ATTACHMENT A

Assessment of the post-fire debris flow and flooding events of January 20, 2017 in the Sherpa Fire burned area:

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Introduction:

On the morning of January 20, 2017 a 4 inch magnitude rainstorm with a peak 15-minute rainfall intensity storm of 2 inch per hour initiated a debris flow in El Capitan Creek, Santa Barbara County, California, which impacted a private resort and the El Capitan State Beach (Figure 1&2). This post-fire debris flow event occurred in the burned area of the Sherpa Fire. The purpose of this report is to describe the events that lead and initiated this post-fire debris flow event, to document the debris flow deposits and discuss variations in predicted debris flows (Sherpa Fire BAER Report) as appose to the actual post-fire debris flows event of January 20, 2017.

The Sherpa Fire started on June 15, 2016, on the Santa Barbara RD of the Los Padres N.F., Santa Barbara County, California, and burned a total of 7,473 acres, out of which 2,594 acres burned on National Forest lands. Out of a total of 7,473 acres, 4% were high soil burn severity, 60% were moderate soil burn severity, 28% were low soil burn severity and 9% were unburned (Sherpa Fire - Geology BAER Report, June, 2016). The unburned acres refer to unburned areas within the fire parameter.

The Sherpa Fire occurred on the south slopes of the Santa Ynez Mountains within the Transverse Ranges of Southern California. The Santa Ynez Mountains parallel the south coast of Santa Barbara County and extend eastward into Ventura County. The Transverse Ranges are some of the most tectonically active mountains in the U.S., and are growing at a rate faster than they are eroding. Unlike the Transverse Ranges to the east (e.g. the San Gabriel and San Bernardino mountains), this range is composed almost entirely of un-metamorphosed, mostly marine sedimentary rocks of Cenozoic and late Mesozoic age, elevated out of the ocean mostly on the Santa Ynez fault along or near the northern base of this range (Dibblee, 1982). In this area, various forms of land-sliding, rock-fall, debris flows and erosion are frequent events in the steep, geologically young mountains, and occur naturally even without the effects of fires. Fires dramatically increase susceptibility of the watersheds to runoff generation, erosion, flooding and debris flow. These processes threaten human and other life, can damage and destroy homes, businesses and other infrastructure, block or carve out sections of roads, sever pipelines and other utilities, block stream channels, add large quantities of sediment to steam channels and water bodies, and disrupt the livelihood of workers and communities. The physiography of the region is dominated by extremely rugged slopes, all draining into five major creeks; Canada del Refugio, Canada del Vendaito, Las Flores Canyon which flows into Canada del Corral and Canada del Capitan. All 5- creeks flowing south directly into the Pacific Ocean (Figure 2).

