wish to post warning signs and/or provide information in another format such as a webpage.

Journey's End ***Unlikely to Possible*** ***Moderate to Major*** ***Intermediate to High***

While a debris flow occurrence at the basin scale is rated as **Unlikely**, the main channel in this drainage has a **Possible** rating. The Journey's End resort structures are located near the channel, and could suffer major damage. The resort is open seasonally, but early spring and fall visitors could be at risk. The structures could suffer major damage in the event of a debris flow. Users and the facility management should be advised of the potential risk - they may wish to post warning signs and/or provide information in another format such as a webpage.

Rutledge Opening ***Unlikely*** ***Moderate to Major*** ***Low to Intermediate***

While debris flow probability is rated as unlikely, there is at least one structure very near the channel of Black Lassic Creek. Any residents could be at risk, and should be advised of the potential risk from flooding or debris flows.

Devil's Backbone - Waggit Spring ***Unlikely*** ***Moderate*** ***Low***

While there is an **Unlikely** chance of a debris flow reaching the basin outlet at the Van Duzen River, it appears **Possible** to **Likely** that a debris flow may affect upstream reaches of the mainstem of this unnamed creek. It most likely would deposit in the wide aggraded reach

downstream of narrow canyons where debris flow probability is rated **Possible**. There is a chance a debris flow could affect Trail 6E01 and /or the dispersed recreational area in this vicinity. Temporary closures or warning signs could be appropriate here.

Mule Slide - Road 1S11 - West Fork Van Duzen River ***Possible*** ***Moderate to Major*** ***Intermediate to High***

Debris flows affecting the basin outlet should be considered **Unlikely**, but it is **Possible** to **Likely** that a debris flow will affect headwater channels, affecting water quality and sediment delivery downstream. It appears **Possible** that the right-lateral scarp of the Mule Slide may extend headward, affecting Road 1S11. This should be closely monitored. If the road is compromised, it may not be possible to reconstruct it if slide enlargement occupies the ridgetop.

Highway 36 ***Likely*** ***Moderate*** ***High***

As periodic or episodic rockfall remains likely until the hillslope stabilizes post-fire, risk to passing motorists will remain. Highway workers that are onsite for longer periods will be at greater risk. CalTrans should provide safety mitigation in the form of reduced exposure times if possible, especially during and immediately following storm or high wind events that may induce rockfall when remaining hazard trees may be mobilized as well. Ongoing PG&E hazard tree removal along the power lines will probably mitigate this risk somewhat.

RESPONSE ACTIONS RECOMMENDED TO MITIGATE THE RISK

Where risk to human life and safety is rated as intermediate or higher, mitigations could include closure of roads and other facilities when storms are predicted, or extending the season of closure. For the Fir Cove and Bailey Canyon Forest Service campgrounds, this could be accomplished by a Forest Order or decision by the District Ranger for safety purposes. For the other private facilities, the risk can be communicated to the responsible parties so that they are informed and can make the best decision regarding their safety and that of their visitors.

Where road treatments are prescribed to alleviate post-fire hazards, temporary closures to protect those investments may be justified. Please see other resource specialist reports for more detailed risk mitigation measures that address multiple concerns, including flooding and erosion hazard.

CONSULTATIONS (People who provided assistance in completing the resource assessment)

Name, Title, and Agency	Telephone
Juan delaFuente, Northern Province Geologist, USDA Forest Service	
Dennis Staley, US Geological Survey, Research Physical Scientist	
Christopher MacDonald, Soil Scientist, USDA Forest Service	
Angela Coleman, Hydrologist, USDA Forest Service	

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PHOTOS

Photo 1. High burn severity in the headwaters of Glen Creek

Photo 2. Oriented schist boulders in colluvial deposit, Glen Creek headwaters

Photo 3. Devil's Backbone Ridge, showing steep headwater channels with accumulated post-fire colluvium (dry ravel), indicative of debris flow initiation sites.

Photo 4. Mule Slide from below Road 1S11

Photo 5. High severity burned area on nested scarps and benches, right-lateral scarp of the Mule Slide below Road 1S11. Area is prone to slide reactivation and headward extension.

FIGURES

Plate 1 - Mad River Complex USGS Debris Flow Model (Attached separately)