

HYBRID ROCKFALL SYSTEMS

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- Flexible barrier systems are now widely used throughout the world. Typical flexible systems include barrier type fences and systems draped on slopes. As development and testing of these systems has advanced so to has their use broadened. Barrier systems are now being modified to fit into difficult topography. Historically drainages, chutes, and swales generating rockfalls have been difficult to mitigate. Either construction is very expensive due to difficult access, or typical system designs are not suitable, or land use is restricted. To conquer these challenges flexible systems are being modified to fit into the terrain. The most widely used application is to span the topography creating a curtain into which rocks fall then directing the rocks to a suitable catchment area at grade.

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- Confidence in such systems is developed by understanding the essential aspect of flexible systems- flexibility. By increasing the time it takes an object to stop there is an decrease on the total force on the systems. Hybrid system construction is much more flexible than the fence and draped systems. That said one can deduce that these hybrid systems have at least equal if not greater capacity but no formal testing has been done to evaluate their capacity. However, in-place systems abound and are being impacted and evaluated.

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- The California Department of Transportation (Caltrans) has installed a number of hybrid systems which are currently being evaluated. In some cases some of the systems have been in use for over 15 years. Discussion of these systems and an empirical assessment of capacity is presented. Caltrans experience has found that these systems have greater capacity than equivalent dimensioned barriers and draperies due to their flexibility. But they are not the panacea for all rockfall as there are maintenance, environmental and rock containment issues that need to be addressed. Hybrid systems, however, are being successfully utilized and are being incorporated into yet another design measure for mitigating rockfall.

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- Confusion Hill 2000
- Feather River Canyon June 2001
- The Narrows 2004
- Lower 18 2004
- Gaviota October 2004
- San Bernardino 330 March 2006
- Trinity 299 April 2007

Confusion Hill 2000

Hybrid Barrier Systems Confusion Hill May 2002

Rockfall mitigation installed in 2000 within an active southern chute.



Hybrid Barrier Systems Confusion Hill May 2002

Rockfall mitigation installed in 2000 within an active southern chute.



Hybrid Barrier Systems

Confusion Hill

May 2022



Hybrid Barrier Systems

Confusion Hill

December 2002



Hybrid Barrier Systems

Confusion Hill

June 2003



Hybrid Barrier Systems

Confusion Hill

September 03



Hybrid Barrier Systems

Confusion Hill

May 2005



Hybrid Barrier Systems

Confusion Hill

May 2005



Hybrid Barrier Systems Confusion Hill May 2005



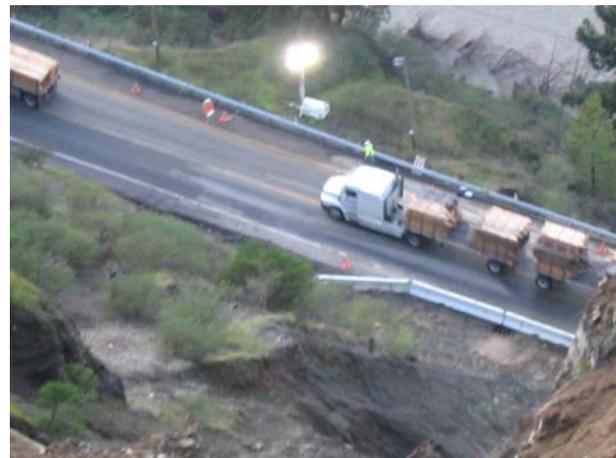
Hybrid Barrier Systems Confusion Hill May 2005



Hybrid Barrier Systems Confusion Hill May 2005



Hybrid Barrier Systems Confusion Hill January 2006



Hybrid Barrier Systems

Confusion Hill

January 2006



Hybrid Barrier Systems

Confusion Hill

February 2006



Hybrid Barrier Systems
Confusion Hill
Specifications From Micro Station
Need to Scan Drawings

