Montecito Debris Flow Mitigation

General Report of Findings

Montecito, California

Project No. KGT18-18

Prepared by:

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Prepared for:

Partnership for Resilient Communities
Montecito, California

October 5, 2018
Revised October 23, 2018

KANE GeoTech, Inc.
Geoengineering Consultants

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EXECUTIVE SUMMARY

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General Report of Findings

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As part of the response to deadly debris flows in Montecito, California following the Thomas Fire of 2017 - 2018, KANE GeoTech was retained to provide engineering design and construction oversight for the installation of debris flow mitigation. Existing infrastructure was overwhelmed by debris flows leading a number of fatalities and extremely high property losses. It was determined that relatively lightweight, flexible, debris nets could be installed quickly in the canyons to catch debris and significantly reduce the material entering the existing debris basins and streams in the Montecito community.

KANE GeoTech provided a phased approach to the mitigation of debris flow events. The first phase was a general overview of existing conditions in the canyons. Next, an assessment of each canyon was made to identify specific locations where debris nets could effectively retain debris flows materials. Seventy-one locations in the five canyons (Hot Spring, Cold Springs, San Ysidro, Buena Vista, and Romero) were selected. Of these, 15 sites were selected for initial permitting.

Geobrugg VX and “Super” VX nets were chosen to be installed. These nets have only lateral anchors and construction will have minimal disturbance in the creek beds. In addition, the nets are environmentally sound in that they are composed of open, high-strength, steel rings which are suspended several feet above the creek channel. During flows water and aquatic animals can move beneath the nets and in times of high water, through the rings. Only during catastrophic debris events do the nets function. They are designed to withstand the high impact and static pressures associate with stopping and retaining debris material.

In addition to engineering the debris nets, KANE GeoTech has produced a conceptual design for a debris flow monitoring/alerting system that works in concert with the debris nets that is being considered for installation in a subsequent construction phase.

KANE GeoTech has extensive experience in debris net engineering and geotechnical instrumentation. For this project it has worked closely with Geobrugg AG, Romanshorn, Switzerland; Access Limited Construction, Oceano, California; BGC Engineering, Golden, Colorado; and Storrer Environmental Services, Santa Barbara, California. Access Limited has worked with KANE GeoTech on a number of design/build debris net projects in the western United States. BGC Engineering is one of the world leaders with respect to hazard assessment associated with debris flows. Storrer Environmental has extensive experience on the Central Coast in assessing biological impacts and in environmental compliance monitoring.

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1. INTRODUCTION

1.1 General

KANE GeoTech, Inc. (KANE GeoTech) was retained by The Partnership for Resilient Communities (TPRC) to assess the debris flow channels and recommend debris flow mitigation to protect the structures and infrastructure in the debris flow hazard area. KANE GeoTech performed field work from May through September of 2018 at the Project site, Figure 1.

As described in this Report, 71 net sites have the potential to catch significant quantities of debris before it carried out into the community of Montecito in a debris event. Of these 71 sites, 15 were subsequently chosen for initial permitting.

This Report describes our work identifying the 71 sites, and also provides details of our activities directed toward gathering information necessary for permitting the 15 nets.

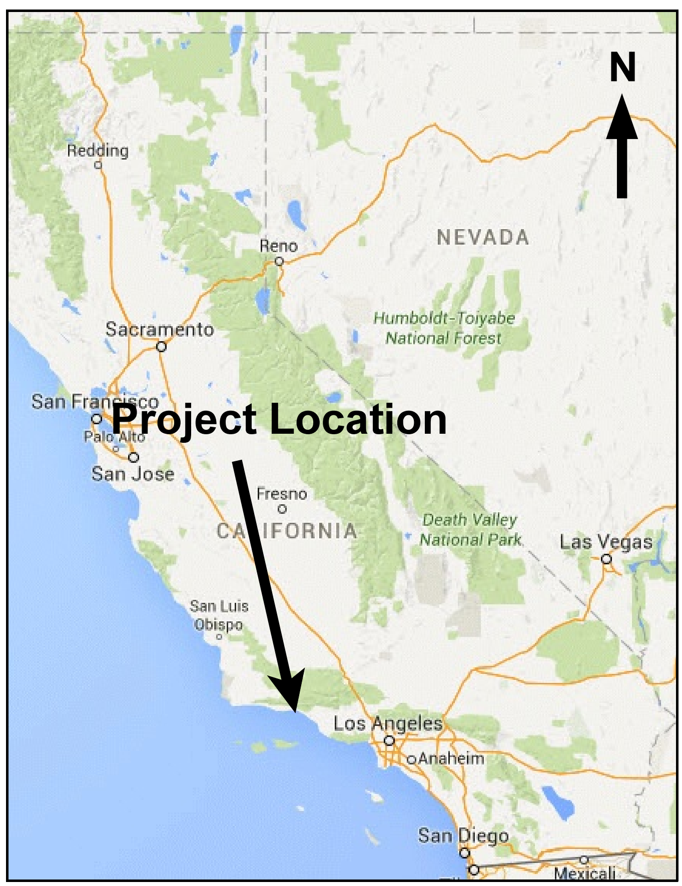

Figure 1. Project location in Santa Barbara County, California.

1.2 Previous Studies

During its KGT Phase 1 Initial Investigation preliminary investigation, KANE GeoTech had visited the site to assess each canyon from a helicopter. Following this initial aerial assessment of the area, KANE GeoTech selected locations in each canyon that were potential sites for debris flow mitigation. These areas were recorded in our KGT Phase 1 Initial Investigation Report, (KANE, 2018), and served as the basis of the KGT Phase 2 Site Investigation field investigation detailed in this Report.

1.3 Purpose

The purpose of this Report is to summarize the KGT Phase 2 Site Investigation, KGT Phase 3 Net Engineering, and additional work. Included are details on the overall debris net Project, as well as the emergency instrumentation warning and monitoring system.

2. SCOPE OF WORK

KGT Phase 1 Initial Investigation has been completed. The following Scope of Work was proposed for KGT Phase 2 Site Investigation of the Montecito Debris Flow Mitigation Project. This Report is provided as a part of the KGT Phase 2 Site Investigation deliverable only. Five additional, canyon-specific reports have been prepared and submitted (KANE, 2018a; KANE, 2018b; KANE, 2018c; KANE, 2018d; KANE, 2018e)

2.1 Phase 2 – Site Investigation and Data Collection

1. **Site Investigation and Analyses.** KANE GeoTech personnel visited the Project site to obtain detailed information on site conditions at specific locations within the Canyons. KANE GeoTech investigated areas that were identified in KGT Phase 1 Initial Investigation as possible locations for mitigation structures.

   KANE GeoTech conducted debris flow analyses for each location identified during the detailed field investigations, to verify the suitability for the proposed mitigation options. We also teamed with an experienced geohazard contractor to perform a preliminary assessment of constructability at the sites.

   Verification anchors were planned to be installed and tested to determine the soil properties and strengths for design purposes.[1] This approach is anticipated to eliminate the need to test anchors during construction operations, resulting in overall time and cost savings for the Project.

2. **Report of Findings.** KANE GeoTech provides this detailed Report of Findings summarizing the site investigation and the analyses. This Report presents the results of the analyses and provides final recommendations for mitigation with estimated construction costs for each location. It also includes information from BGC Engineering, Inc. who KANE GeoTech contacted and worked with in developing the start of the risk assessment for Montecito.

   The KGT Phase 2 Site Investigation field work for was separated into five canyons: Cold Spring, Hot Springs, San Ysidro, Buena Vista, and Romero Canyons. Canyon-specific reports detailing each canyon net location are contained in KANE GeoTech, 2018a - 2018d.

3. **Project Review Meetings**. Project review meetings were held via telephone and in-person to discuss technical aspects and construction issues. These meetings are ongoing.

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[1]Due to permitting issues, the verification test anchors could not be installed in time for this Report. They will be installed after permitting and the information used to obtain precise anchor depths during the construction phase (KGT Phase 3 Net Engineering).

2.2 Phase 3 – Engineering Design, Construction Drawings, and Specifications

1. **Description.** KANE GeoTech provided to TPRC Construction Drawings, Specifications and Calculations, for TPRC to submit to the permitting agencies. This information is necessary for the approval and subsequent construction of the debris nets in Montecito. Seven nets will be installed in Buena Vista Canyon and two each in Hot Springs, Cold Spring, San Ysidro and Romero Canyons. This is a total of 15 nets installed.

2. **Site Work.** KANE GeoTech personnel worked with Storrer Environmental Services (Storrer) personnel to assess the 15 initial net locations for footprint, accessibility by construction equipment, and locations of construction material staging. We also worked with Access Limited Construction (Access) personnel, visiting each of the 15 net locations to further discuss constructability issues and obtain final measurements for engineering design.

3. **Engineering Design.** KANE GeoTech utilized the information obtained during the site visits, as well as other available information, to design the debris flow mitigation systems required. KANE GeoTech provided a Calculation Report containing engineering calculations, stamped by a registered Civil Engineer experienced in debris flow mitigation, used for the engineering design.

4. **Construction Drawings.** KANE GeoTech provided a complete set of engineered Construction Drawings, stamped by a registered California Civil Engineer experienced in debris flow mitigation suitable for the construction of the debris flow nets. The Drawings consisted of layout and construction details.

5. **Specifications.** KANE GeoTech provided Construction Specifications, stamped by a registered California Civil Engineer experienced in debris flow mitigation suitable for the construction of the debris flow mitigation and be delivered electronically.

6. **Project Review Meetings**. Project review meetings were held via telephone and in-person to discuss technical aspects and construction issues. These meetings are ongoing.

For convenience and continuity, a description fo Phase 4 is included below. This work will be conducted once permits are obtained.

2.3 Phase 4 – Construction

1. **Construction Oversight.** KANE GeoTech will provide construction oversight services including a pre-construction meeting, system layout inspection, and quality assurance testing. We will also supply daily construction oversight to streamline the construction process and keep it on schedule. KANE GeoTech will provide a final inspection of the installed debris flow mitigation system, including a letter of acceptance stamped by a registered California Civil Engineer. Daily field reports describing the progress made each day will be supplied to the TPRC.

3. SITE DESCRIPTION

3.1 Background

The Project site is located in Santa Barbara County, California. The Project location is within the Santa Ynez mountains located north of the community of Montecito. This area was a part of the 281,893 acres burned during the 2017-2018 Thomas Fire, (CalFire, 2018).The focus of the project consists of the five major watersheds that contributed to large debris flows that impacted Montecito January 9, 2018, Figure 2.

Following the loss of anchoring vegetation as a result of the Thomas Fire, heavy, intense rainfall led to rapid erosion of the topsoil of the Santa Ynez Mountain slopes. The debris flows consisted of large sandstone boulders, cobbles, sand, and silt. The flows were most likely originated at higher elevations in the steep areas of the Santa Ynez Mountains. As the flows advanced downstream, large amounts of additional material were scoured from the canyon channel beds and sides of connecting channels. As larger amounts of fine material were added to the flow, the energy drastically increased, enabling the flow to scour more material and entrain large boulders that were previously embedded in the main canyon channels and side channels, Figure 3.

The Montecito debris flows resulted in overflowing of all debris basins and plugging of culverts and bridges throughout Montecito. As a result of the flow de-channelization, the high-energy flows spread laterally over areas of the town resulting in 23 deaths, and numerous residential homes and commercial buildings damaged or destroyed.

3.2 Potential Debris Flow Volumes

It is estimated that approximately two million cubic yards of material was cleared from the city of Montecito following the January 9 debris flows. Despite the significant burn damage from the

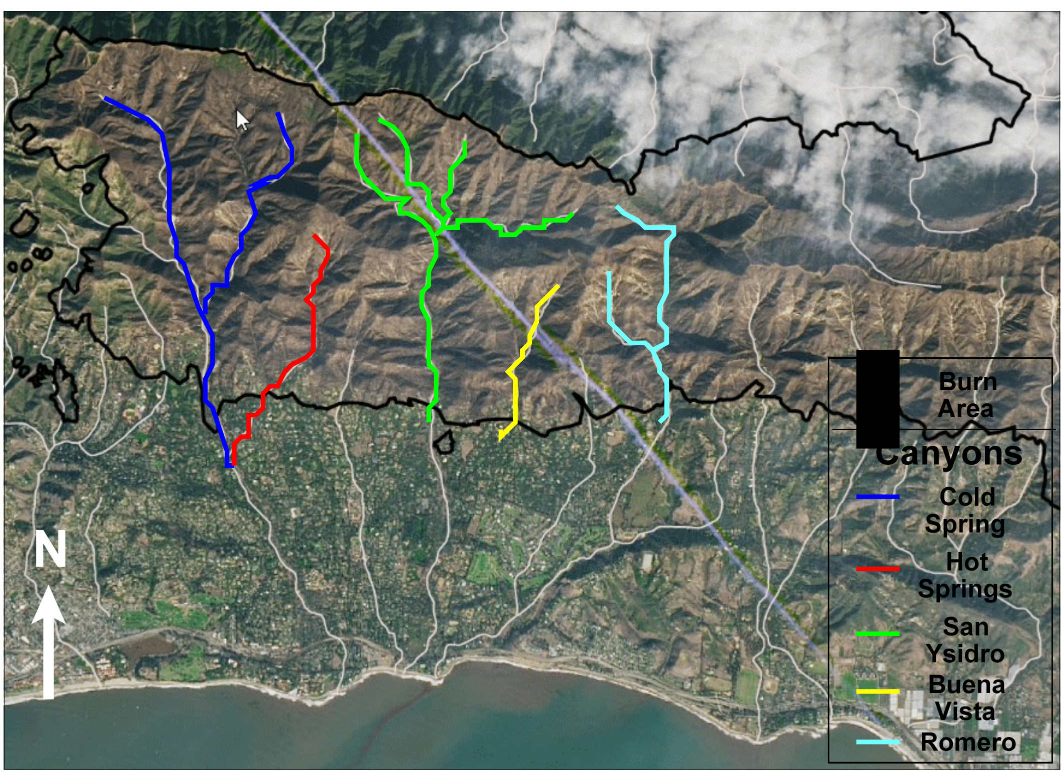

Figure 2. Primary drainages in the Santa Ynez Mountains that contributed to debris flows.

Thomas Fire in the Santa Ynez Mountains, it was predicted that at least 20-30% of the area would be re-vegetated by Spring of 2018. Unfortunately, the current estimate is that a mere 5-10% of the vegetation has re-established, leaving a large amount of un-anchored material in the burn area ready to mobilize with intense precipitation rates, Figure 4.

Figure 3. Massive boulder transported by a debris flow in Buena Vista Creek channel.

There are four debris basins located within Montecito: Cold Springs, Montecito Creek, San Ysidro, and Romero, Figure 5. Cold Spring and San Ysidro debris basins were previously scheduled for removal within the next 10 years. However, it is understood, following the devastation from recent debris flow events, that the basins will be left in place and will potentially expanded and upgraded for environmental purposes. The fifth canyon, Buena Vista, does not have a debris basin, and it is our understanding there is no future plan to construct one. Montecito Creek Basin, located approximately two miles from the project canyons, provides no protection to the residences to its north.

Figure 4. Rapid erosion on bare slope in Romero Canyon.

4. GEOLOGY

Montecito is located in the approximately five mile wide area between the Pacific Coast and the Santa Ynez Mountains. Lower elevations in this area are composed of thick, Quaternary alluvial deposits including flood plain deposits and large, prominent alluvial fan resulting from earlier debris flow events.

The Santa Ynez Mountains are a part of the Transverse Ranges of Southern California. Bedrock is almost entirely composed of interbedded sandstone and shale strata ranging from the Jurassic Franciscan formation to Eocene sandstone and shale. These beds exhibit differential weathering causing large, blocky sandstone overhangs seen throughout the area. The blocks eventually weather and fall, resulting in sandstone boulders of various sizes to collect in the drainages. These boulders weather spheroidally. The bedding dip varies throughout the site and is governed by the extensive folding and faulting in the area. The Mission Ridge Fault is located in the western area

Figure 5. Debris basins located within the limits of Montecito, California.

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, (Dibblee, 1966). The Santa Ynez Mountains are just south of the northward thrusting Santa Ynez Fault and associated fault zones. The result is a left-lateral displacement. Other faults in the area are the result of large synclinal and anticlinal folds. The Santa Ynez Mountains are covered in Quaternary Alluvium of varying thickness. The alluvium above Paleocene to Miocene age formations, result in the ubiquitous sandstone and shale found in the Mountains. The oldest units mapped from the Paleocene, including the Anita, Sierra Blanca, and Juncal Formations, are predominantly shale.

The Middle Eocene Juncal Formation also contains the widespread Camino Cielo Sandstone member. These are overlain by the Upper Eocene Matilija and Cozy Dell formations which are comprised of buff sandstone and gray clay shale with minor sandstone beds, respectively. These units originated in a marine environment, indicated by the presence of turbidites. Turbidites are the result of gravity-induced turbidity flows, essentially underwater debris flows, depositing great amounts of clastic sediment into deeper ocean waters.

Above the Upper Eocene formations lie the younger Oligocene Coldwater Formation. The Coldwater is a sandstone containing thinner beds of sandy siltstone deposited in a coastal-shallow marine environment. Above the Coldwater is the non-marine Sespe Formation, predominantly red sandstone, shale, and conglomerate (Olson, 1982). The youngest, Miocene units of this sequence include the thin Vaqueros Formation (mostly buff sandstone) and the Rincon Shale.

The stratigraphy of the area reveals a period of land subsidence followed by a major classic influx that was succeeded by marine transgression. These events are illustrated in the rock record in the form of marine deposits (the Anita through the Juncal formations), the shallower deposits of the Matilija, and the deeper marine deposits of the Cozy Dell and the older part of the Coldwater. In the later years of the development of the Coldwater formation, the increase of sediment on the continent led to a shallower deposition of sediments, partially due to tectonic uplift (Van de Kamp, 1974). This resulted in the deposition of the Sespe Formation, evident in fanglomerate[2] deposits associated with alluvial fans which can be seen throughout the canyons. The area was exposed to displacement thrust faulting associated with disharmonic folding as the Santa Ynez Mountains continued to be uplifted and eroded (Olson, 1982).

5. SITE EVALUATION

5.1 Net Locations

Beginning May 29, 2018 and continuing through September 2018, KANE GeoTech investigated the five Montecito canyons to assess the suitability for flexible debris flow protection systems and to collect the data required for analyses for net design. KANE GeoTech began the detailed evaluation of each site by thoroughly reviewing topographic maps, preexisting trails, and local routes through every canyon.

To complete the site investigations, KANE GeoTech personnel developed a field methodology by hiking from the trail head to the back of each of the five canyons to mark preliminary net locations. While hiking downstream back toward the trail head after the preliminary assessment of the entire canyon, final net locations were noted, measured, and other data recorded. This method allowed the evaluation of the entire canyon, ending near the source material at higher elevations. Observing the canyon in its entirety allowed a full reconnaissance, optimizing net locations prior to collecting specific data.

Locations were chosen at significant "choke points" within each canyon. These sites were where debris material would be forced through the channel at a narrow point but had a relatively large, flat area upstream to store a large amount of debris, Figure 6. After choosing prime locations for flexible debris flow nets, KANE GeoTech personnel took rough measurements of channel dimensions,

Figure 6. Choke-point in channel with upslope storage.

[2]Conglomeratic rock containing rock fragments of various types and sizes that is deposited in an alluvial an.

videoed each area with use of the DJI Mavic Pro Drone, and marked the locations with a handheld Garmin GPS, Figures 7 and 8. A total of 71 net potential net locations were identified. All net numbers and GPS locations are provided in Appendix A. Please see Canyon-Specific Reports for images with net locations shown.

Figure 7. KANE GeoTech geologists and engineers hiking a canyon. Note the large boulders remaining in the channel.

6. DEBRIS FLOW NET DESIGN

6.1 Background

Geobrugg Debris Flow Protection Systems (Roth, 2004) were selected for the Project site. Geobrugg is the global leading manufacturer of flexible debris flow protection systems and has been involved in substantial research regarding debris flow mitigation (Wendeler, 2016). After catastrophic flooding in Switzerland in 2005, the Swiss government partnered with Geobrugg to conduct a major research program to determine if the nets could be used as light weight, low-cost, environmentally sound replacements for concrete check dams and debris basins.

Geobrugg debris nets have been installed in hundreds of locations around the world to protect people and infrastructure in a low-impact, environmentally sound way. Figure 9 shows a debris net installed in Camarillo Springs, California protecting the community from debris flow.

The principle behind debris nets is to catch debris flows close to the source, usually 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

Figure 8. KANE GeoTech geologist in Romero Canyon channel. Note large amounts of fine to boulder debris in channel.

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.

Figure 9. Geobrugg VX debris net protecting the community of Camarillo Springs, California. The net is easily cleaned after filling.

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.

There are two basic versions of the Geobrugg debris net systems. The VX net which is intended for relatively narrow (up to 40-ft wide), Figure 10. The UX net is installed in wider channels (up to 90-ft wide) and has posts to keep the top net support rope from sagging. In wide channels where foundations cannot be constructed, such as in the Montecito canyons, a “Super VX” net can be installed, Figure 11. It is a essentially a VX net with additional and stronger top net support ropes. Due to the environmental conditions in the Canyons above Montecito, Super VX nets will be constructed, rather than UX nets, to eliminate the need for foundations in the channel beds.

6.3 Debris Flow Net Design

6.3.1 Debris Flow Net Design Methodology

Existing methods for determining debris flow volumes are meant for large watersheds and large-scale structures such as basins and bridges impacted by timber (Bradley, et al., 2005). Conventional debris flow net design is based on field observations (Duffy and Peilia, 1999) and full-scale testing in controlled situations (De Natale, et al., 1996; Muraishi and Sano, 1997). Other publications related to the design of debris flow protection systems includes Mitzuyama, et al. (1992), Rickenmann (1999, 2001), and PWRI (1988).

Figure 10. Post-fire VX net installed above running stream on the Nambé Pueblo, New Mexico. Note basal opening allowing water and fish passage beneath.

As a result of its extensive research,

Figure 11.“Super VX” debris net installed in British Columbia, Canada. Note freeboard beneath net to allow stream flow and animal traffic. Basal opening freeboard is adjustable to eliminate construction excavation in stream channel.

Geobrugg (2003) developed a methodology suitable for the design of its debris flow net systems. A peak discharge is calculated and the flow velocity can be estimated. Once the mass and velocity are known, the 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, Figure 12.

Geobrugg has developed a software program, DEBFLOW, which determines the appropriate Geobrugg debris flow system as a function of the characteristics of a given debris flow basin and channel. The DEBFLOW program is based on the Geobrugg methodology, full scale testing in controlled situations, and finite element modeling.

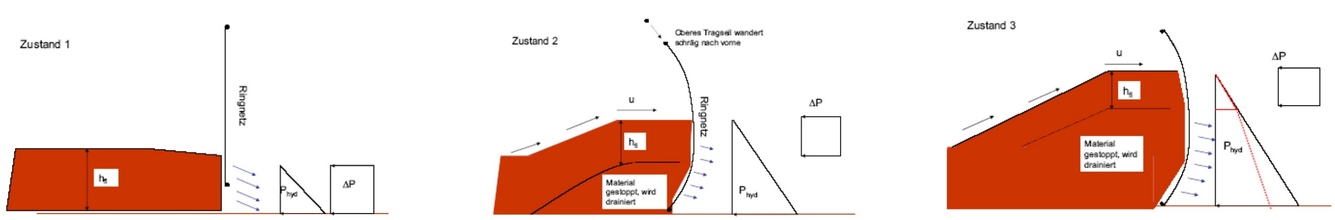

Figure 12. Schematic showing successive impact pressures from a debris flow being applied to a net. The net and its anchorages must be designed to withstand dynamic and static (Rankine) pressures. Note that successive debris impacts after the first flow lose energy by having to go up the previous flow and also stop debris material back up in the channel.

6.3.2 Debris Net Engineering

In order to produce installation plans for the nets, it is necessary to consider strength of the anchoring rock and, if required, the design of foundations for the posts. Design loads are supplied to the engineer by Geobrugg as a result of their testing and finite element modeling. Rock and soil properties are determined during the field investigation at each installation site.

Anchor design for UX and VX nets consists of determining the depth required to support the loads on the wire ropes. Previous work by the Post Tension Institute (PTI) (2014) gives a methodology for anchor design that is used for soil walls, tie-back walls, slope post-tensioning, slope stabilization system design, and rockfall and debris net anchor design. The PTI provides design charts with a recommended shear, or bond, strength for a particular rock/grout combination as determined by the geologist. The data comes from thousands of actual installations. Figure 14 is an example of PTI tabulated data. Equation (1) is then used to calculate a nominal design depth for the anchor.

For example, a weathered and fractured sandstone, as found in the Santa Ynez Mountains, will have a bond strength of 100-psi to 120-psi, Figure 13. The maximum test load for a debris net anchor is given by Geobrugg at 80,000-lbs. Using Equation (1), and assuming a 4-in drill hole and minimum bond strength of 100-psi, the necessary depth to hold the anchor in the fractured sandstone is 10.6-ft. This is well-within the capability of a small rock drill.

$$L_b = \frac{2\,P}{\pi\,d\,\tau_w} \qquad (1)$$

where:

L_b = *depth required for anchor*
2 = *PTI recommended Factor of Safety*
P = *design load for the anchor*
π = 3.14
d = *drill hole diameter*
τ_w = *working bond stress along the interface between the rock and grout* (*interface shear strength*)

Another example, might be the weathered and fractured shale found in the Santa Ynez Mountains. Using Figure 13, a soft shale will have bond strengths of 30-psi to 120-psi. Using the very conservative value of 30-psi, an anchor in shale in a 4-in hole would have to be drilled to a maximum of 35-ft. This is not out of the range of the typical drill.

Table 6.1 Typical Average Ultimate Bond Stresses-Rock/Grout

ROCK	AVERAGE ULTIMATE BOND STRESS-ROCK/GROUT	
	MPa	*PSI*
Granite & Basalt	1.7 - 3.1	250 - 450
Dolomite Limestone	1.4 - 2.1	200 - 300
Soft Limestone	1.0 - 1.4	150 - 200
Slates & Hard Shales	0.8 - 1.4	120 - 200
Soft Shales	0.2 - 0.8	30 - 120
Sandstones	0.8 - 1.7	120 - 250
Weathered Sandstones	0.7 - 0.8	100 - 120
Chalk	0.2 - 1.1	30 - 155
Weathered Marl	0.15 - 0.25	25 - 35
Concrete	1.4 - 2.8	200 - 400

Figure 13. Table from PTI showing estimated bond strengths between rock and anchor grout.

Rather than estimate the bond strength, it is better, when possible, to perform actual field test anchors to determine the bond strength. Verification anchors are sacrificial anchors installed in typical sections of rock. The anchors are drilled to various depths and tested. The load at pullout can then be back-calculated to determine the actual bond strength for the particular rock in the field. KANE GeoTech has found that PTI bond strengths tend to be very conservative and time and money can be saved by performing verification tests prior to net installation. Verification anchor testing will be conducted for the Montecito project to ensure quality in anchor installation.

6.4 Debris Flow Volume Storage Determination

Debris flow volume storage area is based on field observations and measurements of channel geometry. For DEBFLOW analyses, the calculated volume of sediment detained by each net is based primarily on a uniform geometry of each net and channel gradient. This assumes the storage area is a trapezoidal prism extending upstream from the net. This volume estimate does not take into account changes in channel shape upstream from each net location. However, sites were chosen to maximize storage area, so the volume estimates should be considered minimum values of sediment retained. Each net location identified in the field is within one of the five canyons identified in KGT Phase 1 Initial Investigation, at locations where channel geometry is constricted and upstream geometry widens to provide maximum storage capacity.

For this project, the approximate net locations, channel geometries, and estimated debris flow volumes were determined by KANE GeoTech from its field investigation and examination of WERT and BAER Reports, Table 1. Conservatively estimated total debris flow volumes exceeded the one-event capacity of the available flexible net designs. Therefore, for design purposes, nets were assumed to fill completely. Volumetric data, field observations, topographic maps, and the Geobrugg DEBFLOW program were used to calculate the design requirements for the recommended Geobrugg Debris Flow Protection Systems.

TABLE 1. STORAGE POTENTIAL OF PHASE 1 NET LOCATIONS

Canyon	Number of Nets	Approximate Retained Volume	
		m^3	yd^3
Cold Spring	2	7,400	9,650
Hot Springs	2	11,200	14,600
San Ysidro	2	11,250	14,700
Buena Vista	7	29,480	38,550
Romero	2	4,000	3,950
TOTAL	**15**	**63,330**	**81,450**

7. DEBRIS NET INSTALLATION

Once permits are obtained, debris nets can be installed by an experienced contractor. Access Limited Construction (Access) of Oceano, California has been identified as the Contractor for the debris net installation. Access is one of the most experienced geohazard contractors in the United States and has installed more debris nets than any other contractor.

The anchor locations are marked by the contractor and the engineer. Accurate measurements must be taken at this point so that the nets can be custom-fabricated for each location. Geobrugg manufactures its nets at its factory in Algodones, New Mexico.

While fabrication is in progress, the Contractor will begin drilling anchors using approved equipment per permit, Figure 14. All anchors will be installed in the channel sides. KANE GeoTech will be on-site to ensure conformance with its plans and to address any engineering issues immediately that may occur. Anchor installation requires the most time in the installation process. It takes a crew of three about one week to drill anchors and install a net.

Figure 14. The Kaiser Spyder S2 Walking Excavator. It is specialized, low-environmental-impact drilling equipment from Access Limited. The machine recently was used to install anchors for debris nets Camarillo, California. Note that machine is supported on sides of channel and does not disturb the channel itself. Pictured here with an excavator bucket. The machine can be configured with a drill for anchor installation or a bucket for net clean-out.

As the fabricated nets are delivered, they are hung on the wire ropes, much like a shower curtain. This process generally only takes about two days per net. Once the nets are hung, the construction process is completed. The Contractor then performs site clean-up and the project is completed.

8. Debris Net Maintenance

8.1 Net Maintenance

All steel components from Geobrugg are hot-dip galvanized with 95% zinc and 5% aluminum to provide corrosion protection. This results in an estimated lifetime of net steel components to be 75-yrs to 100-yrs.

Periodic clean-out is generally recommended. However, although not planned for this Project, a net can be left full and effectively reduce the channel gradient. The change in gradient will significantly reduce the energy from any subsequent flows.

The ring nets do not conform to the bottom of the channel, allowing the passage of water and fine sediment. They are also corrosion protected and can be powder coated for aesthetic purposes. Vegetation can easily grow around the debris nets, allowing for rapid assimilation into the surrounding environment. The debris nets should be considered temporary and removed when full area revegetation occurs.

Maintenance costs associated with the nets include the replacement of brake elements once activated beyond 50% of their capacity, and the cost cleaning-out of retained material. Clean-out frequency will depend on the frequency, intensity, and the amount of precipitation experienced in the surrounding watershed. The brake elements will generally only be activated during a high-energy debris flow event and may not activate at all with low energy sediment loading. If a debris net is filled with sediment or debris and will not be cleaned out, there is no need to replace the brake elements.

8.2 Net Clean-out

Clean-out can be accomplished in two ways. First, a backhoe or excavator can remove material and place it on the downstream side of the debris net. In this method, the debris material is returned to the natural system and free to continue downstream albeit less catastrophic conditions. If another debris event should occur, the material will be stopped and captured by the next net downstream. This approach, when used in Montecito will assure material is safely brought to the ocean to provide natural beach replenishment. Alternatively, in areas with road access, or by hauling material out of the canyons with a helicopter, the material can be loaded and placed in haul trucks for removal to a spoil site.

In either situation, the net can be disconnected from the top support ropes, laid on the ground and a small backhoe or loader used to distribute or remove the material. Only vehicles with rubber tires should be used while cleaning out the net to reduce impacts to the channel and avoid damaging the net. After the net has been cleared of retained debris, the net should be inspected for damage. For additional information on maintenance, it is recommended to follow the manufacturer's published guidelines.

Concerns regarding the nets becoming long-term "barriers" for steelhead migration can be addressed by rapid assessment, channel clearing, and re-distribution of material should the nets be partially or completely filled following an event.

Following the revegetation of the slopes and when the nets are no longer needed for debris flow protection, the nets are planned to be removed. It is common practice, to remove infrastructure within stream channels, create a passage for fish, and allow the natural stream flow re-distribute the sediment downstream by natural processes, (Matilija Coalition, 2018).

Additional detailed information about clean-out of each proposed net has been developed by Access Limited Construction (2018).

9. ENVIRONMENTAL ASPECTS OF DEBRIS NETS

The debris nets were developed in Switzerland to be environmentally sound protective measures against debris flow. They are engineered to replace environmentally destructive rigid barriers and debris basins. They can be installed without impacting channel bottoms.

The rings are large enough for small animals to pass through. Wendeler, et al. (2017) described ten years of world-wide experience with debris nets noting that when filled, the rings allow for the passage of animals. The authors noted that owners often request that the nets be left filled to allow rapid revegetation and fit into the landscape more rapidly.[3] Although this is an option, the Montecito nets will be cleaned out after filling.

Generally, the nets are designed with a gap, or freeboard, beneath them of at least 3-ft In some circumstances, such as debris chutes where a stream channel may not be present, large rings can be installed along the bottom to allow animal traffic. The Montecito project will not utilize this approach as all canyons have stream channels. Animals will be able to travel beneath the nets which will have basal openings of between 3-ft and 5-ft.

VX and Super VX nets have all their anchors on the sides eliminating the need to disturb a channel during construction. All the nets are lightweight and can easily be removed in post-fire situations once vegetation has been reestablished. For this project, VX and Super VX nets only will be used.

These systems have been in use for decades in one form or another, from rockfall protection systems to debris nets. Debris nets have been diligently researched and tested with over ten years of experience with them (Wendeler, et al., 2017). They have tremendous environmental advantages:

1. *The nets do not act as barriers to fish transport*. The nets are installed above the stream channels. During high flows the fish can easily swim through the rings. If the nets fill, they can be opened relatively quickly, the material placed downstream in a way to enhance habitat by creating pools for steelhead. The alternative is to allow debris to travel at high velocities downstream wiping out any fish and carrying toxic debris and water down to the ocean.

2. *Rock nets and debris nets do not trap animals.* They have been used in thousands of locations with great success throughout the world. There is not one recorded instance of an animal being trapped in a net. The animals simply pass under or around the nets.

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[3]The advantage to not removing vegetation is to save money, but also to allow the stream gradient to change, reducing flow velocities and consequential damage downstream.

3. *The nets are a rapidly-installed, engineered solution.* The nets can be deployed relatively rapidly and provide extensive and much-needed protection to the stream channels, structures, wildlife, and people. The creeks are already "messed up" from debris that will continue if left unchecked. Further debris flows without mitigation may further destroy the channel, preventing fish transport.

4. *The nets work in harmony with the natural rock sedimentation cycle.* The debris nets remain dormant until a large debris event occurs. Once debris has been stopped, the nets are excavated and the material placed downstream and to the side to allow transport as part of the natural erosion/beach replenishment cycle. In addition, clean-out equipment can be used to enhance pools used by steelhead and other species for spawning.

5. *The nets will allow the return of the natural system vegetation much sooner than if debris flows were allowed to continue unchecked.* The debris catch-and-release-under-controlled-circumstances nature of the project facilitates the regrowth of plants to establish and remain in place, rather than be destroyed in successive uncontrolled debris flows.