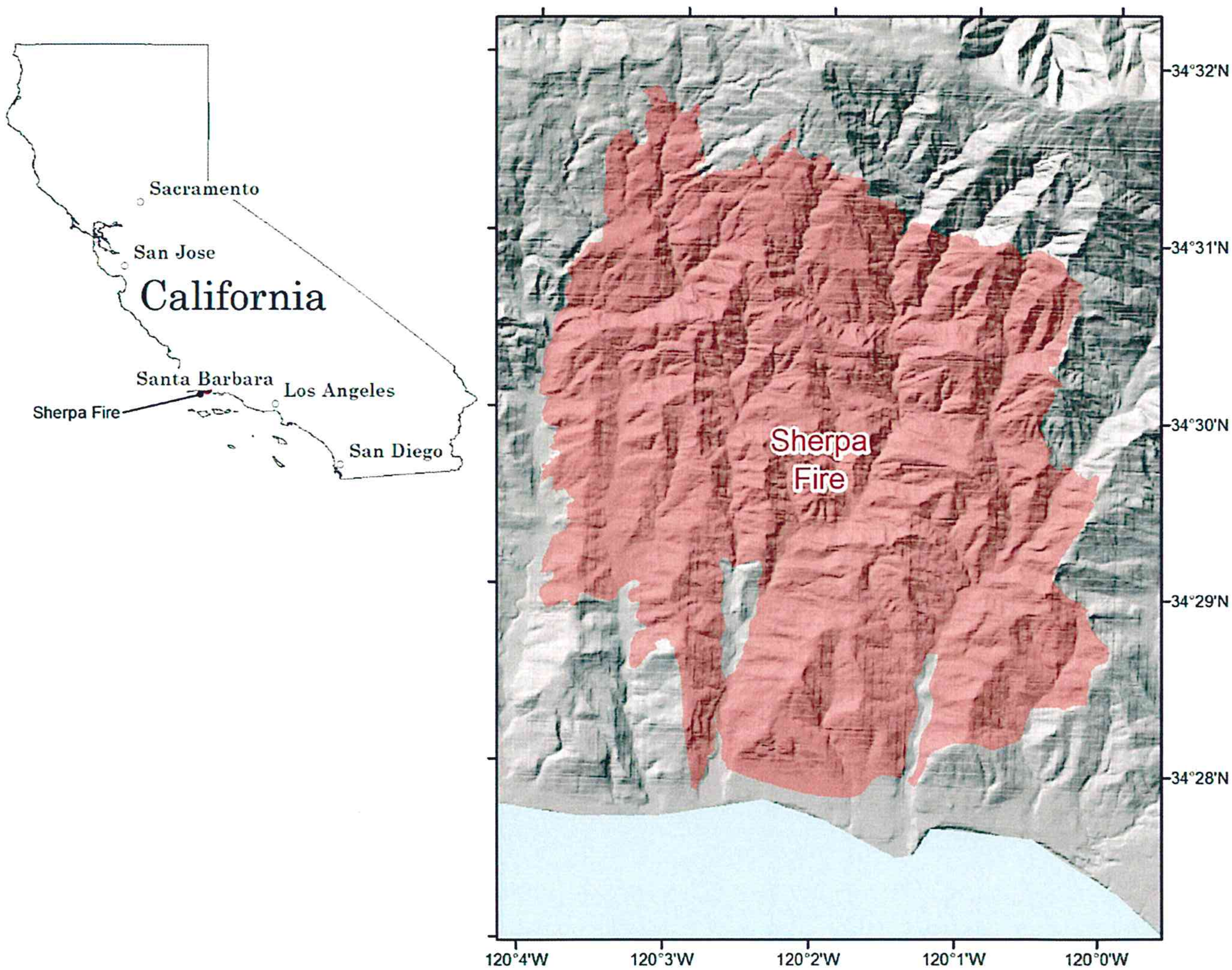


Figure 1: Sherpa Fire burned area map

Watersheds within the fire area that have significant volumes of sediment in the channels or are likely to experience increases in runoff and erosion from fire-affected slopes, are most vulnerable to debris flows. Sediment increase from enhanced runoff generation and erosion is closely related to the amounts of area burned at high or moderate burn severity. Rather than being the result of infiltration-induced slope movements into the channels, wildfire-generated debris flows are a result of progressive bulking of storm flow with sediment within the channel and washed from the adjacent slopes (Cannon, 2000, 2001).

Destructive debris flows bring side-slope materials and channel deposits racing down channel bottoms in a slurry similar to the consistency of concrete, in masses from a few hundred cubic yards to hundreds of thousands of cubic yards of saturated material. As these materials impact drainage infrastructure, they tend to clog culverts, bridges and underpasses which either results in a diversion of the flow or/and ends up taking out and destroying the structure.

