REDUCING POST-WILDFIRE DEBRIS FLOW RISK THROUGH THE BURNED AREA EMERGENCY RESPONSE (BAER) PROCESS

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Abstract: The focus of Burned Area Emergency Response (BAER) on national forests is a rapid assessment of post-wildfire threats to life, property and natural resources. These threats frequently include debris flows. BAER assessments for a wildfire are required within seven days of fire containment. The urgency is to ensure that any counter-measures are in place before the first storm events and, thereby, reduce risk to people and property. The recognition of the potential for debris flow from recently burned basins throughout the western United States, increasing urban growth and more extensive wildfires highlight the necessity of accurate and timely BAER assessments.

Recently developed models for assessing debris flow hazards can be used by BAER teams in their assessments. Input data includes burn severity maps, and soils and elevation data that can be manipulated in a geographic information system (GIS). For a given basin and rainfall event, the models calculate the probability of debris flow and a potential volume of material that can issue from the basin outlet. The model results are used to produce maps that identify those basins most likely to produce the largest debris-flow events. This method satisfies both the need for rapid and timely assessments required under BAER.

INTRODUCTION

Television images of advancing flames and the blackened foundations of burned homes remind us of the awesome destructive force of wildfires in southern California. Later, there are often stories from the same places of floods and debris flows when the seasonal rains begin. The "fire-flood cycle" is a phenomenon recognized in southern California as early as the 1930s. It results from the loss of vegetation by wildfire on the chaparral-covered watersheds to the subsequent rapid runoff and increased sediment being washed down stream channels. With increased urbanization, especially in the Los Angeles Basin, the impact of one natural disaster, wildfire, is exacerbated by the subsequent natural disaster of flooding. In the early 1960s, watershed specialists on national forests within the Los Angeles Basin initiated a process of assessing and mitigating flooding from fire-affected watersheds. This evolved into the Burned Area Emergency Response (BAER) program which is now implemented on all national forests as well as other Federal lands.

The need for BAER assessment throughout the western United States is greater now than it ever has been. One of the central aspects of BAER assessment is the identification of threats to life and property. Debris flows initiated from burned areas certainly represent as great a threat to life and property as water floods. Like water floods, their impact can be a significant distance from their point of initiation or even from the boundaries of the burned area. The damage to a number of homes in the Santaquin, Utah area by debris flows produced from the area burned by the 2001 Mollie Fire and loss of life and destroyed homes in Waterman Canyon, California from basins burned by the 2003 Old-Grand Prix Fires dramatically illustrate the reality of this threat (Figure 1).

Figure 1. St. Sophia Church Camp in upper Waterman Canyon near San Bernardino, CA. In Dec. 2003, a debris flow (moving from bottom to top of this view) left deposits and only the foundation of the caretaker's residence.

Two factors have expanded the concern for debris flows after wildfires beyond the geographic area of southern California. One is the expansion of urban areas to near the boundaries of national forest and other Federal lands. The other is the greater potential for large-scale wildfires due to increased fuel loads resulting from past fire suppression practices. Consequently, the risk posed by post-wildfire debris flows is greater than in the past and more widespread in the western United States. The assessment procedure used by Burned Area Emergency Response teams need to keep pace with this increased risk. Methods for determining the potential for post-wildfire debris flows need to be able to address larger areas potentially impacted and to ensure that accurate estimations of the risk are rapidly available to support emergency response actions.

THE FIRE-FLOOD CYCLE, DEBRIS FLOWS AND THE DEVELOPMENT OF BAER

The available literature suggests that the cause and effect relationship between wildfire and floods in southern California was recognized by the 1920s or 1930s (Wells, 1987). Debris flows were first described as part of the post-wildfire flooding regime in papers dealing with the January 1, 1934 flooding from burned watersheds that affected the towns of Montrose and La Crescenta in the Los Angeles Basin (Eaton, 1935). Eaton (1935) actually referred to these floods as being debris flows, which was not a commonly recognized phenomenon at that time (Wells, 1987). For example, C.S. F. Sharpe (1938) described what we know to be debris flows as “mudflows” in his classification of landslides. Sharpe cites, as an example of a mudflow, what is known today to have been a 1930 debris flow that issued from Parrish Canyon along the Wasatch Front north of Salt Lake City. Wells (1987) also points out that a later paper on the 1934 flooding at Montrose and La Crescenta, California gave details of the flooding that clearly describes what would be considered today to be debris-flow behavior.