10. RISK ASSESSMENT

After the flooding of August 2005 in Switzerland, the Swiss government and Geobrugg worked to reduce the debris risk to residents living in high risk zones using environmentally sound debris nets. Figure 15 shows the changes in risk in the town of Brienz, Switzerland along the Trachtbach River after two catastrophic debris flows in summer 2005. Figure 16 shows the post debris flow damage to the town. A similar design and result using the Geobrugg debris nets is the goal of this project.

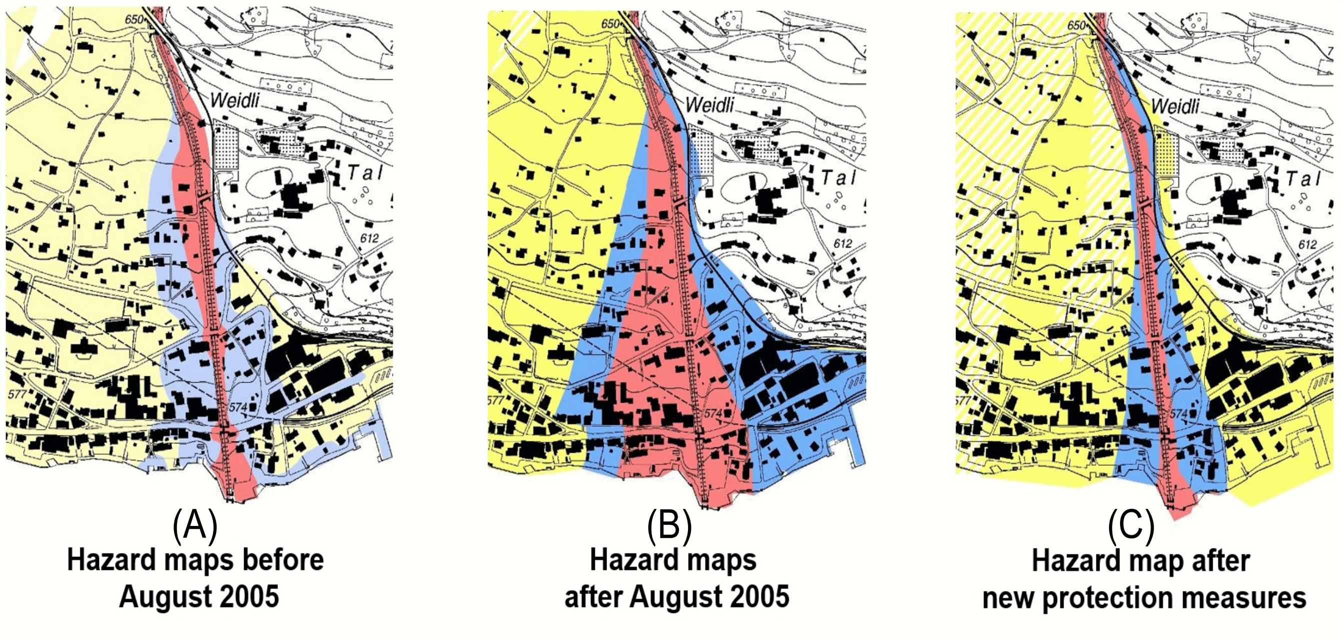

Figure 15. Changes in risk in the town of Brienz, Switzerland before (A), after the catastrophic debris flows of 2005 (B), and after the installation of a system of Geobrugg debris nets in the Alpine drainages above the town (Geobrugg, 2017).

Figure 16. Catastrophic damage to the town of Brienz, Switzerland in summer 2005 was similar to that experienced by Montecito after the January 9, 2018 debris flows.

KANE GeoTech contacted BGC Engineering (BGC)) concerning risk assessment and the need for debris flow mitigation prior to the upcoming rainy season. BGC made a preliminary assessment fo the Montecito area and the canyons above (BGC, 2018), Appendix B.

Personnel from BGC hiked Buena Vista Canyon, which has no debris basin at all, with a KANE GeoTech engineer and geologist. BGC also toured the Montecito community with Montecito Fire personnel, to make a preliminary assessment of the risk involved.

BGC concluded that a large supply of fine-grained sediment, boulders, tree-trunks, and branches remain in the canyons and is readily available for future debris flow events in the coming rainy season. They also pointed out that the existing sediments basins in Montecito are inadequate to catch and store the volume of debris likely to be mobilized during a debris flow event similar to the January 9, 2018 event.

BGC recommended that immediate mitigation action be taken and that an instrumentation and warning system be installed. They also agreed with TPRC and KANE GeoTech that flexible debris nets could be placed in the canyons to help protect against large-scale debris flow events.

11. INSTRUMENTATION

Additional weather and a debris monitoring/warning instrumentation system is being considered for implementation in subsequent construction. A detailed literature review and conceptual designs for a weather station, rain gauges, and debris flow monitoring/warning system are included as Appendix C.

12. CONSTRUCTION DRAWINGS, CALCULATIONS, AND SPECIFICATIONS

Construction drawings, calculations, and specifications for the 15 initial debris nets have been completed and submitted separately for permitting.

13. ESTIMATED COSTS

Due to the difficult access and time sensitivity of this project, TPRC has retained Access Limited Construction, LLC to construct the nets. Access has extensive experience in debris flow net construction. They have worked with private and public agencies and under rigorous timelines and constraints.

They are one of the few contractors in the United States that own and operate The Kaiser Spyder, Figure 14. This specialized excavator will allow for rapid drilling and anchor installation within difficult access channels. Access involvement in the Project prior to construction has allowed them to become familiar with the sites. This has allowed Access to work closely with KANE GeoTech and Storrer to address constructability and environmental issues in advance of construction.

14. CONSTRUCTION METHODOLOGY AND SEQUENCE

Drilling and grouting anchors is the most time consuming task of the net construction. Therefore, drilling and grouting can be performed during net fabrication. In the interest of time savings, it is our recommendation that the anchor installation by multiple crews begin as soon as possible. While anchors are being installed additional crews can follow and install support ropes and nets in each canyon after grouting is completed.

We recommend that KANE GeoTech personnel be present to document debris net anchor locations and hole depths, authorize changes, and take detailed notes while construction is taking place. This will help ensure the debris flow nets are constructed per KANE GeoTech's design, and will help maximize construction efficiency.

15. CONCLUSION

15.1 Conclusion

Due to the lack of significant revegetation in the canyons impacted by the Thomas Fire, topsoil and loose debris material does not have a substantial anchorage. Consequently, a high potential for large quantities of loose debris still remains. A substantial volume of rainfall in a relatively small time frame will likely trigger large debris flow in the already impacted areas. Given this, debris flow is still of paramount threat to the Montecito community and should be mitigated immediately before winter rains begin.

The limited storage capacity of the existing debris basins will be greatly enhanced with the installation of all 71 nets, Table 2 and KANE GeoTech (2018a - 2018d).

Additionally, the installation of the nets is an excellent way to protect Montecito residents and property without harming the environment. In fact, installation of the nets most likely will facilitate the environmental recover process.

TABLE 2. DEBRIS STORAGE CAPACITY INCREASE WITH INSTALLATION OF GEOBRUGG DEBRIS NETS

Canyon	Basin Capacity (m^3)	Total Net Capacity (m^3)	1-yr Vol. Est. (m^3)	% Retained Basin + Nets (m^3)	5-yr Vol. Est. (m^3)	% Retained Basin + Nets (m^3)
Cold Spring	15,300	78,200	90,000	104	130,000	72
San Ysidro	8,400	70,400	80,000	99	120,000	66
Romero	20,600	60,800	60,000	136	80,000	99

15.2 Addendum

For initial permitting, the installation of 15 Geobrugg debris flow protection systems will retain significant volumes of debris and greatly reduce flow energy by retaining material at higher elevations in the canyons, Figure 16. By reducing the flow energy and removing boulders from the sediment conveyance system, the likelihood that destructive debris flows will occur will be significantly reduced.

Table 3 shows the type of net for each proposed location and the amount of material that can be retained when a debris flow occurs. A total 81,400-yd^3 can be retained. This alone is twice the capacity of all the existing debris basins combined.

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TABLE 3. NET LOCATIONS AND RETENTION VOLUMES FOR 15 PROPOSED LOCATIONS

Canyon and Net Location	Net Location Identification	Latitude	Longitude	Geobrugg Net Type	Geobrugg Net Material Retention Volume		
					Cubic Meters (m^3)	Cubic Feet (ft^3)	Cubic Yards (Yd^3)
Buena Vista Canyon	BV-2	34°27'2.88"N	119°36'39.84"W	VX140-H4	1,001	35,350	1,309
Buena Vista Canyon	BV-4	34°27'17.04"N	119°36'41.42"W	SVX180-H6	5,509	194,549	7,205
Buena Vista Canyon	BV-5	34°27'19.02"N	119°36'37.33"W	VX140-H4	1,432	50,571	1,873
Buena Vista Canyon	BV-6	34°27'30.13"N	119°36'31.63"W	VX160-H6	1,793	63,319	2,345
Buena Vista Canyon	BV-7	34°27'22.06"N	119°36'34.06"W	VX160-H6	5,296	187,027	6,927
Buena Vista Canyon	BV-10	34°27'8.78"N	119°36'40.56"W	VX160-H6	3,426	120,988	4,481
Buena Vista Canyon	BV-11	34°27'20.26"N	119°36'40.59"W	SVX180-H6	11,025	389,345	14,420
				Estimated Debris Retention Volume:	**29,482**	**1,041,148**	**38,561**
Hot Springs Canyon	HS-6	34°27'23.44"N	119°38'19.77"W	SVX180-H6	9,838	347,426	12,868
Hot Springs Canyon	HS-7	34°27'18.12"N	119°38'21.08"W	VX140-H4	1,332	47,039	1,742
				Estimated Debris Retention Volume:	**11,170**	**394,465**	**14,610**
Cold Spring Canyon	CS-11	34°27'36.75"N	119°39'14.40"W	VX160-H6	2,942	103,896	3,848
Cold Spring Canyon	CS-18	34°27'36.89"N	119°39'18.01"W	SVX180-H6	4,421	156,126	5,782
				Estimated Debris Retention Volume:	**7,363**	**260,022**	**9,630**
San Ysidro Canyon	SY-7	34°28'7.06"N	119°37'23.09"W	SVX180-H6	6,477	228,733	8,472
San Ysidro Canyon	SY-18	34°27'34.39"N	119°37'23.92"W	SVX180-H6	4,728	166,968	6,184
				Estimated Debris Retention Volume:	11,205	395,701	14,656
Romero Canyon	RC-12	34°27'54.46"N	119°35'27.46"W	SVX180-H6	2,055	72,572	2,688
Romero Canyon	RC-15	34°27'31.52"N	119°35'29.40"W	VX160-H6	960	33,902	1,256
				Estimated Debris Retention Volume:	3,015	106,474	3,943
				Total Estimated Debris Retention Volume:	**62,235**	**2,197,810**	**81,400**

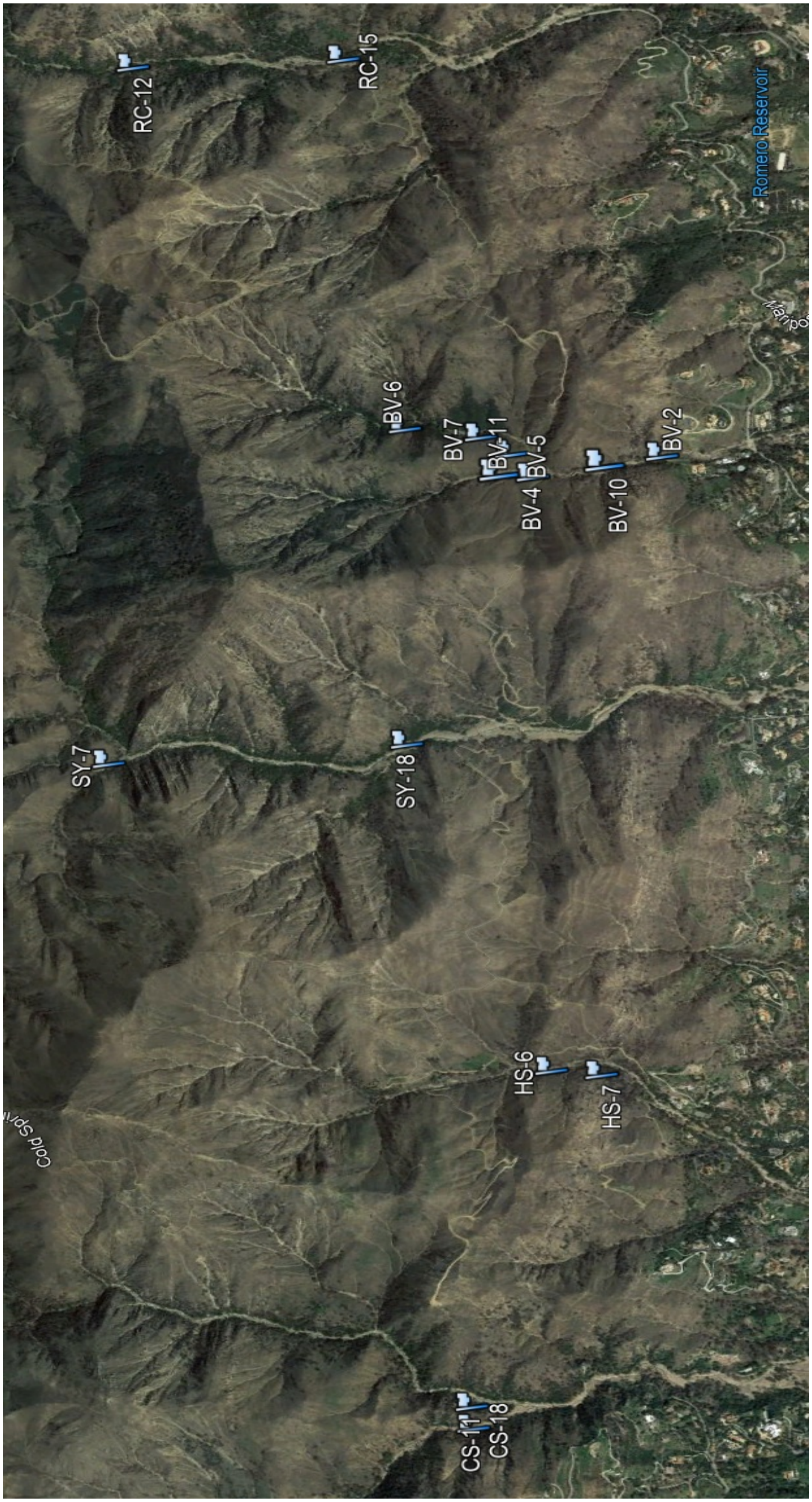

Figure 16. Locations of 15 proposed debris nets

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17. LIMITATIONS

Debris flows and rockfall are sporadic and unpredictable. Causes range from human construction to environmental (e.g., weather, wildfire) effects. Because of the multiplicity of factors affecting debris flow dynamics, debris flow and rockfall are not, and cannot be, exact sciences that guarantee the safety of individuals and property. However, by the application of sound engineering principles to a predictable range of geodynamics, the risk of injury and property loss can be substantially reduced by the use of properly designed nets in identified risk areas. Inspection and maintenance of nets is necessary to ensure that the desired protection level is not degraded by impact damage exceeding the design limits of a particular system or by corrosion from pollution or other man-made factors.

The analyses, conclusions and recommendations contained in this report are based on the site conditions observed by KANE GeoTech, Inc. personnel and derived from the information provided to KANE GeoTech, Inc. by others. If there is a substantial lapse of time between the submission of our report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, we urge that our report be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse. This report is applicable only for the project and site studied. This report should not be used after three years.

Our professional services were performed, our findings obtained, and our recommendations proposed in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties either expressed or implied. Findings and statements of professional opinion do not constitute a guarantee or warranty, expressed or implied.

In order to assure that the project conforms to our specifications and design plans, and for satisfactory construction and performance, we urge that KANE GeoTech, Inc. be retained to observe construction, anchor testing, and to complete a final inspection. We cannot be responsible for constructed products built without our oversight.

Yours truly,

***KANE* GeoTech, Inc.**

William F. Kane, PhD, PG, PE
California Licensed Civil Engineer No. 55714

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APPENDIX A

DEBRIS NET GPS LOCATIONS

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TABLE A.1 NET LOCATIONS IN BUENA VISTA CANYON

Canyon	Debris Net Name	GPS Coordinates
Buena Vista	BV-1	N 34° 26.964' W 119° 36.670'
Buena Vista	BV-2	N 34° 27.048' W 119° 36.664'
Buena Vista	BV-3	DELETED
Buena Vista	BV-4	N 34° 27.284' W 119° 36.690'
Buena Vista	BV-5	N 34° 27.317' W 119° 36.622'
Buena Vista	BV-6	N 34° 27.502' W 119° 36.527'
Buena Vista	BV-7	N 34° 27.368' W 119° 36.568'
Buena Vista	BV-8	DELETED
Buena Vista	BV-9	DELETED
Buena Vista	BV-10	N 34° 27.2067' W 119° 36.415'
Buena Vista	BV-11	N 34° 27.205' W 119° 36.407'

TABLE A.2 NET LOCATIONS IN HOT SPRINGS CANYON

Canyon	Debris Net Name	GPS Coordinates
Hot Springs	HS-1	N 34° 27.762' W 119° 38.366'
Hot Springs	HS-2	N 34° 27.710' W 119° 38.371'
Hot Springs	HS-3	N 34° 27.625' W 119° 38.341'
Hot Springs	HS-4	N 34° 27.550' W 119° 38.347'
Hot Springs	HS-5	N 34° 27.527' W 119° 38.273'
Hot Springs	HS-6	N 34° 27.391' W 119° 38.329'
Hot Springs	HS-7	N 34° 27.302' W 119° 38.351'
Hot Springs	HS-8	N 34° 27.183' W 119° 38.515'

TABLE A.3 NET LOCATIONS IN ROMERO CANYON

Canyon	Debris Net Name	GPS Coordinates
Romero Canyon	RC-1	N 34° 27.474' W 119° 35.750'
Romero Canyon	RC-2	N 34° 27.468' W 119° 35.830'
Romero Canyon	RC-3	N 34° 27.424' W 119° 35.783'
Romero Canyon	RC-4	N 34° 27.430' W 119° 35.713'
Romero Canyon	RC-5	N 34° 27.457' W 119° 35.610'
Romero Canyon	RC-6	N 34° 27.152' W 119° 35.187'
Romero Canyon	RC-7	N 34° 27.207' W 119° 35.173'
Romero Canyon	RC-8	N 34° 27.178' W 119° 35.353'
Romero Canyon	RC-9	N 34° 27.230' W 119° 35.570'
Romero Canyon	RC-10	N 34° 27.161' W 119° 35.395'
Romero Canyon	RC-11	N 34° 27.007' W 119° 35.474'
Romero Canyon	RC-12	N 34° 27.908' W 119° 35.457'
Romero Canyon	RC-13	N 34° 27.863' W 119° 35.454'
Romero Canyon	RC-14	N 34° 27.605' W 119° 35.506'
Romero Canyon	RC-15	N 34° 27.525' W 119° 35.490'
Romero Canyon	RC-16	N 34° 27.482' W 119° 35.080'
Romero Canyon	RC-17	N 34° 27.461' W 119° 35.129"
Romero Canyon	RC-18	N 34° 27.488' W 119° 35.242'
Romero Canyon	RC-19	N 34° 27.496' W 119° 35.320'

TABLE A.4 NET LOCATIONS IN COLD SPRING CANYON

Canyon	Debris Net Name	GPS Coordinates
Cold Spring	CS-1	N 34° 28.226' W 119° 38.902'
Cold Spring	CS-2	N 34° 28.151' W 119° 38.939'
Cold Spring	CS-3	N 34° 28.059' W 119° 38.955'
Cold Spring	CS-4	N 34° 27.962' W 119° 39.000'
Cold Spring	CS-5	N 34° 27.808' W 119° 39.029'
Cold Spring	CS-6	N 34° 28.797' W 119° 38.986'
Cold Spring	CS-7	N 34° 27.789' W 119° 39.039'
Cold Spring	CS-8	N 34° 27.757' W 119° 39.094'
Cold Spring	CS-9	N 34° 27.759' W 119° 39.189'
Cold Spring	CS-10	N 34° 27.685' W 119° 39.201'
Cold Spring	CS-11	N 34° 27.613' W 119° 39.245'
Cold Spring	CS-12	N 34° 27.486' W 119° 39.264'
Cold Spring	CS-13	N 34° 28.016' W 119° 39.538'
Cold Spring	CS-14	N 34° 27.928' W 119° 39.492'
Cold Spring	CS-15	N 34° 27.882' W 119° 39.483'
Cold Spring	CS-16	N 34° 27.790' W 119° 39.379'
Cold Spring	CS-17	N 34° 27.691' W 119° 39.307'
Cold Spring	CS-18	N 34° 27.615' W 119° 39.300'

TABLE 1.5 NET LOCATIONS IN SAN YSIDRO CANYON

Canyon	Debris Net Name	GPS Coordinates
San Ysidro	SY-1	N 34° 28.216' W 119° 36.620'
San Ysidro	SY-2	N 34° 28.214' W 119° 36.827'
San Ysidro	SY-3	N 34° 28.231' W 119° 36.957'
San Ysidro	SY-4	N 34° 28.257' W 119° 36.976'
San Ysidro	SY-5	N 34° 28.210' W 119° 37.166'
San Ysidro	SY-6	N 34° 28.155' W 119° 37.298'
San Ysidro	SY-7	N 34° 28.118' W 119° 37.385'
San Ysidro	SY-8	N 34° 28.087' W 119° 37.378'
San Ysidro	SY-9	N 34° 28.002' W 119° 37.365'
San Ysidro	SY-10	N 34° 27.885' W 119° 37.409'
San Ysidro	SY-11	N 34° 27.820' W 119° 37.436'
San Ysidro	SY-12	N 34° 27.754' W 119° 37.451'
San Ysidro	SY-13	N 34° 28.279' W 119° 37.259'
San Ysidro	SY-14	N 34° 28.217' W 119° 37.256'
San Ysidro	SY-15	N 34° 28.302' W 119° 37.386'
San Ysidro	SY-16	N 34° 28.235' W 119° 37.344'
San Ysidro	SY-17	N 34° 27.657' W 119° 37.446'
San Ysidro	SY-18	N 34° 27.573' W 119° 37.399'

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APPENDIX B

BGC RISK ASSESSMENT

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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
701 12th Street – Suite 211
Golden, CO USA 80401
Telephone (720) 598-5982

August 31, 2018
Project No.: 1890-001

Suzanne Elledge
Planning & Permitting Services, Inc.
1625 State Street, Suite 1
Santa Barbara, CA 93101

Dear Suzanne,

Re: Montecito Debris-Flow Risk Management – Urgent Action Needed

The Partnership for Resilient Communities (TPRC) retained BGC Engineering Inc. (BGC) to support their debris-flow risk management efforts. TPRC requested that BGC submit this letter to you in support of urgent mitigative action to manage debris-flow risk faced by residents of Montecito. Debris flows in Montecito have occurred repeatedly in the past and will without doubt occur again. The series of high-magnitude debris flows on January 9, 2018 demonstrated that mud, large boulders, and up-rooted trees from the burned area can race into populated areas with very little warning and cause loss of life and devastation to property and infrastructure.

Urgent action is needed to protect life and property in Montecito from the impacts of future debris flows. The January 2018 debris flows did by no means "remove" the hazard or return the watersheds to "pre-fire" conditions. The likelihood of debris flows this winter remains high because vegetation has only tentatively begun to re-establish following the fire, and the approaching season of rainfall beginning in November could trigger a subsequent round of debris flows from the denuded watersheds above Montecito.

The following points demonstrate the reality of debris-flow threat and urgency to prepare:

1. The community of Montecito is located on geologic landforms called alluvial fans (or debris-flow fans) which were created by debris flows and debris floods of the past (Minor et al. 2009). The fans of the individual creeks merge and overlap between the mountain front and the ocean where Montecito is located. Debris flows in the Santa Ynez mountains above Montecito have occurred repeatedly in the past (Minor et al. 2009; Kean et al., 2011, Gartner et al., 2014) both before and after development, and will without doubt occur again.
2. The increased threat of debris flows following wildfire has been recognized in southern California since the early 1900's (Eaton et al., 1935) and have periodically caused extensive damage and fatalities including: extensive damage in Glendora, CA in 1969 (Scott et al., 1971), 16 fatalities on Christmas Day 2003 in San Bernardino, CA (Los

Angeles Times, 2003) and extensive damage following the 2009 Station Fire near La Canada-Flintridge, CA (USGS 2018).

3. As demonstrated on January 9, 2018, debris flows at Montecito can be highly destructive, and greatly exceeded the impacts predicted by FEMA[1]'s map of clear-water flood hazards (FEMA 2018). Debris flows travel at higher speeds, carry up-rooted trees and large boulders (car-sized or greater), and greatly exceed the capacity of Montecito's existing sediment basins and channels.
4. An abundant supply of fine-grained sediment, boulders, tree-trunks, and branches remains in the watershed to be entrained in future flows (Appendix A). The January 2018 debris flows did not exhaust the supply of sediment and large woody debris.
5. The debris flows in January 2018 do not preclude repeat events from occurring in the same watersheds, triggered by subsequent storms. Technical literature documents several examples of multiple debris flows occurring in the same watershed in the years after a fire (Booker 1998; Cleveland 1973; Kean et al. 2011; Scott 1971; Slosson et al. 1989). For example, up to 13 debris-flow events were recorded in basins burned by the nearby Station Fire which burned in the San Gabriel Mountains in 2009 (Staley et al., 2013).
6. Debris flows in California are most likely to occur within the first several winter seasons following a fire (e.g., Cannon et al. 2008). Therefore, debris-flow hazard at Montecito is currently still near its peak level, and the likelihood of a debris flow is still elevated compared to preceding winters when the watersheds were fully vegetated. Recovery of watershed vegetation will diminish debris-flow hazard with time, but will not eliminate it.
7. Occurrence and magnitude of near-future (i.e., next 1 to 5 years) debris flows will be controlled primarily by the intensity of rainfall runoff. The likelihood of a debris flow during the approaching winter is directly related to the likelihood of a heavy or intense rainstorm.
8. The rainfall measured on January 9, 2018 at Montecito was rare (NOAA 2018a), but was not unprecedented in southern California (Cannon et al. 2011). Rainfall intensity was comparable to others that have triggered post-wildfire debris flows in southern California (Cannon et al. 2011). Furthermore, debris flows from burned areas are commonly initiated from rainfall conditions with recurrence intervals of less than five years (Cannon et al. 2008). Figure 1 compares January 9, 2018 rainfall reported by NOAA (2018a) with rainfall events that triggered debris flows in southern California between 1928 and 2010. It also shows that a 1-year return period storm correlates with Magnitude II or Magnitude III debris-flows, which are capable of damaging or destroying infrastructure.

[1] U.S. government, Federal Emergency Management Agency (FEMA)

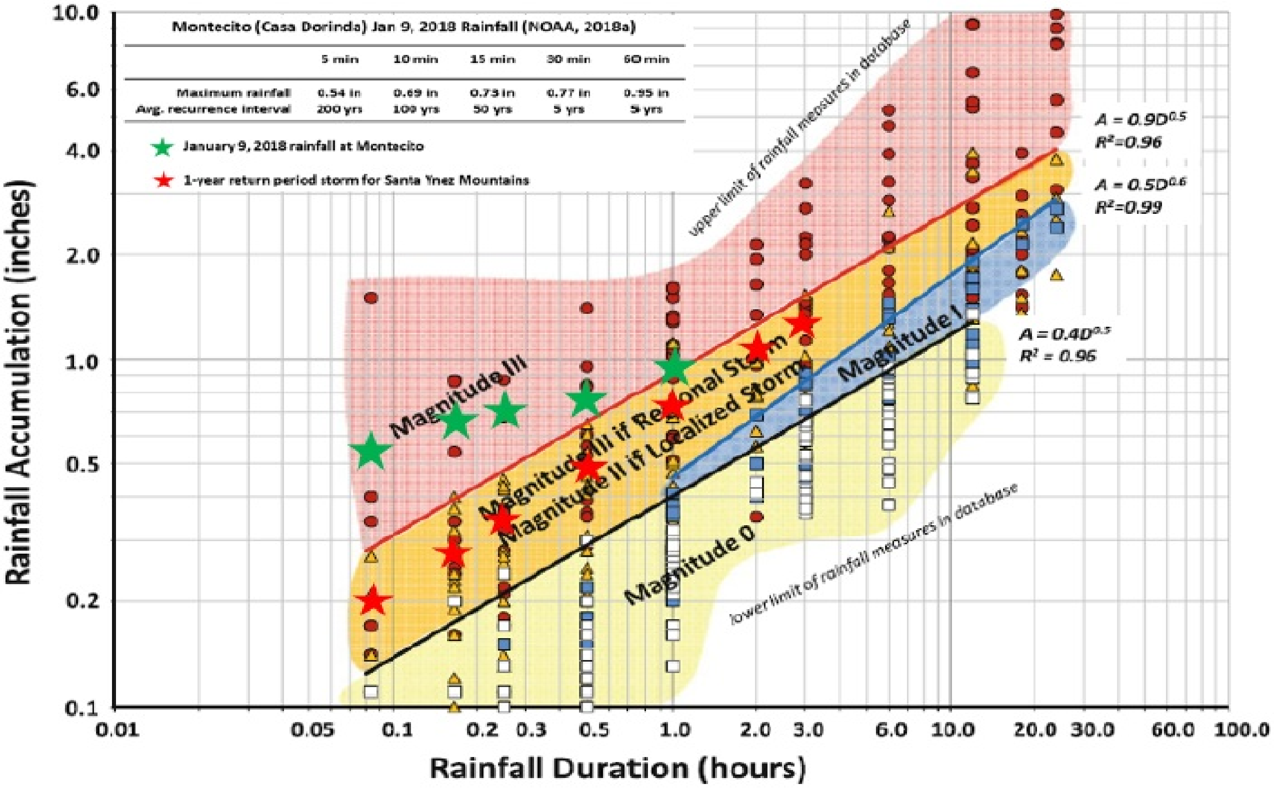

Figure 1. Adapted from Fig. 3 of Cannon et al. 2011. Within-storm rainfall accumulations for storms that triggered debris flows and floods. Open squares are storms with negligible response; blue squares are magnitude I events (small flows, houses damaged, but few large buildings threatened); orange triangles are magnitude II events (moderate flows, damage to houses and infrastructure); red circles are magnitude III events (large flows, buildings and infrastructure may be destroyed); green stars are rainfall reported at Montecito on January 9, 2018 by NOAA (2018a); red stars are rainfall for a 1-year return period in the Santa Ynez Mountains above Montecito (NOAA 2018b)

9. Sediment retention structures in Montecito are not large enough to retain potential post-wildfire debris-flow volumes estimated using U.S. Geological Survey methods (USGS, 2017). Table 1 compares the sediment retention basin capacities to volumes predicted by the USGS debris-flow volume models.

Table 1. Summary of sediment retention basin capacities (Santa Barbara County, 2017) and the range of potential sediment yield from debris flows within the first two years of the fire (USGS, 2017).

Sediment Retention Basin Name	Sediment Retention Basin Capacity (m^3)[1]	Estimated Post-wildfire Debris-Flow Volume (m^3)[2]			
		1-yr	5-yr	10-yr	100-yr
Cold Springs	15,300	90,000	130,000	170,000	330,000
San Ysidro	8,400	80,000	120,000	150,000	290,000
Romero	20,600	60,000	80,000	100,000	200,000

1. Debris basin capacities are from SBC (2017)
2. Volumes estimated using models in the scientific background presented in USGS (2017) based on rainfall intensities at various return periods for Montecito watersheds from NOAA (2018b).

10. The National Oceanic and Atmospheric Administration (NOAA) is predicting a 70% chance of El Niño conditions for January, February, and March 2019 (NOAA 2018c). El Niño conditions cause the jet stream to come ashore in California instead of the Pacific Northwest, carrying moisture and storms, which increases the likelihood of severe rainfall events in Southern California (NOAA 2018d). Table 2 shows that El Niño conditions correlate with maximum rainfall intensity events in Santa Barbara County.

Table 2. Correlation between El Niño conditions and rainfall intensity maximums in Santa Barbara County.

Duration	Location	Water Year	Maximum Rain[1] (inches)	El Niño Conditions[2]?
5 min	UCSB	1998	0.72	Yes
10 min	San Marcos Pass	2015	1.09	Yes
15 min	San Marcos Pass	2015	1.39	Yes
30 min	Stanwood Fire Station	1984	1.80	No
1 hr	San Marcos Pass	1998	2.51	Yes
2 hr	Doulton Tunnel	1973	4.5	Yes
6 hr	Jameson Reservoir	1969	8.78	Yes

Notes:
1. Maximum rainfall recorded in Santa Barbara County from County of Santa Barbara (2018)
2. El Niño conditions based on the Oceanic Niño Index, NOAA (2018e)

In summary, winter rains are coming to Montecito soon, via atmospheric river or otherwise, and a period of high debris-flow hazard will come with them. BGC strongly encourages urgent action to protect public safety and property in Montecito from subsequent debris-flow disasters. Short-term mitigative actions could include upgrades to the early-warning and evacuation protocol, and installation of physical protection such as debris-flow nets. BGC is available to support these efforts, as needed by TPRC and their partners.

CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of The Partnership for Resilient Communities. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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ABS/MJ/mjp

Attachment(s): Appendix A: BGC Montecito Debris-Flow Risk - Site Reconnaissance Summary

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Appendix A
BGC: Montecito Debris-Flow Risk – Site Reconnaissance Summary

THE PARTNERSHIP FOR RESILIENT COMMUNITIES

Montecito Debris-Flow Risk

BGC Site Reconnaissance Summary

What happened?

A series of debris flows impacted the community of Montecito, Santa Barbara County, California on January 9, 2018, **resulting in 23 fatalities, damage to more than 400 homes, and extensive economic loss.** The Partnership for Resilient Communities (TPRC) invited BGC to complete a reconnaissance-level site visit to Montecito and adjacent watersheds from July 25 to July 27, 2018.

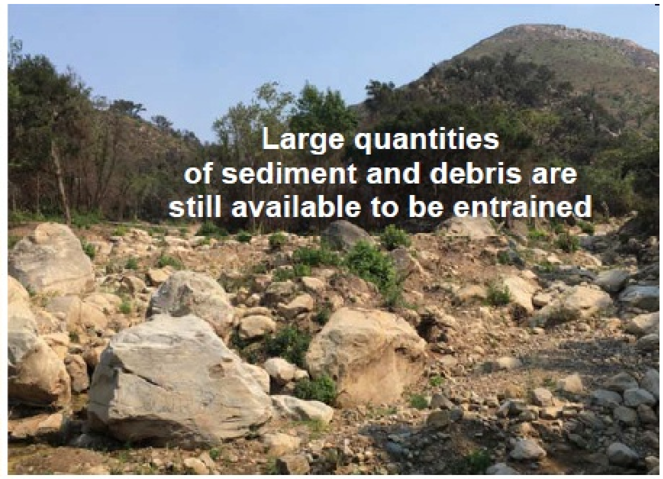
Who is BGC?

BGC Engineering Inc. (BGC) is a consulting firm providing specialist services in applied earth sciences since 1990, with specific expertise in geohazard risk management. BGC has completed hundreds of debris-flow assessments at individual creeks as well as several regional debris-flow and debris-flood risk prioritization studies. BGC staff have authored key publications on the subject of debris flows.