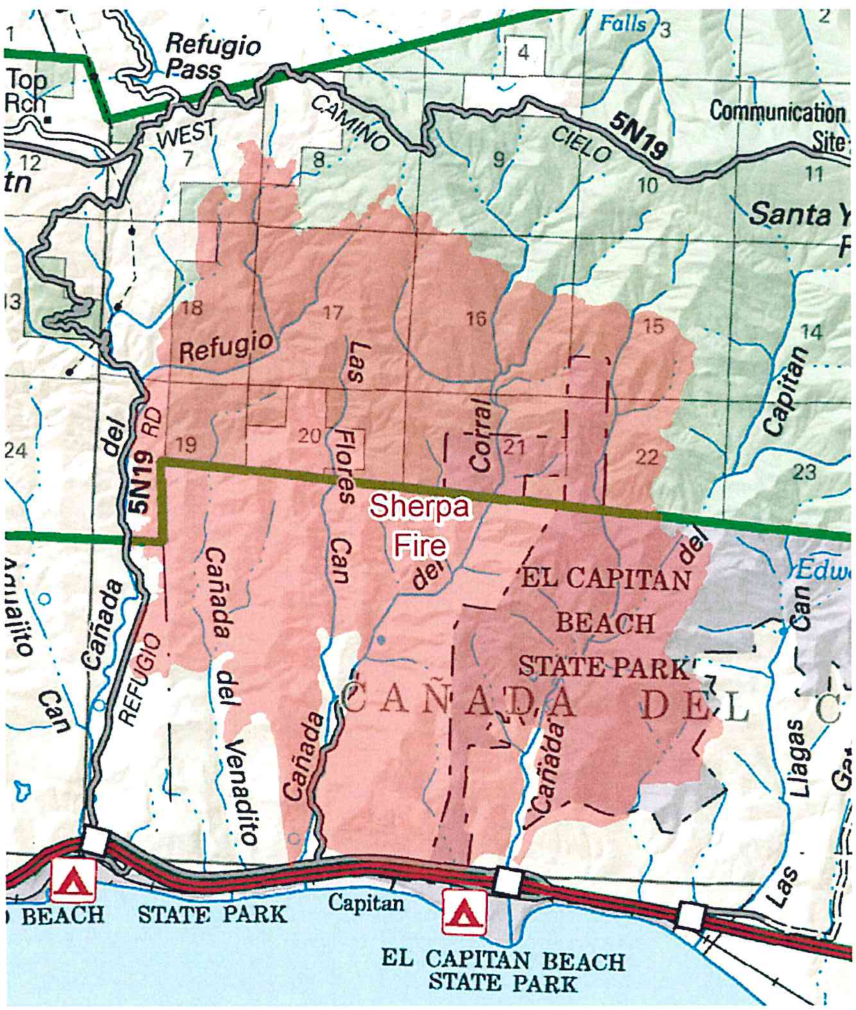


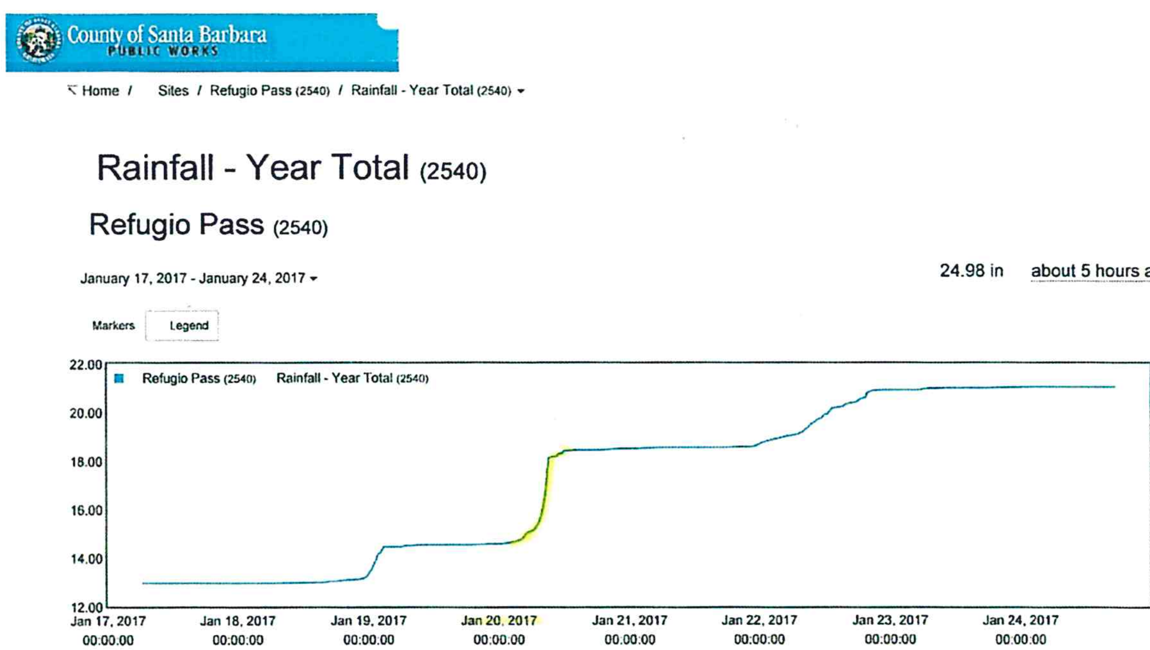
Figure 2: Main watersheds in the Sherpa Fire burned area

Canada del El Capitan watershed - The Canada del El Capitan watershed is situated to the east of the Canada del Corral watershed (Figure 2). At the mouth of this watershed is the El Capitan State Beach / State Park, located on the south side of Hwy 101. Above the State Park, on the north side of Hwy 101 along the valley bottom / floodplain is situated the El Capitan Canyon Resort, which includes about 160 cabins, yurts and tent sites, all surrounded by El Capitan State Park lands. The area of this watershed that was burned in the Sherpa Fire was 1,588 acres out of which 57 aces of high soil burn severity, 1,078 acres of moderate soil burn severity, and 453 acres of low to no soil burn severity, mostly located at the lower end of the watershed.

Based on pre-flooding aerial and ground surveys it is clear that in the past, mass wasting have occurred in areas dominated by the Sespe and Sacate Formations. Along the El Capitan road above the El Capitan Canyon Resort, in the Sespe Formation mass wasting as rock-fall, and occasional debris slides dominate the active slope processes, even in the absence of wildfires (Figure 3)

Figure 3: Pre-fire, mass wasting in the Sespe Formation – Upper El Capitan Watershed

On the morning of January 20, 2017 a second consecutive rainstorm in a 3-day period started coming down at about 2:00 a.m. and continued till 11:45 a.m. PST. Over this time period of about 10 hours 4 inches of rain came down at the Refugio Pass rain gage station (which best represents the upper El Capitan watershed) with the maximum 1-hour rainfall (2.05 inches) occurring between 8:10 and 9:10 a.m. PST (Figure 4 & 5). This rainstorm had a peak 15-minute rainfall intensity storm of 0.75 inches occurring between 8:53 and 9:08 a.m. PST, which is equivalent to a precipitation frequency of 25 to 50 year-storm (NOAA, 2016, Hydrometeorological Designs Study Center Precipitation Frequency Data Server (PFDS). National Oceanic and Atmospheric Administration. http://hdsc.nws.noaa.gov/hdsc/pfds/index.html. Accessed February 2017). From the start of the 2016-17 rain season, this upper watershed area received 21.04" of rain (Figure 6), which means that by Jan. 20, 2017, when this event took place, the soil and channel-bed moisture was likely elevated, which potentially contributes to an increase in surface runoff and mobility of materials (Kean et. Al., 2013).