From the 1930s through 1970s, researchers in the Los Angeles area clarified the relationship between recent fires and subsequent floods and also the frequent occurrence of debris flows as a component of the post-wildfire flooding events (Wells, 1987). This clarification raised a serous issue for National Forests in the Los Angeles Basin. A significant number of wildfires each year were wholly or partly on national forest system land in close proximity to a rapidly expanding urban area. Watershed specialists on the Angeles and San Bernardino National Forests began to develop practices for post-wildfire assessment of impacts. Their focus was preventing loss of soil needed to restore healthy vegetation in forest watersheds, preventing damage within the stream channels, and mitigating threats to life or property.

Experience in the 1960s supported development of erosion control measures and agreed upon assessment procedures to determine when and where control measures were needed. Initially it was formalized as being Burned Area Emergency Rehabilitation (BAER) and instituted to ensure emergency funding was available for rapid implementation of mitigation measures. Because concerns for loss of productive soil and loss of water control resulting in channel damage were common concerns on all National Forests, this program and its formalized procedures were expanded to all of the Pacific Southwest Region of the USDA Forest Service and later to all National Forests.

Over time, the U.S. Department of the Interior established a comparable program to address similar post-wildfire issues on land administered by the National Parks, Bureau of Land Management and Bureau of Indian Affairs. Currently, both the USDA Forest Service and the U.S. Department of the Interior refer to this program as Burned Area Emergency Response and retain the acronym, BAER.

From this early recognition of a causal relationship between burned watersheds and debris flow occurrence in southern California, it is understood that most of the western United States is influenced by this cycle. Since the early 1970s, all national forests are directed to undertake BAER assessments for wildfires involving 300 or more acres or smaller ones that potentially threaten life or property. This is a rapid assessment to identify how the wildfire has caused an emergency situation that threatens life and property, excessive loss of productive soil or potential flooding. Initial reports documenting emergency situations are required within seven days of a fire being contained, i.e., being surrounded by firelines to prevent further expansion beyond that perimeter. The emphasis on rapid assessment is to ensure that funding is approved and implementation of counter-measures is complete before the first damaging storm event. Counter-measures can range from emergency evacuations during storm events to construction of closed debris basins or deflection walls (DeGraff and Lewis, 1989). In many areas, the wildfires may occur late in the late summer or early fall leaving little time for implementation before the beginning of the winter rains. The Southern California wildfires in 2003 created an extremely difficult situation with implementation hampered by their occurrence late in the fire season (October) and the large area they affected.

BAER teams are composed of hydrologists, soil scientists, geologists, foresters, biologists, and other specialists needed to assess the effects of the fire on the watershed and identify where it has caused emergency situations. Assessing landslide hazard is an important aspect of identifying threats to life or property. Specifically, the burned area may be subject to increased rock fall and debris flow occurrence which can threaten life and property. It is certainly an emergency situation when the burned area is more likely to have debris flows and their likely path is into a down gradient urban development.

Debris flows are a serious concern to BAER assessment because of the threat they can pose to life and property. The danger debris flows pose is a consequence of where and how quickly they may travel as well as their composition. First, debris flows travel significant distances beyond their point of origin to cause impacts well outside the burned area perimeter. Therefore, BAER assessment must consider that an emergency condition due to debris flows may extend significantly beyond the limits of the burned area.