Field Observations

- The January 2018 debris flows destroyed homes across the entire length of the alluvial fan, from the mouth of canyons to the ocean.
- Some houses close to the fan apex collapsed and were carried away by the flows. **Rapidly flowing mud, large boulders, and woody debris all contributed to damaging and destroying homes.**
- Flow depths of the January 2018 debris flows at the mouth of some Montecito Watershed canyons ranged between 16 and 20 ft.
- The width affected by each flow was commonly between 300 ft to 1,000 ft, while the previously defined creek channels through the community are typically on the order of 16 ft to 32 ft wide.
- Evidence of previous debris flows has been reported and observed, including an anecdote of a swimming pool that filled with mud near San Ysidro creek several times in the previous decades, and landforms on the upper fan area interpreted to be debris flow levees.
- **Large quantities of fine-grained sediment, boulders, and woody debris are still abundantly available to be entrained in flows.**

A destroyed home on San Ysidro Creek.



Interpretation

- The community of Montecito was built on geologic landforms called 'debris-flow fans' that were created by sediment deposited during repeated historical debris flows and floods. **These landforms and other field evidence indicate that debris flows have occurred in the past, and debris flows will occur in the future.**
- The existing sediment basins and channels in Montecito are designed to manage flows that are substantially less than the January 2018 debris flows.
- The January 2018 debris flows appear to have scoured more than 3 ft of material from the channels near the mouth of the canyons. However, **an abundant supply of sediment and debris remains**, including loose sediment on the watershed slopes, loose sediment concentrated in watershed channels, and erodible sediment exposed in channel banks.
- Occurrence and magnitude of near-future (i.e., next 1 to 5 years) debris flows will be controlled more by the intensity of rainfall runoff rather than the abundant availability of sediment. Intensity of runoff is controlled by rainfall intensity, and vegetation cover (which intercepts rainfall and slows runoff). Vegetation cover is currently substantially less than the pre-fire condition.
- **Recovery of vegetation** on watershed slopes will eventually reduce debris flow hazard over time, but vegetation **will not eliminate debris flow hazard.**

Risk Management

- **Implementation of risk management measures is urgent**, as the rainy season begins in November, and NOAA predicts a 70% chance of El Niño in Winter 2019, which increases likelihood of severe rainfall in California.
- The currently proposed debris flow nets should help reduce, but will not eliminate, the debris flow hazard. Additional risk management strategies need to be developed in parallel with the debris flow net design to reduce debris-flow risk to levels deemed tolerable by TPRC, local regulators, and the community of Montecito.
- Debris-flow risk management measures include development of a system for early warning and evacuation, and installation of debris flow nets in the short-term, followed by improvements to physical protection that could include upgrades to debris basins and installation of check dams and conveyance channels.

The January 2018 debris flows were exceptional in historical times in terms of their degree of destruction; however, this does not preclude similar-sized or larger debris flows from occurring in the future. In the absence of adequate risk management, **the consequence of future debris flows could meet or exceed the exceptional consequences of the January 2018 debris flows.**

THIS DOCUMENT IS AN EXCERPT FROM BGC'S LETTER TITLED "MONTECITO DEBRIS-FLOW RISK—SITE RECONNAISSANCE SUMMARY" DATED AUGUST 29, 2018. OBSERVATIONS THAT SUPPORT THE INTERPRETATIONS PRESENTED HERE ARE PROVIDED IN THAT LETTER.

Issue Date: August 29, 2018, version 4

Project No.: 1890-001

BGC

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August 29, 2018
Project No.: 1890-001

Les Firestein
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Dear Les,

Re: Montecito Debris-Flow Risk – Site Reconnaissance Summary

1.0 INTRODUCTION

A series of debris flows impacted the community of Montecito, Santa Barbara County, California on January 9, 2018, resulting in 23 fatalities, damage to more than 400 homes, and extensive economic loss. The debris flows were caused by high intensity rainfall on Santa Ynez mountain watersheds that had experienced a wildfire (Thomas Fire) during the preceding weeks. After the debris flows, Montecito community members formed a nonprofit organization called The Partnership for Resilient Communities (TPRC) to support disaster recovery and longer-term debris-flow risk reduction.

TPRC invited BGC Engineering Inc. (BGC) to complete a reconnaissance-level site visit to Montecito and adjacent watersheds from July 25 to July 27, 2018. The purpose of the site visit was to observe the state (e.g. burn areas, surficial geology) of the watersheds that generated the January 2018 debris flows and the developed areas of Montecito that were impacted. These observations will inform development of a proposed scope of work that BGC is preparing for TPRC that includes debris-flow hazard assessment, debris-flow risk assessment, and debris-flow risk management.

This letter summarizes BGC's site reconnaissance observations, preliminary interpretations, and recommended short-term actions for debris-flow risk management. It also describes the qualifications and experience of BGC's debris-flow risk management team. This letter is intended to be used by TPRC to inform development of risk management plans for the winter 2018/2019 rainy season. This letter was requested in an email from Les Firestein dated July 30, 2018, and prepared under terms of contract between BGC and TPRC dated August 1, 2018.

2.0 SCOPE OF WORK

BGC's work to date has involved the following components:

1. Approximately 4 hours of review of reports and background information related to the January debris flows that is available on the internet.

2. Reconnaissance-level site visit (July 25-27, 2018) by one BGC representative, Alex Strouth, including:
   a. Meetings with Les Firestein of TPRC.
   b. Meetings with KANE GeoTech Inc. (KANE), who have been retained by TPRC to design debris flow nets to be installed in the canyons upstream of Montecito development.
   c. Meeting with Kerry Kellogg, wildfire specialist at the Montecito Fire Department.
   d. Observation of developed areas of Montecito that were impacted by the January 9, 2018 debris flows.
   e. Observation of the lower portion of Cold Spring, San Ysidro, Buena Vista, and Romero canyons from the start of development to approximately 500 m (1/3 mile) upstream
   f. Observation of the burned watersheds above Montecito from the Camino Cielo Road, located near the ridge line at the top of the watersheds.

3.0 OBSERVATIONS

The following points summarize BGC's observations. Figures that support these observations are attached to this letter.

1. Debris flows that impacted Montecito occurred in the following creeks[1] (from west to east; Figure 1):
   a. Cold Spring Creek and Hot Spring Creek (which join to form Montecito Creek)
   b. Oak Creek (which is a smaller watershed, causing less damage than other creeks)
   c. San Ysidro Creek
   d. Buena Vista Creek
   e. Romero Creek
2. Chaparral shrubland plants densely cover watersheds adjacent to these creeks that were not burned by the Thomas Fire; the slope surface is generally not visible through the Chaparral from a distance except where vegetation has been removed for development or fire break lines (Figure 2). Google Earth imagery suggests that the watersheds that produced the January 9 debris flows had a similar Chaparral cover prior to the Thomas Fire.
3. The Thomas Fire burned most vegetation in the Montecito Watersheds (Figure 3), although the burn severity appears to be somewhat less in Romero watershed compared to the other Montecito Watersheds (Figure 4, Figure 5). The Montecito fire department (K. Kellogg, pers. comm.) reports that the watersheds burned between December 13 and 16, 2017.

[1] Collectively, the watersheds that feed these creeks are referred to as the 'Montecito Watersheds' in this report.

4. Large quantities of fine-grained sediment, boulders, and woody debris are still available to be entrained in flows. This material is located on the watershed slopes, within creek channels in the canyons, and in the scoured banks of the January 2018 debris flow channel (Figure 6, Figure 7).

5. Flow depths of the January 2018 debris flows at the mouth of the Montecito Watershed canyons (as indicated by mud lines on trees and channel banks) typically ranged between 5 m and 6 m (16 ft and 20 ft)[2]. The width of the flow areas typically ranged between 20 m and 50 m (70 ft to 160 ft) within the canyons, near the canyon mouth. A superelevation[3] angle of 8° was measured at a channel bend (50 m radius of curvature, 40 m flow width) in Cold Spring Canyon, approximately 300 m (1000 ft) upstream from the development interface (Figure 8).

6. The January 2018 debris flows destroyed homes across the entire length of the alluvial fan, from the mouth of canyons to the ocean (a distance of 3 km to 4 km (1.9 to 2.5 miles), with a 5% average gradient). Some houses within approximately 1 km to 2 km (0.6 to 1.2 miles) from the fan apex collapsed entirely and were carried away by the flows. The width affected by each flow was commonly between 100 m and 300 m (300 ft to 1000 ft), while the defined creek channels through the community are typically on the order of 5 m to 10 m (16 ft to 32 ft) wide. Rapidly flowing mud, large boulders, and woody debris all contributed to damaging and destroying homes (Figure 9, Figure 10, Figure 11).

7. Evidence of previous debris flows has been reported and observed, including an anecdote of a swimming pool that filled with mud near San Ysidro creek several times in the previous decades, and landforms on the upper fan area interpreted to be debris flow levees (Figure 12).

4.0 INTERPRETATIONS

The following interpretations are based on BGC's observations:

1. The community of Montecito is located on geologic landforms called 'debris flow fans' that were created by sediment deposited during debris flows and floods. The fans of the individual creeks coalesce and overlap on the piedmont between the mountain side and the ocean. These landforms and evidence of boulder levees on the fan indicate that debris flows have occurred episodically in the past (both before and after development of Montecito), and debris flows will occur in the future.

2. The existing sediment basins and channels in Montecito are designed to manage flows that are substantially less than the January 2018 debris flows. For example, superelevation of the Cold Spring creek debris flow (Figure 8) suggests it travelled at

[2] BGC recorded observations in metric units. Approximately equivalent imperial dimensions are provided for the benefit of readers not familiar with metric units.
[3] Superelevation means that a high velocity flow at a channel bend has a higher flow surface on the outside of the channel bend than on the inside. This can be used to estimate flow velocity.

approximately 6 m/s to 8 m/s (13 to 18 miles per hour) at the canyon mouth, through an approximately 200 m^2 (2100 ft^2) channel area, yielding a peak discharge that may have approached 1600 m^3/s (57,000 ft^3/s). The San Ysidro creek debris flow appears to be of a similar scale, with relatively smaller debris flows in the other creeks.

3. The January 2018 debris flows appear to have scoured more than 1 m (3 ft) depth in channels near the mouth of the canyons and fan apex areas. However, an abundant supply of sediment remains, including loose sediment on the watershed slopes, loose sediment concentrated in watershed channels, and erodible sediment exposed in channel banks.

4. Occurrence and magnitude of near-future (i.e., next 1 to 5 years) debris flows will be controlled more by the intensity of rainfall runoff rather than the availability of sediment. Intensity of runoff is controlled by rainfall intensity, and vegetation cover (which intercepts rainfall and slows runoff). Vegetation cover is currently substantially less than the pre-fire condition (compare Figure 2 and Figure 3), but is expected to re-grow and contribute to stabilizing the watersheds with time.

5. Recovery of vegetation on watershed slopes will reduce debris flow hazard but will not eliminate debris flow hazard. Vegetation can be pictured as a 'sponge' sitting atop erodible sediment. The 'sponge' is absent in the first years following a fire, so relatively low rainfall intensities can directly impact erodible sediment, leading to a debris flow. The 'sponge' is thick after vegetation has recovered and can absorb substantial rainfall and soil moisture; however, debris flows can still occur when rainfall continues after the 'sponge' becomes saturated. This example illustrates that relatively low-intensity rainfall that is unlikely to trigger a debris flow in a vegetated watershed can trigger debris flows in a recent burn area, and relatively high-intensity rainfall can trigger debris flows in both burned and vegetated watersheds.

6. Debris flow nets proposed by TPRC and KANE are meant to reduce the volume and intensity of debris flows that reach the community of Montecito. The degree of hazard reduction depends on the number, location, and design of the nets, as well as the magnitude of future events, and has not yet been assessed by BGC or others because net design is in-progress.

7. The currently proposed debris flow nets will not eliminate the debris flow hazard. Other risk management strategies need to be developed in parallel with the debris flow net design to reduce debris-flow risk to levels deemed tolerable by TPRC, local regulators, and the community of Montecito.

8. The January 2018 debris flows were exceptional in historical times in terms of their degree of destruction; however, this does not preclude similar-sized or larger debris flows from occurring in the future. In the absence of adequate risk management, the consequence of future debris flows could meet or exceed the exceptional consequences of the January 2018 debris flows.

5.0 RECOMMENDED SHORT-TERM ACTIONS

The peak debris flow hazard period at Montecito is during the rainy season (typically November to March), particularly during the next few winters before watershed vegetation has fully recovered. Implementation of risk management measures is urgent, as the rainy season begins in 3 months. Furthermore, the National Oceanic and Atmospheric Administration (NOAA) is predicting a 70% chance of El Niño conditions for January, February, and March 2019, which suggests a relatively higher likelihood of severe rainfall events in California (NOAA, 2018). The following recommended short-term actions are intended to guide TPRC as they prepare for the upcoming rainy season.

5.1. Early Warning System and Evacuation

1. Develop an early warning and monitoring system and response protocol that includes evacuation. The short time before the rainy season limits the number and scale of physical mitigation measures (e.g. debris flow nets) that can be constructed. The best method to reduce life-loss risk in the absence of physical protection is timely evacuation of people from hazard zones[4].
2. Educate community members about debris flow hazards, monitoring, and evacuation plans, including for example: debris flow causes and triggers; how the monitoring system works; potential for false alarms; where to go during an evacuation; what to do following a debris flow event.
3. Monitoring and evacuation plans should be informed by the following information:
    a. Establish thresholds for rainfall intensity that could trigger debris flows of varying magnitude.
    b. Debris flow hazard maps identifying zones of relatively high and low debris flow hazard.
    c. Evacuation route maps identifying roads with relatively high and low debris flow hazard.
    d. Assessment of the time needed to alert and evacuate residents.
4. Consider the following monitoring phases:
    a. Monitor forecasted rainfall to identify storms capable of triggering debris flows.
    b. Monitor rainfall intensity observed in Doppler radar and at weather stations along the storm's path.
    c. Install instruments in the debris flow channels, for example cameras and load cells on debris flow nets that identify when a debris flow has initiated. Note that this system will provide only a few minutes of warning prior to the debris flow impacting

[4] Evacuation does not prevent economic loss

6.0 BGC EXPERIENCE AND QUALIFICATIONS

BGC is a consulting firm providing specialist services in applied earth sciences since 1990, with specific expertise in geohazard risk management. BGC has completed hundreds of debris-flow assessments at individual creeks as well as several regional debris-flow and debris-flood risk prioritization studies. BGC staff have also authored one of the key publications on the subject of debris flows (Jakob and Hungr, 2005: Debris Flows and Related Phenomena). BGC senior staff have also acted as expert witnesses for debris-flow related litigations and are thus well aware of the intricacies of projects with high litigative potential.

The following recent projects are most relevant to Montecito's debris flow setting and TPRC's objectives:

- Town of Canmore, Alberta: Debris-flood hazard assessment, quantitative risk assessment, mitigation design, and assistance with public policy development related to steep creek hazards. This work followed debris floods in 2013 that caused widespread damage to the town. Many of BGC's reports (including quantitative risk assessments) are available on the town's website: https://canmore.ca/projects/mountain-creek-hazard-mitigation/creek-resources
- Seton Portage, British Columbia: Detailed debris flow hazard and risk assessment for four steep creeks that have impacted homes in the past and led to their abandonment. The work is arguably one of the most sophisticated debris flow and debris flood risk assessments conducted in Canada to date.
- District of North Vancouver, British Columbia: BGC completed quantitative flood, debris flood and debris flow risk assessment and conceptual risk reduction designs for 35 steep creeks within the District of North Vancouver (DNV). The lower portion of these creeks flow through areas containing over 20,000 buildings and a network of roads, utilities, and stormwater management infrastructure. BGC developed an interactive web application to manage complex datasets of development characteristics, hazard scenarios, risk assessment results, and mitigation options in a clear, simple format that can be used for community and risk reduction planning.
- British Columbia Ministry of Forests: BGC completed post-wildfire geohazard risk assessments at four recently burned areas of southern British Columbia. The work focused on assessing debris flow risk to homes and infrastructure, and on prioritizing debris flow mitigation locations and strategies.
- Rio Tinto, Holden Mine near Chelan, Washington: BGC provided a quantitative post-fire risk assessment to guide shutdown criteria at various work sites and along a 10-mile long access road, and to evaluate the safety of the lodging facilities. A warning system was developed to guide when to shut down work activities on the mine in response to intense rainfall. BGC installed a telemetered rain gage at the site to assist Rio Tinto staff to implement the warning system.

BGC's team of debris-flow risk management specialists includes approximately 20 members with diverse backgrounds in geomorphology, hydrology, engineering geology, geotechnical engineering, construction, and geomatics. The team is highly experienced with all project phases, development, if the debris flow magnitude is significantly greater than the net capacity. This is not enough time to evacuate, but may allow individuals who have not evacuated to react to the approaching hazard, and the system may be a tool for first responders.

5. Develop a communication plan for informing and alerting residents and first responders along with response and evacuation plans.
6. Consider the following response phases:
   a. Warn residents that a storm capable of triggering debris flows is approaching.
   b. Evacuate residents.
   c. Audible and visual alarms (e.g., sirens, flashing lights) when a debris flow is occurring.

5.2. Physical Debris Flow Mitigation Measures

1. Install debris flow nets proposed by KANE. The nets provide physical protection by capturing debris and potentially slowing the initiation and volumetric growth of debris flows, and can be an important component of the monitoring system.
2. Identify other physical protection that can be installed or improved in the short term. This may include things like removing sediment and debris from existing basins and channels and improving the conveyance capacity of channels.

5.3. Long-term Risk Management Plans

1. Begin developing long-term risk management plans. Elements of the plan may include measures to accelerate revegetation of the watershed, and physical protection such as debris flow basins, check dams, and conveyance channels designed for debris flow magnitudes estimated from a detailed assessment of the watershed.

including hazard recognition, detailed hazard assessment, numerical modeling, quantitative safety and economic risk assessment, and design and implementation of risk reduction strategies. Our team has extensive geomatics capabilities, including digital terrain analysis based on high-resolution LiDAR imagery, change detection and quantification, and development of web-based interfaces that allow spatial data to be comprehended, queried, communicated, and modified by our clients.

Key members of BGC's proposed Montecito debris flow risk management team include:

- Dr. Matthias Jakob, PGeo, LG (BGC) – Dr. Jakob is a leading expert in debris-flow hazard and risk assessment, and has completed several hundred such assessments around the world. Dr. Jakob is co-author and editor of the book "Debris-flow Hazards and Related Phenomena", which is the standard reference text book for this topic. Dr. Jakob has also co-authored relevant guidelines for British Columbia and Alberta and continues to research various aspects of applied debris flow science.
- Dr. Joseph Gartner, PE (BGC) – Dr. Gartner is an expert in post-fire debris flow assessment. Before joining BGC in 2014, Dr. Gartner spent 12 years at the U.S. Geological Survey, where he developed models for post-fire debris-flow probability and volume, and rainfall intensity-duration thresholds for post-fire debris flow initiation. His work is used by government agencies to guide design of post-fire erosion mitigation, evacuation route planning, and post-fire debris-flow watches and warnings issued by the National Weather Service. Dr. Gartner is a co-author of the "Wildfire-related debris flow from a hazards perspective" chapter in the book "Debris-flow Hazards and Related Phenomena."
- Alex Strouth, MASc, PE, PEng (BGC) - Mr. Strouth is a specialist in debris-flow risk assessment and risk reduction engineering at scales ranging from site-specific to broad regions. He has worked in a wide variety of settings around the world for linear infrastructure, municipal, and major industry developments. His experience includes all project phases from initial hazard assessment to mitigation design and construction.
- Dr. Paul Santi (CSM) – Dr. Santi is a professor in the Department of Geology and Geological Engineering at Colorado School of Mines (CSM). He will act as a technical reviewer of BGC's work. Dr. Santi's research emphasis is on debris flow analysis and mitigation, with a focus on post-wildfire debris flows in Southern California. He has authored more than 20 peer-reviewed articles related to post-wildfire debris flows during the past decade.

7.0 CLOSURE

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Yours sincerely,

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FIGURES

Figure 2. Typical chaparral shrubland in a watershed that has not recently burned. This watershed is located immediately north of San Ysidro Creek watershed, adjacent to the Thomas Fire burn area. BGC photo, July 2018, looking north from Camino Cielo Road.

Figure 3. Typical watershed slope following the Thomas Fire. Note lack of vegetation and lack of organic duff layer, and loose soil directly exposed to rainfall. Pioneer vegetation has developed since the Thomas Fire. BGC photo, July 2018, looking northwest from lower Buena Vista Creek watershed.

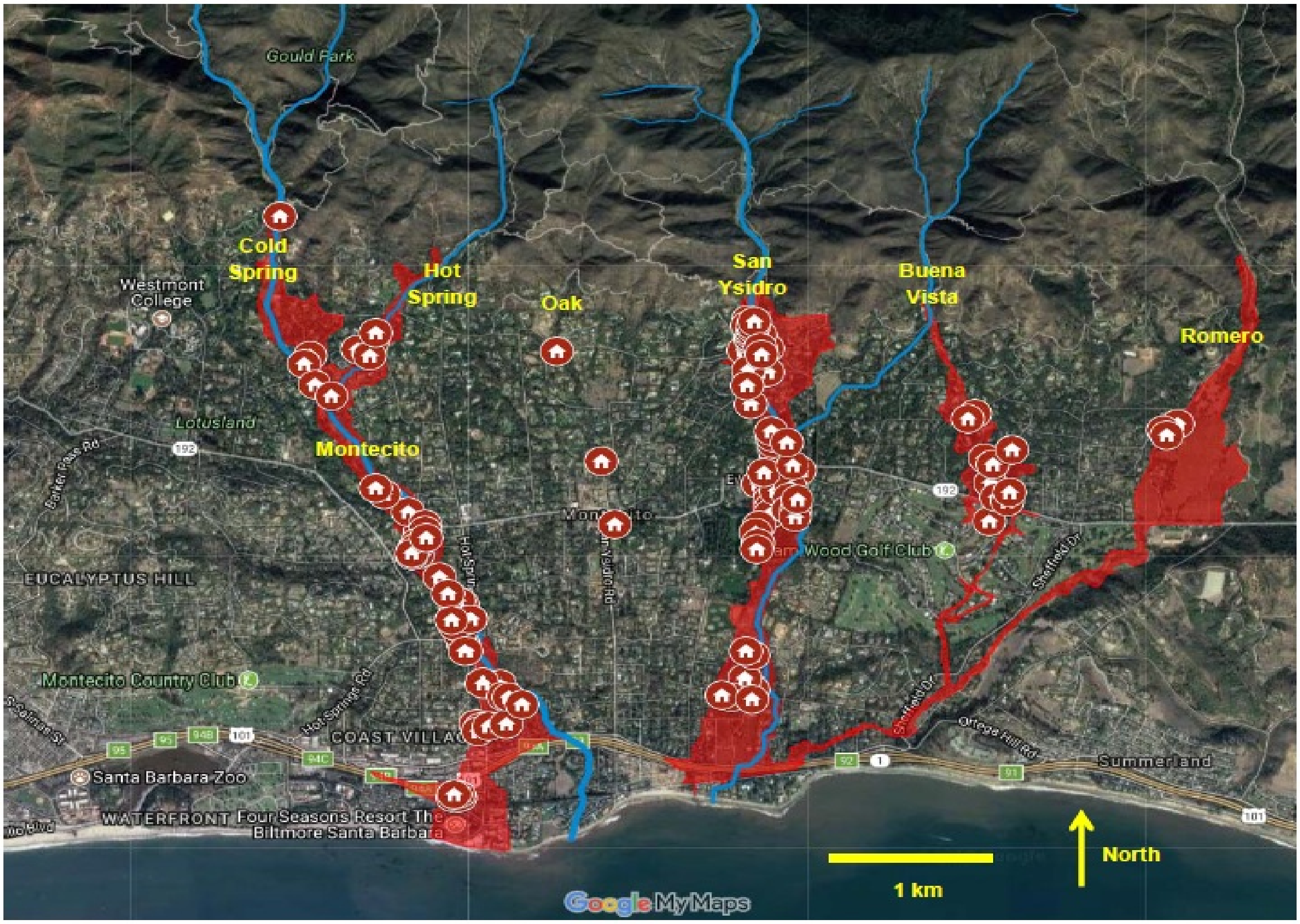

Figure 1. **Map of January 9, 2018 debris flows created by the Santa Barbara Independent newspaper (SBI, 2018). Red polygons indicate the debris flow extents, and red symbols indicate homes that 'appear destroyed or majorly damaged'. Yellow labels indicate creek names (by BGC).**

Figure 6. Sediment and boulders in Cold Spring Canyon approximately 400 m upstream from the development interface. Boulders up to 1.5 m diameter in foreground. BGC photo, July 2018, looking north.

Figure 7. Woody debris and erodible channel banks in San Ysidro Canyon approximately 200 m upstream from the development interface. BGC photo, July 2018, looking west.

Figure 4. San Ysidro Creek watershed following the Thomas fire. BGC photo, July 2018, looking south from Camino Cielo Road.

Figure 5. Romero Creek watershed showing a mixture of un-burned and burned areas from the Thomas fire. BGC photo, July 2018, looking south from Camino Cielo Road.

Figure 8. **Superelevation of January 2018 flow indicated by mud lines in Cold Spring Canyon approximately 300 m upstream from the development interface. BGC photo, July 2018, looking north.**

Figure 9. **Destroyed home on San Ysidro Creek, located approximately 1 km from the fan apex. BGC photo, July 2018, looking east.**

Figure 10. Woody debris immediately upstream of a destroyed home on Montecito Creek located approximately 2 km from the fan apex. BGC photo, July 2018, looking west.

Figure 11. Boulders, up to 4 m diameter, transported by San Ysidro Creek debris flow more than 1 km from the fan apex. BGC photo, July 2018, looking east.

Figure 12. A landform interpreted to be a debris flow levee from an event that pre-dates construction of the home in the background, located 500 m from the Hot Spring Creek fan apex. Boulders up to 1 m diameter in foreground. BGC photo, July 2018, looking south.

APPENDIX C

MONTECITO INSTRUMENTATION

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C. INSTRUMENTATION

C.1 Debris Net Instrumentation

C.1.1 Debris Net Instrumentation Review

In Preonzo, Switzerland, a torrent, or channel, produced debris flows in the spring of 2008. These flows were monitored using geophones mounted on large boulders in contact with the flow (Graf & McArdell, 2009). The geophones measured the debris flow front velocity. They emitted an analog signal that was digitized within the geophone to filter and reduce the amount of necessary data.

During the 2008 event, the geophone signal recorded a number of pulses per second that surpassed a pre-determined threshold. This signal was sustained for several seconds indicating a significant flow event was occurring.

A radar sensor was used in combination with the geophones to measure the depth of the debris flow. Researchers programmed a smoothing algorithm providing a stable signal as the depth of debris rapidly changed. Although the signal from radar sensors were delayed slightly, and the changes in the surface of the flow are not as accurate as laser sensors, they are capable of measuring a larger surface area. This resulted in a signal that was more stable. The location of the radar sensor was suspended by two wires over the channel where the initial depth was not greatly affected by a flow event.

The data was stored on a data logger and collected via public GSM (Global System for Mobile communications) network. Rainfall was also measured at the top of the watershed area. Two video cameras were also installed to record the event.

After two deflection dams were constructed, the observation station was moved to a more active debris flow channel system. A geophone was then mounted below the upper deflection dam at the lower end of the intermediate deposition zone. The purpose of the geophone was to trigger the main instrument station that a flow event was approaching. The main monitoring station was located at the lower deflection dam with geophones placed at the upper and lower end of the dam to calculate front velocity.

Penna (2014) described two types of debris flow warning systems: advance warning and event warning. An advance warning system compares current precipitation to the threshold value of precipitation that could potentially cause a debris flow. An advance warning could allow for a longer period of time for evacuation, but are often inaccurate due to variability in causing factors such as weather paths and system evolution.

An event warning is stimulated by the data collected from measurable sources such as wire sensors, ground vibration sensors, or stage meters placed upstream. Event warnings are highly accurate but only permit a short interval between the notification and the event.

Penna described how these debris warning systems were used at a debris flow location in the Italian Alps in the Spring of 2011. The system consisted of five rain gauges placed at various elevations, radar sensors, geophones, video cameras, piezometers, and soil moisture probes. The rain gauges, stored and transmitted data to a server via radio. The depth of debris flow was monitored by three stage radar sensors mounted on cable suspended sledges, dataloggers recorded the data. The stage radar data was used to calculate the mean velocity of debris flow. Five vertical geophones were placed at the same sites as the radar sensors.

Debris flows peak frequencies ranged between 30 and 80 Hz which is well within the operating range of the geophones (which were found to be highly reliable). Three video cameras with spotlights were installed. Twenty-eight soil moisture probes were installed as well as 14 different pressure transducers. Monitoring of slope hydrology with pore pressure transducers did not prove to be useful nor did the piezometers. The instruments were powered by the standard electric line extended to the main station from nearby farms. The radar sensors and geophones were connected directly to the server by the Ethernet cable. At another similar location, all the instruments were powered by batteries and solar panels.

The Illgraben test location for the Geobrugg debris net test was instrumented by Badoux, et al. (2008). At the Illgraben, tested under the direction of Alexander Badoux, a range of detection sensors were used in order to create an early detection warning system. Geophones measured ground vibrations, ultrasonic and radar sensors were used to measure flow height, and microwave sensors measured water table variation. The time between the warning and the flow event was slightly under an hour but there was no other reliable way of warning that could occur any earlier. Locations in China and Canada have used multiple rain gauges as a way of predicting debris flow events, but this method has been ineffective since the spacial variability of rainfall is too high for isolated rain gauges to accurately represent the rainfall within a wide range. Early warning is highly imprecise and built on more speculation and comparison than event warnings.

The instrumentation installed along the final kilometer of the channel were geophones that determined velocity and triggered the system, radar, laser, and ultrasonic devices were used to determine flow depth, video cameras were installed, as well as a force plate. It was determined that the radar devices for measuring were better suited for a warning mechanism than the laser devices which produced faster and more accurate data but did not provide a signal that could be used in the case of flooding and flowing.

The geophones were bolted to concrete check dams because the signal of a geophone is highly influenced by whatever material is surrounding it, and concrete has proven to be an effective surface. The sensor system sends the first alarm then activates the light and auditory alerts. Two radar sensors were suspended over the check dam at a place where bed depth stays consistent. When the threshold number of pulses per second has been surpassed, detection installations in the geophones activate the lights, sirens, texts, emails, or faxes to notify the community. A rainfall density threshold is dependent upon the region where the debris flow was to take place. Geophones and radar sensors have proven to be highly reliable in the Illgraben as well as in various other locations where they have been implemented.

Designed to provide a fast and reliable alert, the alarm system included a number of sensors and sent a daily email that could be used to determine if any aspect of the system was malfunctioning. The alert system was hosted by the GSM which was proved to be reliable and is what is used by many local emergency response personnel.

Abancó, et al. (2014) described the how debris flow ground vibrations were measured using a series of seismic and sonic devices at the Rebaixader monitoring site in the Central Pyrenees, Spain. Geophones were used to monitor debris flows because they are sturdy and do not consume much power. In order for a ground velocity signal to not be continuously recording data, a trigger must turn it on so that it primarily records events. A level trigger occurs when a fixed value for ground velocity is reached- which is typically established by combining past knowledge and expert advice, the threshold value must be defined at each geophone with site-specific factors that must be taken into consideration. The extenuating factors that affect the geophones include the distance between the geophone and the debris-flow path, the substance upon which the geophone is placed, the material surrounding the geophones, and the assembly of the geophone itself. The distance between the geophone and the actual flow is crucial- therefore, geophones are typically located on the channel banks. The substance upon which the geophones are mounted when they cannot be buried has a great impact upon frequency amplification.

The signal transformation consists of a two-part process where the voltage from the geophone is filtered such that low frequencies are not taken into consideration, then the voltage that surpasses a threshold number is transformed into an impulse signal by electrical resistors in the conditioning circuit acting as a threshold voltage.

To determine how the geophones reacted in different substances, they were placed in different locations then compared against each other, the highest recorded amplitudes were from the geophone located in a thin layer of colluvium, the geophone that was burred 2m below the surface emitted the weakest signal, the geophone fixed to the bedrock produced a signal that was similar to the geophone in the alluvium. One geophone was mounted on a metal sheet box which amplified the signal greatly. The main issue to be figured out with geophones is filtering out irrelevant ground velocity and finding the correct detection threshold so that false alarms do not occur. Geophones have been proven to be highly efficient in the monitoring of torrents around the world and by several researchers.

A surveillance system had been installed for monitoring debris flows in the Italian Alps for a period of ten years (Marchi, et al., 2001). The instrumentation applied consisted of rain gauges, ultrasonic sensors, seismic sensors, and a video camera. The rainfall was recorded and separated into two categories: storms that caused a debris flow, and storms that did not cause a debris flow, however, this data was not consistent with itself proving that there are other factors responsible for triggering a flow event. The ultrasonic sensors measured the torrent stage for the recording of debris-flow hydrographs, they were also used in finding the estimates of mean velocity, volume, and peak discharge. The sensors were also utilized for calculating the front velocity. The seismic detection devices implemented were seismometers and geophones which used ground oscillation velocity to measure the flows' velocity. There was a video camera installed for estimating surface velocity and was triggered by an ultrasonic sensor placed upstream.

Hürlimann, et al. (2011) implemented a debris flow monitoring station in the Eastern Pyrenees with following instruments: geophones, ultrasonic measuring devices, dataloggers, a video camera, a meteorological station, a flexible ring net, and load cells. The geophones were used to calculate front velocity, determine when the flow started, and to trigger other measurement devices further down the channel. The ultrasonic devices measure flow depth and can be used in conjunction with the data from the geophones to estimate a mean flow velocity. A spotlight was installed next to a standard GANZ security camera. The meteorological station consisted of tipping-bucket rain gauges and a thermometer to ascertain whether the substance collected was rain or snow. A flexible GEOBRUGG VX160 net was installed, fitted with tension load cells on the horizontal cables. The net was installed in order such that its effectiveness could be quantified. Two different dataloggers with GSM modems were installed, one was placed at the meteorological station and the other was placed at the flow site with the remaining instruments. Power is supplied to the dataloggers by batteries that are recharged by a solar panel. The dataloggers must be programmed to differentiate between "event" and "no-event" mode, which was accomplished by scanning the four geophones to see if the threshold number was surpassed. The conclusion from testing was that monitoring was possible with only geophones and ultrasonic devices, but cannot provide enough data alone, which was why the video cameras were a necessity.

Arrattano and Marchi (2008) described the difficulties in setting debris warning sensor threshholds. The purpose of an event warning system is to provide an alarm when a debris flow is in progress. The principal sensors in those systems are geophones to measure ground vibrations. They are easy and safe to install. However, setting warning thresholds can be complicated; video cameras offer a recognition of debris flows and are safe to install which will allow for visual confirmation of a flow event. The maximum depth of debris flow can be measured after the event by the use of a GPS or theodolite since the flow will leave behind distinct tracks. A set of wires stretched across the channel can determine flow height based upon the lowest wire left unbroken. Photocells along with photobeam sensors are also used in detecting depth since the path of the beam is cut short by the waves of debris. Ultrasonic gauges are most commonly used as they provide for the measurement of channel erosion. Ultrasonic sensors suspended over the channel bed measure the distance between the device itself and the height of the flow, that value can be subtracted from the known value of the distance between the bed of the channel and the sensor to provide the height of the flow. Since the initial ground measurement is crucial, the sensor must be placed above part of the channel bed that will not decrease as the flow rushes over it- which is often why concrete is poured at the designated area. Because debris flows emit strong ground vibrations, the need for underground sensors is apparent, these sensors do not have to be installed within the channel bed and will still transmit the detected vibrations. The output signal is a voltage that is equal to the oscillation velocity of the ground.