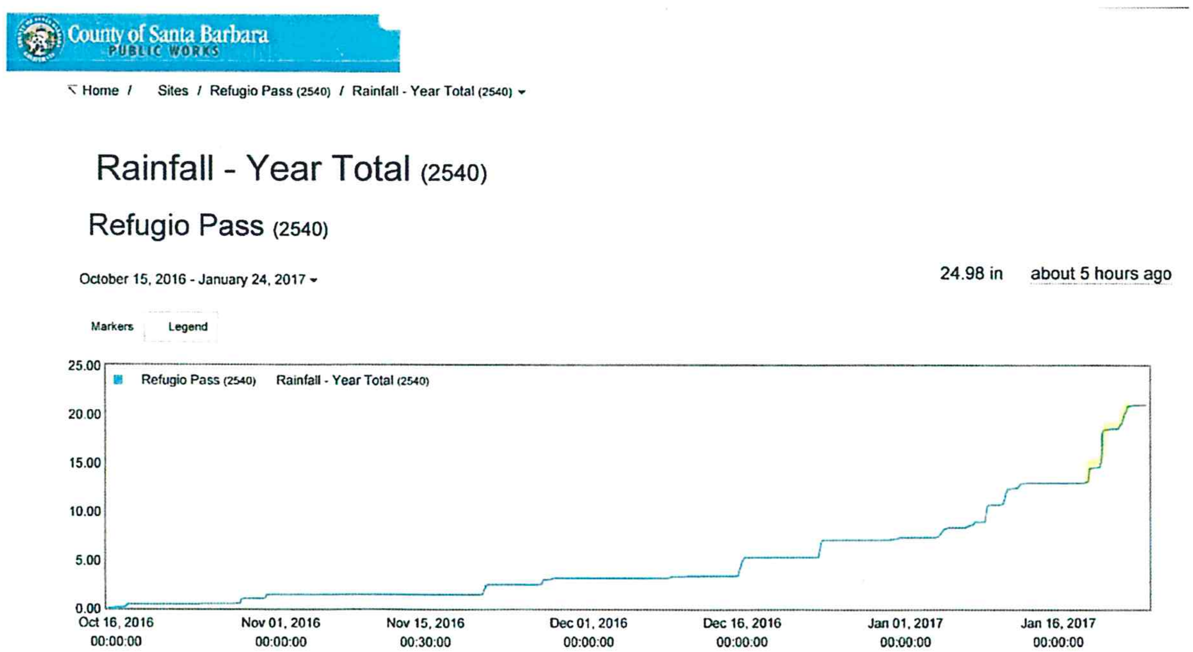


<u>Figure 4</u>: Precipitation data – Jan. 20, 2017 – Refugio Pass Rain-gage Station

Refugio Pass
Site ID: 2540
Sensor ID: 2540

Duration	Depth	Time of First Occur
0:05:00	0.28	2017-01-20 08:42:42
0:10:00	0.51	2017-01-20 08:57:13
0:15:00	0.75	2017-01-20 08:53:05
0:30:00	1.34	2017-01-20 08:38:12
1:00:00	2.05	2017-01-20 08:10:49
2:00:00	2.80	2017-01-20 07:15:56
3:00:00	3.03	2017-01-20 06:27:54
6:00:00	3.47	2017-01-20 03:24:24
8:00:00	3.70	2017-01-20 04:03:36
12:00:00	3.86	2017-01-20 00:41:02
1 day, 0:00:00	3.94	2017-01-20 00:41:02

<u>Figure 5</u>: Refugio Pass Rain-gage data – Jan. 20, 2017



<u>Figure 6</u>: 2016-2017 rain season total precipitation data – Refugio Pass Station

Findings / Observations:

Based on a field assessments (Jan. 24 & 26, 2017), discussions with witnesses of the debris flow / flooding event and photos / videos from eyewitnesses, the following are our observations of the flood and post-fire debris-flow event occurring on January 20, 2017 in the El Capitan watershed:

