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Field investigation and design of debris nets in an environmentally sensitive area

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Abstract. Flexible debris nets are an excellent choice for emergency debris protection. They are lightweight, have a small footprint, and are relatively easy to construct. Available design methodology based on testing and modelling makes engineering simplified with straightforward calculations. After a huge wildfire, Montecito, California sustained devasting debris flows. The need to quickly design and construct protection was made possible proven methodologies under difficult environmental restrictions.

1 Introduction

The community of Montecito, California is one of the most well-to-do in the state. Its residents include many wealthy and well-known individuals such as talk show host and entrepreneur Oprah Winfrey and former Prince Harry, Duke of Sussex, and his wife actress Meghan Markle, among others.

Montecito is situated east of Santa Barbara, California between the beautiful Santa Ynez Mountains and the Pacific Ocean in Southern California, Fig 1.

Fig. 1. View of Montecito, California, from the crest of the Santa Ynez Mountains.

1.1 Thomas fire

In the western United States, wildfires scorch vegetation that normally anchor soil and changes the soil chemistry. As a result, rapid runoff and erosion causes debris flows especially following large fire events in mountainous areas.

In December and January 2018, the Thomas Fire became largest fire in California history. In early January 2018, torrential rains stalled in the Santa Ynez Mountains triggering devastating debris. These flows overtopped debris basins and creeks resulting in major property damage, injuries, and loss of life in the areas below the mountains. This event resulted in the deaths of 23 people, destroyed 10% of the housing, and blocked U.S. Highway 101, a major California transportation corridor.

1.2 Geology

Geological evidence indicates the area has undergone many such events in the past. It is in an approximately 8 km wide region between the Pacific coast and the Santa Ynez Mountains. The area is composed of thick, Quaternary alluvium including flood plain deposits and prominent alluvial fan deposits most likely resulting from debris flow events.

The Santa Ynez Mountains are a part of the Transverse Ranges of Southern California. The bedrock is almost entirely composed of interbedded sandstone and shale beds ranging from the Jurassic Franciscan formation to Eocene sandstone and shale. Bedding varies from thick to very thin. These beds exhibit differential weathering causing large, blocky sandstone overhangs seen throughout the area. These blocks eventually weather and collapse, creating boulders of various sizes collect in the drainages. These boulders then weather into rounded spheroids.

The bedding dip changes throughout the site and is governed by extensive folding and faulting throughout the area. The Mission Ridge Fault is in the western area of Montecito, while the extensive Santa Ynez Fault runs along the entire width of the Santa Ynez Mountain above Montecito. Vertical and overturned beds are found in the south-eastern area of the Santa Ynez Mountains of Montecito, [1].

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1.3 Environmental Concerns

California has some of the strictest and most daunting environmental laws in the world. In addition to the standards of the United States Environmental Protection Agency, California also has the California Environmental Quality Act (CEQA), and projects are also subject to environmental review by the California Department of Fish and Wildlife, and the California Coastal Commission. The County of Santa Barbara, where Montecito is located, has additional requirements. Santa Barbara claims it is the originator of the modern environmental movement. Inspired by g a massive oil spill in the Santa Barbara Channel in 1969, Earth Day was inaugurated on April 22, 1970.

The mountains are heavily used by residents and vacationers for hiking and mountain biking and clubs have been formed to protect and maintain the many trails.

Prior to obtaining permits for construction environmental hearings were required and permits obtained. The typical timeline for a typical project can range from one to several years. It is not uncommon for projects to never reach construction because the owners finally give up or run out of money.

2 Site investigation

The project had a tight timeline. Beginning in May 2018, debris mitigation had to be completed prior to the next year's rainy season. After research of debris protection mitigation strategies, it was decided that temporary flexible ring net barriers were the best solution. The barriers would have the smallest environmental footprint and could be quickly constructed. The philosophy was to retain portions of the massive number of available debris close to their source rather than construct large debris basins at the mouths of the canyons.

2.1 Aerial Reconnaissance

Aerial reconnaissance was made in early May 2018 with a helicopter. The purpose was to identify areas in each of five major canyons that might serve as optimal locations for debris catchment and retention, Figure 2.

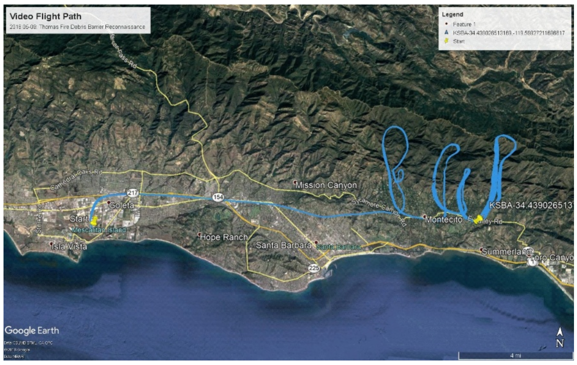

Fig. 2. Flight path used for aerial reconnaissance investigation.

Following the aerial reconnaissance, potential barrier locations were determined. The criteria used were the following:

- Channel dimensions
- Storage potential
- Constructability and access
- Maintenance and access
- Environmental impacts
- Property easements
- Anchoring material

A total of 46 potentially suitable sites were identified from the aerial phase. Fig. 3 is an example of location determination from the air photographs.