When a pair of ultrasonic sensors are placed at a known distance somewhere along the torrent, the average velocity of the flow is able to be calculated as the ratio between the distance between the sensors and the time elapsed between the front signal between the two. This same technique would work with several different devices such as, wire detectors, geophones, photocells, and microphones. Doppler speedometers are capable of measuring surface velocity. Doppler speedometers measure the frequency of radio waves reflected by moving objects. Load cells along the channel bottom can be used to measure the load of the debris flow. Vertical and horizontal load cells make the measurement of shear stress and normal stress possible.

The impact force of debris flows in contingent upon the dynamic pressure of fluid, (which is the kinetic energy per unit volume of a particle of fluid) and the collision force of single boulders.

Abanco, et al. (2012) also discussed the difficulties with establishing warning levels for geophones. Geophones are a type of ground vibration sensor that record the velocity of small ground movements because of the passage of debris flows. The geophone signal date acquisition process and its analysis show the relevant complexities of debris flow monitoring. On one hand, the characteristics of the measured signal requires high frequency ground vibration sampling rates.

On the other hand, it is crucial to define an appropriate level of vibration to distinguish between the seismic noise of the site which can be originated by many other factors and the vibrations generated by a debris flow. Definition level of threshold is a key task. Geophones are the most common ground vibration sensors in debris flow monitoring systems. Moving-coil geophones consist of a magnetic moving mass oscillating inside a wire coil, a mechanism that generates an output voltage proportional to the velocity of the ground vibration in the direction of the coil. They are installed outside the wetted area. Three main issues affect the vibration measured by geophones: distance between sensor and flow path, characteristics of the underground material at sensor location and between sensor and channel, and type of sensor assembly. Geophones should be installed, at the most, a few tens of meters from the channel. The output of the geophone is a continuous voltage proportional to ground velocity. Analog signal recording consists of continuous lagging of the voltage measured at the sensor. Digital signal recording consists of non-continuous voltage sounds from the output signal. Transforming a ground vibration velocity into impulses removes ground vibration noise and external distinguishing factors. On the case study, data are stored in a Campbell Scientific CR10X datalogger every second.

Jun et al. (2017) attempted to use an analytical hierarchical process to determine the best installation location of sensors for debris flow events. Two stages of warning systems, advance systems and event warning were used. The event warning was issued using sensors installed in the debris flow channel when a flow occurred. A ratio was calculated to find the relationship between applied number of targeted devices and surveyed total devices. Based on this ratio, the most frequent indicator of impending debris flow was rainfall intensity. Rainfall was selected as a trigger and the monitoring system automatically operated to warn of impending debris flow when precipitation exceeded the threshold values. The geophones were shown to be excellent devices for measuring the velocity of debris flows. Geophones were installed on an embankment that was safe with regard to debris flow. A camera was used as a complementary technique to the debris flow event and was installed safely above the channel on a supporting beam.

Debris flows in Sakurajima Island were monitored by a system that used steel plated load cells to determine flow characteristics (Itoh and Mizuyama, 2014). Included in the system are four pin-type load cells, a 2mX4m steel plate, two pressure sensors, ultrasonic sensors, and CCTV cameras. The pressure sensors on the steel plate measured interstitial water pressure in the channel bed and the ultrasonic sensors measured the depth and velocity of the flow. The camera's purpose was to monitor the conditions within and surrounding the flow, such as flow width and surface velocity. Data from both fine and course material flows was collected. The load cells measured normal stress as well as temporal changes in the flow itself. Rainfall was measured by a rain gauge and the data was averaged by X-band MP radar which provides for estimates regarding the special distribution of rain. However, at peak rainfall discharge a flow event may not necessarily occur.

Various methods of detecting debris flows were tested on a small flow channel in Switzerland as a method of testing their accuracy and reliability (Arattano and Marchi, 2005). Ultrasonic sensors prove to be difficult to install on steep channels as they need to be suspended by wires which are often broken by accidents not pertaining to a flow event. Doppler speedometers, spatial-filter speedometers, and video cameras are expensive and require clear visibility of the channel and a safe base to be constructed upon. Ground vibration sensors do not require visibility of the flow nor are supplemental structures necessary for their installation. However, if the ground vibration sensor is placed in a location where there are often vibrations (railroad tracks, freeway, etc.) interpretation of the data becomes difficult.

The use of a cross-correlation function between two signal devices placed at a known distance from each other provide for the calculation of debris flow front velocity, and the time difference between the two devices allows for the estimation of an average velocity. However, all measurements and estimates require the presences of a clearly defined debris-flow front.

A monitoring system installed in the eastern Dolomites by the USGS (Berti et al., 1999) consisted of a rain gauge positioned at the upper initiation area as well an anemometer for the measurement of wind speed because the flow of debris greatly relies upon the speed at which rain comes upon it. Pore fluid pressures were also installed at the upper initiation area, five pressure transducers were installed at various depths, four of them are located shallowly and are destroyed and must be replaced after each flow event. To measure front velocity, seven geophones were installed, grouped at three different stations the average velocity is derived from the time lag between geophone signals. The depth of debris flow was measured by an ultrasonic sensor that was suspended over the channel. A hydraulic pressure cell and a pressure transducer measured the total normal stress and the fluid pressure. The average debris flow density was able to be estimated from the ration between debris flow depth and total normal stress. The monitoring system included three cameras which were positioned at different angles and at different locations. The videos would only activate once the geophones or rainfall threshold values were exceeded. The surface velocity of the debris flow was ascertained from the time interval between photographs taken. Remote control of the entire monitoring system was possible through connection to a phone modem.

C.2 Weather Station

C.2.1 Weather Station Instruments And Their Function

Weather stations rely on several basic instruments in order to gather data for interpretation by forecasters. Below is a list of commonly used weather sensors and their descriptions:

- **Wind Vane -** measures which direction the wind is blowing, and the anemometer measures the velocity of the wind- together they provide for the calculation of a wind vector (a measurement consisting of speed and inverse direction). Wind speed greatly impacts the kinetic energy of rain, and the greater the velocity of rain, the faster a debris flow.

- **Tipping-bucket Rain Gauge -** The amount of rainfall at the higher elevations of mountains is a major factor in the initiation of a debris flow. The tipping-bucket rain gauge collects water through the lid funnel which then drips down to a balance. The bucket will tip and emit an electrical signal when a pre-determined amount of water fills it. This will continue during the period of rainfall to communicate the amount of rain as well as its intensity rate.

- **Air Temperature and Humidity Probe -** Measures air temperature and humidity at the location by using vents that read radiation and humidity from air that flows through them rather than heat generated from the sun shining on it. A radiation shield is necessary and will give more accurate data and increases the longevity of the probe.

- **Barometer -** A barometer measures atmospheric (or barometric) pressure which is used in forecasting weather. A low atmospheric pressure indicates cold, rainy weather. Whereas a higher atmospheric pressure suggests clear and sunny weather. Barometers are an essential aspect of any functioning weather station and have been used since the 1600s.

- **Soil Moisture Probe -** This instrument is used to determine the saturation of soil. It operates by measuring electrical resistance, and which results in the determination of volumetric water content of the soil. Soil moisture is thought to be an indicator of a potential debris flow event depending upon the amount of water the soil is able to retain.

C.2.2 Existing Santa Barbara Weather Stations

There are three weather stations located in Santa Barbara County, Table C.1. The weather station utilized by the NWS is a Fixed Remote Automated Weather Station (RAWS), made by Forest Technology Systems (FTS). The other two weather stations are not part of the NWS and are attached to two different fire stations in Santa Barbara- information regarding the equipment and instruments used by these two fire stations is not readily available to the public aside from the fact they employ the use of the WeatherLink Network software designed by Davis Instruments which may imply that Davis instruments are used.

The RAWS manufactured by FTS contains every instrument for weather detection and is known to meet the qualifications of the NWS, Instruments are mounted upon a tripod frame that does not require concrete bases. The Axiom F6 datalogger is used and is simple to install and connect to the instruments.

TABLE C.1 EXISTING SANTA BARBARA COUNTY WEATHER STATIONS

Location	Factor Measured	Instrument Used	Instrument Manufacturer
Fire Station 1 121 West Carrillo Street Santa Barbara, Ca	• Temperature • Humidity • Dew point • Air pressure • wind speed • Wind direction • Rain	• Max/Min Temp. • Hygrometer • Psychrometer • Barometer • Anemometer • Anemometer • Rain gauge	Davis Instruments (?) WeatherLink Network
Fire Station 7 2411 Starwood Drive Santa Barbara, Ca	• Temperature • Humidity • Dew point • Air pressure • wind speed • Wind direction • Rain	• Max/Min Temp. • Hygrometer • Psychrometer • Barometer • Anemometer • Anemometer • Rain gauge	Davis Instruments (?) WeatherLink Network
Montecito #2 (**MOIC1) NWS** lat: 34.445° long: 119.625°	• Humidity • Wind Speed • Air pressure • Dew Point • Visibility • Rain	• Hygrometer • Anemometer • Barometer • Psychrometer • Transmissometer • Rain Gauge	FTS inc.

C.2.3 COOP with the National Weather Service (NWS)

The NWS runs the Cooperative Observer Program (COOP), which is a weather network that is run by trained volunteers who check provided weather instruments and upload the data to NWS servers, there are three different classes of COOP stations: “a”, “b”, and “c”. Class “a” network stations are the most basic, the class “b” network support in forecast and warning programs, and the “c” network stations are the more complex stations that include those made for research, experiments, or special purpose.

The Montecito Debris flow monitoring could likely be classified as a “Special Purpose” placing it under the “c” network.

C.3 Proposed Instrumentation and Monitoring/Alert System

C.3.1 Description and Philosophy

KANE GeoTech recommends the implementation of several forms of instrumentation in conjunction to the construction of debris flow nets. These systems will monitor the debris flow nets and possibly provide emergency warnings in the event that major debris flows occur. The utilization of this proposed instrumentation plan does not replace the necessity of existing emergency warning and management systems.

The instrumented systems will consist of two forms of monitoring: systems put in place to monitor the meteorological conditions leading up to debris flow and systems designed to monitor the debris flow event as it progresses. Within the system monitoring meteorological conditions, a fully equipped weather station can be programmed and installed at the northern ridge of San Ysidro canyon. This station will be connected to a network of eight rain gauges, one per canyon and three additional, which will constantly monitor precipitation rates. The network will also include wind direction and speed sensors, probes for temperature and relative humidity, a radiation sensor, a soil moisture sensor, and a barometer. Data from the rain gauges and weather station will be accessible through a public web page. In addition, it can be interfaced with existing weather stations to enhance the array of weather data available to forecasters and researchers.

Within the systems monitoring the debris flow event as it progresses, each canyon can be instrumented with a set of sensors attached to the debris flow nets as well as sensors within the canyon walls. Geophones, Figure C.1, will be installed upstream of each net to measure and record vibrations in the ground. Geophones are commonly associated with seismic activity; however, they can be installed in the canyons to record tremors caused by debris flows. Tension load cells, Figure C.2, installed on the top and bottom support ropes of the nets will actively measure added loads on the nets resulting from debris retention.

Each canyon will be equipped with a central station that includes a datalogger. This datalogger will receive the information from the geophones, tension load cells, and the cameras installed at


Figure C.1. Geophone installed in subsurface.

each net. When geophones and rain gauges exceed a threshold, the video cameras, Figure C.3, will be triggered to power on and record the debris flow as it impacts the nets.

Figure C.2. Tension load cell.

The monitoring system is also capable of sending out text message and/or email alerts as debris flows progress. Alerts can be customized according to a user's preference. All data can be uploaded to a public web page from the automated data acquisition system (ADAS). In addition the video feed and data will be sent to a central emergency facility for real time monitoring of debris activity in the canyons. Figure C.4 shows a typical ADAS similar to the systems to be installed for the debris nets.

C.3.2 Proposed Instrumentation

The instrumentation proposed for the weather station system is listed in Table C.2. Table C.3 lists the ancillary instrumentation required for the Central Canyon Monitoring Stations. Table C.4 contains the list of instrumentation required each net.

Figure C.3. Infrared video camera.

C.3.3 Installation

The ADAS's will be placed on poles on the slopes above the top net anchors and within the disturbed zone footprints of the nets, Figure C.5. The nets will be instrumented during construction or easily after they are constructed.

Approximate locations and schematic concepts for the instrumentation are shown in Figures C.6 and C.7. The weather station instrumentation and repeaters for the net stations have not been checked for environmental impacts and will have to be assessed before installation.

Figure C.4. Automated Data Acquisition System (ADAS) similar to the systems to be installed in Montecito.

C.4 REFERENCES

Abancó, C.; Hürlimann, M.; Abancó, C.: Moya, J.; Raïmat, C.; Luis-Fonseca, R. (2011). Casa Editrice Università La Sapienza, , M.; Fritschi, B.; Graf, C.; Moya, J. (2012). "Transformation of Ground Vibration Signal for Debris-Flow Monitoring and Detection in Alarm Systems". Technical University of Catalonia, Barcelona, Spain, April 13, 2012.

Abancó, C.; Hürlimann, M.; Moya, J. (2014). "Analysis of the ground vibration generated by debris flows and other torrential processes at the Rebaixader monitoring site (Central Pyrenees, Spain)". Geotechnical Engineering and Geosciences Department, Technical University of Catalonia, Barcelona, Spain, April 17, 2014.

TABLE C.2 INSTRUMENTATION FOR WEATHER MONITORING SYSTEM

ITEM	QUANTITY
Mounting tower for weather base station	1
Stainless steel enclosure	1
Fiberglass enclosures for rain gauges)	8
Datalogger, radio, and Verizon LTE Modem	1
Additional dataloggers rain gauges	8
Additional radios for rain gauges	8
Rain gauges - one or two per canyon depending on canyon size	9
Barometer	1
Anemometer	1
Wind vane	1
Temperature and relative humidity sensor	1
Radiation sensor	1
Soil moisture sensors	3
Solar panels	9
Storage batteries	9

TABLE C.3 INSTRUMENTATION FOR NET CENTRAL DATA STATIONS

ITEM	QUANTITY
Fiberglass enclosures - one per canyon	5
Mounting Poles	5
Dataloggers	5
Radios	5
Verizon LTE Modems	5
Solar Panels	5
Storage Batteries	2

TABLE C.4 INSTRUMENTATION FOR NET MONITORING SYSTEMS

ITEM	QUANTITY
Fiberglass enclosures	1
Mounting Pole	1
Dataloggers	1
Radios	1
Geophones	1
Video Cameras	1
Net tension load cells	2
Solar panels	1
Storage batteries	1

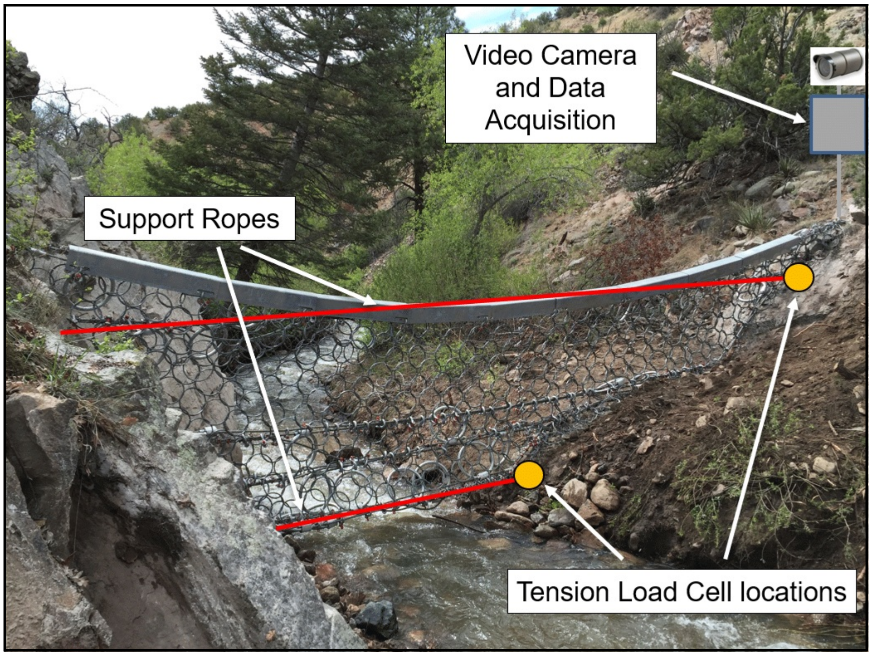

Figure C.5. Conceptual schematic of proposed instrumentation system.

Arattano, M.; Marchi, L. (2005). "Measurement of debris flow velocity through cross-correlation of instrumentation data". Copernicus Publications, Padova, Italy, January 4, 2005.

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Graf, C. and McArdell, B. W. (2009). "Debris-flow monitoring and debris-flow runout modeling before and after construction of mitigation measures: an example from and unstable zone in the Southern Swiss Alps". WSL Swiss Federal Research Institute Zürcherstrasse 111 CH - Birmensdorf, September 3-5, 2009.

Itoh, T. and Mizuyama, T (2014). "Debris Flow Monitoring using Load Cells in Sakurajima Island". ResearchGate, Tokyo, Japan, December 3, 2014.

Jun, H.; Min, D.-H.; Yoon, H.-K. (2017). "Determination of monitoring systems and installation location to prevent debris flow through web-based database and AHP". Taylor & Francis Group, Daejeon, Korea, January 7, 2017.

Hürlimann, M.; Abancó, C.: Moya, J.; Raïmat, C.; Luis-Fonseca, R. (2011). Casa Editrice Università La Sapienza, Padua, Italy, June 14-17, 2011.

Marchi, L.; Arattano, M., Deganutti, A. M. (2001). "Ten years of debris-flow monitoring in the Moscardo Torrent (Italian Alps)". ELSEVIER, Turin, Italy, October 13, 2001.

Penna, D. (2014). "A new monitoring station for debris flows in the European Alps: first observations in the Gadria basin.". University of Florence, Florence, Italy, January, 2014.

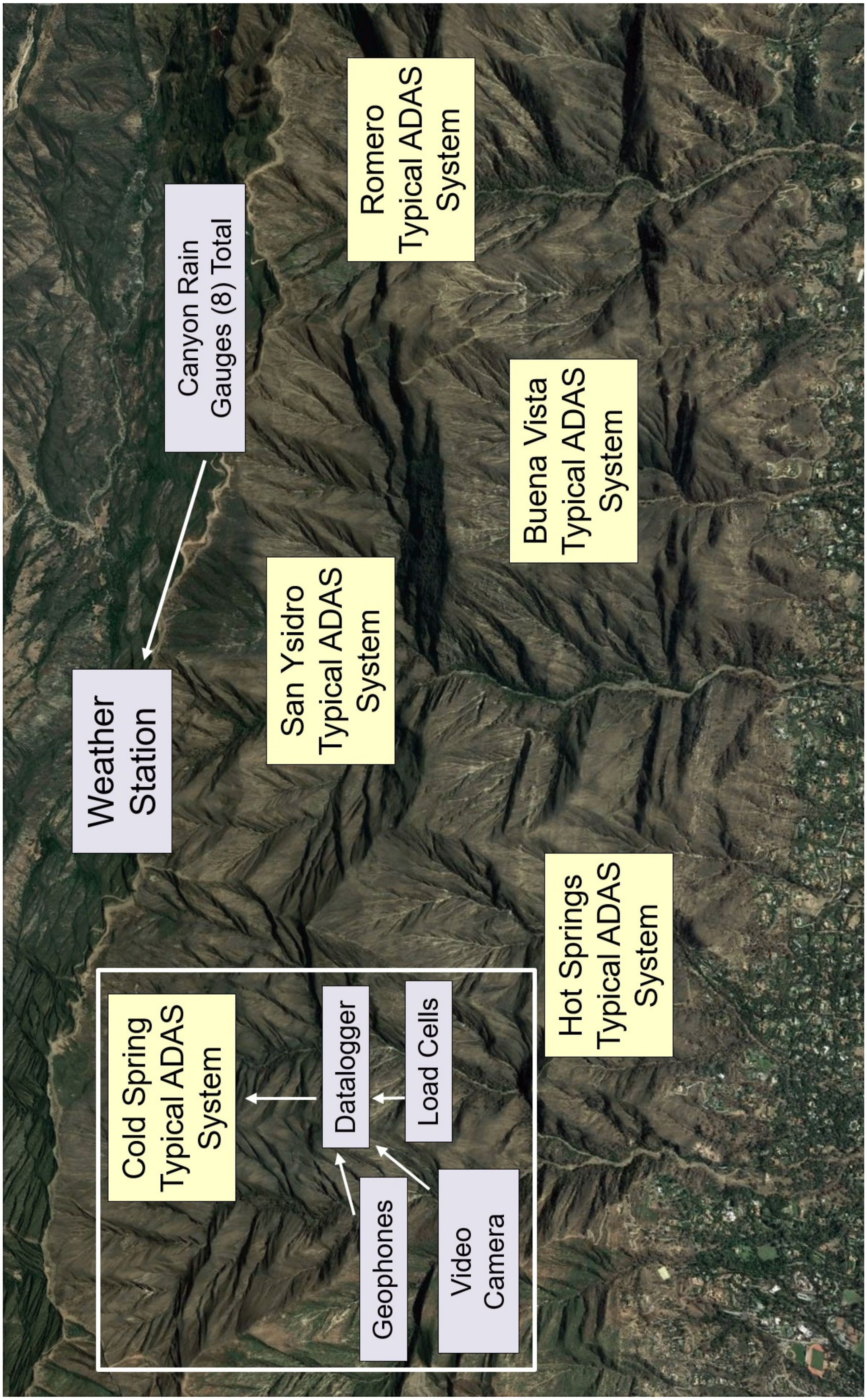

Figure C.6. Schematic layout of Montecito debris weather and monitoring systems.

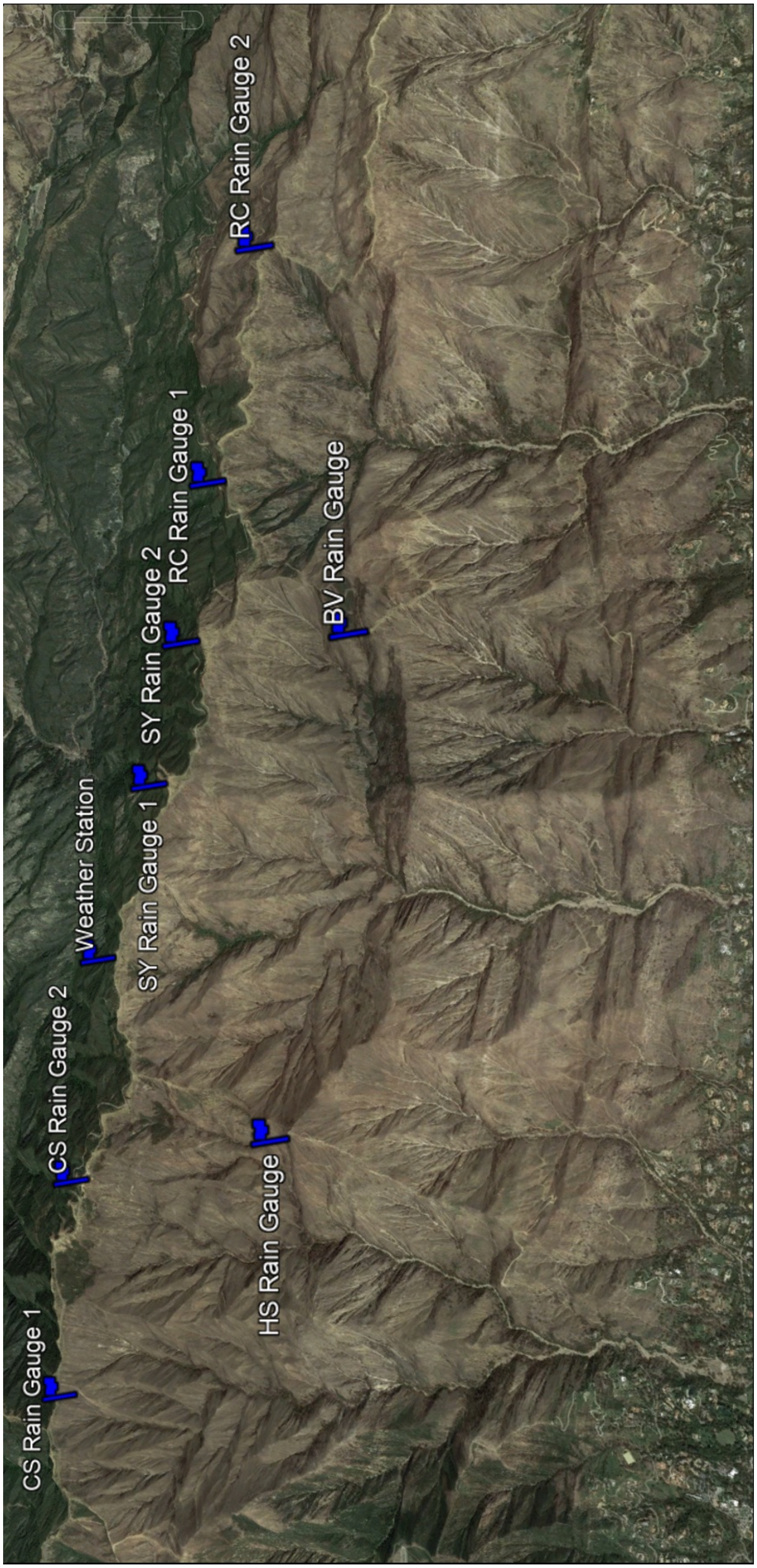

Figure C.7. Schematic of Montecito weather station system.

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Montecito Debris Flow Mitigation

Geobrugg Debris Nets

Project Specifications

Project No. KGT18-18

Prepared by:

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Prepared for:

Partnership for Resilient Communities
Montecito, California

October 5, 2018

REGISTERED PROFESSIONAL ENGINEER
WILLIAM F. KANE
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STATE OF CALIFORNIA

KANE GeoTech, Inc.
Geoengineering Consultants

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TABLE OF CONTENTS

1 GENERAL REQUIREMENTS

1-1 Definitions and References

All applicable standards and statements from the following references shall apply:

1. California Building Standards Commission (CBSC) (2016). 2016 California Building Code of Regulations Title 24. Effective January 1, 2017.

2. Geobrugg AG (2017). Wire Rope Strength Properties Chart. 22 Centro Algodones, New Mexico.

3. Geobrugg AG (2017). Technical Data Sheet: High-tensile Spiral Rope Net SPIDER® S4-130. Geobrugg AG CH-8590 Romanshorn, Switzerland.

4. Geobrugg AG (2017). Debris Flow Protection System VX Type: VX160-H6, Drawing No. GD-1004.1e. CH-8590 Romanshorn, Switzerland. 2017 12-07.

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8. Post-Tensioning Institute (PTI) (2014). Recommendations for Prestressed Rock and Soil Anchors DC35.1-14. 5th Ed. Michigan, Print.

9. State of California Department of Transportation (2015). 2015 State of California Standard Specifications. Sacramento, California.

It is the responsibility of the Contractor to determine and meet all applicable standards.

1-2 Contractor Qualifications

The Contractor shall be a Licensed Construction Contractor. The Contractor shall have a minimum of five years experience installing similar systems under similar conditions. The Contractor shall submit a project reference list verifying the successful construction of the following:

1. The Contractor shall be experienced in the construction of permanent debris flow protection nets and have successfully constructed at least three systems in the last five years.

2. Submit a listing of personnel including on-site supervisors, drill operators, and other personnel to be used for the construction operations under this contract who possess the required experience for performing an installation of a debris flow system, as shown and specified herein. Include personnel in the listing that has relevant experience from the past 5-years pertaining to a debris flow system installation.

3. The list of job-related experience with a brief description should contain names and phone numbers of the project owner's representative who can verify the Contractor's participation in the project.

4. Drilling operators and foreman shall have a minimum of 2 years of experience installing permanent ground anchors with the Contractor's organization. Submit documentation that the project's personnel have appropriate qualifications. Changes to previously approved personnel shall be approved in writing. Inadequate proof of personnel qualifications shall cause approval hold.

When necessary, the Contractor shall locate and retain a specialty contractor(s) to perform tasks per the specifications. The specialty contractor(s) shall be approved by the Engineer prior to being mobilized and commencing work.

The Contractor shall not use consultants or manufacturer's representatives to satisfy the requirements of this section.

1-3 Contractor Submittals

The Contractor shall develop and submit a "Project Submittal Document Package" to the Engineer no less than one week prior to construction commencement. The submittal package document shall be in Portable Document Format (PDF) form and all information contained shall be legible. The submittal package shall include;

1. Contractor qualifications as described in the referenced project specifications Section 1-2 "Contractor Qualifications".

2. Project start date and schedule that includes a detailed construction seq uence.

3. Drilling, grouting methods, and equipment to be used on the project.

4. All appropriate material and installation documentation to be used on the project including; material specification sheets, manuals, product technical data, manufacturer's names, ASTM conformance, material handling sheets, and warranties.

5. Proposed grout mix design and compressive strength data
   a. To the Engineer for approval a minimum of one week prior to grouting commencement.
   b. See Project Specifications Section 8-2 "Grout Testing" for additional information to see if testing is required.

6. Verification anchor testing equipment, calibration certificates, and loading graphs to the Engineer for Approval a minimum of one week prior to testing.

7. Anchor testing cribbing (load frame) information for materials to be used.

The Engineer shall approve or reject the Contractor's submittal within five (5) working days after receipt. Work shall not be started nor materials ordered until the Contractor's submittal has been approved by the Engineer. Approval of the construction plan does not relieve the Contractor of his responsibility for the successful completion of the work.

1-4 Requests for Information (RFI)

Substitution Requests or Requests for Information (RFI) shall be submitted by the Contractor in writing and approved by the Engineer prior to any change implementation.

1-5 Permits

The Contractor must meet all Federal, State, and local permitting requirements and must obtain all necessary permits before construction commences. The Contractor must also obtain site-specific permits including, but not limited to, Hot Work Permits (if applicable) when required for any activity that can be a source of ignition when a flammable material is present or can be a potential fire hazard.

1-6 General Notes

Details shown on the Drawings are typical and similar. Dimensions, schedules, specific notes, and details take precedence over general notes and typical details. Dimensions shown on the Drawings are based on best available information provided to and may not be precisely indicative of field conditions.

The Contractor shall verify all utility lines, dimensions, and elevations, as well as anchor locations, indicated on the Drawings prior to any clearing, excavation, fabrication, or construction.

All dimensions and details shown on the Drawings shall be reviewed and verified by the contractor prior to the start of any construction. Any discrepancies shall be brought to the attention of the Engineer immediately for clarification.

1-7 Site Layout

Prior to ordering the materials, for the Debris Nets, field stake-out limits and anchor locations shall be accomplished using the Drawings as a guide. No materials shall be ordered or any construction activities begun until the Debris Net stake-out has been reviewed and approved by the Engineer.

2 SITE PREPARATION

2-1 Earthwork

Any earthwork. trimming, pruning or raising of trees by the Contractor shall comply with permits and be under the supervision of the Project Biologist. The Contractor shall bear all expenses involved in the disposal of the material. Burning shall not be permitted. All vegetation for trimming and removal shall be marked and identified prior to construction commencement and approval by the Project Biologist.

Unless otherwise specified, payment for clearing and grubbing conforming to the provisions of this section, including saw cutting, removal, haul, disposal, backfilling, cleanup, payment of all fees, and specified in these specifications shall be considered as included in the various related bid items and no additional compensation shall be made therefore.

2-2 Final Clean Up

Throughout all phases of the mitigation construction, including suspension of work, and until final acceptance of the project, the Contractor shall keep the work site clean and free of rubbish and debris. The Contractor shall also abate dust nuisance when drilling by cleaning and other means.

Materials and equipment shall be removed from the site when they are deemed no longer required, or when required by permit conditions.

Upon completion of the work and before final inspection, the entire work site shall be cleared of equipment, unused materials, and rubbish to present a satisfactory cleanup. All cleanup costs shall be included in the Contractor's bid items.

Removed materials that are not to be salvaged or reused in the work shall become the property of the Contractor and shall be disposed or removed from the project site per State of California Department of Transportation Standard Specifications.

Nothing herein shall be construed as relieving the Contractor of responsibility for final cleanup as directed by the Engineer or Owner.

Final acceptance of the work by the Owner shall be withheld until the Contractor has satisfactorily completed the required requirements for final cleanup of the work site.

2-3 Protection of Neighboring Structures

The Contractor is responsible for protecting any structures which may be affected by installation operations.

The Contractor shall relocate, repair, replace, or re-establish all existing improvements within the project limits which are not designated for removal which is damaged or a result of the construction operations or as required by the Drawings and Specifications.

Relocations, repairs, replacements, or re-establishment shall be at least equal to the existing improvements and shall match such improvements in finish and dimensions unless otherwise specified.

3 Geobrugg VX and “Super” VX Debris Nets

3-1 Geobrugg VX and “Super” VX

Installation of the Geobrugg VX and “Super” VX Debris Nets shall consist of furnishing, transporting, and constructing the system in accordance with the Drawings, these Specifications, and permit requirements.

The Geobrugg VX and “Super” VX shall be capable of absorbing surficial events with no distress of connecting elements. The Steel wire Ring Net shall be suspended from wire ropes spanning unsupported between the channel span. The system dimensions are shown on the Drawings. The General Requirements established in Section 1 of this Specification shall apply.

All material dimensions and details shown on the Drawings and specified in the specifications shall be reviewed and verified by the contractor prior to the start of any construction. Any discrepancies between the on-site material and the project Drawings or specifications shall be brought to the attention of the Engineer immediately for clarification.

3-2 Geobrugg VX and “Super” VX Steel Ring Net

3-2-1 Geobrugg ROCCO 16/3/300 Ring Net

Ring Net used for the Geobrugg VX160-H6 Debris Flow Barrier System shall be Geobrugg ROCCO® 16/3/300. The Geobrugg ROCCO® 16/3/300 shall consist of 16 windings, 0.12-in (3-mm) diameter steel wire, and a ring diameter of 11.8-in (300-mm). The steel wire material shall be alloyed high-strength wire with a minimum tensile strength of 256-ksi (1,770-N/mm^2). The tensile load capacity per ring shall be greater than or equal to 31.5-kips (140-kN). The steel wire shall be galvanized with a 95% zinc and 5% aluminum compound containing a minimum coating of 0.0256-psf (150-g/m^2). The Ring Net shall be installed as shown in the Drawings.

The Geobrugg ROCCO®/ 16/3/300 ring net panels shall be fastened together using shackles. See Section 4-5 "Shackles" for specifications. Connection strength of the ring nets shall be equal to or greater than the strength of the steel rings.

3-3 Ring Net Seam Connections

The Geobrugg ROCCO® Ring Net end panel seams shall be fastened together vertically using 3/4-in screw pin anchor shackles. A shackle shall be installed as shown on the Drawings to connect the end panels. See Section 3-5 “Shackles” for specifications.

Connection strength of the ring net shall be equal to or greater than the strength of the rings.

3-4 Ring Net To Support Rope Connections

The Geobrugg ROCCO® Ring Net shall connect to vertical & horizontal support ropes using 1-in screw pin anchor shackles. A shackle shall be installed as shown on the Drawings. See Section 4-5 “Shackles” for specifications.

Connection strength of the ring net shall be equal to or greater than the strength of the rings. A shackle shall be installed in every open ring.