Compared to many other landslide types, a debris flow moves at relatively high rates of speed. When the 2003 debris flow that impacted the St. Sophia Church Camp was one mile upstream from the camp, its estimated speed was 7 meters per second (m/s). One-half mile later, it was traveling at an estimated 4 m/s. These velocities are considered very to extremely rapid for landslides movement (Cruden and Varnes, 1996). Debris flow occurring at Wrightwood, CA in this same mountain range in 1941 and 1969 had maximum velocities of 4.4 and 3.8 m/s (Costa, 1984). The travel distance and speed means people may have little warning that a debris flow is coming.

A debris flow is typically composed of a slurry of finer-grained particles with large rock fragments including boulders entrained within it. It is not unusual for large pieces of woody debris to be carried along with the debris flow mass. Therefore, damage to structures and property along the transport path of the debris flow are from impact and lateral pressure. In the deposition area, damage results from burial, inundation, and lateral impact. Cannon et al. (2001) and Giraud and McDonald (2003) describe recent examples of damage inflicted by post-wildfire debris flows.

Identifying a post-wildfire emergency situation due to landslides, including debris flow, is primarily the responsibility of the geologist on a BAER team. This is typically done in concert with information provided by hydrologist and soil scientist team members. The rapid time frame for completing an assessment necessitates using available information together with limited field data. Most of the field information is related to determining where the fire was of sufficient severity to have changed conditions enough to increase the risk of debris flows above what existed naturally before the wildfire, and to identify structures and resources that could potentially be impacted by such an event.

Where threats to property and life exist, the BAER assessment procedure proposes counter-measures to be implemented. This includes a wide range of measures from administrative actions such as evacuation, warning systems as well as physical defenses such as closed debris basins (Hungr et al., 1987). To be effective, these measures must consider how big the debris flow might be, how the debris flow may affect the property (lateral impact, burial, etc.), the site conditions (area, slope, land ownership) and, most important, the ability to put the measure in place before the first triggering event. DeGraff (1994) illustrates BAER assessment and implementation results after a 1990 wildfire near Yosemite National Park.

THE INCREASING THREAT

Throughout the western United States, increased urban development often extends to the boundaries of national forests and other Federal lands. In recent years, notable large wildfires like the 2000 Cerro Grande fire near Los Alamos, New Mexico, the 2003 Old and Grand Prix

Fires in San Bernardino County, CA, the 2003 Simi Fire in Ventura County, CA and the 2004 Waterfall fire near Carson City, Nevada highlight the widespread occurrence of wildfires near urban centers. They typify a situation culminating from two long-term trends in the western United States; increasing population and larger wildfires.

Population in the United States between 1900 and 1990 has grown by 225% (Chourre and Wright, 2006). The population of the southwestern United States increased by about 1,500% during the same period. A significant proportion of this increased population density took place following World War II, and resulted in expansion of urban centers into areas with wildland fuels. The term 'wildland-urban interface' was coined to describe these conditions. Southern California, the urban corridor along the Wasatch Front extending from Ogden to Provo, Utah and the Colorado Front Range from Fort Collins to Colorado Springs, Colorado are good examples of significant wildland-urban interface. However, this problem is not limited to these urban areas. Development in formerly rural areas has also increased the wildland-urban interface. The Lake Tahoe Basin straddling the California-Nevada border, Sun Valley, Idaho and Vail, Colorado are examples of some of the places with significant development largely surrounded by wildlands.

During the last 80 years, fire management policy for national forests and other wildlands in the western United States has generally emphasized suppression. Only in recent decades has the importance of fire to many ecosystems been fully understood. The effective suppression of both natural and man-caused fires has resulted in a build up of fuels within many wildland areas (Minnich, 1989). While efforts continue to reintroduce fire as a frequent and natural feature of these ecosystems, most wildlands host fuel concentrations conducive to large and intense wildfires.