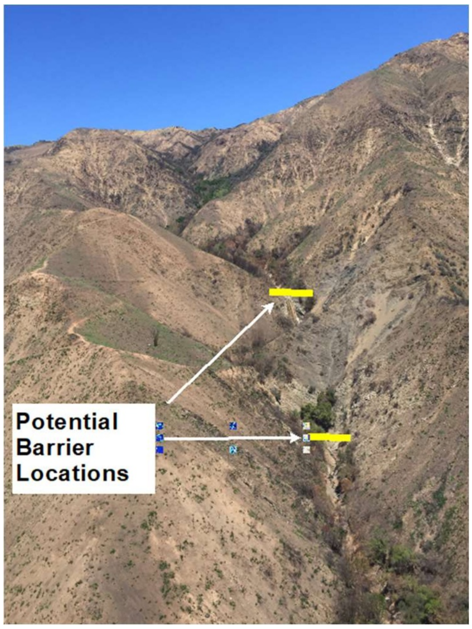

Fig. 3. Potential sites determined from the air.

2.2 Ground Reconnaissance

Ground reconnaissance was performed from June through September. Each canyon was hiked by teams using drones, cameras, handheld GPS units, measuring tapes, and range finders. The locations noted from the aerial reconnaissance were given special attention as well as new potential sites not observed in the air photos. This phase located additional barrier locations for a total of 71 possible suitable sites.

3 Debris flow net design

Flexible ring net barriers were selected for the project. The nets could be constructed quickly without much environmental impact. However, certain environmental constraints were imposed on the project. No construction was allowed in the channel itself.

Therefore, no barriers using post and foundation were allowed. Construction could only occur in relatively small areas with no access roads permitted. Therefore, helicopters had to be used for the entire construction. Finally, no materials such as anchor grout were allowed in the streams. All construction was strictly monitored by an on-site biologist to ensure that the conditions of permitting were strictly followed.

3.1 Principles of debris flow net design

The principle behind debris nets is to catch debris flows close to the source, usually high in mountain canyons, stop the massive flow, and then, if desired, allow the material to be placed back in the channel to allow natural process to return it safely to the rock/hydrologic cycles.

The basic debris flow protection system consists of a custom ring net engineered to resist the velocities and dynamic and static pressures unique to debris flows. Support ropes are installed into channel banks and transfer debris impact and pressure loads from ring nets to the ground. Excessive energy is absorbed by net braking elements in the support ropes. In addition, the ring net in the system allows the passage of water and fine sediment, eliminating the need to consider any bulking factor when determining net height.

Flexible debris nets can be constructed rapidly with minimal environmental impact and can be combined with the existing debris basins to maximize material storage in the canyons. They have a small construction footprint and do not change channel flow unless a debris flow event occurs.

3.2 Montecito debris net design

3.2.1 Net Design Methodology

As a result of extensive research at its Illgraben test site, [2, 3] Geobrugg A.G. of Romanshorn, Switzerland developed a methodology suitable for the design of its debris flow net systems. A peak discharge is calculated, and the flow velocity estimated. Once the mass and velocity are known, design pressures can be determined. Finally, the design height is calculated. It should be noted that debris flows tend to be linear features so that after an initial dynamic impact, additional surges add only a quasi-static load to the net, instead of a fully dynamic load. In addition, the debris material already impacted and de-watered on the net serves to absorb some of the energy of subsequent surges. The result is that much of the debris flow material is not against the net, resulting in decreased energy absorption and height requirements.

Geobrugg developed a software program, DEBFLOW, which determines the appropriate Geobrugg debris flow system as a function of the parameters given above and site characteristics of a particular debris flow basin and channel. The DEBFLOW program was used in the engineering of the Montecito nets at each individual location.

Design loads were for the standard Geobrugg nets were determined by testing and finite element modelling of the Illgraben net.

3.2.2 Net Engineering

There are two basic versions of the Geobrugg debris net systems. The VX net is intended for relatively narrow channels up to 12 metres wide. The UX net is installed in wider channels (up to 27 metres wide and has posts to keep the top net support rope from sagging. For the wide Montecito channels where foundations were not allowed a “Super VX” net was developed. It is a modified VX net with additional and stronger top net support ropes. This eliminated the need for foundations in the channel beds.

To produce construction drawings, it was also necessary to determine the strength of the anchoring rock. Rock and soil properties were estimated during the field investigation for each installation site.

Anchor design for the nets consisted of determining the depth required to support the loads on the wire ropes. The Post-tensioning Institute [4] methodology was used. The Institute provides design charts with a recommended shear, or bond, strength for a particular rock/grout combination.

The weathered and fractured sandstone in the Santa Ynez Mountains was estimated to have a bond strength of about 700 kilopascals. The maximum test load for the net anchors was 356 kN. Anchor depths were determined to be 3.35 m. Field anchor testing was done prior to construction to verify capacities.

3.3 Net construction

A total of six nets were constructed according to plans. Helicopters were used to ferry materials to the sites. Anchor drilling was done using wagon drills powered by compressors. Construction was completed in mid-winter 2018-2019. Fig 4. shows a typical completed net.

Fig.4. Completed SVX barrier above stream channel.

In the winter of 2022 – 2023, California experienced a series of large and powerful storms. Debris flows in wildfire burn areas were common. However, the highest net in the system was filled and prevented debris from flowing further downstream into the development sections of Montecito.

Fig.5. Filled SVX barrier after debris flow event (Photo: Pat McElroy).

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References

1. T. W. Dibblee, *Geology of the Central Santa Ynez Mountains, Santa Barbara County, California*, California Division of Mines and Geology. Bulletin 186. (1966)

2. Geobrugg, *Design Concept, VX/UX Protection System Against Debris Flow*, Fatzer AG, Geobrugg Protections Systems, Switzerland (2003)

3. Geobrugg AG (2018). *DEBFLOW Debris Flow Analysis Program*. CH-8590 Romanshorn, Switzerland (2018)

4. Post-tensioning Institute, (2014). *Recommendations for Prestressed Rock and Soil Anchors*. PTI DC35.1-14 (2014)