3-5 Shackles

Shackles shall be screw pin anchor shackles and comply with Federal Specification RR-C-271D Type IVA, Class 2. Shackles shall be corrosion resistant by hot dip galvanization and comply with ASTM A123. Shackles shall be Chicago drop forged supplied by Geobrugg. Shackles shall be installed as shown on the Drawings. Thread locker adhesive may be used to securely fixed shackles from unscrewing.

3-6 Wire Rope Clips

All wire rope clips installed shall be attached as shown on the Drawings and in referenced product manuals. Wire rope clips shall be Chicago drop forged and supplied by Geobrugg. Wire rope clips shall be corrosion resistant by hot dipped galvanization and shall meet all applicable ASTM standards and meet Federal Specifications FF-C-450, Type 1, Class 1 for performance requirements. Wire rope clip quantity, spacing, and tightening values are shown in the Drawings. Wire rope clips shall be oriented as shown in the Drawings. Wire rope saddles shall be installed on the "live" end and the U-bolts installed on the "dead" end of the wire rope termination loop.

3-7 Top Support, Bottom Support, and Vertical Support Wire Ropes

All support wire rope shall be Independent Wire Rope Core (IWRC), Extra Improved Plow Steel (EIPS) 6x19 rope classification and hot-dipped galvanized. Wire rope shall be supplied by Geobrugg and comply with ASTM A123 for wire rope corrosion protection. Wire rope shall be 7/8-in (22-mm) diameter wire rope with a minimum breaking strength of 79.6-kips (354.1-kN) and comply with ASTM A1023 and Federal Specification RR-W-410E. The Contractor shall follow minimum wire rope requirements provided by the manufacturer and shown on the Drawings.

3-8 Top Support, Bottom Support, and Vertical Support Wire Rope Termination

Support wire ropes shall terminate by making a loop around the wire rope anchor loop. When loops are made in the wire rope, a heavy-duty thimble shall be used.

Termination loops shall include (5) 7/8-in wire rope clips with 2-3-in spacing between clips. Each wire rope clip shall be tightened to a torque of 110-ft-lb (150-Nm) with lubrication or 243 ft-lb (330-Nm) without lubrication. Each 7/8-in diameter wire rope termination loop shall have a minimum turn back tail of 12-in after installation of last wire rope clip.

3-9 Wire Rope Anchors

Wire rope anchors shall be provided by Geobrugg North America. Wire rope shall be Independent Wire Rope Core (IWRC), Extra Improved Plow Steel (EIPS) 6x19 rope classification and hot-dipped galvanized. Anchors shall comply with ASTM A123 for wire rope corrosion protection. The length of the wire rope anchors is shown on the Drawings. The Contractor shall follow minimum wire rope requirements provided by the manufacturer and shown on the Drawings

Wire rope anchors shall be minimum 1-1/4-in (32-mm) diameter single legged wire rope with a minimum breaking strength of 159.8-kips (711-kN) and comply with ASTM A1023 and Federal Specification RR-W-410E.

Termination loop shall include a heavy duty thimble in the wire rope anchor loops. Steel swaged ferrule by the manufacturer shall be used to secure the loops.

A steel swaged ferrule shall be installed at the bottom of the anchors or splayed end. Steel swaged ferrules shall be corrosion resistant.

3-10 Anchor Centralizers

Centralizers shall be used in all wire rope anchor holes. Centralizers shall adequately support the anchor in the center of the hole and shall be placed within 1-ft of each end of the anchor, or as shown on the Drawings. A minimum of two centralizers must be used per anchor unless otherwise indicated on the Drawings. Centralizers shall be Schedule 40 PVC. Steel tie wire shall be used to attach the centralizers to the anchors. Tie wire shall be 16 gauge black annealed carbon steel wire.

3-11 Grout

The Grout shall be non-shrink cement grout mixed with water as recommended by the manufacturer and conform to ASTM C845 for Expansive Hydraulic Cement. The grout shall have a minimum of 4,000-psi, 28-day compressive strength.

If Portland cement is used, cement type shall be Type I or Type II and conform to ASTM C150 "Standard Specification for Portland Cement." The contractor shall use an expansive additive in accordance with the cement manufacturer's recommendations. Alternate types of cement shall have fineness as in high early strength cement as measured by the Blaine method. The Contractor shall submit the proposed grout mix design submittal and grout strength data to the Engineer for approval one week prior to grouting commencement.

3-12 Miscellaneous Materials

All shackles, wire rope clips, thimbles, and miscellaneous hardware shall be corrosion resistant by hot dipped galvanization or epoxy coating and comply with ASTM Designation A153. All miscellaneous hardware shall be supplied by the Contractor.

4 INSTALLATION

4-1 Anchor Installation

The work by the Contractor for the anchors shall be in accordance with the Drawings. The distance from the center of the anchors shall be within 6-in of the distance indicated on the Drawings. Anchors shall be installed with methods approved by the Engineer. Anchor alignments shall conform to methods described in the referenced product manual. Location specific details for the inclination of the anchors are provided on the Drawings.

Holes shall be cleaned of all drill cuttings, sludge, and debris before an anchor is placed into the hole. Anchors shall be placed in the hole and positioned not less than 3-in from the bottom of the hole, and as shown on the Drawings. Dewatering or pre-grouting may be required for proper installation of anchors in groundwater conditions.

Centralizers shall be used in all anchor holes. Centralizers shall adequately support the anchor in the center of the hole and shall be placed within 1-ft of each end of the anchor, or as shown on the Drawings. A minimum of two centralizers must be used per anchor unless otherwise indicated on the Drawings.

Centralizers shall be attached to the wire rope anchor by tie wire. Tie wire shall be 16-gauge black annealed carbon steel wire.

Prior to grouting, the Contractor shall moisten the subgrade to a minimum of 2-in from the soil/grout interface and remove all loose soil and rocks from the hole. Anchor installations with dimensions are provided on the Drawings.

The Contractor is responsible for the correct installation of all anchors. Incorrect installations shall be replaced and reinstalled at no cost to the Owner.

4-2 Grouting

The Contractor shall submit the proposed grout mix design and grout strength data as a Submittal to the Engineer for approval a minimum of one week prior to grouting commencement per Section 1-3 "Submittals." See Project Specifications Section 6-2 "Grout Testing" for additional information to see if grout testing is required.

Grouting shall conform to State of California Standard Specifications. Grouting of the annular space around an anchor shall be accomplished by pressure grouting through a heavy duty plastic grout tube with a portable grout pump as recommended by the manufacturer, or by tremie. Grout pump shall provide 90-psi to 120-psi capacity.

Pressure grouting shall use sufficient pressure to overcome the hydrostatic head or as directed by the Engineer.

All grout tubes, tremie pipes, and fittings shall be clean and free from dirt particles, grease, hardened grout, or other contamination before grouting is commenced for any anchor. All surplus water and diluted grout shall be flushed or blown from all lines before commencing injections. The grout tube shall be attached to the tremie pipe with suitable fittings, as recommended by the manufacturer, such that leakage is entirely prevented.

Grout tubes shall be attached to the anchors or furnished in anchor lengths and inserted into the hole. Grouting shall commence from the bottom of the hole to the slope surface. Grout tubes shall be removed after grouting or filled and cut off after grout curing. Hand packing of grout may be required to provide complete grout installation to top of borehole grade.

Grout curing shall be 3 days prior to testing if air temperature (degrees Fahrenheit) is above 60° during the curing duration.

5 ANCHOR TESTING

5-1 General

Performance testing for wire rope anchors shall be performed on six sacrificial verification anchors. The performance testing procedure shall be in accordance with the Post-Tensioning Institute (PTI) standards. Anchors shall be tested up to a maximum of 133% of the design test load(s). Both design and maximum test loads are specified on the referenced construction Drawings and design calculation report.

Verification anchor testing shall be observed by the Engineer and performed by qualified testing personnel provided by the Contractor. The Contractor testing personnel shall be competent in the testing procedure and equipment setup. The anchor testing equipment shall be observed prior to testing by the Engineer and determined if acceptable.
For the sacrificial verification anchor testing, a minimum of six anchors shall be tested or at the discretion of the Engineer. Sacrificial anchors shall either be a threaded bar or wire rope anchor. The location(s) of the sacrificial anchors to be tested shall be determined by the Engineer. The Engineer shall be present to locate and observe the testing of the sacrificial verification anchors.

Sacrificial verification anchor testing is to verify anchor depths and to determine ultimate geologic material bond strengths limits prior to anchor drilling.

The Contractor shall notify the Engineer no less than 72 hours prior to testing anchors. Anchor Testing shall not be performed until the grout has reached adequate compressive strength or at the discretion or the Engineer.

The cost to provide testing shall be considered as included in the contract unit price and no additional payment shall be made.

5-2 Testing Equipment Requirements

All test equipment shall be calibrated within 1 year prior to the day of anchor testing. Calibrations of testing equipment shall be done to an accuracy of ±2%. Dial gauges shall permit the measurement of total anchor movement at every load increment to be read to the nearest 0.001-in.

Current calibration certificates and load graphs for all test equipment shall be submitted to the Engineer one week prior to the commencement of the testing per Section 1-3 "Submittals".

Equipment shall be capable of stressing the anchor to the maximum specified test load within the rated capacity and permit the anchor to be stressed in loading increments.

5-3 Test Equipment Re-Calibration

Re-calibration of testing equipment shall be performed if the anchor testing results are inconsistent, and or the testing equipment has been damaged during or before anchor testing.

If re-calibration is necessary of anchors tested since the previous test, the anchors shall be re-evaluated or re-tested at the Contractor's expense, including the cost of the Engineer to observe and review the test(s).

5-4 Performance Test

5-4-1 General

Anchor testing shall be performed against a temporary yoke or load frame of adequate strength to support the test load without failure or significant deformation. No part of the yoke or load frame shall bear within 1.5-ft of the anchors outside diameter.

Prior to testing commencement, Contractor shall have a current copy of the testing equipment calibration certificates and loading graphs on site the day of testing.

No anchor shall be tested that exceeds the minimum yield strength or 80% of the specified minimum anchor strength. Anchor testing shall be performed in the Presence of the Engineer or the Engineer's Representative.

5-4-2 Performance Test Procedure

The performance test shall consist of cyclically and incrementally loading and unloading the anchor to the maximum test load of 133% of the design load (DL)) or failure, whichever comes first.
An alignment load (AL) shall be placed on the anchor prior to each test to secure all testing

components and ensure accurate residual movements during the anchor testing.
If creep data is required, measurements for the creep displacement begin after the alignment load has been applied. No other loading can be placed on the anchor prior to testing. The alignment load shall be approximately 10% of the design load (DL) or at the discretion of the Engineer.

The Engineer shall monitor and record the displacement if required at each load increment with respect to the fixed independent reference point. Total displacement shall be recorded at the maximum test load every minute with respect to the fixed reference point.

TABLE 1 PERFORMANCE TEST STEPS

Loading Cycle	Load Increments	Loading Cycle	Load Increments
Cycle 1	AL	Cycle 5	AL
	0.25 DL		0.25 DL
Cycle 2	AL		0.50 DL
	0.25 DL		0.75 DL
	0.50 DL		1.00 DL
Cycle 3	AL		1.20 DL
	0.25 DL	Cycle 6	AL
	0.50 DL		0.25 DL
	0.75 DL		0.50 DL
Cycle 4	AL		0.75 DL
	0.25 DL		1.00 DL
	0.50 DL		1.20 DL
	0.75 DL		1.33 DL
	1.00 DL		

Legend: DL: Design Load AL: Alignment Load

The cyclic and incremental loading steps shall be as shown in Table 1. Each loading increment as shown in Table 1 shall be held for 1 minute to obtain movement readings if required.

Upon reaching the maximum test load (last loading increment), the load shall be maintained constant for a minimum of ten minutes without failure of the anchor or loss of load.

Failure shall be the point where movement of the anchor continues without an increase in load or when the anchor has displaced 1-in. The failure load corresponding to the failure point shall be recorded as part of the test data. Anchors shall be unloaded only after completion of the test. Each tested anchor shall contain its own test reading record.

6 SPECIAL INSPECTIONS

6-1 General

Special inspections listed below are recommended to be performed for the project to ensure construction is in conformance with the engineering design, specifications, and construction Drawings.

6-1-1 Site Layout

The Engineer shall inspect on-site and approve the Debris Net layouts prior to drilling commencement. The site layout staking shall be performed by the Contractor or the Engineer. Site layout includes staking or marking locations for the Debris Flow Net limits and anchor locations.

After completion of the site layout, the Engineer shall verify the site layout if performed by the Contractor for approval. If site layout is approved the Engineer shall provide a Letter of Conformance.

6-1-3 Verification Anchor Testing

The Contractor shall test verification anchors in accordance with Section 5 "Anchor Testing". The Engineer shall be on-site to observe and inspect the anchor testing to ensure the testing procedure is in conformance with the engineering design and Drawings. The Engineer shall approve the anchor testing based on testing results and provide a Letter of Conformance.

6-1-4 Final Inspection

The Engineer shall inspect on-site and approve the final constructed product and provide a signed and stamped Letter of Approval.

6-2 Grout Testing

The Contractor shall have a certified testing laboratory perform Grout Compressive Strength Tests for non-approved grout mixtures. The number of compressive tests shall be determined by the Engineer. The testing shall conform to ASTM C1019 "Standard Test Method for Sampling and Testing Grout". Grout shall have a minimum of 4,000-psi, 28-day compressive strength. Approved grout mixtures that do not require testing consist of; Williams Form Engineering S5Z Wil-X Cement Grout and US Spec RA Cement Grout.

Additional grout types not identified can be submitted to the Engineer for review and approval. The Contractor shall include (if published) the manufacturer's grout mix design and grout strength data. Grout material ordering are grouting commencement are prohibited prior to the Engineer's approval.

6-5 Warranty of Workmanship

The Contractor shall warrant all materials and installation as required by the Owner.

6-6 Construction Oversight

To ensure that the completed project meets these Drawings and Specifications, it is recommended that KANE GeoTech, Inc. be retained to observe construction. KANE GeoTech, Inc. is not responsible for construction performed without its oversight.

7 DISCLAIMER

7-1 General

Landslides and debris flow events can be sporadic and unpredictable. Causes range from human construction to environmental effects (weather, earthquakes, etc.). Because of the multiplicity of factors affecting such events it is not, and cannot be, an exact science that guarantees the safety of individuals and property. However, by the application of sound engineering principles to a predictable range of parameters, the risk of injury and property loss can be substantially reduced using properly designed protection measures in identified risk areas.

Inspection and maintenance of such systems are necessary to ensure the desired protection level is not degraded by impact damage, corrosion, or other factors.

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Montecito Debris Flow Mitigation

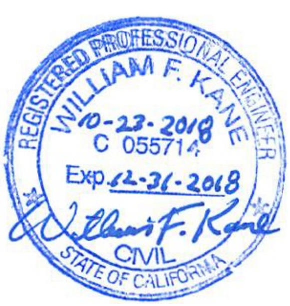
Geobrugg Debris Flow Mitigation Systems

Design Calculation Report

Montecito, California

KGT Project No. KGT18-28

Prepared by:



KANE GeoTech, Inc.
7400 Shoreline Drive, Suite 6
Stockton, California 95219

Prepared for:

Partnership for Resilient Communities
Montecito, California

Original Date: October 5, 2018
Revised Date: October 23, 2018

KANE GeoTech, Inc.
Geoengineering Consultants

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- Anchorage Quantity
- Top Support Rope Loading
- Wire Rope Catenary

Geobrugg VX and SVX Wire Rope Anchorage Design Calculations

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4. Federal Emergency Management Agency (FEMA) (2018). Santa Barbara Flood Recovery Mapping - Hydrology. Contract No. HSFE60-15-D-0005. Task Order 70FBR9-18-F00000051. April 2018.

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22. U.S. Department of Transportation Federal Highway Administration (2013). Federal Highway Administration Design Manual: Deep Mixing for Embankment and Foundation Support. Publication No. FHWA-HRT-13-046.

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Geologic Material Properties

1. Bedrock Subgrade: Shale
   a. Bedrock Quality: Fractured (Assumed)
   b. Ultimate Grout/Ground Bond Strength: 120-psi (PTI, 2014)

2. Bedrock Subgrade: Sandstone
   a. Bedrock Quality: Fractured (Assumed)
   b. Ultimate Grout/Ground Bond Strength: 120-psi (PTI, 2014)

3. Soil Subgrade: Alluvium
   a. Ultimate Grout/Ground Bond Strength: 10-psi (PTI, 2014)

4. Debris Flow Material Case 1 - Mud Flow
   i. Density: 1,800-kg/m^3 (112-pcf)
   ii. Case with more fines and water content
      (1) Water content: 0.52
   b. Case 2 - Granular
   i. Density: 2,000-kg/m^3 (125-pcf)
   ii. Case with more granular material
      (1) Water content: 0.39

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Site Dimensions & Approximate Locations

Table 1. Site Dimensions & Approximate Locations

*Site Designation	Net Height (ft)	Bottom Net Width (ft)	Top Net Width (ft)	Latitude	Longitude
BV2	10	14	41	N 34° 27.048'	W 119° 36.664'
BV4	17	45	77	N 34° 27.284'	W 119° 36.690'
BV5	12	27	37	N 34° 27.317'	W 119° 36.622'
BV6	15	22.5	44	N 34° 27.502'	W 119° 36.527'
BV7	20	20	50	N 34° 27.368'	W 119° 36.568'
BV10	15	14	56	N 34° 27.067'	W 119° 36.415'
BV11	20	98	150	N 34° 27.205'	W 119° 36.407'
HS6	17	94	48	N 34° 27.391'	W 119° 38.329'
HS7	11	49	19	N 34° 27.183	W 119° 38.515'
CS11	18	60	35	N 34° 27.613'	W 119° 39.245'
CS18	12	81	47	N 34° 27.615'	W 119° 39.300'
RC12	12	61	40	N 34° 28.118'	W 119° 37.385'
RC15	10	50	18	N 34° 27.573'	W 119° 37.399'
SY7	20	75	41	N 34° 27.908'	W 119° 35.457'
SY18	16	67	13	N 34° 27.525'	W 119° 35.490'

*Site Designation Code:
BV: Buena Vista Canyon
HS: Hot Springs Canyon
CS: Cold Springs Canyon
SY: San Ysidro Canyon
RC: Romero Canyon

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Assumptions and Design Criteria

1. Geobrugg SVX180-H6, VX160-H6 & VX140-H4 Wire Rope Anchor Size
   a. Diameter = 1-1/8-in

2. Geobrugg SVX180-H6, VX160-H6 & VX140-H4 Wire Rope Breaking Strength
   a. Support / Border Ropes
      i. 7/8-in diameter wire rope = 354-kN (79.6-kips)
      ii. Independent Wire Rope Core (IWRC) 6x19 Class

   b. Wire Rope Anchors
      i. 1-1/8-in diameter wire rope = 578-kN (130-kips)
      ii. Independent Wire Rope Core (IWRC) 6x19 Class

3. Geobrugg SVX180-H6, VX160-H6 & VX140-H4 Wire Rope Anchor Loading: 80-kips (Geobrugg VX System Drawing,2017)

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Summary of Results

Table 2. Debris Flow Analysis Results		
***Site Designation**	**Geobrugg Barrier Selected**	**Factor of Safety**
BV2	VX140-H4	2.93
BV4	SVX180-H6	1.73
BV5	VX140-H4	2.43
BV6	VX160-H6	2.39
BV7	VX160-H6	1.61
BV10	VX160-H6	2.09
BV11	SVX180-H6	1.55
CS11	VX160-H6	1.61
CS18	SVX180-H6	2.11
HS6	SVX180-H6	1.59
HS7	VX140-H4	2.26
SY7	SVX180-H6	1.85
SY18	SVX180-H6	2.35
RC12	SVX180-H6	3.34
RC15	VX160-H6	3.57

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Summary of Results (Continued)

Table 3. Geobrugg VX & SVX System Wire Rope Anchor Design							
Geologic Material	**Min. Wire Rope Diameter (in)**	*** Min. Anchor Hole Diameter (in)**	**** Min. Anchor Depth into Competent Bedrock (ft)**	***** Est. Min. Anchor Embedment Depth (ft)**	****** Anchor Embedment Resistance (kip/ft)**	**Design Load (kips)**	**Max. Testing Load (kips)**
Colluvium	1.125	6	-	41	2.3	80	106.4
Sandstone	1.125	6	8	11	11.3	80	106.4
Shale	1.125	6	9	12	9	80	106.4

* Minimum borehole diameter required.
** Minimum anchor depth into competent geologic material defined in Table 3.
*** Estimated minimum anchor embedment depth.
**** Anchor embedment resistance into competent geologic material defined in Table 3.
Sacrificial anchor verification performance load testing shall be performed for lateral anchors.
See project specifications for testing setup, procedure, quantity and additional requirements.

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GEOBRUGG DEBRIS FLOW MITIGATION SYSTEM CALCULATIONS

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18

Project name Montecito - Buena Vista Canyon BV-2

Date/Author 2018 09-27, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	1000	1000		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	250	250		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	375	375		m^3
Volume of first surge (chosen)	V_{N1} =	380	380		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	13.9	13.9		m^3/s
Peak discharge (chosen)	Q_P =	14	14		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

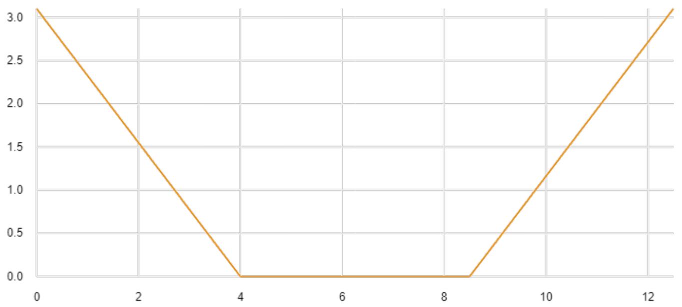
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX140-H4	No. 1 Buena Vista Canyon BV-2	2.93	fulfilled !	1,001.4 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	1,001	m^3	
Required retention volume	$V_{tot,max}$ =	1000	m^3	
Reserve	$V_{r,reserve}$ =	1	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	3.1	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	12.5	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	4.5	m
Distance to the next barrier upstream	$L_{0,1}$ =	190	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	2.3	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	7	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	4.7	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	4.7	%
Angle between ring net and river bed		91.0	°
Length of deposited material behind barrier	L_1 =	101.4	m
Retention volume	$V_{r,1}$ =	1,001.4	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	3.0	3.0		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.0	3.0		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	3	3		m/s
Flow height	$h_{fl,1}$ =	1.0	1.0		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.7			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX140-H4	
Max. system height	$H_{0,max}$ =	4	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.85			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	26	48		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	171	171		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	6.50	3.57		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	51	56		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	165	165		kN/m^2
Safety factor	$SF_{stat,1}$ =	3.26	2.93		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito - Buena Vista Canyon BV-4
Date/Author	2018 09-26, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m³
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m³
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	5600	5600		m³
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	1,400	1,400		m³
Volume of first surge (recommended)	$V_{N1,rec}$ =	2,100	2,100		m³
Volume of first surge (chosen)	V_{N1} =	2100	2100		m³

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	52.7	52.7		m³/s
Peak discharge (chosen)	Q_P =	53	53		m³/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

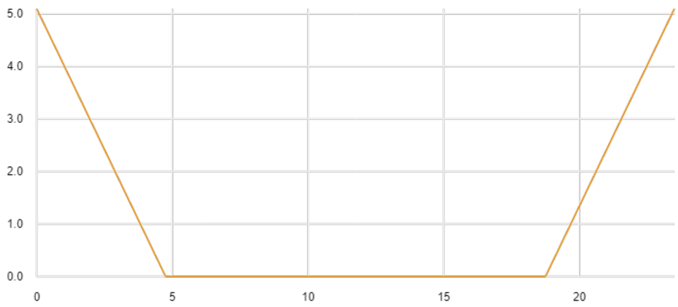
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 Buena Vista Canyon BV-4	1.73	fulfilled !	5,509.1 m³

Retention volume

Total retention volume	$V_{r,tot}$ =	5,509	m³
Required retention volume	$V_{tot,max}$ =	5500	m³
Reserve	$V_{r,reserve}$ =	9	m³
Proof of retention volume		fulfilled !	
Proof of overall system		fulfilled !	

Barrier Location No. 1

System height	$H_{0,1}$ =	5.1	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	23.5	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	14	m
Distance to the next barrier upstream	$L_{o,1}$ =	120	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	3.8	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	7	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	4.7	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	4.7	%
Angle between ring net and river bed		91.0	°
Length of deposited material behind barrier	L_1 =	120.0	m
Retention volume	$V_{r,1}$ =	5,509.1	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.8	4.8		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.2	3.2		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.8	4.8		m/s
Flow height	$h_{fl,1}$ =	0.8	0.8		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.5			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.04			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	38	79		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	136	136		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	3.57	1.73		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	73	81		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	173	173		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.38	2.14		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18

Project name Montecito - Buena Vista Canyon BV-5

Date/Author 2018 09-27, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	1500	1500		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	375	375		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	563	563		m^3
Volume of first surge (chosen)	V_{N1} =	570	570		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	19.1	19.1		m^3/s
Peak discharge (chosen)	Q_P =	19	19		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

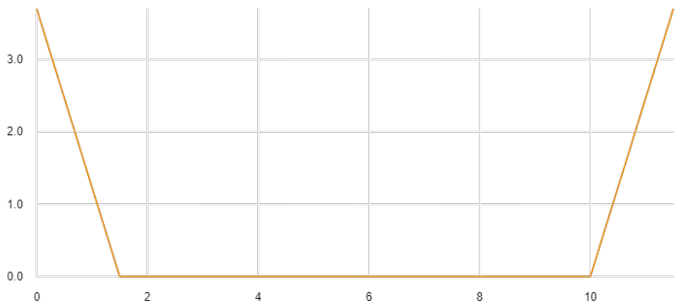
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX140-H4	No. 1 Buena Vista Canyon BV-5	2.43	fulfilled !	1,431.7 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	1,432	m^3	
Required retention volume	$V_{tot,max}$ =	1430	m^3	
Reserve	$V_{r,reserve}$ =	2	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	3.7	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	11.5	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	8.5	m
Distance to the next barrier upstream	$L_{0,1}$ =	135	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	2.8	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	8	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	5.3	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	5.3	%
Angle between ring net and river bed		90.4	°
Length of deposited material behind barrier	L_1 =	103.2	m
Retention volume	$V_{r,1}$ =	1,431.7	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	3.4	3.4		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	2.7	2.7		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	3.4	3.4		m/s
Flow height	$h_{fl,1}$ =	0.7	0.7		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.4			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX140-H4	
Max. system height	$H_{0,max}$ =	4	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.00			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	17	35		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	92	92		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	5.26	2.66		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	52	58		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	140	140		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.70	2.43		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito - Buena Vista Canyon BV-6
Date/Author	2018 09-27, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m³
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m³
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	1800	1800		m³
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	450	450		m³
Volume of first surge (recommended)	$V_{N1,rec}$ =	675	675		m³
Volume of first surge (chosen)	V_{N1} =	680	680		m³

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	21.9	21.9		m³/s
Peak discharge (chosen)	Q_P =	22	22		m³/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

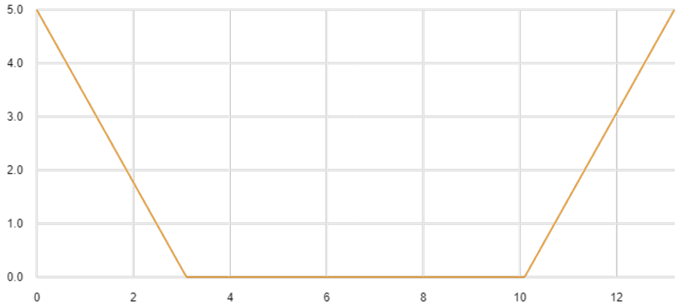
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX160-H6	No. 1 Buena Vista Canyon BV-6	2.39	fulfilled !	1,792.9 m³

Retention volume

Total retention volume	$V_{r,tot}$ =	1,793	m³
Required retention volume	$V_{tot,max}$ =	1790	m³
Reserve	$V_{r,reserve}$ =	3	m³
Proof of retention volume		fulfilled !	
Proof of overall system			fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	5	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	13.2	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	7	m
Distance to the next barrier upstream	$L_{0,1}$ =	150	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	3.8	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	12	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	8.0	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	8	%
Angle between ring net and river bed		88.2	°
Length of deposited material behind barrier	L_1 =	94.7	m
Retention volume	$V_{r,1}$ =	1,792.9	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	3.9	3.9		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.5	3.5		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	3.9	3.9		m/s
Flow height	$h_{fl,1}$ =	0.8	0.8		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.5			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX160-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.84			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	28	55		kN/m*h_{fl}
Resistance against dynamic loading	$RD_{dyn,1}$ =	153	153		kN/m*h_{fl}
Safety factor	$SF_{dyn,1}$ =	5.51	2.77		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	72	80		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	190	190		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.65	2.39		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18

Project name Montecito - Buena Vista Canyon BV-7

Date/Author 2018 09-27, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m³
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m³
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	5300	5300		m³
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	1,325	1,325		m³
Volume of first surge (recommended)	$V_{N1,rec}$ =	1,988	1,988		m³
Volume of first surge (chosen)	V_{N1} =	1990	1990		m³

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	50.5	50.5		m³/s
Peak discharge (chosen)	Q_P =	51	51		m³/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

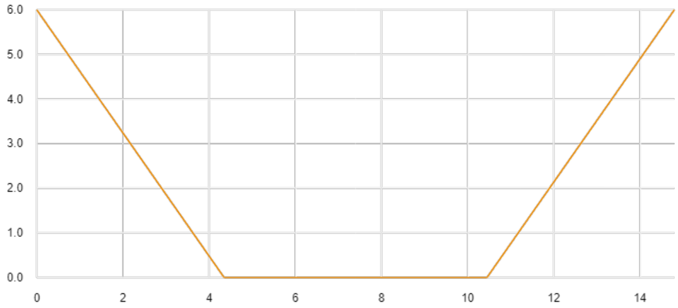
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX160-H6	No. 1 Buena Vista Canyon BV-7	1.61	fulfilled !	5,296.2 m³

Retention volume

Total retention volume	$V_{r,tot}$ =	5,296	m³	
Required retention volume	$V_{tot,max}$ =	5290	m³	
Reserve	$V_{r,reserve}$ =	6	m³	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{o,1}$ =	6	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	14.8	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	6.1	m
Distance to the next barrier upstream	$L_{o,1}$ =	265	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	4.5	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	6	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	4.0	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	4	%
Angle between ring net and river bed		91.6	°
Length of deposited material behind barrier	L_1 =	225.3	m
Retention volume	$V_{r,1}$ =	5,296.2	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.6	4.6		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	4.2	4.2		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.6	4.6		m/s
Flow height	$h_{fl,1}$ =	1.8	1.8		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	1.2			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX160-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.87			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	98	186		kN/m*h_{fl}
Resistance against dynamic loading	$RD_{dyn,1}$ =	334	334		kN/m*h_{fl}
Safety factor	$SF_{dyn,1}$ =	3.39	1.79		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	103	114		kN/m²
Resistance against static loading	$RD_{stat,1}$ =	184	184		kN/m²
Safety factor	$SF_{stat,1}$ =	1.79	1.61		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18

Project name Montecito - Buena Vista Canyon BV-10

Date/Author 2018 09-27, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	3500	3500		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	875	875		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	1,313	1,313		m^3
Volume of first surge (chosen)	V_{N1} =	1320	1320		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	36.7	36.7		m^3/s
Peak discharge (chosen)	Q_P =	37	37		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

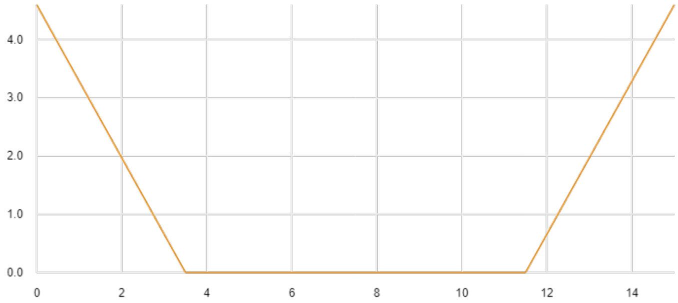
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX160-H6	No. 1 Buena Vista Canyon BV-10	2.09	fulfilled !	3,425.7 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	3,426	m^3	
Required retention volume	$V_{tot,max}$ =	3420	m^3	
Reserve	$V_{r,reserve}$ =	6	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	4.6	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	15	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	8	m
Distance to the next barrier upstream	$L_{0,1}$ =	261	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	3.5	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	6	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	4.0	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	4	%
Angle between ring net and river bed		91.6	°
Length of deposited material behind barrier	L_1 =	172.8	m
Retention volume	$V_{r,1}$ =	3,425.7	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.1	4.1		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.3	3.3		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.1	4.1		m/s
Flow height	$h_{fl,1}$ =	1.1	1.1		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.8			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX160-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.96			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	45	88		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	188	188		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	4.15	2.13		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	72	80		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	167	167		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.32	2.09		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito - Buena Vista Canyon BV-11
Date/Author	2018 09-26, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m³
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m³
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	11100	11100		m³
Number of surges	N =	8	8		
Volume per surge (average)	V_N =	1,388	1,388		m³
Volume of first surge (recommended)	$V_{N1,rec}$ =	2,081	2,081		m³
Volume of first surge (chosen)	V_{N1} =	2080	2080		m³

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	52.3	52.3		m³/s
Peak discharge (chosen)	Q_P =	52	52		m³/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

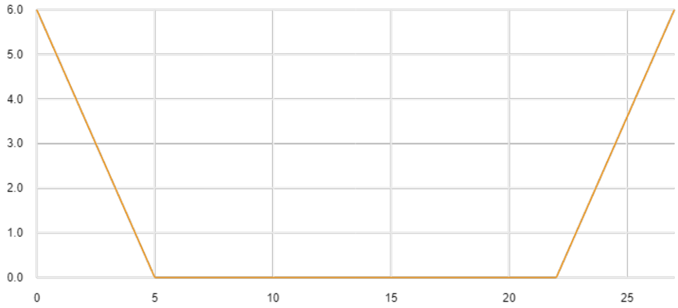
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 Buena Vista Canyon BV-11	1.55	fulfilled !	11,024.7 m³

Retention volume

Total retention volume	$V_{r,tot}$ =	11,025	m³
Required retention volume	$V_{tot,max}$ =	10000	m³
Reserve	$V_{r,reserve}$ =	1,025	m³
Proof of retention volume		fulfilled !	
Proof of overall system			fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	6	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	27	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	17	m
Distance to the next barrier upstream	$L_{0,1}$ =	200	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	4.5	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	7	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	4.7	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	5	%
Angle between ring net and river bed		91.0	°
Length of deposited material behind barrier	L_1 =	200.0	m
Retention volume	$V_{r,1}$ =	11,024.7	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.7	4.7		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.0	3.0		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.7	4.7		m/s
Flow height	$h_{fl,1}$ =	0.7	0.7		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.4			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

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Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.22			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	30	62		kN/m*h_{fl}
Resistance against dynamic loading	$RD_{dyn,1}$ =	96	96		kN/m*h_{fl}
Safety factor	$SF_{dyn,1}$ =	3.24	1.55		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	82	91		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	147	147		kN/m^2
Safety factor	$SF_{stat,1}$ =	1.79	1.61		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18
Project name Montecito - Cold Spring Canyon CS-11
Date/Author 2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	3000	3000		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	750	750		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	1,125	1,125		m^3
Volume of first surge (chosen)	V_{N1} =	1130	1130		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	32.5	32.5		m^3/s
Peak discharge (chosen)	Q_P =	33	33		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX160-H6	No. 1 Cold Spring Canyon CS-11	1.61	not fulfilled !	2,942.0 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	2,942	m^3
Required retention volume	$V_{tot,max}$ =	2940	m^3
Reserve	$V_{r,reserve}$ =	2	m^3
Proof of retention volume		fulfilled !	
Proof of overall system			not fulfilled !