- As a result of this post-fire debris flow event major infrastructure damage occurred in the El Capitan Canyon Resort, including damage to roads, bridges, pipelines, cabins etc. Multiple cabins were forced off their foundations and swept downstream, in addition to, as many as 15 cars which were swept downstream and crushed, some ending out in the ocean.
- According to Santa Barbara County Fire officials, no fatalities or injures took place as a result of the event, but several people were trapped in cabins requiring immediate rescues from first responders. By the end of the rescue operation twenty-two people were removed from the campground.
- Based on eyewitness's reports, the debris flow reached the lower portions of the El Capitan Canyon Resort at approximately 9:20 a.m. PST.
- The higher portions of the El Capitan watershed that were burned delivered large amounts of coarse woody debris that ended up plugging foot and vehicle bridges, culverts and the highway underpass. In addition, large amounts of riparian vegetation including trees and shrubs that survived the fire were stripped as a result of the powerful flooding and debris flow, which was all added to the burned coarse woody debris that plugged the bridges and culverts (Figure 8).
- The first bridge to be impacted by the debris flow was the Mid-canyon Bridge. This bridge was a large wood deck bridge (15 feet wide x 45 feet long) located half way up the El Capitan Canyon Resort. This bridge was supported on both sides of the creek by concrete foundation. Attach to the top of these foundations and supporting a wooden deck were 3 metal I-beams (18" high, 7.5" wide and 3/8" thick x 45 feet long). As a result of the debris flow this bridge was demolished. The metal I-beams were carried downstream and twisted agents large trees (Figure 9).
- As a result of coarse woody debris plugging the lower bridge in the El Capitan Canyon Resort (just below the Canyon Market), the flood was diverted out of the channel and into the large dirt parking lot space (below and to the west of the lower bridge).
- As a result of debris plugging the concrete box culvert / underpass Hwy 101 (dimensions 12x15 feet) the large dirt parking lot turned into a debris catchment basin (Figure 7).

- Based on eyewitness's reports, at about 9:45 a.m. PST, when the pressure was high enough, the debris plugging the Hwy underpass broke through and large amounts of debris (including several cars) were transported all the way out to the ocean (Figure 10).
- As a result of Hwy 101 underpass being cleared of debris, the high level of water in the dirt parking lot area subsided and much of the debris (including cars and cabins) were deposited in this large dirt parking lot space (Figure 11).
- Along 1.1 miles of the El Capitan creek from the Canyon Market (El Capitan Canyon Resort) all the way up to the large water tanks (above the resort) there are large rocky deposits of debris flows, including rocks ranging in size from 1 foot to over 8 feet in diameter (Figure 13). These debris flow deposits, for the most case, appear as elongated deposits, ranging in size from 200 to 450 feet long and about 30-60 feet wide (Figure 12).
- Based on high water marks, the flooding of the channel in some areas (between the cabins) reached a width of 90+ feet.
- Based on accounts of local personal and field observations, the channel-bed (creek-bed) in some locations was excavated (degradation) 4-5 feet by the floods and in other locations accrued (aggradation) 15 feet deposition of rocks and other materials (Figure 13).
- At the lower end of the creek (by the Canyon Market) the gradient of the creek-bed is low, ranging from 0.5% to 1%. This segment of the creek was mostly a deposition area. As one travels up the creek the gradient of the creek-bed increases. By the upper end of the El Capitan Canyon Resort (by the large water tanks) the creek-bed gradient is 4% and getting steeper as the creek climbs up the canyon.