The wildland-urban interface has serious implications for Burned Area Emergency Response. Until recently, the consequences of not recognizing a possible emergency due to post-wildfire debris flow potential were limited. There might be damage to a ranch building, summer cabin, mine or hydroelectric facilities or local roads (DeGraff and Lewis, 1989). Where wildfires involve the wildland-urban interface, the consequences can involve possible loss of life as well as damage to homes and business amounting to millions of dollars (Slosson et al., 1989). This makes it imperative that geologists participating in BAER teams employ the best means available to identify potential emergency situations due to debris flows (King et al., 2002).

METHOD FOR IDENTIFYING THE POTENTIAL FOR POST-FIRE DEBRIS FLOW

Methods for assessing potential debris-flow hazards from basins recently burned by wildfires in response to given rainfall events are needed to carry out rapid assessments over extensive areas and to enable implementation of counter-measures before a triggering storm event. Such an approach has recently been developed that relies on data that is readily available immediately after a fire, and can be implemented in a Geographical Information System (GIS). The assessments identify the probability that a given basin will produce debris flows, and estimate the volume of the possible debris-flow response at the basin outlet. This approach addresses two of the fundamental questions in debris-flow hazard assessments: where might debris flows occur and how big might they be?

A model for the probability of debris-flow production from individual drainage basins was developed using logistic regression analyses of a database from 401 basins burned by 15 recent fires located throughout the U.S. Intermountain West. The model describes debris-flow probability as a function of the area of the basin burned at high and moderate severity, the percent of the basin area with slopes greater than 30 percent, the basin ruggedness (the area of the basin divided by the square root of the change in elevation (Melton, 1965)), the percent clay in the soil and its liquid limit, and the average storm rainfall from short-duration convective rainstorms. In addition, a model for estimating the volume of material that may issue from a basin mouth was developed using a series of multiple regression analyses on a database from 56 basins burned by eight fires. The model describes debris-flow volume as a function of the area of the basin burned at high and moderate severities and with slopes greater than 30 percent, and total storm rainfall.

Following the 2003 Hot Creek Fire in central Idaho, the methodology for rapid assessment of post-fire debris flow hazards was applied over the area as part of the BAER assessment. The Hot Creek Fire is located in the upper Middle Fork Boise River drainage, approximately two miles west of historic backcountry mining community of Atlanta, Idaho (Fig. 2). Input to the models is obtained from maps of burn severity that indicate where the wildfire has most strongly impacted the vegetation and soil, the STATSGO soils database (Schwartz and Alexander, 1995), and Digital Elevation Models (DEMs). Rainfall input was for a one-hour duration, 10-year recurrence storm.

Figure 2 shows a map of the probability of debris flow occurrence for the Hot Creek Fire that was generated by calculating a probability for each basin based on the distribution of burn severity, gradient and soils within the basin and the probability model. Calculated values are