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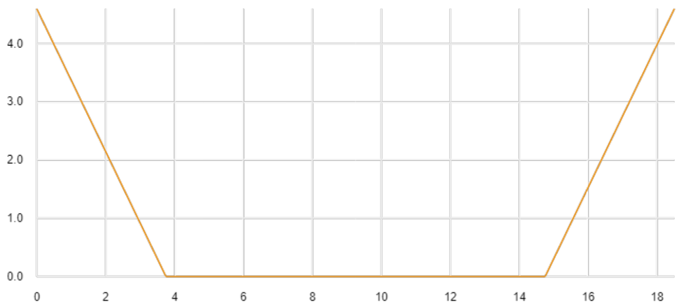
Barrier Location No. 1

System height	$H_{0,1}$ =	4.6	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	18.5	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	11	m
Distance to the next barrier upstream	$L_{0,1}$ =	152	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	3.5	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	9	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	6.0	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	6	%
Angle between ring net and river bed		89.9	°
Length of deposited material behind barrier	L_1 =	115.6	m
Retention volume	$V_{r,1}$ =	2,942.0	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.3	4.3		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.2	3.2		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.3	4.3		m/s
Flow height	$h_{fl,1}$ =	0.7	0.7		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.5			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX160-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		not fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.23			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	28	56		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	91	91		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	3.30	1.61		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	64	72		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	130	130		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.02	1.82		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				not fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18

Project name Montecito - Cold Spring Canyon CS-18

Date/Author 2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	4500	4500		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	1,125	1,125		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	1,688	1,688		m^3
Volume of first surge (chosen)	V_{N1} =	1690	1690		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	44.5	44.5		m^3/s
Peak discharge (chosen)	Q_P =	45	45		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

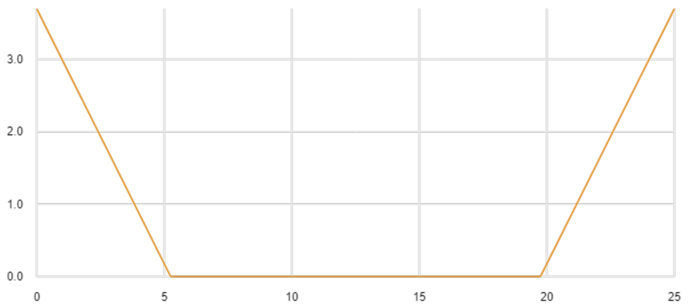
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 Cold Spring Canyon CS-18	2.11	fulfilled !	4,421.4 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	4,421	m^3
Required retention volume	$V_{tot,max}$ =	4420	m^3
Reserve	$V_{r,reserve}$ =	1	m^3
Proof of retention volume		fulfilled !	
Proof of overall system			fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	3.7	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	25	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	14.5	m
Distance to the next barrier upstream	$L_{0,1}$ =	146	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	2.8	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	5	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	3.3	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	3.3	%
Angle between ring net and river bed		92.1	°
Length of deposited material behind barrier	L_1 =	146.0	m
Retention volume	$V_{r,1}$ =	4,421.4	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.2	4.2		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	2.7	2.7		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.2	4.2		m/s
Flow height	$h_{fl,1}$ =	0.7	0.7		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.5			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.10			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	28	57		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	121	121		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	4.29	2.11		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	53	59		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	164	164		kN/m^2
Safety factor	$SF_{stat,1}$ =	3.08	2.77		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18

Project name Montecito - Hot Springs Canyon HS-6

Date/Author 2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	9400	9400		m^3
Number of surges	N =	6	6		
Volume per surge (average)	V_N =	1,567	1,567		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	2,350	2,350		m^3
Volume of first surge (chosen)	V_{N1} =	2350	2350		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	57.5	57.5		m^3/s
Peak discharge (chosen)	Q_P =	58	58		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

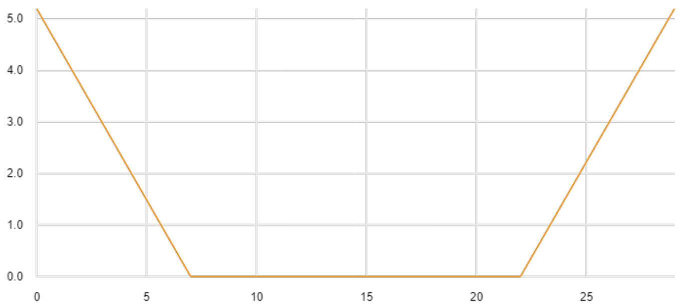
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 Hot Springs Canyon HS-6	1.59	fulfilled !	9,838.1 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	9,838	m^3	
Required retention volume	$V_{tot,max}$ =	9830	m^3	
Reserve	$V_{r,reserve}$ =	8	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	5.2	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	29	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	15	m
Distance to the next barrier upstream	$L_{o,1}$ =	300	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	3.9	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	5	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	3.3	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	3.3	%
Angle between ring net and river bed		92.1	°
Length of deposited material behind barrier	L_1 =	229.5	m
Retention volume	$V_{r,1}$ =	9,838.1	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.6	4.6		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	2.9	2.9		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.6	4.6		m/s
Flow height	$h_{fl,1}$ =	0.8	0.8		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.6			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.22			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	38	78		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	124	124		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	3.24	1.59		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	75	83		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	147	147		kN/m^2
Safety factor	$SF_{stat,1}$ =	1.97	1.77		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito - Hot Springs Canyon HS-7
Date/Author	2018 09-27, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	1400	1400		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	350	350		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	525	525		m^3
Volume of first surge (chosen)	V_{N1} =	530	530		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	18.0	18.0		m^3/s
Peak discharge (chosen)	Q_P =	18	18		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

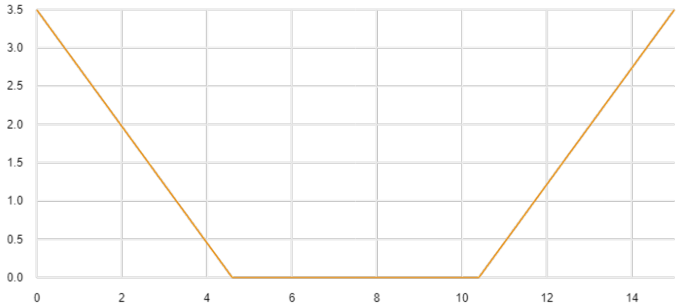
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX140-H4	No. 1 Hot Springs Canyon HS-7	2.26	fulfilled !	1,332.4 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	1,332	m^3	
Required retention volume	$V_{tot,max}$ =	1330	m^3	
Reserve	$V_{r,reserve}$ =	2	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	3.5	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	15	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	5.8	m
Distance to the next barrier upstream	$L_{o,1}$ =	185	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	2.6	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	8	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	5.3	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	5.3	%
Angle between ring net and river bed		90.4	°
Length of deposited material behind barrier	L_1 =	97.6	m
Retention volume	$V_{r,1}$ =	1,332.4	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	3.4	3.4		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.1	3.1		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	3.4	3.4		m/s
Flow height	$h_{fl,1}$ =	0.9	0.9		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.6			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX140-H4	
Max. system height	$H_{0,max}$ =	4	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	1.04			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	26	50		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	123	123		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	4.66	2.44		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	54	60		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	135	135		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.51	2.26		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito - Romero Canyon RC-12
Date/Author	2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	2100	2100		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	525	525		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	788	788		m^3
Volume of first surge (chosen)	V_{N1} =	800	800		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	24.8	24.8		m^3/s
Peak discharge (chosen)	Q_P =	25	25		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

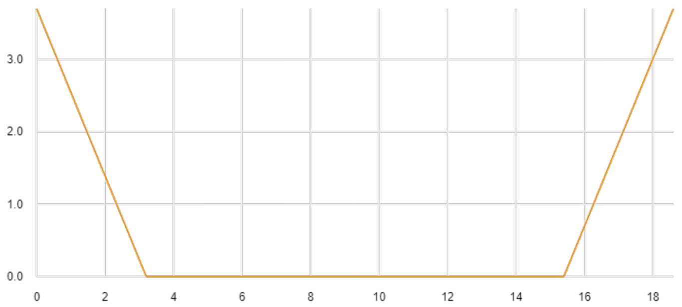
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 Romero Canyon RC-12	3.34	fulfilled !	2,054.9 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	2,055	m^3	
Required retention volume	$V_{tot,max}$ =	2050	m^3	
Reserve	$V_{r,reserve}$ =	5	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	3.7	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	18.6	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	12.2	m
Distance to the next barrier upstream	$L_{0,1}$ =	192	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	2.8	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	8.7	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	5.8	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	5.8	%
Angle between ring net and river bed		90.0	°
Length of deposited material behind barrier	L_1 =	96.2	m
Retention volume	$V_{r,1}$ =	2,054.9	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	3.8	3.8		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	2.7	2.7		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	3.8	3.8		m/s
Flow height	$h_{fl,1}$ =	0.5	0.5		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.4			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.86			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	17	34		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	113	113		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	6.84	3.34		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	50	55		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	210	210		kN/m^2
Safety factor	$SF_{stat,1}$ =	4.23	3.81		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito - Romero Canyon RC-15
Date/Author	2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	$\rho =$	1800	2000		kg/m^3
Specific weight of the debris flow material	$\gamma =$	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	$V_{tot} =$	1000	1000		m^3
Number of surges	N =	4	4		
Volume per surge (average)	$V_N =$	250	250		m^3
Volume of first surge (recommended)	$V_{N1,rec} =$	375	375		m^3
Volume of first surge (chosen)	$V_{N1} =$	400	400		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec} =$	14.5	14.5		m^3/s
Peak discharge (chosen)	$Q_P =$	15	15		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

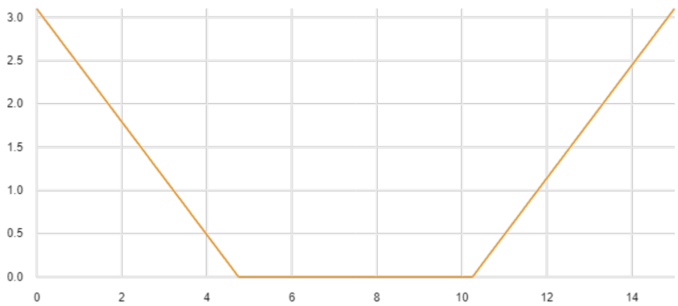
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG VX160-H6	No. 1 Romero Canyon RC-15	3.57	fulfilled !	960.1 m^3

Retention volume

Total retention volume	$V_{r,tot} =$	960	m^3	
Required retention volume	$V_{tot,max} =$	960	m^3	
Reserve	$V_{r,reserve} =$	0	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	3.1	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	15	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	5.5	m
Distance to the next barrier upstream	$L_{0,1}$ =	165	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	2.3	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	8.7	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	5.8	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	5.8	%
Angle between ring net and river bed		90.0	°
Length of deposited material behind barrier	L_1 =	80.6	m
Retention volume	$V_{r,1}$ =	960.1	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	3.2	3.2		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.0	3.0		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	3.2	3.2		m/s
Flow height	$h_{fl,1}$ =	0.9	0.9		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.6			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG VX160-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	15	m
Max. system width below	$b_{u,max}$ =	15	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.85			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	22	42		$kN/m*h_{fl}$
Resistance against dynamic loading	$RD_{dyn,1}$ =	160	160		$kN/m*h_{fl}$
Safety factor	$SF_{dyn,1}$ =	7.22	3.80		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	47	53		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	187	187		kN/m^2
Safety factor	$SF_{stat,1}$ =	3.96	3.57		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No. KGT18-18
Project name Montecito - San Ysidro Canyon SY-7
Date/Author 2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	6500	6500		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	1,625	1,625		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	2,438	2,438		m^3
Volume of first surge (chosen)	V_{N1} =	2440	2440		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	59.2	59.2		m^3/s
Peak discharge (chosen)	Q_P =	59	59		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

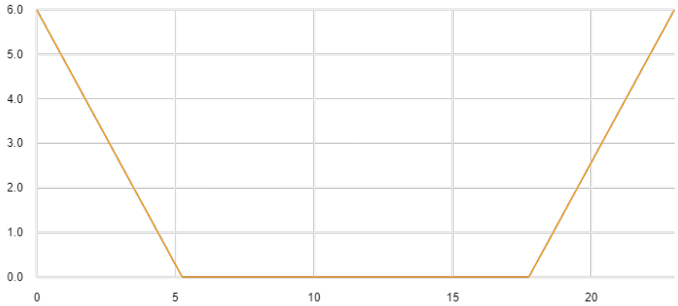
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 San Ysidro Canyon SY-7	1.85	fulfilled !	6,477.3 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	6,477	m^3	
Required retention volume	$V_{tot,max}$ =	6477	m^3	
Reserve	$V_{r,reserve}$ =	0	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	6	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	23	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	12.5	m
Distance to the next barrier upstream	$L_{o,1}$ =	100	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	4.5	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	5	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	3.3	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	3.3	%
Angle between ring net and river bed		92.1	°
Length of deposited material behind barrier	L_1 =	100.0	m
Retention volume	$V_{r,1}$ =	6,477.3	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.6	4.6		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	3.2	3.2		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.6	4.6		m/s
Flow height	$h_{fl,1}$ =	1.0	1.0		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	0.7			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

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Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.99			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	48	97		kN/m*h_{fl}
Resistance against dynamic loading	$RD_{dyn,1}$ =	187	187		kN/m*h_{fl}
Safety factor	$SF_{dyn,1}$ =	3.87	1.93		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	89	99		kN/m^2
Resistance against static loading	$RD_{stat,1}$ =	183	183		kN/m^2
Safety factor	$SF_{stat,1}$ =	2.06	1.85		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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Safety is our nature

DEBFLOW ONLINE TOOL

Dimensioning of the flexible Debris Flow Protection System GEOBRUGG VX/UX - DEBFLOW

Project No.	KGT18-18
Project name	Montecito San Ysidro Canyon SY-18
Date/Author	2018 09-28, JAM/BJF

Type and density of the debris flow

		Load case 1	Load case 2	Load case 3	
Type of debris flow (granular or mud flow)	Type	mud flow	granular	no load case	
Density of the debris flow material	ρ =	1800	2000		kg/m^3
Specific weight of the debris flow material	γ =	17.7	19.6		kN/m^3
Water content	W =	0.52	0.39		-

Debris flow volume and number of surges

		Load case 1	Load case 2	Load case 3	
Total debris flow volume (incl. water)	V_{tot} =	4800	4800		m^3
Number of surges	N =	4	4		
Volume per surge (average)	V_N =	1,200	1,200		m^3
Volume of first surge (recommended)	$V_{N1,rec}$ =	1,800	1,800		m^3
Volume of first surge (chosen)	V_{N1} =	1800	1800		m^3

Peak discharge

		Load case 1	Load case 2	Load case 3	
Peak discharge (acc. to Rickenmann)	$Q_{P,rec}$ =	46.7	46.7		m^3/s
Peak discharge (chosen)	Q_P =	47	47		m^3/s

Safety factor

Global safety factor	SF =	1.5	-

Summary of Results

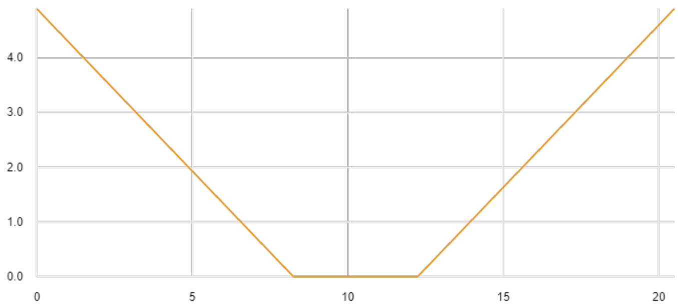
Multi-level debris flow protection system	No.	Safety Factor	Proof	Retention volume
GEOBRUGG UX180-H6	No. 1 San Ysidro Canyon SY-18	2.35	fulfilled !	4,727.6 m^3

Retention volume

Total retention volume	$V_{r,tot}$ =	4,728	m^3	
Required retention volume	$V_{tot,max}$ =	4727	m^3	
Reserve	$V_{r,reserve}$ =	1	m^3	
Proof of retention volume		fulfilled !		
Proof of overall system				fulfilled !

Barrier Location No. 1

System height	$H_{0,1}$ =	4.9	m
Width of torrent on the level of the top support ropes	$b_{o,1}$ =	20.5	m
Width of torrent on the level of the bottom support ropes	$b_{u,1}$ =	4	m
Distance to the next barrier upstream	$L_{0,1}$ =	180	m



Torrent inclination and retention volume

System height of the filled barrier	$H_{1,1}$ =	3.7	m
Average torrent inclination upstream of the barrier	$I_{s,1}$ =	5	%
Deposition inclination of filled barrier (acc. to Rickenmann)	$I'_{s,1,rec}$ =	3.3	%
Deposition inclination of filled barrier (chosen)	$I'_{s,1}$ =	3.3	%
Angle between ring net and river bed		92.1	°
Length of deposited material behind barrier	L_1 =	180.0	m
Retention volume	$V_{r,1}$ =	4,727.6	m^3

Front velocity and flow height

		Load case 1	Load case 2	Load case 3	
Front velocity (acc. to Rickenmann)	$v_{1,base}$ =	4.3	4.3		m/s
Front velocity according to Strickler (v1>vstr)	v_{str} =	4.6	4.6		m/s
Impact velocity at barrier location (chosen,max. v-value)	v_1	4.6	4.6		m/s
Flow height	$h_{fl,1}$ =	2.6	2.6		m
Recommended max. basal opening height (acc. to Wendeler)	$h_{d,1}$ =	1.7			m

Flexible, permeable debris flow protection system

System type	Type	GEOBRUGG UX180-H6	
Max. system height	$H_{0,max}$ =	6	m
Max. system width above	$b_{o,max}$ =	30	m
Max. system width below	$b_{u,max}$ =	25	m
Proof of system height and system width		fulfilled !	

Proof of max. dynamic loading (stopping)

		Load case 1	Load case 2	Load case 3	
Width factor (width at barrier location to standard width)	BF_1 =	0.68			
Dynamic loading (Pressure and impulse acc. to Wendeler)	$MD_{dyn,1}$ =	155	280		kN/m*h_{fl}
Resistance against dynamic loading	$RD_{dyn,1}$ =	676	676		kN/m*h_{fl}
Safety factor	$SF_{dyn,1}$ =	4.36	2.41		
Proof of max. dynamic loading		fulfilled !	fulfilled !		

Proof of max. static loading (overflowing)

		Load case 1	Load case 2	Load case 3	
Reduction factor hydrostat. pressure (Permeability)	HF =	1.0			
Static loading (hydrostat. pressure acc. to Wendeler)	$MD_{stat,1}$ =	101	112		kN/m²
Resistance against static loading	$RD_{stat,1}$ =	264	264		kN/m²
Safety factor	$SF_{stat,1}$ =	2.61	2.35		
Proof of max. static loading		fulfilled !	fulfilled !		
Proof barrier 1				fulfilled !	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for BV-4, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**$MD_{dyn,1}$**):	79	$kN/m*h_{fl}$	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**$RD_{dyn,1}$**):	136	$kN/m*h_{fl}$	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**$SF_{dyn,1}$**):	1.73		Reference No. 1
Calculated Flow Height (**h_{fl}**):	0.80	m	Reference No. 1
	2.62	ft	

Geobrugg DEBFLOW Static Loading (Overflowing)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for BV-4, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**$MD_{stat,1}$**):	81	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**$RD_{stat,1}$**):	173	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**$SF_{stat,1}$**):	2.14		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			**Notes**
Width Factor (**BF_1**):	1.04		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			**Notes**
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			**Notes**
Design Impact Pressure:	**81**	**kN/m^2**	
	1,692	**psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			**Notes**
Top Support Ropes:	77	ft	Reference No. 1 - Maximum top support ropes span for BV-4
Intermediate Support Ropes Section (1):	69	ft	Reference No. 1 - Intermediate support ropes section (1) span for BV-4
Intermediate Support Ropes Section (2):	54	ft	Reference No. 1 - Intermediate support ropes section (2) span for BV-4
Bottom Support Ropes:	45	ft	Reference No. 1 - Maximum bottom support ropes span for BV-4

Geobrugg ROCCO Ring Net Areas			**Notes**
Top Support Ring Net Section Area:	213	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	389	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	311	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	134	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			**Notes**
Geobrugg ROCCO Ring Net Total Area	1,047	sq.ft.	

Design Impact Pressure			**Notes**
Design Impact Pressure:	1,692	psf	Reference No. 5

Design Load - Top Section			**Notes**
Design Load Top Section:	**360,336**	**lbf**	
	360	**kips**	

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	**658,079**	**lbf**	
	658	**kips**	

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	**526,125**	**lbf**	
	526	**kips**	

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	**226,691**	**lbf**	
	227	**kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Support Wire Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			**Notes**
Design Load Top Section:	360,336	lbf	
	360	kips	
Top Support Ropes:	77	ft	Reference No. 1 - Maximum top support ropes span for BV-4

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	658,079	lbf	
	658	kips	
Intermediate Support Ropes Section (1):	69	ft	Reference No. 1 - Intermediate support ropes section (1) span for BV-4

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	526,125	lbf	
	526	kips	
Intermediate Support Ropes Section (2):	54	ft	Reference No. 1 - Intermediate support ropes section (2) span for BV-4

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	226,691	lbf	
	227	kips	
Bottom Support Ropes:	45	ft	Reference No. 1 - Maximum bottom support ropes span for BV-4

Wire Rope Anchorage Loading			**Notes**
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			**Notes**
Top Support Ropes - Design Load:	**4.68**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**9.54**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**9.74**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			**Notes**
Bottom Support Ropes - Design Load:	**5.04**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Anchorage Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths			**Notes**
Top Support Ropes:	77	ft	Reference No. 1 - Maximum top support ropes span for BV-4
Top Support Rope Sectional Length	39	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	19.3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**514.8**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths			**Notes**
Intermediate Support Ropes:	69	ft	Reference No. 1 - Intermediate support ropes section (1) span for BV-4
Intermediate Support Rope Sectional Length:	35	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	17.3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**548.4**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths			**Notes**
Intermediate Support Ropes:	54	ft	Reference No. 1 - Intermediate support ropes section (2) span for BV-4
Intermediate Support Rope Sectional Length:	27	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	14	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**438.4**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths			**Notes**
Bottom Support Ropes:	45	ft	Reference No. 1 - Maximum bottom support ropes span for BV-4
Bottom Support Rope Sectional Length	23	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	11	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**377.8**	**kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Anchorage Quantity

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Anchorage Loading*

INPUT

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**514.8**	**kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**548.4**	**kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**438.4**	**kips**	Reference No. 5

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**377.8**	**kips**	Reference No. 5

Allowable Anchorage Tensile Load			**Notes**
Allowable Anchorage Tensile Load:	80	kips	Reference No. 4

Output

Top Support Anchorage Quantity			**Notes**
Top Support Anchorage Quantity:	**7**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity			**Notes**
Intermediate Support Section 1 Anchorage Quantity:	**7**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity			**Notes**
Intermediate Support Section 2 Anchorage Quantity:	**5**	**Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity			**Notes**
Bottom Support Anchorage Quantity:	**5**	**Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for BV-11, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**$MD_{dyn,1}$**):	62	$kN/m*h_{fl}$	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**$RD_{dyn,1}$**):	96	$kN/m*h_{fl}$	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**$SF_{dyn,1}$**):	1.55		Reference No. 1
Calculated Flow Height (**h_{fl}**):	0.70 2.30	m ft	Reference No. 1

Geobrugg DEBFLOW Static Loading (Overflowing)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for BV-11, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**$MD_{stat,1}$**):	91	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**$RD_{stat,1}$**):	147	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**$SF_{stat,1}$**):	1.61		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			**Notes**
Width Factor (**BF_1**):	1.23		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			**Notes**
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			**Notes**
Design Impact Pressure:	**91**	**kN/m^2**	
	1,901	**psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			**Notes**
Top Support Ropes:	150	ft	Reference No. 1 - Maximum top support ropes span for BV-11
Intermediate Support Ropes Section (1):	134	ft	Reference No. 1 - Intermediate support ropes section (1) span for BV-11
Intermediate Support Ropes Section (2):	116	ft	Reference No. 1 - Intermediate support ropes section (2) span for BV-11
Bottom Support Ropes:	98	ft	Reference No. 1 - Maximum bottom support ropes span for BV-11

Geobrugg ROCCO Ring Net Areas			**Notes**
Top Support Ring Net Section Area:	487	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	892	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	774	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	342	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			**Notes**
Geobrugg ROCCO Ring Net Total Area	2,495	sq.ft.	

Design Impact Pressure			**Notes**
Design Impact Pressure:	1,901	psf	Reference No. 5

Design Load - Top Section			**Notes**
Design Load Top Section:	**925,580**	**lbf**	
	926	**kips**	

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	**1,695,312**	**lbf**	
	1,695	**kips**	

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	**1,471,045**	**lbf**	
	1,471	**kips**	

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	**649,996**	**lbf**	
	650	**kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Support Wire Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			**Notes**
Design Load Top Section:	925,580	lbf	
	926	kips	
Top Support Ropes:	150	ft	Reference No. 1 - Maximum top support ropes span for BV-11

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	1,695,312	lbf	
	1,695	kips	
Intermediate Support Ropes Section (1):	134	ft	Reference No. 1 - Intermediate support ropes section (1) span for BV-11

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	1,471,045	lbf	
	1,471	kips	
Intermediate Support Ropes Section (2):	116	ft	Reference No. 1 - Intermediate support ropes section (2) span for BV-11

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	649,996	lbf	
	650	kips	
Bottom Support Ropes:	98	ft	Reference No. 1 - Maximum bottom support ropes span for BV-11

Wire Rope Anchorage Loading			**Notes**
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			**Notes**
Top Support Ropes - Design Load:	**6.17**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**12.65**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**12.68**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			**Notes**
Bottom Support Ropes - Design Load:	**6.63**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Anchorage Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths			**Notes**
Top Support Ropes:	150	ft	Reference No. 1 - Maximum top support ropes span for BV-11
Top Support Rope Sectional Length	75	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	37.5	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**661.1**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths			**Notes**
Intermediate Support Ropes:	134	ft	Reference No. 1 - Intermediate support ropes section (1) span for BV-11
Intermediate Support Rope Sectional Length:	67	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	33.5	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**678.1**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths			**Notes**
Intermediate Support Ropes:	116	ft	Reference No. 1 - Intermediate support ropes section (2) span for BV-11
Intermediate Support Rope Sectional Length:	58	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	29	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**612.9**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths			**Notes**
Bottom Support Ropes:	98	ft	Reference No. 1 - Maximum bottom support ropes span for BV-11
Bottom Support Rope Sectional Length	49	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	25	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**541.7**	**kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Anchorage Quantity

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Anchorage Loading*

INPUT

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**661.1**	**kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**678.1**	**kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**612.9**	**kips**	Reference No. 5

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**541.7**	**kips**	Reference No. 5

Allowable Anchorage Tensile Load			**Notes**
Allowable Anchorage Tensile Load:	80	kips	Reference No. 4

Output

Top Support Anchorage Quantity			**Notes**
Top Support Anchorage Quantity:	**9**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity			**Notes**
Intermediate Support Section 1 Anchorage Quantity:	**9**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity			**Notes**
Intermediate Support Section 2 Anchorage Quantity:	**8**	**Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity			**Notes**
Bottom Support Anchorage Quantity:	**7**	**Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for CS-18, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**$MD_{dyn,1}$**):	57	kN/m*h_{fl}	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**$RD_{dyn,1}$**):	121	kN/m*h_{fl}	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**$SF_{dyn,1}$**):	2.11		Reference No. 1
Calculated Flow Height (**h_{fl}**):	0.70	m	Reference No. 1
	2.30	ft	

Geobrugg DEBFLOW Static Loading (Overflowing)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for BV-1, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**$MD_{stat,1}$**):	59	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**$RD_{stat,1}$**):	164	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**$SF_{stat,1}$**):	2.77		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			**Notes**
Width Factor (**BF_1**):	1.10		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			**Notes**
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			**Notes**
Design Impact Pressure:	**59**	**kN/m^2**	
	1,232	**psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			**Notes**
Top Support Ropes:	81	ft	Reference No. 1 - Maximum top support ropes span for CS-18
Intermediate Support Ropes Section (1):	70	ft	Reference No. 1 - Intermediate support ropes section (1) span for CS-18
Intermediate Support Ropes Section (2):	60	ft	Reference No. 1 - Intermediate support ropes section (2) span for CS-18
Bottom Support Ropes:	47	ft	Reference No. 1 - Maximum bottom support ropes span for CS-18

Geobrugg ROCCO Ring Net Areas			**Notes**
Top Support Ring Net Section Area:	157	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	281	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	247	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	101	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			**Notes**
Geobrugg ROCCO Ring Net Total Area	786	sq.ft.	

Design Impact Pressure			**Notes**
Design Impact Pressure:	1,232	psf	Reference No. 5

Design Load - Top Section			**Notes**
Design Load Top Section:	**193,462** **193**	**lbf** **kips**	

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	**346,260** **346**	**lbf** **kips**	

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	**304,363** **304**	**lbf** **kips**	

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	**124,456** **124**	**lbf** **kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Support Wire Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			**Notes**
Design Load Top Section:	193,462	lbf	
	193	kips	
Top Support Ropes:	81	ft	Reference No. 1 - Maximum top support ropes span for CS-18

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	346,260	lbf	
	346	kips	
Intermediate Support Ropes Section (1):	70	ft	Reference No. 1 - Intermediate support ropes section (1) span for CS-18

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	304,363	lbf	
	304	kips	
Intermediate Support Ropes Section (2):	60	ft	Reference No. 1 - Intermediate support ropes section (2) span for CS-18

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	124,456	lbf	
	124	kips	
Bottom Support Ropes:	47	ft	Reference No. 1 - Maximum bottom support ropes span for CS-18

Wire Rope Anchorage Loading			**Notes**
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			**Notes**
Top Support Ropes - Design Load:	**2.39**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**4.95**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**5.07**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			**Notes**
Bottom Support Ropes - Design Load:	**2.65**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Anchorage Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths		**Notes**
Top Support Ropes:	81 ft	Reference No. 1 - Maximum top support ropes span for CS-18
Top Support Rope Sectional Length	41 ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	20.3 ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load		**Notes**
Total Top Support Tensile Load	**483.7 kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths		**Notes**
Intermediate Support Ropes:	70 ft	Reference No. 1 - Intermediate support ropes section (1) span for CS-18
Intermediate Support Rope Sectional Length:	35 ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	17.5 ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load		**Notes**
Total Intermediate Support Section 1 Tensile Load	**577.1 kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths		**Notes**
Intermediate Support Ropes:	60 ft	Reference No. 1 - Intermediate support ropes section (2) span for CS-18
Intermediate Support Rope Sectional Length:	30 ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	15 ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load		**Notes**
Total Intermediate Support Section 2 Tensile Load	**507.3 kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths		**Notes**
Bottom Support Ropes:	47 ft	Reference No. 1 - Maximum bottom support ropes span for CS-18
Bottom Support Rope Sectional Length	24 ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	12 ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load		**Notes**
Total Bottom Support Tensile Load	**414.9 kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Anchorage Quantity

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.*
	2	*Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.*
	3	*Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.*
	4	*Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*
	5	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Anchorage Loading*

INPUT

Top Support Tensile Load		Notes
Total Top Support Tensile Load	**483.7 kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load		Notes
Total Intermediate Support Section 1 Tensile Load	**577.1 kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load		Notes
Total Intermediate Support Section 2 Tensile Load	**507.3 kips**	Reference No. 5

Bottom Support Tensile Load		Notes
Total Bottom Support Tensile Load	**414.9 kips**	Reference No. 5

Allowable Anchorage Tensile Load		Notes
Allowable Anchorage Tensile Load:	80 kips	Reference No. 4

Output

Top Support Anchorage Quantity		Notes
Top Support Anchorage Quantity:	**7 Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity		Notes
Intermediate Support Section 1 Anchorage Quantity:	**8 Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity		Notes
Intermediate Support Section 2 Anchorage Quantity:	**6 Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity		Notes
Bottom Support Anchorage Quantity:	**6 Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for HS-6, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**$MD_{dyn,1}$**):	78	kN/m*h_{fl}	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**$RD_{dyn,1}$**):	124	kN/m*h_{fl}	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**$SF_{dyn,1}$**):	1.59		Reference No. 1
Calculated Flow Height (**h_{fl}**):	0.80 2.62	m ft	Reference No. 1

Geobrugg DEBFLOW Static Loading (Overflowing)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for HS-6, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**$MD_{stat,1}$**):	83	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**$RD_{stat,1}$**):	147	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**$SF_{stat,1}$**):	1.77		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			**Notes**
Width Factor (**BF_1**):	1.23		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			**Notes**
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			**Notes**
Design Impact Pressure:	**83** **1,733**	**kN/m^2** **psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			Notes
Top Support Ropes:	94	ft	Reference No. 1 - Maximum top support ropes span for HS-6
Intermediate Support Ropes Section (1):	81	ft	Reference No. 1 - Intermediate support ropes section (1) span for HS-6
Intermediate Support Ropes Section (2):	67	ft	Reference No. 1 - Intermediate support ropes section (2) span for HS-6
Bottom Support Ropes:	48	ft	Reference No. 1 - Maximum bottom support ropes span for HS-6

Geobrugg ROCCO Ring Net Areas			Notes
Top Support Ring Net Section Area:	258	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	458	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	377	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	150	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			Notes
Geobrugg ROCCO Ring Net Total Area	1,243	sq.ft.	