Figure 7: Debris flows and flooding – El Capitan Watershed just above Hwy 101

Figure 8: Coarse woody debris clogging the lower El Capitan Creek Bridge

Figure 9: Twisted metal I-beams which supported a bridge prior to the debris flow event

Figure 10: Cars and other debris deposited at El Capitan Beach

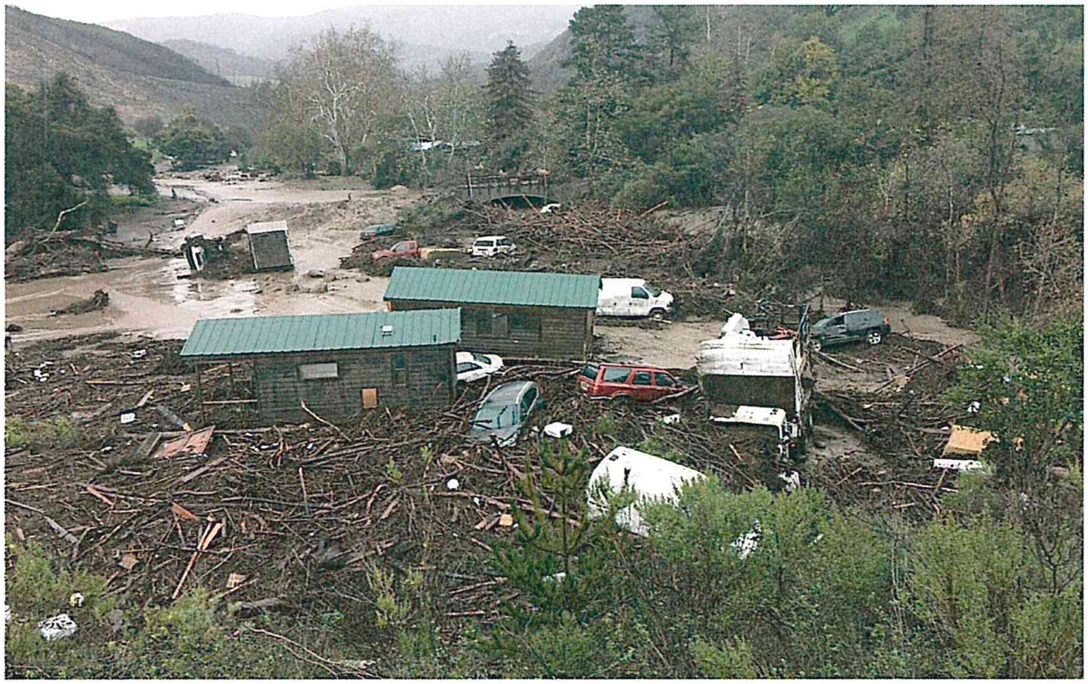


Figure 11: Large amounts of debris deposits in the large dirt parking lot area

Figure 12: Large elongated rocky deposits – El Capitan Creek

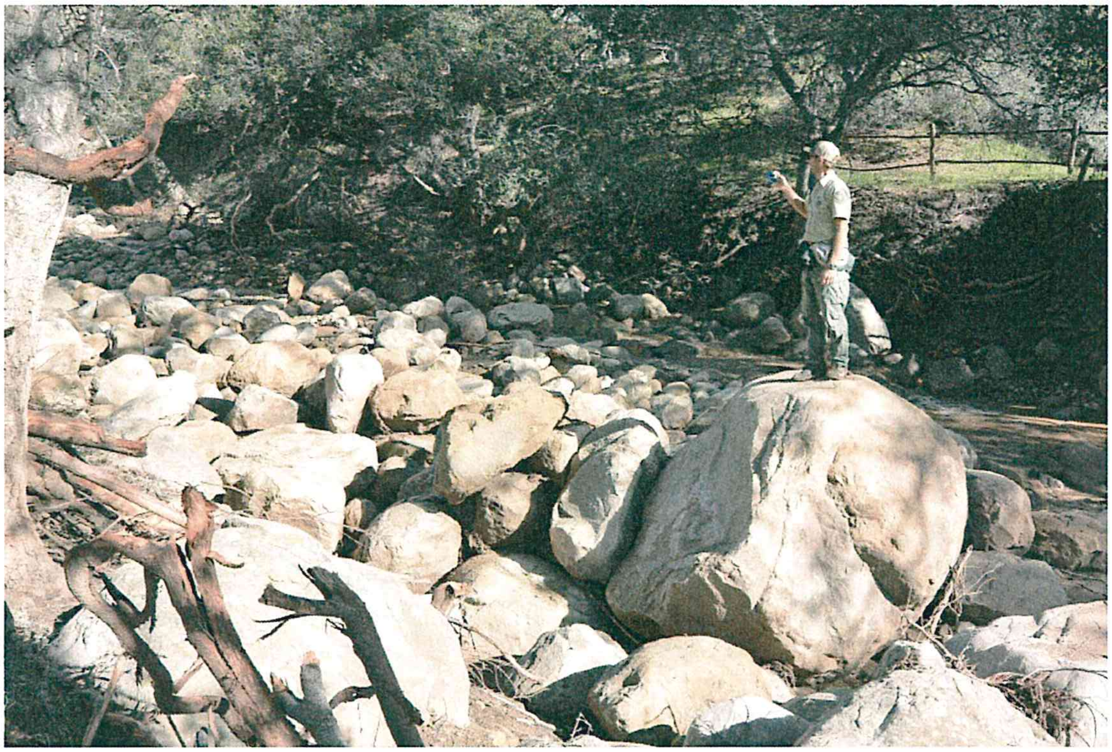


Figure 13: Rock deposits ranging in size from 1 foot to over 8 feet in diameter – El Capitan Creek

Discussion:

When evaluating / compering flooding and debris flows predicted to occur in the Sherpa fire burned area (Geological Hazards Report – Sherpa Fire, June 30, 2016) and the actual flooding and debris flow event that took place during the January 20, 2017 event, it is obvious that all that was anticipated to take place in the burned area indeed came to pass and more. In the El Capitan drainage, Canada del Corral and the Las Flores Canyon the Values At Risk (VAR) that were predicted to be impacted by flooding and debris flows included: The road / trail system in El Capitan State Park, El Capitan Canyon Resort, the 101 Hwy underpass, El Capitan State Beach and the Exxon Mobile facility. Some explanations as to the magnitude of impacts that took place on January 20, 2017 (beyond whatever was described in the Sherpa Fire, Geological Hazard Report) include:

- Estimates of probability, volume, and combined hazard predicted by the USGS model are based upon a design storm with a peak 15-minute rainfall intensity of 12 – 40 millimeters per hour rate (0.47 – 1.57 inches / hr.). The rainstorm that took place on January 20, 2017 had a peak 15-minute rainfall depth of 0.75 inches, equivalent to an intensity storm of 3 inches/hr. or 76 mm/hr., which was beyond the scope of analysis.