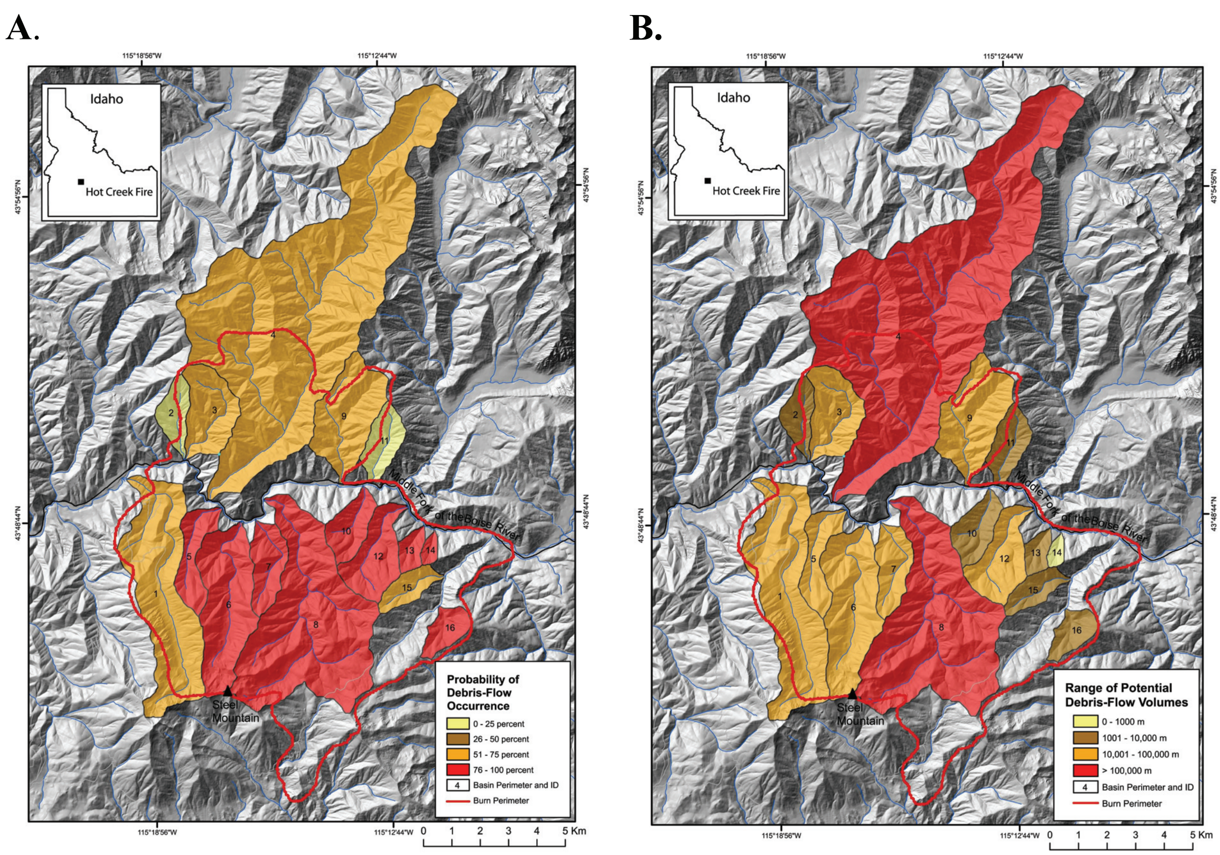

Figure 2. A) Map of probability of debris flow occurrence, and B) map of volume of material from basin mouth for basins burned by the Hot Creek Fire in response to a 1-hour duration, 10-year recurrence storm.

then parsed into classes. Similar maps of the volume of material that can issue from basin outlets are generated using a similar procedure. When used in combination, the debris flow probability and potential volume maps identify those basins most likely to produce the largest events, and could be used to locate and design mitigation treatments and to plan for emergency response.

In response to a storm similar to that used in the assessment, four of the 16 basins evaluated produced debris flows. These were among the basins identified as having the highest probabilities of producing the largest events. This experience demonstrated that a rapid assessment procedure could be incorporated into the established BAER assessment to make a meaningful contribution to define areas at risk from debris flows. Because measures to counter debris flow risk are sometimes quite costly and difficult to put in place before potential triggering events, improved assessment methods better support the decision-making and funding of such measures.

CONCLUSIONS

More people and property will be threatened in the foreseeable future by post-wildfire debris flows. The dual threats of wildfire followed by floods and debris flows during the following rainy season are not confined to southern California. The western United States has many areas where urban areas are now close to wildlands. Wildfires near the wildland-urban interface are unlikely to diminish in the near future. The re-introduction of fire as a natural component of these wildland ecosystems will take many years. In the meantime, the fires are likely to remain frequent and often large.

Burned Area Emergency Response teams assessing the potential threat of debris flows will need to use the best available techniques to meet their mandate of protecting life and property. The model described in this paper represents one of the available techniques that should be widely used. It provides probability and volume estimates of debris flows which can be used to evaluate what values are at risk and the likely successful counter-measures. It also has the advantage of drawing on some of the data commonly collected as part of initial BAER assessments and being compatible with GIS for data manipulation and map production. Continuing efforts should focus on developing models that are specific to particular settings, including southern California.

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