Design Impact Pressure			Notes
Design Impact Pressure:	1,733	psf	Reference No. 5

Design Load - Top Section			Notes
Design Load Top Section:	**447,241** **447**	**lbf** **kips**	

Design Load - Intermediate Section 1			Notes
Design Load Intermediate Section (1):	**793,939** **794**	**lbf** **kips**	

Design Load - Intermediate Section 2			Notes
Design Load Intermediate Section (2):	**653,526** **654**	**lbf** **kips**	

Design Load - Bottom Section			Notes
Design Load Bottom Section:	**260,024** **260**	**lbf** **kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Support Wire Rope Loading

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		October 3, 2018
Calculations By Inititals:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.*
	2	*Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.*
	3	*Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.*
	4	*Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*
	5	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			Notes
Design Load Top Section:	447,241	lbf	
	447	kips	
Top Support Ropes:	94	ft	Reference No. 1 - Maximum top support ropes span for HS-6

Design Load - Intermediate Section 1			Notes
Design Load Intermediate Section (1):	793,939	lbf	
	794	kips	
Intermediate Support Ropes Section (1):	81	ft	Reference No. 1 - Intermediate support ropes section (1) span for HS-6

Design Load - Intermediate Section 2			Notes
Design Load Intermediate Section (2):	653,526	lbf	
	654	kips	
Intermediate Support Ropes Section (2):	67	ft	Reference No. 1 - Intermediate support ropes section (2) span for HS-6

Design Load - Bottom Section			Notes
Design Load Bottom Section:	260,024	lbf	
	260	kips	
Bottom Support Ropes:	48	ft	Reference No. 1 - Maximum bottom support ropes span for HS-6

Wire Rope Anchorage Loading			Notes
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			Notes
Top Support Ropes - Design Load:	**4.76**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			Notes
Intermediate Section (1) Support Rope Design Load:	**9.80**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			Notes
Intermediate Section (1) Support Rope Design Load:	**9.75**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			Notes
Bottom Support Ropes - Design Load:	**5.42**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Anchorage Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths			**Notes**
Top Support Ropes:	94	ft	Reference No. 1 - Maximum top support ropes span for HS-6
Top Support Rope Sectional Length	47	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	23.5	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**559.1**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths			**Notes**
Intermediate Support Ropes:	81	ft	Reference No. 1 - Intermediate support ropes section (1) span for HS-6
Intermediate Support Rope Sectional Length:	41	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	20.3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**496.2**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths			**Notes**
Intermediate Support Ropes:	67	ft	Reference No. 1 - Intermediate support ropes section (2) span for HS-6
Intermediate Support Rope Sectional Length:	34	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	17	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**466.8**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths			**Notes**
Bottom Support Ropes:	48	ft	Reference No. 1 - Maximum bottom support ropes span for HS-6
Bottom Support Rope Sectional Length	24	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	12	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**433.4**	**kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Anchorage Quantity

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Anchorage Loading*

INPUT

Top Support Tensile Load			Notes
Total Top Support Tensile Load	**559.1**	**kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load			Notes
Total Intermediate Support Section 1 Tensile Load	**496.2**	**kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load			Notes
Total Intermediate Support Section 2 Tensile Load	**466.8**	**kips**	Reference No. 5

Bottom Support Tensile Load			Notes
Total Bottom Support Tensile Load	**433.4**	**kips**	Reference No. 5

Allowable Anchorage Tensile Load			Notes
Allowable Anchorage Tensile Load:	80	kips	Reference No. 4

Output

Top Support Anchorage Quantity			Notes
Top Support Anchorage Quantity:	**7**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity			Notes
Intermediate Support Section 1 Anchorage Quantity:	**7**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity			Notes
Intermediate Support Section 2 Anchorage Quantity:	**6**	**Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity			Notes
Bottom Support Anchorage Quantity:	**6**	**Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Romero Canyon RC-12 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			Notes
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for RC-12, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**MD**$_{dyn,1}$):	34	kN/m*h_{fl}	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**RD**$_{dyn,1}$):	113	kN/m*h_{fl}	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**SF**$_{dyn,1}$):	3.34		Reference No. 1
Calculated Flow Height (**h**$_{fl}$):	0.50 1.64	m ft	Reference No. 1

Geobrugg DEBFLOW Static Loading (Overflowing)			Notes
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for RC-12, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**MD**$_{stat,1}$):	55	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**RD**$_{stat,1}$):	210	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**SF**$_{stat,1}$):	3.81		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			Notes
Width Factor (**BF**$_1$):	0.86		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			Notes
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			Notes
Design Impact Pressure:	**55**	**kN/m^2**	
	1,149	**psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Romero Canyon RC-12 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			Notes
Top Support Ropes:	61	ft	Reference No. 1 - Maximum top support ropes span for RC-12
Intermediate Support Ropes Section (1):	52	ft	Reference No. 1 - Intermediate support ropes section (1) span for RC-12
Intermediate Support Ropes Section (2):	45	ft	Reference No. 1 - Intermediate support ropes section (2) span for RC-12
Bottom Support Ropes:	40	ft	Reference No. 1 - Maximum bottom support ropes span for RC-12

Geobrugg ROCCO Ring Net Areas			Notes
Top Support Ring Net Section Area:	118	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	210	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	182	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	82	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			Notes
Geobrugg ROCCO Ring Net Total Area	592	sq.ft.	

Design Impact Pressure			Notes
Design Impact Pressure:	1,149	psf	Reference No. 5

Design Load - Top Section			Notes
Design Load Top Section:	**135,546** **136**	**lbf** **kips**	

Design Load - Intermediate Section 1			Notes
Design Load Intermediate Section (1):	**241,227** **241**	**lbf** **kips**	

Design Load - Intermediate Section 2			Notes
Design Load Intermediate Section (2):	**209,063** **209**	**lbf** **kips**	

Design Load - Bottom Section			Notes
Design Load Bottom Section:	**94,193** **94**	**lbf** **kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Romero Canyon RC-12 - Support Wire Rope Loading

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		October 3, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.*
	2	*Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.*
	3	*Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.*
	4	*Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*
	5	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			**Notes**
Design Load Top Section:	135,546	lbf	
	136	kips	
Top Support Ropes:	61	ft	Reference No. 1 - Maximum top support ropes span for RC-12

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	241,227	lbf	
	241	kips	
Intermediate Support Ropes Section (1):	52	ft	Reference No. 1 - Intermediate support ropes section (1) span for RC-12

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	209,063	lbf	
	209	kips	
Intermediate Support Ropes Section (2):	45	ft	Reference No. 1 - Intermediate support ropes section (2) span for RC-12

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	94,193	lbf	
	94	kips	
Bottom Support Ropes:	40	ft	Reference No. 1 - Maximum bottom support ropes span for RC-12

Wire Rope Anchorage Loading			**Notes**
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			**Notes**
Top Support Ropes - Design Load:	**2.22**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**4.64**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**4.65**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			**Notes**
Bottom Support Ropes - Design Load:	**2.35**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Romero Canyon RC-12 - Anchorage Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths			**Notes**
Top Support Ropes:	61	ft	Reference No. 1 - Maximum top support ropes span for RC-12
Top Support Rope Sectional Length	31	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	15.3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**225.9**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths			**Notes**
Intermediate Support Ropes:	52	ft	Reference No. 1 - Intermediate support ropes section (1) span for RC-12
Intermediate Support Rope Sectional Length:	26	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	13.0	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**241.2**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths			**Notes**
Intermediate Support Ropes:	45	ft	Reference No. 1 - Intermediate support ropes section (2) span for RC-12
Intermediate Support Rope Sectional Length:	23	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	11	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**209.1**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths			**Notes**
Bottom Support Ropes:	40	ft	Reference No. 1 - Maximum bottom support ropes span for RC-12
Bottom Support Rope Sectional Length	20	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	10	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**157.0**	**kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 Romero Canyon RC-12 - Anchorage Quantity

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Anchorage Loading*

INPUT

Top Support Tensile Load			Notes
Total Top Support Tensile Load	**225.9**	**kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load			Notes
Total Intermediate Support Section 1 Tensile Load	**241.2**	**kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load			Notes
Total Intermediate Support Section 2 Tensile Load	**209.1**	**kips**	Reference No. 5

Bottom Support Tensile Load			Notes
Total Bottom Support Tensile Load	**157.0**	**kips**	Reference No. 5

Allowable Anchorage Tensile Load			Notes
Allowable Anchorage Tensile Load:	80	kips	Reference No. 4

Output

Top Support Anchorage Quantity			Notes
Top Support Anchorage Quantity:	**3**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity			Notes
Intermediate Support Section 1 Anchorage Quantity:	**4**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity			Notes
Intermediate Support Section 2 Anchorage Quantity:	**3**	**Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity			Notes
Bottom Support Anchorage Quantity:	**2**	**Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for SY-7, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**$MD_{dyn,1}$**):	97	kN/m*h_{fl}	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**$RD_{dyn,1}$**):	187	kN/m*h_{fl}	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**$SF_{dyn,1}$**):	1.93		Reference No. 1
Calculated Flow Height (**h_{fl}**):	1.00 3.28	m ft	Reference No. 1

Geobrugg DEBFLOW Static Loading (Overflowing)			**Notes**
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for SY-7, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**$MD_{stat,1}$**):	99	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**$RD_{stat,1}$**):	183	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**$SF_{stat,1}$**):	1.85		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			**Notes**
Width Factor (**BF_1**):	0.99		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			**Notes**
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			**Notes**
Design Impact Pressure:	**99** **2,068**	**kN/m^2** **psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			Notes
Top Support Ropes:	75	ft	Reference No. 1 - Maximum top support ropes span for SY-7
Intermediate Support Ropes Section (1):	65	ft	Reference No. 1 - Intermediate support ropes section (1) span for SY-7
Intermediate Support Ropes Section (2):	58	ft	Reference No. 1 - Intermediate support ropes section (2) span for SY-7
Bottom Support Ropes:	41	ft	Reference No. 1 - Maximum bottom support ropes span for SY-7

Geobrugg ROCCO Ring Net Areas			Notes
Top Support Ring Net Section Area:	242	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	436	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	379	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	151	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			Notes
Geobrugg ROCCO Ring Net Total Area	1,208	sq.ft.	

Design Impact Pressure			Notes
Design Impact Pressure:	2,068	psf	Reference No. 5

Design Load - Top Section			Notes
Design Load Top Section:	**500,373**	**lbf**	
	500	**kips**	

Design Load - Intermediate Section 1			Notes
Design Load Intermediate Section (1):	**901,499**	**lbf**	
	901	**kips**	

Design Load - Intermediate Section 2			Notes
Design Load Intermediate Section (2):	**783,642**	**lbf**	
	784	**kips**	

Design Load - Bottom Section			Notes
Design Load Bottom Section:	**312,216**	**lbf**	
	312	**kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Support Wire Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	October 3, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			**Notes**
Design Load Top Section:	500,373	lbf	
	500	kips	
Top Support Ropes:	75	ft	Reference No. 1 - Maximum top support ropes span for SY-7

Design Load - Intermediate Section 1			**Notes**
Design Load Intermediate Section (1):	901,499	lbf	
	901	kips	
Intermediate Support Ropes Section (1):	65	ft	Reference No. 1 - Intermediate support ropes section (1) span for SY-7

Design Load - Intermediate Section 2			**Notes**
Design Load Intermediate Section (2):	783,642	lbf	
	784	kips	
Intermediate Support Ropes Section (2):	58	ft	Reference No. 1 - Intermediate support ropes section (2) span for SY-7

Design Load - Bottom Section			**Notes**
Design Load Bottom Section:	312,216	lbf	
	312	kips	
Bottom Support Ropes:	41	ft	Reference No. 1 - Maximum bottom support ropes span for SY-7

Wire Rope Anchorage Loading			**Notes**
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			**Notes**
Top Support Ropes - Design Load:	**6.67**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**13.87**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			**Notes**
Intermediate Section (1) Support Rope Design Load:	**13.51**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			**Notes**
Bottom Support Ropes - Design Load:	**7.62**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Anchorage Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths			**Notes**
Top Support Ropes:	75	ft	Reference No. 1 - Maximum top support ropes span for SY-7
Top Support Rope Sectional Length	38	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	18.8	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**417.0**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths			**Notes**
Intermediate Support Ropes:	65	ft	Reference No. 1 - Intermediate support ropes section (1) span for SY-7
Intermediate Support Rope Sectional Length:	33	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	16.3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**450.7**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths			**Notes**
Intermediate Support Ropes:	58	ft	Reference No. 1 - Intermediate support ropes section (2) span for SY-7
Intermediate Support Rope Sectional Length:	29	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	15	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**391.8**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths			**Notes**
Bottom Support Ropes:	41	ft	Reference No. 1 - Maximum bottom support ropes span for SY-7
Bottom Support Rope Sectional Length	21	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	10	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**260.2**	**kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Anchorage Quantity

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Anchorage Loading*

INPUT

Top Support Tensile Load		Notes
Total Top Support Tensile Load	**417.0 kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load		Notes
Total Intermediate Support Section 1 Tensile Load	**450.7 kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load		Notes
Total Intermediate Support Section 2 Tensile Load	**391.8 kips**	Reference No. 5

Bottom Support Tensile Load		Notes
Total Bottom Support Tensile Load	**260.2 kips**	Reference No. 5

Allowable Anchorage Tensile Load		Notes
Allowable Anchorage Tensile Load:	80 kips	Reference No. 4

Output

Top Support Anchorage Quantity		Notes
Top Support Anchorage Quantity:	**6 Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity		Notes
Intermediate Support Section 1 Anchorage Quantity:	**6 Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity		Notes
Intermediate Support Section 2 Anchorage Quantity:	**5 Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity		Notes
Bottom Support Anchorage Quantity:	**4 Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Design Impact Pressure

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*

INPUT

Geobrugg DEBFLOW Dynamic Loading (Stopping)			Notes
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for SY-18, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Dynamic Loading Pressure (**$MD_{dyn,1}$**):	280	$kN/m*h_{fl}$	Reference No. 1 - Granular Load Case No. 2, Dynamic Loading (Pressure and Impulse)
Dynamic Loading Pressure Resistance (**$RD_{dyn,1}$**):	676	$kN/m*h_{fl}$	Reference No. 1 - Allowable Resistance for Dynamic Load Pressure
Factor of Safety (**$SF_{dyn,1}$**):	2.41		Reference No. 1
Calculated Flow Height (**h_{fl}**):	2.60 8.53	m ft	Reference No. 1

Geobrugg DEBFLOW Static Loading (Overflowing)			Notes
Governing Design Load Case:	Load Case 2		Reference No. 1 - Geobrugg DEBFLOW Analysis for SY-18, Granular Geologic Material Load Case Governs for highest impact pressure applied.
Static Loading Pressure (**$MD_{stat,1}$**):	112	kN/m^2	Reference No. 1 - Granular Load Case No. 2, Static Loading (Hydrostatic Pressure)
Static Loading Pressure Resistance (**$RD_{stat,1}$**):	264	kN/m^2	Reference No.1 - Allowable Resistance for Static Load Pressure, based on Ultimate Pressure Capacity and Width Factor
Factor of Safety (**$SF_{stat,1}$**):	2.35		Reference No. 1

Geobrugg DEBFLOW Static Loading Width Factor			Notes
Width Factor (**BF_1**):	0.68		Reference No. 1

OUTPUT

Ultimate Impact System Pressure Verification			Notes
Ultimate System Impact Pressure:	**180**	**kN/m^2**	Reference No. 2 & No. 3 - Largest Pressure Load Capacity for the Analyized System

Design Impact Pressure			Notes
Design Impact Pressure:	**280**	**kN/m^2**	
	5,848	**psf**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Impact Pressure Distribution

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Design Impact Pressure*

INPUT

Geobrugg Support Rope Lengths			Notes
Top Support Ropes:	67	ft	Reference No. 1 - Maximum top support ropes span for SY-18
Intermediate Support Ropes Section (1):	57	ft	Reference No. 1 - Intermediate support ropes section (1) span for SY-18
Intermediate Support Ropes Section (2):	47	ft	Reference No. 1 - Intermediate support ropes section (2) span for SY-18
Bottom Support Ropes:	13	ft	Reference No. 1 - Maximum bottom support ropes span for SY-18

Geobrugg ROCCO Ring Net Areas			Notes
Top Support Ring Net Section Area:	172	sq.ft	Tributary area between top and intermediate support section 1
Intermediate Support Ring Net Section (1) Area:	304	sq.ft	Tributary area between top and intermediate support section 2
Intermediate Support Ring Net Section (2) Area:	235	sq.ft	Tributary area between intermediate support sections 1 and 2
Bottom Section Area:	58	sq.ft	Tributary area between bottom and intermediate support section 2

OUTPUT

Geobrugg ROCCO Ring Net Total Area			Notes
Geobrugg ROCCO Ring Net Total Area	769	sq.ft.	

Design Impact Pressure			Notes
Design Impact Pressure:	5,848	psf	Reference No. 5

Design Load - Top Section			Notes
Design Load Top Section:	**1,005,843**	**lbf**	
	1,006	**kips**	

Design Load - Intermediate Section 1			Notes
Design Load Intermediate Section (1):	**1,777,768**	**lbf**	
	1,778	**kips**	

Design Load - Intermediate Section 2			Notes
Design Load Intermediate Section (2):	**1,374,262**	**lbf**	
	1,374	**kips**	

Design Load - Bottom Section			Notes
Design Load Bottom Section:	**339,179**	**lbf**	
	339	**kips**	

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Support Wire Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.* 2 *Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.* 3 *Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.* 4 *Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.* 5 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Impact Pressure Distribution*

INPUT

Design Load - Top Section			Notes
Design Load Top Section:	1,005,843	lbf	
	1,006	kips	
Top Support Ropes:	67	ft	Reference No. 1 - Maximum top support ropes span for SY-18

Design Load - Intermediate Section 1			Notes
Design Load Intermediate Section (1):	1,777,768	lbf	
	1,778	kips	
Intermediate Support Ropes Section (1):	57	ft	Reference No. 1 - Intermediate support ropes section (1) span for SY-18

Design Load - Intermediate Section 2			Notes
Design Load Intermediate Section (2):	1,374,262	lbf	
	1,374	kips	
Intermediate Support Ropes Section (2):	47	ft	Reference No. 1 - Intermediate support ropes section (2) span for SY-18

Design Load - Bottom Section			Notes
Design Load Bottom Section:	339,179	lbf	
	339	kips	
Bottom Support Ropes:	13	ft	Reference No. 1 - Maximum bottom support ropes span for SY-18

Wire Rope Anchorage Loading			Notes
Wire Rope Anchorage Loading	80,000	lbf	Reference No. 4
	80	kips	

OUTPUT

Top Support Ropes - Design Load			Notes
Top Support Ropes - Design Load:	**15.01**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 1 - Design Load			Notes
Intermediate Section (1) Support Rope Design Load:	**31.19**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Intermediate Support Section 2 - Design Load			Notes
Intermediate Section (1) Support Rope Design Load:	**29.24**	**kips/ft**	Distributed Loading Along Length of Support Ropes

Bottom Support Ropes - Design Load			Notes
Bottom Support Ropes - Design Load:	**26.09**	**kips/ft**	Distributed Loading Along Length of Support Ropes

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Anchorage Loading

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.*
	2	*Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.*
	3	*Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.*
	4	*Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*
	5	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Support Wire Rope Loading*

OUTPUT

Top Support Section Lengths			**Notes**
Top Support Ropes:	67	ft	Reference No. 1 - Maximum top support ropes span for SY-18
Top Support Rope Sectional Length	34	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	16.8	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**314.3**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 1 Lengths			**Notes**
Intermediate Support Ropes:	57	ft	Reference No. 1 - Intermediate support ropes section (1) span for SY-18
Intermediate Support Rope Sectional Length:	29	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	14.3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 1 Tensile Load			**Notes**
Total Intermediate Support Section 1 Tensile Load	**444.4**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Intermediate Support Section 2 Lengths			**Notes**
Intermediate Support Ropes:	47	ft	Reference No. 1 - Intermediate support ropes section (2) span for SY-18
Intermediate Support Rope Sectional Length:	24	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	12	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Intermediate Support Section 2 Tensile Load			**Notes**
Total Intermediate Support Section 2 Tensile Load	**343.6**	**kips**	Total Tensile Load Applied to Each Anchorage Side

Bottom Support Section Lengths			**Notes**
Bottom Support Ropes:	13	ft	Reference No. 1 - Maximum bottom support ropes span for SY-18
Bottom Support Rope Sectional Length	7	ft	For FBD Half Distance
Free Body Diagram Moment Break Length:	3	ft	For FBD Half Distance for centerline location of load distribution for moment calculation

Bottom Support Tensile Load			**Notes**
Total Bottom Support Tensile Load	**169.6**	**kips**	Total Tensile Load Applied to Each Anchorage Side

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Montecito Debris Flow Mitigation - Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Anchorage Quantity

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Inititals:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.*
	2	*Geobrugg AG (2004). VX/UX Protection Systems Against Debris Flows Design Concept. June 2004.*
	3	*Geobrugg AG (2018). Geobrugg DEBFLOW Debris Flow Protection Software Manual. 2018 02-19.*
	4	*Geobrugg AG (2016). Geobrugg VX/UX Debris Flow Nets Product Manual. 2016 11-07. Edition 164-N-FO / 05.*
	5	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Anchorage Loading*

INPUT

Top Support Tensile Load			Notes
Total Top Support Tensile Load	**314.3**	**kips**	Reference No. 5

Intermediate Support Section 1 Tensile Load			Notes
Total Intermediate Support Section 1 Tensile Load	**444.4**	**kips**	Reference No. 5

Intermediate Support Section 2 Tensile Load			Notes
Total Intermediate Support Section 2 Tensile Load	**343.6**	**kips**	Reference No. 5

Bottom Support Tensile Load			Notes
Total Bottom Support Tensile Load	**169.6**	**kips**	Reference No. 5

Allowable Anchorage Tensile Load			Notes
Allowable Anchorage Tensile Load:	80	kips	Reference No. 4

Output

Top Support Anchorage Quantity			Notes
Top Support Anchorage Quantity:	**4**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 1 Anchorage Quantity			Notes
Intermediate Support Section 1 Anchorage Quantity:	**6**	**Quantity**	Quanitity of Anchorage Required per Side

Intermediate Support 2 Anchorage Quantity			Notes
Intermediate Support Section 2 Anchorage Quantity:	**4**	**Quantity**	Quanitity of Anchorage Required per Side

Bottom Support Anchorage Quantity			Notes
Bottom Support Anchorage Quantity:	**3**	**Quantity**	Quanitity of Anchorage Required per Side

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-2 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-2. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	41	ft	Reference No. 1 - Maximum top support rope span for BV-2

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	41	ft	Reference No. 1 - Maximum top support rope span for BV-2
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	287	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	670	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	4.0	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**44.0**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-2 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-2. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-2 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	41	ft	Reference No. 1 - Maximum top support rope span for BV-2

Total Design Weight			Notes
Total Design Weight:	44.0	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			Notes
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			Notes
Top Support Rope Sectional Length	21	ft	
Free Body Diagram Moment Break Length:	10.3	ft	

Design Top Support Weight			Notes
Design Top Support Weight:	902	lbf	For FBD Half Distance

Total Top Support Tensile Load			Notes
Total Top Support Tensile Load	**9,249**	**lbf**	Total Tensile Load

Top Support Tensile Load			Notes
Top Support Tensile Load:	**2,312** **1.2**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-2 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-2. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-2 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT			
Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)
Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	41 492	ft in	Reference No. 1 - Maximum top support rope span for BV-2
Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	2.3	kips	Reference No. 6

OUTPUT			
Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.13**	**in**	$(\Delta L) = (F*L_o) / (A_o* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX Buena Vista Canyon BV-4 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	6	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			**Notes**
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			**Notes**
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	77	ft	Reference No. 2 - Maximum top support rope span for BV-4

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Length of Section:	77	ft	Reference No. 2 - Maximum top support rope span for BV-4
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			**Notes**
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Ring Net Top Section Area:	539	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			**Notes**
Ring Net Total Top Section Weight:	1,259	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			**Notes**
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			**Notes**
Wire Rope Weight:	8.5	lb/ft	

Geobrugg Miscellaneous Material Weight			**Notes**
Geobrugg Miscellaneous Material Weight:	4.3	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			**Notes**
Total Design Weight:	**47.1**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX Buena Vista Canyon BV-4 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Buena Vista Canyon BV-4 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length		Notes
Top Support Rope Length:	77 ft	Reference No. 2 - Maximum top support rope span for BV-4

Total Design Weight		Notes
Total Design Weight:	47.1 lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement		Notes
Allowable Top Support Rope Sag Displacement:	1.5 ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length		Notes
Top Support Rope Sectional Length	39 ft	
Free Body Diagram Moment Break Length:	19.3 ft	

Design Top Support Weight		Notes
Design Top Support Weight:	1,814 lbf	For FBD Half Distance

Total Top Support Tensile Load		Notes
Total Top Support Tensile Load	**23,282 lbf**	Total Tensile Load

Top Support Tensile Load		Notes
Top Support Tensile Load:	**5,820 lbf** **2.9 tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX Buena Vista Canyon BV-4 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-4. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-4 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Buena Vista Canyon BV-4 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	77 924	ft in	Reference No. 1 - Maximum top support rope span for BV-4

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	5.8	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.64**	**in**	(ΔL) = ($F*L_o$) / (A_o* E) Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-5 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-5. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	37	ft	Reference No. 1 - Maximum top support rope span for BV-5

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	37	ft	Reference No. 1 - Maximum top support rope span for BV-5
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	259	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	605	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	4.0	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**44.0**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-5 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-5. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-5 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	37	ft	Reference No. 1 - Maximum top support rope span for BV-5

Total Design Weight			**Notes**
Total Design Weight:	44.0	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			**Notes**
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			**Notes**
Top Support Rope Sectional Length	19	ft	
Free Body Diagram Moment Break Length:	9.3	ft	

Design Top Support Weight			**Notes**
Design Top Support Weight:	814	lbf	For FBD Half Distance

Total Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**7,533**	**lbf**	Total Tensile Load

Top Support Tensile Load			**Notes**
Top Support Tensile Load:	**1,883** **0.9**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-5 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-5. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-5 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

- E is the Young's modulus (modulus of elasticity)
- F is the force exerted on an object under tension;
- A_0 is the original cross-sectional area through which the force is applied;
- ΔL is the amount by which the length of the object changes;
- L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	37 444	ft in	Reference No. 1 - Maximum top support rope span for BV-5

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	1.9	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.10**	**in**	$(\Delta L) = (F^*L_o) / (A_o^* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-6 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-6. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8 0.875	in in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254 88.7	kg lbf	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
Abrasion Section Length:	1,500 5	mm ft	Reference No. 4 - Length of a single abrasion component

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	44	ft	Reference No. 1 - Maximum top support rope span for BV-6

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	44	ft	Reference No. 1 - Maximum top support rope span for BV-6
Height of Section:	6.5	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	286	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	668	lbf	
Ring Net Top Section Weight:	15	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	3.9	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**42.7**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-6 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-6. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-6 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	44	ft	Reference No. 1 - Maximum top support rope span for BV-6

Total Design Weight			**Notes**
Total Design Weight:	42.7	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			**Notes**
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			**Notes**
Top Support Rope Sectional Length	22	ft	
Free Body Diagram Moment Break Length:	11.0	ft	

Design Top Support Weight			**Notes**
Design Top Support Weight:	940	lbf	For FBD Half Distance

Total Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**10,342**	**lbf**	Total Tensile Load

Top Support Tensile Load			**Notes**
Top Support Tensile Load:	**2,585** **1.3**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-6 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-6. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-6 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			Notes
Original Top Support Rope Length (**L_o**):	44 528	ft in	Reference No. 1 - Maximum top support rope span for BV-6

Design Tensile Catenary Load			Notes
Design Tensile Catenary Load (**F**):	2.6	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			Notes
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.16**	**in**	$(\Delta L) = (F^*L_o) / (A_o{}^* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-7 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-7. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	50	ft	Reference No. 1 - Maximum top support rope span for BV-7

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	50	ft	Reference No. 1 - Maximum top support rope span for BV-7
Height of Section:	6.5	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	325	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	759	lbf	
Ring Net Top Section Weight:	15	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	3.9	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**42.7**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-7 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK

References:

1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-7. 2018 09-28.*
2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.*
3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.*
4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.*
5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-7 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	50	ft	Reference No. 1 - Maximum top support rope span for BV-7

Total Design Weight			**Notes**
Total Design Weight:	42.7	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			**Notes**
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			**Notes**
Top Support Rope Sectional Length	25	ft	
Free Body Diagram Moment Break Length:	12.5	ft	

Design Top Support Weight			**Notes**
Design Top Support Weight:	1,068	lbf	For FBD Half Distance

Total Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**13,355**	**lbf**	Total Tensile Load

Top Support Tensile Load			**Notes**
Top Support Tensile Load:	**3,339** **1.7**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-7 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-7. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-7 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	50 600	ft in	Reference No. 1 - Maximum top support rope span for BV-7

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	3.3	kips	Reference No. 6

OUTPUT

Wire Rope Deformation		**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.24 in**	$(\Delta L) = (F*L_o) / (A_o * E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-10 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-10. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			**Notes**
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			**Notes**
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	56	ft	Reference No. 1 - Maximum top support rope span for BV-10

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Length of Section:	56	ft	Reference No. 1 - Maximum top support rope span for BV-10
Height of Section:	6.5	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			**Notes**
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Ring Net Top Section Area:	364	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			**Notes**
Ring Net Total Top Section Weight:	850	lbf	
Ring Net Top Section Weight:	15	lb/ft	

Geobrugg Abrasion Weight			**Notes**
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			**Notes**
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			**Notes**
Geobrugg Miscellaneous Material Weight:	3.9	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			**Notes**
Total Design Weight:	**42.7**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-10 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK

References:

1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-10. 2018 09-28.*
2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.*
3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.*
4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.*
5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-10 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	56	ft	Reference No. 1 - Maximum top support rope span for BV-10

Total Design Weight			Notes
Total Design Weight:	42.7	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			Notes
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			Notes
Top Support Rope Sectional Length	28	ft	
Free Body Diagram Moment Break Length:	14.0	ft	

Design Top Support Weight			Notes
Design Top Support Weight:	1,197	lbf	For FBD Half Distance

Total Top Support Tensile Load			Notes
Total Top Support Tensile Load	**16,752**	**lbf**	Total Tensile Load

Top Support Tensile Load			Notes
Top Support Tensile Load:	**4,188**	**lbf**	Tensile Load per Top Support Rope
	2.1	**tons**	

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Montecito Debris Flow Mitigation - Geobrugg VX Buena Vista Canyon BV-10 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-10. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Buena Vista Canyon BV-10 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			Notes
Original Top Support Rope Length (**L_o**):	56 672	ft in	Reference No. 1 - Maximum top support rope span for BV-10

Design Tensile Catenary Load			Notes
Design Tensile Catenary Load (**F**):	4.2	kips	Reference No. 6

OUTPUT

Wire Rope Deformation		Notes
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.33 in**	$(\Delta L) = (F^*L_o) / (A_o^* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX Buena Vista Canyon BV-11 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	7	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			**Notes**
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			**Notes**
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	150	ft	Reference No. 2 - Maximum top support rope span for BV-11

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Length of Section:	150	ft	Reference No. 2 - Maximum top support rope span for BV-11
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			**Notes**
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Ring Net Top Section Area:	1,050	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			**Notes**
Ring Net Total Top Section Weight:	2,452	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			**Notes**
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			**Notes**
Wire Rope Weight:	9.9	lb/ft	

Geobrugg Miscellaneous Material Weight			**Notes**
Geobrugg Miscellaneous Material Weight:	4.4	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			**Notes**
Total Design Weight:	**48.7**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX Buena Vista Canyon BV-11 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Buena Vista Canyon BV-11 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	150	ft	Reference No. 2 - Maximum top support rope span for BV-11

Total Design Weight			Notes
Total Design Weight:	48.7	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			Notes
Allowable Top Support Rope Sag Displacement:	3.0	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			Notes
Top Support Rope Sectional Length	75	ft	
Free Body Diagram Moment Break Length:	37.5	ft	

Design Top Support Weight			Notes
Design Top Support Weight:	3,650	lbf	For FBD Half Distance

Total Top Support Tensile Load			Notes
Total Top Support Tensile Load	**45,630**	**lbf**	Total Tensile Load

Top Support Tensile Load			Notes
Top Support Tensile Load:	**11,407** **5.7**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX Buena Vista Canyon BV-11 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Buena Vista Canyon BV-11. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Buena Vista Canyon BV-11 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Buena Vista Canyon BV-11 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	150 1,800	ft in	Reference No. 1 - Maximum top support rope span for BV-11

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	11.4	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**2.43**	**in**	$(\Delta L) = (F*L_o) / (A_o* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Cold Spring Canyon CS-11 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-11. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8 0.875	in in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140 31.5	kN kips	Reference No. 3 Reference No. 3
Ring Net Weight:	11.4 2.33	kg/m^2 psf	Reference No. 3 Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254 88.7	kg lbf	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
Abrasion Section Length:	1,500 5	mm ft	Reference No. 4 - Length of a single abrasion component

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	60	ft	Reference No. 1 - Maximum top support rope span for CS-11

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	60	ft	Reference No. 1 - Maximum top support rope span for CS-11
Height of Section:	6.5	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	390	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	911	lbf	
Ring Net Top Section Weight:	15	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	3.9	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**42.7**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Cold Spring Canyon CS-11 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-11. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Cold Spring Canyon CS-11 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	60	ft	Reference No. 1 - Maximum top support rope span for CS-11

Total Design Weight			**Notes**
Total Design Weight:	42.7	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			**Notes**
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			**Notes**
Top Support Rope Sectional Length	30	ft	
Free Body Diagram Moment Break Length:	15.0	ft	

Design Top Support Weight			**Notes**
Design Top Support Weight:	1,282	lbf	For FBD Half Distance

Total Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**19,231**	**lbf**	Total Tensile Load

Top Support Tensile Load			**Notes**
Top Support Tensile Load:	**4,808** **2.4**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Cold Spring Canyon CS-11 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-11. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Cold Spring Canyon CS-11 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	60 720	ft in	Reference No. 1 - Maximum top support rope span for CS-11

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	4.8	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.41**	**in**	$(\Delta L) = (F*L_o) / (A_o* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX Cold Spring Canyon CS-18 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	5	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	81	ft	Reference No. 2 - Maximum top support rope span for CS-18

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	81	ft	Reference No. 2 - Maximum top support rope span for CS-18
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	567	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	1,324	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	7.1	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	4.1	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**45.6**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX Cold Spring Canyon CS-18 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Cold Spring Canyon CS-18 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length		Notes
Top Support Rope Length:	81 ft	Reference No. 2 - Maximum top support rope span for CS-18

Total Design Weight		Notes
Total Design Weight:	45.6 lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement		Notes
Allowable Top Support Rope Sag Displacement:	1.5 ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length		Notes
Top Support Rope Sectional Length	41 ft	
Free Body Diagram Moment Break Length:	20.3 ft	

Design Top Support Weight		Notes
Design Top Support Weight:	1,846 lbf	For FBD Half Distance

Total Top Support Tensile Load		Notes
Total Top Support Tensile Load	**24,915 lbf**	Total Tensile Load

Top Support Tensile Load		Notes
Top Support Tensile Load:	**6,229 lbf** **3.1 tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX Cold Spring Canyon CS-18 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Cold Spring Canyon CS-18. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Cold Spring Canyon CS-18 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Cold Spring Canyon CS-18 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			Notes
Original Top Support Rope Length (**L_o**):	81 972	ft in	Reference No. 1 - Maximum top support rope span for CS-18

Design Tensile Catenary Load			Notes
Design Tensile Catenary Load (**F**):	6.2	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			Notes
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.72**	**in**	$(\Delta L) = (F*L_o) / (A_o* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX Hot Springs Canyon HS-6 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	6	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			**Notes**
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			**Notes**
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	94	ft	Reference No. 2 - Maximum top support rope span for HS-6

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Length of Section:	94	ft	Reference No. 2 - Maximum top support rope span for HS-6
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			**Notes**
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Ring Net Top Section Area:	658	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			**Notes**
Ring Net Total Top Section Weight:	1,536	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			**Notes**
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			**Notes**
Wire Rope Weight:	8.5	lb/ft	

Geobrugg Miscellaneous Material Weight			**Notes**
Geobrugg Miscellaneous Material Weight:	4.3	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			**Notes**
Total Design Weight:	**47.1**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX Hot Springs Canyon HS-6 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Hot Springs Canyon HS-6 - Top Support Rope Loading Calculation*

INPUT		
Geobrugg Top Support Rope Length		**Notes**
Top Support Rope Length:	94 ft	Reference No. 2 - Maximum top support rope span for HS-6
Total Design Weight		**Notes**
Total Design Weight:	47.1 lb/ft	Reference No. 6
Allowable Top Support Rope Sag Displacement		**Notes**
Allowable Top Support Rope Sag Displacement:	2.0 ft	