- We selected a design storm of a peak 15-minute rainfall intensity of 28 millimeters per hour (1.1 inches/hr.) rate to evaluate debris flow potential and volumes since this magnitude of storm seems likely to occur in any given year, and is equivalent to a precipitation frequency of a 2 year-storm. The storm that took place on January 20, 2017 had a peak 15-minute rainfall intensity of 76 mm/hr., (3 inches / hr.) which is equivalent to a precipitation frequency of 50-100 year-storm.
- From the start of the 2016-17 rain season and up in till January 20, 2017, the area of these upper watersheds received 21.04" of rain, which means that by the time this flooding event took place, soil were saturated, the channel-beds moisture was likely elevated, which contributed to an increase in surface runoff and mobility of materials.

It is important to stress that post-fire / pre flooding communications with the community and warning of potential flooding and debris flows were carried out via the Office of Emergency Services (OES), direct communication with maintenance personnel, and the USFS presentations at OES, in addition to NOAA flood alerts distributed to the community in this area the evening of January 19, 2017. These communications / presentations clarified and emphasized that the ultimate drivers of flooding and debris flow events are rainfall intensity, pre-saturation, and total precipitation, all unpredictable. In addition, it was made clear that the

USFS and USGS watershed response models do not represent a maximum event that could potentially take place, rather a relative point for comparison, and that flooding is a real threat.

References

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