OUTPUT		
Geobrugg Top Support Rope Sectional Length		**Notes**
Top Support Rope Sectional Length	47 ft	
Free Body Diagram Moment Break Length:	23.5 ft	
Design Top Support Weight		**Notes**
Design Top Support Weight:	2,215 lbf	For FBD Half Distance
Total Top Support Tensile Load		**Notes**
Total Top Support Tensile Load	**26,023 lbf**	Total Tensile Load
Top Support Tensile Load		**Notes**
Top Support Tensile Load:	**6,506 lbf** **3.3 tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX Hot Springs Canyon HS-6 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-6. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Hot Springs Canyon HS-6 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Hot Springs Canyon HS-6 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

- E is the Young's modulus (modulus of elasticity)
- F is the force exerted on an object under tension;
- A_0 is the original cross-sectional area through which the force is applied;
- ΔL is the amount by which the length of the object changes;
- L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	94 1,128	ft in	Reference No. 1 - Maximum top support rope span for HS-6

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	6.5	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (Δ**L**):	**0.87**	**in**	$(\Delta L) = (F*L_o) / (A_o* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Hot Springs Canyon HS-7 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon BV-7. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	49	ft	Reference No. 1 - Maximum top support rope span for HS-7

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	49	ft	Reference No. 1 - Maximum top support rope span for HS-7
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	343	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	801	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	4.0	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**44.0**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Hot Springs Canyon HS-7 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-7. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Hot Springs Canyon HS-7 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	49	ft	Reference No. 1 - Maximum top support rope span for HS-7

Total Design Weight			**Notes**
Total Design Weight:	44.0	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			**Notes**
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			**Notes**
Top Support Rope Sectional Length	25	ft	
Free Body Diagram Moment Break Length:	12.3	ft	

Design Top Support Weight			**Notes**
Design Top Support Weight:	1,078	lbf	For FBD Half Distance

Total Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**13,211**	**lbf**	Total Tensile Load

Top Support Tensile Load			**Notes**
Top Support Tensile Load:	**3,303** **1.7**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Hot Springs Canyon HS-7 - Top Support Rope Deformation

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Hot Springs Canyon HS-7. 2018 09-28.*
	2	*Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.*
	3	*Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.*
	4	*Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.*
	5	*Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
	6	*KANE GeoTech, Inc. (2018). Geobrugg VX Hot Springs Canyon HS-7 - Top Support Rope Catenary*
	7	*NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT			
Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)
Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	49 588	ft in	Reference No. 1 - Maximum top support rope span for HS-7
Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	3.3	kips	Reference No. 6
OUTPUT			
Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.23**	**in**	(ΔL) = (F*L_o) / (A_o* E) Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX San Ysidro Canyon SY-7 - Top Support Rope Loading

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.*
	2	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Design and Anchorage Quantity*
	3	*Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.*
	4	*Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.*
	5	*Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	6	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	75	ft	Reference No. 2 - Maximum top support rope span for SY-7

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	75	ft	Reference No. 2 - Maximum top support rope span for SY-7
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	525	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	1,226	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	8.5	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	4.3	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**47.1**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX San Ysidro Canyon SY-7 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX San Ysidro Canyon SY-7 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	75	ft	Reference No. 2 - Maximum top support rope span for SY-7

Total Design Weight			**Notes**
Total Design Weight:	47.1	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			**Notes**
Allowable Top Support Rope Sag Displacement:	1.5	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			**Notes**
Top Support Rope Sectional Length	38	ft	
Free Body Diagram Moment Break Length:	18.8	ft	

Design Top Support Weight			**Notes**
Design Top Support Weight:	1,767	lbf	For FBD Half Distance

Total Top Support Tensile Load			**Notes**
Total Top Support Tensile Load	**22,088**	**lbf**	Total Tensile Load

Top Support Tensile Load			**Notes**
Top Support Tensile Load:	**5,522** **2.8**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX San Ysidro Canyon SY-7 - Top Support Rope Deformation

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-7. 2018 09-28.*
	2	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-7 - Design and Anchorage Quantity*
	3	*Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.*
	4	*Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.*
	5	*Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
	6	*KANE GeoTech, Inc. (2018). Geobrugg SVX San Ysidro Canyon SY-7 - Top Support Rope Catenary*
	7	*NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	75 900	ft in	Reference No. 1 - Maximum top support rope span for SY-7

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	5.5	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.59**	**in**	$(\Delta L) = (F*L_o) / (A_o * E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX San Ysidro Canyon SY-18 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	6	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			**Notes**
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			**Notes**
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	67	ft	Reference No. 2 - Maximum top support rope span for SY-18

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Length of Section:	67	ft	Reference No. 2 - Maximum top support rope span for SY-18
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			**Notes**
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Ring Net Top Section Area:	469	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			**Notes**
Ring Net Total Top Section Weight:	1,095	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			**Notes**
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			**Notes**
Wire Rope Weight:	8.5	lb/ft	

Geobrugg Miscellaneous Material Weight			**Notes**
Geobrugg Miscellaneous Material Weight:	4.3	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			**Notes**
Total Design Weight:	**47.1**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX San Ysidro Canyon SY-18 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX San Ysidro Canyon SY-18 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length		Notes
Top Support Rope Length:	67 ft	Reference No. 2 - Maximum top support rope span for SY-18

Total Design Weight		Notes
Total Design Weight:	47.1 lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement		Notes
Allowable Top Support Rope Sag Displacement:	1.5 ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length		Notes
Top Support Rope Sectional Length	34 ft	
Free Body Diagram Moment Break Length:	16.8 ft	

Design Top Support Weight		Notes
Design Top Support Weight:	1,579 lbf	For FBD Half Distance

Total Top Support Tensile Load		Notes
Total Top Support Tensile Load	**17,627 lbf**	Total Tensile Load

Top Support Tensile Load		Notes
Top Support Tensile Load:	**4,407 lbf** **2.2 tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX San Ysidro Canyon SY-18 - Top Support Rope Deformation

KGT Project Name:		Montecito Debris Flow Mitigation
KGT Project No:		KGT18-18
Date:		September 28, 2018
Calculations By Initials:		JAM
Checked Initials:		WFK
References:	1	*KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, San Ysidro Canyon SY-18. 2018 09-28.*
	2	*KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 San Ysidro Canyon SY-18 - Design and Anchorage Quantity*
	3	*Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.*
	4	*Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.*
	5	*Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
	6	*KANE GeoTech, Inc. (2018). Geobrugg SVX San Ysidro Canyon SY-18 - Top Support Rope Catenary*
	7	*NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	67 804	ft in	Reference No. 1 - Maximum top support rope span for SY-18

Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	4.4	kips	Reference No. 6

OUTPUT

Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.42**	**in**	$(\Delta L) = (F^*L_o) / (A_o^* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg SVX Romero Canyon RC-12 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	5	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			**Notes**
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			**Notes**
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			**Notes**
Top Support Rope Length:	61	ft	Reference No. 2 - Maximum top support rope span for RC-12

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Length of Section:	61	ft	Reference No. 2 - Maximum top support rope span for RC-12
Height of Section:	7.0	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			**Notes**
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			**Notes**
Ring Net Top Section Area:	427	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			**Notes**
Ring Net Total Top Section Weight:	997	lbf	
Ring Net Top Section Weight:	16	lb/ft	

Geobrugg Abrasion Weight			**Notes**
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			**Notes**
Wire Rope Weight:	7.1	lb/ft	

Geobrugg Miscellaneous Material Weight			**Notes**
Geobrugg Miscellaneous Material Weight:	4.1	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			**Notes**
Total Design Weight:	**45.6**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg SVX Romero Canyon RC-12 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Romero Canyon RC-12 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length		Notes
Top Support Rope Length:	61 ft	Reference No. 2 - Maximum top support rope span for RC-12

Total Design Weight		Notes
Total Design Weight:	45.6 lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement		Notes
Allowable Top Support Rope Sag Displacement:	1.0 ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length		Notes
Top Support Rope Sectional Length	31 ft	
Free Body Diagram Moment Break Length:	15.3 ft	

Design Top Support Weight		Notes
Design Top Support Weight:	1,390 lbf	For FBD Half Distance

Total Top Support Tensile Load		Notes
Total Top Support Tensile Load	**21,196 lbf**	Total Tensile Load

Top Support Tensile Load		Notes
Top Support Tensile Load:	**5,299 lbf** **2.6 tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg SVX Romero Canyon RC-12 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-12. 2018 09-28.* 2 *KANE GeoTech, Inc. (2018). Geobrugg SVX180-H6 Romero Canyon RC-12 - Design and Anchorage Quantity* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg SVX Romero Canyon RC-12 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{F L_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT			
Geobrugg Top Support Rope - Properties			**Notes**
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)
Geobrugg Top Support Rope Length			**Notes**
Original Top Support Rope Length (**L_o**):	61 732	ft in	Reference No. 1 - Maximum top support rope span for RC-12
Design Tensile Catenary Load			**Notes**
Design Tensile Catenary Load (**F**):	5.3	kips	Reference No. 6
OUTPUT			
Wire Rope Deformation			**Notes**
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.46**	**in**	$(\Delta L) = (F*L_o) / (A_o* E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Romero Canyon RC-15 - Top Support Rope Loading

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-15. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	7/8	in	Reference No. 2 - 22mm (7/8-in) size diameter single leg wire rope.
	0.875	in	
Wire Rope Minimum Breaking Strength:	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Wire Rope Weight:	1.41	lb/ft	Reference No. 5
Top Support Ropes:	4	Quantity	Reference No. 2. Top Support Rope Quantity

Geobrugg ROCCO Ring Net - Properties			Notes
Ring Net Type:	16/3/300		Reference No. 3
Ring Diameter:	300	mm	Reference No. 3
Ring Windings:	16	Quantity	Reference No. 3
Wire Bundle Diameter:	15	mm	Reference No. 3
Ring Load Capacity:	140	kN	Reference No. 3
	31.5	kips	Reference No. 3
Ring Net Weight:	11.4	kg/m^2	Reference No. 3
	2.33	psf	Reference No. 3

Geobrugg Abrasion Protection - Properties			Notes
Abrasion Section Weight:	40.254	kg	Reference No. 4 - Includes all additional steel componets manufactured with the abrasion.
	88.7	lbf	
Abrasion Section Length:	1,500	mm	Reference No. 4 - Length of a single abrasion component
	5	ft	

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	50	ft	Reference No. 1 - Maximum top support rope span for RC-15

Geobrugg ROCCO Ring Net Top Section Area			Notes
Length of Section:	50	ft	Reference No. 1 - Maximum top support rope span for RC-15
Height of Section:	6.5	ft	Reference No. 2 - Maximum vertical height spacing for a VX support rope span

Miscellaneous Material Weight Increase			Notes
Miscellaneous Material Weight Increase:	10.0	%	Additional weight approximation for attached wire rope clips, brake rings, and shackles

OUTPUT

Geobrugg ROCCO Ring Net Top Section Area			Notes
Ring Net Top Section Area:	325	sq.ft.	Top ROCCO Ring Net sectional area.

Geobrugg ROCCO Ring Net Top Section Weight			Notes
Ring Net Total Top Section Weight:	759	lbf	
Ring Net Top Section Weight:	15	lb/ft	

Geobrugg Abrasion Weight			Notes
Abrasion Weight:	18.0	lb/ft	

Geobrugg Top Support Rope Weight			Notes
Wire Rope Weight:	5.6	lb/ft	

Geobrugg Miscellaneous Material Weight			Notes
Geobrugg Miscellaneous Material Weight:	3.9	lb/ft	10% of Ring Net, Top Support Ropes, and Abrasion Weight

Total Design Weight			Notes
Total Design Weight:	**42.7**	**lb/ft**	

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Montecito Debris Flow Mitigation - Geobrugg VX Romero Canyon RC-15 - Top Support Rope Catenary

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-15. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Romero Canyon RC-15 - Top Support Rope Loading Calculation*

INPUT

Geobrugg Top Support Rope Length			Notes
Top Support Rope Length:	50	ft	Reference No. 1 - Maximum top support rope span for RC-15

Total Design Weight			Notes
Total Design Weight:	42.7	lb/ft	Reference No. 6

Allowable Top Support Rope Sag Displacement			Notes
Allowable Top Support Rope Sag Displacement:	1	ft	

OUTPUT

Geobrugg Top Support Rope Sectional Length			Notes
Top Support Rope Sectional Length	25	ft	
Free Body Diagram Moment Break Length:	12.5	ft	

Design Top Support Weight			Notes
Design Top Support Weight:	1,068	lbf	For FBD Half Distance

Total Top Support Tensile Load			Notes
Total Top Support Tensile Load	**13,355**	**lbf**	Total Tensile Load

Top Support Tensile Load			Notes
Top Support Tensile Load:	**3,339** **1.7**	**lbf** **tons**	Tensile Load per Top Support Rope

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Montecito Debris Flow Mitigation - Geobrugg VX Romero Canyon RC-15 - Top Support Rope Deformation

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK
References:	1 *KANE GeoTech, Inc. (2018). Geobrugg DEBFLOW Analysis, Romero Canyon RC-15. 2018 09-28.* 2 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.* 3 *Geobrugg AG (2017). Technical Data Sheet ROCCO 16/3/300. ROCCO 300_TechData_100305_e.* 4 *Geobrugg AG (2015). Debris Flow Protection System VX Abrasion Drawing No. GA-8055. 2015 08-20.* 5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.* 6 *KANE GeoTech, Inc. (2018). Geobrugg VX Romero Canyon RC-15 - Top Support Rope Catenary* 7 *NCEES (2013). Fundamental Engineering, Reference Handbook. 9.4 Edition.*

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

where

E is the Young's modulus (modulus of elasticity)

F is the force exerted on an object under tension;

A_0 is the original cross-sectional area through which the force is applied;

ΔL is the amount by which the length of the object changes;

L_0 is the original length of the object.

INPUT

Geobrugg Top Support Rope - Properties			Notes
Wire Rope Type:	Steel Strand	Galvanized	Reference No. 2
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter (**d**):	7/8 0.875	in	Reference No. 5
Wire Rope Cross-Sectional Area (**A_o**):	0.29	in^2	Approximately 38% of the wire rope diameter
Wire Rope Minimum Breaking Strength (**f_{ult}**):	79.61	kips	Reference No. 5 - US 7/8-in diameter single leg wire rope minimum breaking strength: 79.61-kips (354.14-kN).
Steel Elastic Modulus (**E**):	29,000	ksi	Reference No. 7 - ASTM A36 Steel E = 29-mpsi (29,000,000-psi)

Geobrugg Top Support Rope Length			Notes
Original Top Support Rope Length (**L_o**):	50 600	ft in	Reference No. 1 - Maximum top support rope span for RC-15

Design Tensile Catenary Load			Notes
Design Tensile Catenary Load (**F**):	3.3	kips	Reference No. 6

OUTPUT

Wire Rope Deformation		Notes
Theoretical Top Support Rope Deformation Length (**ΔL**):	**0.24 in**	$(\Delta L) = (F*L_o) / (A_o * E)$ Reference No. 7 - pg. 78

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Montecito Debris Flow Mitigation - Geobrugg VX Debris Catchment Net - Wire Rope Anchorage - Shale Conditions

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK

References:

1. *U.S. Department of Transporation Federal Highway Administration (FHWA) (1999). Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems. Publication No. FHWA-IF-99-015. June 1999.*
2. *U.S. Department of Transporation Federal Highway Administration (FHWA) (2015). Geotechnical Engineering Circular No. 7, Soil Nail Walls Reference Manual. Publication No. FHWA-NHI-14-007. FHWA GEC 007. February 2015.*
3. *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.*
4. *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.*
5. *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
6. *United States Department of Agriculture (USDA) (2018). Web Soil Survey, Soils Map and Engineering Properties Data. Santa Barbara County, California. South Coastal. Los Padres National Forest Area.*
7. *Post-Tensioning Institute (PTI) (2014). PTI DC35.1-14 Recommendations for Prestressed Rock and Soil Anchors.*

PTI Anchor Bond Length Equation Section 6.7

$$L_b = \frac{P \cdot FS}{\pi \cdot d \cdot \tau_u}$$

where:

- L_b = bond length
- P = design load for the anchor
- π = 3.14
- d = diameter of the drill hole
- τ_u = average ultimate bond strength along interface between grout and ground
- FS = factor of safety on average ultimate bond strength (refer to Section 6.6)

Table C6.1 Typical Average Ultimate Bond Strengths - Rock / Grout

Rock Type	Average Ultimate Bond Strength - Rock / Grout	
	MPa	*psi*
Granite and Basalt	1.7 - 3.1	250 - 450
Dolomite Limestone	1.4 - 2.1	200 - 300
Soft Limestone	1.0 - 1.4	150 - 200
Slates and Hard Shales	0.8 - 1.4	120 - 200
Soft Shales	0.2 - 0.8	30 - 120
Sandstones	0.8 - 1.7	120 - 250
Weathered Sandstones	0.7 - 0.8	100 - 120
Chalk	0.2 - 1.1	30 - 155
Weathered Marl	0.15 - 0.25	25 - 35
Concrete	1.4 - 2.8	200 - 400

Assumptions			**Notes**
Bedrock Design Type:	Shale		Reference No. 6 - USDA, Bedrock Shale
Bedrock Quality:	Weathered		Reference No. 6 - USDA, Weathered Surficial Bedrock Geologic Material

INPUT

Anchor and Wire Rope - Parameters			**Notes**
Grout/Ground Bond Strength (τ_u):	80	psi	Reference No. 5 - pg. 47 Section 6.7.1 Table C6.1. Reference No. 2 - FHWA GEC 007, Table 4.5
Anchor Type:	Wire Rope	Galvanized	Reference No. 3 & No. 4
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	1 1/8 1.125	in in	Reference No. 3 & 4 - S.A. 22.5-mm (7/8-in) size diameter. Single leg 7/8-in wire rope strength not sufficient for testing increase. Using 1-1/8-in wire rope single leg.
Wire Rope Minimum Breaking Strength:	130.02	kips	Reference No. 5 - US 1-1/8-in diameter single leg wire rope minimum breaking strength: 130.02-kips (578.37-kN).
Drill Hole Diameter (**d**):	6	in	Anchor drill hole diameter
Drill Hole Grout Cover:	0.5	in	Reference No. 7 - pg. 50 Section 6.9.2, 0.5-in min. grout cover around anchor
Drill Hole Overdrill Depth:	3	in	Reference No. 7 - pg. 50 Section 6.9.3, minimum overdrill depth
Anchor Unbonded Depth:	3	ft	Reference No. 6 - USDA, Weathered Surficial Bedrock Geologic Material. Assumption 3-ft surficial bedrock weathering and breakout cone.
Wire Rope Length Above Side Slope Surface:	1	ft	Above side slope surface / between top of grout column and ferrule / last wire rope clip
Maximum Anchor Test Increase:	33%		Reference No. 7 - pg. 77 Section C8.3.2 - Performance Testing 133% of Design Load
Factor of Safety (**FS**):	2.0		Reference No. 7 - pg. 45 Section C6.6 permanent anchors FOS: 2.0 minimum
Tensile Anchor Load (**P**):	**80.0**	**kips**	Reference No. 3 & 4 - Tensile load applied to wire rope anchor: 80-kips (350-kN)

OUTPUT

Anchor - Depth			**Notes**
Anchor Bonded Length (L_b):	**9**	ft	Reference No. 7 - pg. 45 Section 6.7 anchor depth into competent bedrock
Anchor Unbonded Length:	3	ft	Reference No. 6 - USDA, Weathered Surficial Bedrock Geologic Material. Assumption 3-ft surficial bedrock weathering and breakout cone.
Anchor Embedment Depth:	**12**	**ft**	Anchor embedment depth into subsurface geologic material
Anchor Drill Hole Depth:	**12.25**	**ft**	Anchor drill hole depth into subsurface geologic material
Estimated Wire Rope Anchor Length:	**13.00**	**ft**	Wire rope anchor length above slope surface and anchor embedment
Allowable Anchor Pullout Resistance:	**9.0**	**kips/ft**	Allowable Anchor Pullout Resistance. Includes PTI FOS. Resistance < Reference No. 1 FHWA GEC No. 4 Table 8 Presumptive ultimate pullout resistance value into bedrock.

Anchor - Theoretical Design Load			**Notes**
Anchor Theoretical Design Load:	**160.0**	**kips**	Anchor Theoretical Design Load (Includes Calculated Tensile Force and FOS)

Anchor - Maximum Test Load			**Notes**
Maximum Anchor Test Load:	**106.4**	**kips**	Maximum anchor testing load (Includes Calculated Tensile Force and PTI maximum load increase)

Anchor - Loading Verification			**Notes**
Max. Anchor Test Load < Anchor Design Load:	**OK**		Maximum Anchor Test Load < Anchor Theoretical Design Load

Sacrifical Anchor - Wire Rope Strength Verification			**Notes**
Allowable Wire Rope Strength:	117	kips	90% of wire rope minimum breaking strength
Max. Anchor Test Load < Allowable Wire Rope Breaking Strength:	**OK**		Maximum Anchor Test Load < Anchor Testing Allowable Wire Rope Breaking Strength

Production Anchor - Wire Rope Strength Verification			**Notes**
Allowable Wire Rope Strength:	104	kips	80% of wire rope minimum breaking strength
Tensile Anchor Load < Allowable Wire Rope Breaking Strength:	**OK**		Tensile Anchor Load < Production Anchor Allowable Wire Rope Breaking Strength

Anchor - Drill Hole Verification			**Notes**
Calculated Drill Hole Diameter (**d**):	3.25	in	Calculated Drill Hole Diameter < Minimum Selected Drill Hole Diameter
Drill Hole Diameter Verification:	**OK**		

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Montecito Debris Flow Mitigation - Geobrugg VX Debris Catchment Net - Wire Rope Anchorage - Sandstone Conditions

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Inititals:	JAM
Checked Initials:	WFK

References:

1 *U.S. Department of Transporation Federal Highway Administration (FHWA) (1999). Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems. Publication No. FHWA-IF-99-015. June 1999.*
2 *U.S. Department of Transporation Federal Highway Administration (FHWA) (2015). Geotechnical Engineering Circular No. 7, Soil Nail Walls Reference Manual. Publication No. FHWA-NHI-14-007. FHWA GEC 007. February 2015.*
3 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.*
4 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.*
5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
6 *United States Department of Agriculture (USDA) (2018). Web Soil Survey, Soils Map and Engineering Properties Data. Santa Barbara County, California. South Coastal. Los Padres National Forest Area.*
7 *Post-Tensioning Institute (PTI) (2014). PTI DC35.1-14 Recommendations for Prestressed Rock and Soil Anchors.*

PTI Anchor Bond Length Equation Section 6.7

$$L_b = \frac{P \cdot FS}{\pi \cdot d \cdot \tau_u}$$

where:

- L_b = bond length
- P = design load for the anchor
- π = 3.14
- d = diameter of the drill hole
- τ_u = average ultimate bond strength along interface between grout and ground
- FS = factor of safety on average ultimate bond strength (refer to Section 6.6)

Table C6.1 Typical Average Ultimate Bond Strengths - Rock / Grout

Rock Type	Average Ultimate Bond Strength - Rock / Grout	
	MPa	*psi*
Granite and Basalt	1.7 - 3.1	250 - 450
Dolomite Limestone	1.4 - 2.1	200 - 300
Soft Limestone	1.0 - 1.4	150 - 200
Slates and Hard Shales	0.8 - 1.4	120 - 200
Soft Shales	0.2 - 0.8	30 - 120
Sandstones	0.8 - 1.7	120 - 250
Weathered Sandstones	0.7 - 0.8	100 - 120
Chalk	0.2 - 1.1	30 - 155
Weathered Marl	0.15 - 0.25	25 - 35
Concrete	1.4 - 2.8	200 - 400

Assumptions		Notes
Bedrock Design Type:	Sandstone	Reference No. 6 - USDA, Bedrock Sandstone
Bedrock Quality:	Weathered	Reference No. 6 - USDA, Weathered Surficial Bedrock Geologic Material

INPUT

Anchor and Wire Rope - Parameters	Value	Unit	Notes
Grout/Ground Bond Strength (**τ_u**):	100	psi	Reference No. 5 - pg. 47 Section 6.7.1 Table C6.1. Reference No. 2 - FHWA GEC 007, Table 4.5
Anchor Type:	Wire Rope	Galvanized	Reference No. 3 & No. 4
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	1 1/8 1.125	in in	Reference No. 3 & 4 - S.A. 22.5-mm (7/8-in) size diameter. Single leg 7/8-in wire rope strength not sufficient for testing increase. Using 1-1/8-in wire rope single leg.
Wire Rope Minimum Breaking Strength:	130.02	kips	Reference No. 5 - US 1-1/8-in diameter single leg wire rope minimum breaking strength: 130.02-kips (578.37-kN).
Drill Hole Diameter (**d**):	6	in	Anchor drill hole diameter
Drill Hole Grout Cover:	0.5	in	Reference No. 7 - pg. 50 Section 6.9.2, 0.5-in min. grout cover around anchor
Drill Hole Overdrill Depth:	3	in	Reference No. 7 - pg. 50 Section 6.9.3, minimum overdrill depth
Anchor Unbonded Depth:	3	ft	Reference No. 6 - USDA, Weathered Surficial Bedrock Geologic Material. Assumption 3-ft surficial bedrock weathering and breakout cone.
Wire Rope Length Above Side Slope Surface:	1	ft	Above side slope surface / between top of grout column and ferrule / last wire rope clip
Maximum Anchor Test Increase:	33%		Reference No. 7 - pg. 77 Section C8.3.2 - Performance Testing 133% of Design Load
Factor of Safety (**FS**):	2.0		Reference No. 7 - pg. 45 Section C6.6 permanent anchors FOS: 2.0 minimum
Tensile Anchor Load (**P**):	**80.0**	**kips**	Reference No. 3 & 4 - Tensile load applied to wire rope anchor: 80-kips (350-kN)

OUTPUT

Anchor - Depth	Value	Unit	Notes
Anchor Bonded Length (**L_b**):	**8**	ft	Reference No. 7 - pg. 45 Section 6.7 anchor depth into competent bedrock
Anchor Unbonded Length:	3	ft	Reference No. 6 - USDA, Weathered Surficial Bedrock Geologic Material. Assumption 3-ft surficial bedrock weathering and breakout cone.
Anchor Embedment Depth:	**11**	**ft**	Anchor embedment depth into subsurface geologic material
Anchor Drill Hole Depth:	**11.25**	**ft**	Anchor drill hole depth into subsurface geologic material
Estimated Wire Rope Anchor Length:	**12.00**	**ft**	Wire rope anchor length above slope surface and anchor embedment
Allowable Anchor Pullout Resistance:	**11.3**	**kips/ft**	Allowable Anchor Pullout Resistance. Includes PTI FOS. Resistance < Reference No. 1 FHWA GEC No. 4 Table 8 Presumptive ultimate pullout resistance value into bedrock.

Anchor - Theoretical Design Load	Value	Unit	Notes
Anchor Theoretical Design Load:	**160.0**	**kips**	Anchor Theoretical Design Load (Includes Calculated Tensile Force and FOS)

Anchor - Maximum Test Load	Value	Unit	Notes
Maximum Anchor Test Load:	**106.4**	**kips**	Maximum anchor testing load (Includes Calculated Tensile Force and PTI maximum load increase)

Anchor - Loading Verification	Value	Notes
Max. Anchor Test Load < Anchor Design Load:	**OK**	Maximum Anchor Test Load < Anchor Theoretical Design Load

Sacrifical Anchor - Wire Rope Strength Verification	Value	Unit	Notes
Allowable Wire Rope Strength:	117	kips	90% of wire rope minimum breaking strength
Max. Anchor Test Load < Allowable Wire Rope Breaking Strength:	**OK**		Maximum Anchor Test Load < Anchor Testing Allowable Wire Rope Breaking Strength

Production Anchor - Wire Rope Strength Verification	Value	Unit	Notes
Allowable Wire Rope Strength:	104	kips	80% of wire rope minimum breaking strength
Tensile Anchor Load < Allowable Wire Rope Breaking Strength:	**OK**		Tensile Anchor Load < Production Anchor Allowable Wire Rope Breaking Strength

Anchor - Drill Hole Verification	Value	Unit	Notes
Calculated Drill Hole Diameter (**d**):	3.25	in	Calculated Drill Hole Diameter < Minimum Selected Drill Hole Diameter
Drill Hole Diameter Verification:	**OK**		

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Montecito Debris Flow Mitigation - Geobrugg VX Debris Catchment Net - Wire Rope Anchorage - Soil Conditions

KGT Project Name:	Montecito Debris Flow Mitigation
KGT Project No:	KGT18-18
Date:	September 28, 2018
Calculations By Initials:	JAM
Checked Initials:	WFK

References:
1 *U.S. Department of Transporation Federal Highway Administration (FHWA) (1999). Geotechnical Engineering Circular No. 4, Ground Anchors and Anchored Systems. Publication No. FHWA-IF-99-015. June 1999.*
2 *U.S. Department of Transporation Federal Highway Administration (FHWA) (2015). Geotechnical Engineering Circular No. 7, Soil Nail Walls Reference Manual. Publication No. FHWA-NHI-14-007. FHWA GEC 007. February 2015.*
3 *Geobrugg AG (2017). Debris Flow Protection System VX140-H4 Type. Drawing No. GD-1002.1e. 2017 07-12.*
4 *Geobrugg AG (2017). Debris Flow Protection System VX160-H6 Type. Drawing No. GD-1004.1e. 2017 07-12.*
5 *Geobrugg North America (2017). Wire Rope Technical Data Sheet.*
6 *United States Department of Agriculture (USDA) (2018). Web Soil Survey, Soils Map and Engineering Properties Data. Santa Barbara County, California. South Coastal. Los Padres National Forest Area.*
7 *Post-Tensioning Institute (PTI) (2014). PTI DC35.1-14 Recommendations for Prestressed Rock and Soil Anchors.*

PTI Anchor Bond Length Equation Section 6.7

$$L_b = \frac{P \cdot FS}{\pi \cdot d \cdot \tau_u}$$

where:
- L_b = bond length
- P = design load for the anchor
- π = 3.14
- d = diameter of the drill hole
- τ_u = average ultimate bond strength along interface between grout and ground
- FS = factor of safety on average ultimate bond strength (refer to Section 6.6)

PTI Table C6.3 Typical Average Ultimate Bond Strengths: Non-Cohesive Soils

Anchor Type	Average Ultimate Bond Strength Soil / Grout	
	MPa	*psi*
Gravity Grouted Anchors (Straight Shaft)	0.07 - 0.14	10 - 20
Pressure Grouted Anchors (Straight Shaft)		
Fine-Med. Sand, Med. Dense - Dense	0.08 - 0.38	12 - 55
Med. - Coarse Sand (w/ gravel), Med. Dense	0.11 - 0.66	16 - 95
Med. - Coarse Sand (w/ gravel), Dense - Very Dense	0.25 - 0.97	35 - 140
Silty Sands	0.17 - 0.41	25 - 60
Dense Glacial Till	0.30 - 0.52	43 - 75
Sandy Gravel, Medium Dense - Dense	0.21 - 1.38	31 - 200
Sandy Gravel, Dense - Very Dense	0.28 - 1.38	40 - 200

Assumptions			**Notes**
Soil Design Type:	Colluvium		Reference No. 6 - USDA Soils Map, Sandy Loam Soil with fines and cobbles.

INPUT

Anchor and Wire Rope - Parameters			**Notes**
Grout/Ground Bond Strength (**τ_u**):	20	psi	Reference No. 7 - pg. 49 Section 6.7.2 Table C6.3. Reference No. 2 - FHWA GEC No. 7, Table 4.4a.
Anchor Type:	Wire Rope	Galvanized	Reference No. 3 & No. 4
Wire Rope Classification:	6x19	Construction	Reference No. 5
Wire Rope Strand Type:	Seale		Reference No. 5
Wire Rope Core Type:	IWRC	EIPS	Reference No. 5
Wire Rope Diameter:	1 1/8 1.125	in in	Reference No. 3 & 4 - S.A. 22.5-mm (7/8-in) size diameter. Single leg 7/8-in wire rope strength not sufficient for testing increase. Using 1-1/8-in wire rope single leg.
Wire Rope Minimum Breaking Strength:	130.02	kips	Reference No. 5 - US 1-1/8-in diameter single leg wire rope minimum breaking strength: 130.02-kips (578.37-kN).
Drill Hole Diameter (**d**):	6	in	Anchor drill hole diameter
Drill Hole Grout Cover:	0.5	in	Reference No. 7 - pg. 50 Section 6.9.2, 0.5-in min. grout cover around anchor
Drill Hole Overdrill Depth:	3	in	Reference No. 7 - pg. 50 Section 6.9.3, minimum overdrill depth
Anchor Unbonded Depth:	5	ft	Depth for anchor locations in potential erosion channel side slopes
Wire Rope Length Above Side Slope Surface:	1	ft	Above side slope surface / between top of grout column and ferrule / last wire rope clip
Maximum Anchor Test Increase:	33%		Reference No. 7 - pg. 77 Section C8.3.2 - Performance Testing 133% of Design Load
Factor of Safety (**FS**):	2.0		Reference No. 7 - pg. 45 Section C6.6 permanent anchors FOS: 2.0 minimum
Tensile Anchor Load (**P**):	**80.0**	**kips**	Reference No. 3 & 4 - Tensile load applied to wire rope anchor: 80-kips (350-kN)

OUTPUT

Anchor - Depth			**Notes**
Anchor Bonded Length (**L_b**):	**36**	ft	Reference No. 7 - pg. 45 Section 6.7 anchor depth into colluvial subsurface material
Anchor Unbonded Length:	5	ft	Depth for anchor locations in potential erosion channel side slopes
Anchor Embedment Depth:	**41**	**ft**	Anchor embedment depth into colluvial subsurface material
Anchor Drill Hole Depth:	**41.25**	**ft**	Anchor drill hole depth into colluvial subsurface material
Estimated Wire Rope Anchor Length:	**42.00**	**ft**	Estimated wire rope anchor length: Includes anchor embedment and above ground surface between last wire rope clip or pressed ferrule
Allowable Anchor Pullout Resistance:	**2.3**	**kips/ft**	Allowable Anchor Pullout Resistance. Includes PTI FOS. Resistance < Reference No. 1 FHWA GEC No. 4 Table 6 presumptive ultimate pullout resistance for gravity grouted anchors in soil.

Anchor - Theoretical Design Load			**Notes**
Anchor Theoretical Design Load:	**160.0**	**kips**	Anchor Theoretical Design Load (Includes Calculated Tensile Force and FOS)

Anchor - Maximum Test Load			**Notes**
Maximum Anchor Test Load:	**106.4**	**kips**	Maximum anchor testing load (Includes Calculated Tensile Force and PTI maximum load increase)

Anchor - Loading Verification			**Notes**
Max. Anchor Test Load < Anchor Design Load:	**OK**		Maximum Anchor Test Load < Anchor Theoretical Design Load

Sacrifical Anchor - Wire Rope Strength Verification			**Notes**
Allowable Wire Rope Strength:	117	kips	90% of wire rope minimum breaking strength
Max. Anchor Test Load < Allowable Wire Rope Breaking Strength:	**OK**		Maximum Anchor Test Load < Anchor Testing Allowable Wire Rope Breaking Strength

Production Anchor - Wire Rope Strength Verification			**Notes**
Allowable Wire Rope Strength:	104	kips	80% of wire rope minimum breaking strength
Tensile Anchor Load < Allowable Wire Rope Breaking Strength:	**OK**		Tensile Anchor Load < Production Anchor Allowable Wire Rope Breaking Strength

Anchor - Drill Hole Verification			**Notes**
Calculated Drill Hole Diameter (**d**):	3.25	in	Calculated Drill Hole Diameter < Minimum Selected Drill Hole Diameter
Drill Hole Diameter Verification:	**OK**		