Feather River Canyon

June 2001

Feather River Canyon Hybrid Drapery System June 2001



Feather River Canyon Hybrid Drapery System June 2001



Feather River Canyon Hybrid Drapery System June 2001



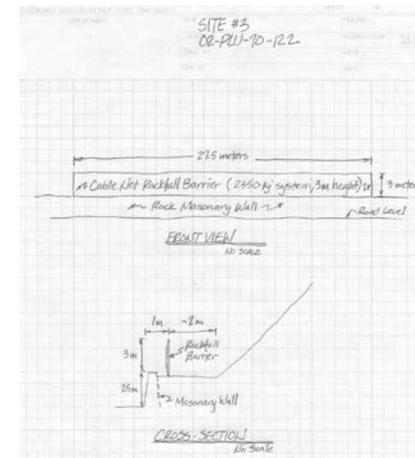
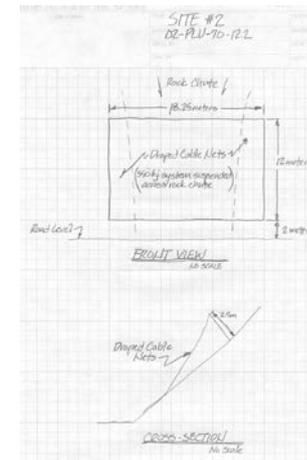
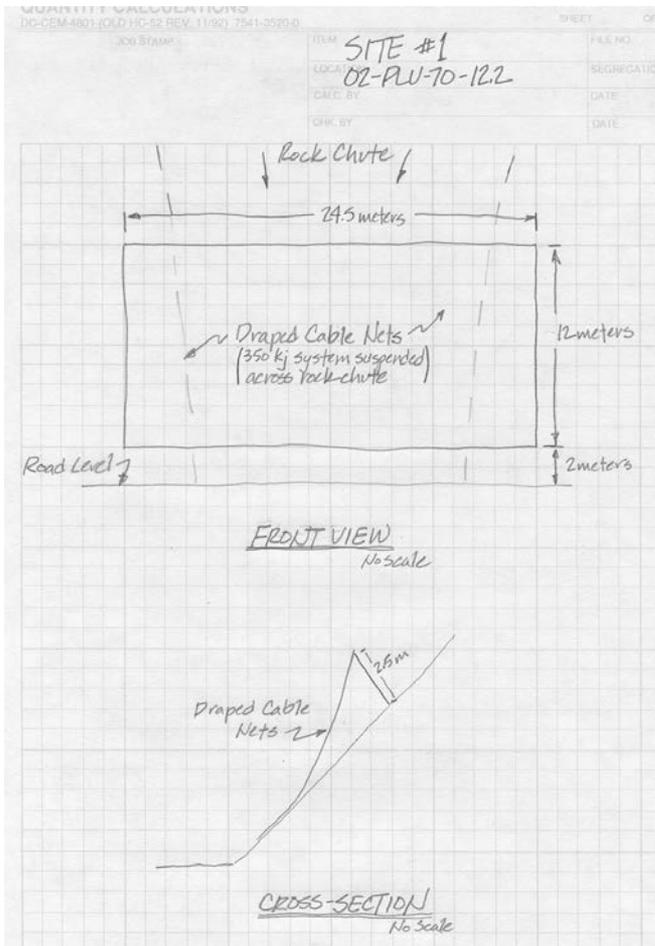
Feather River Canyon Hybrid Drapery System March 2004



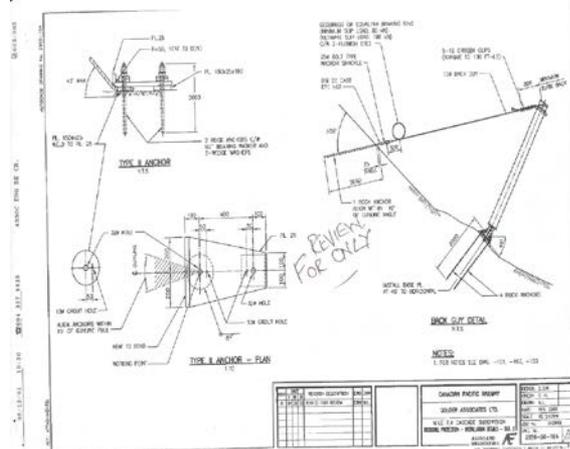
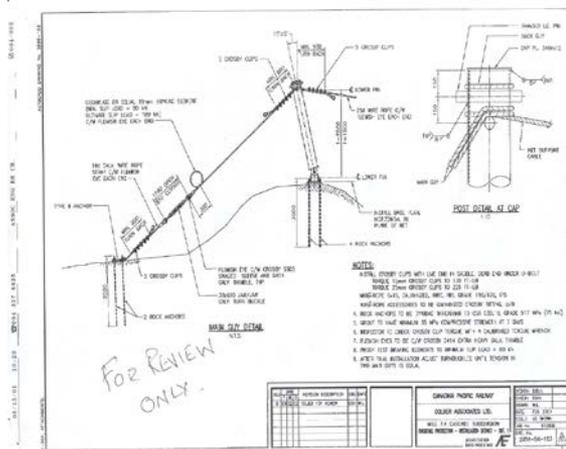
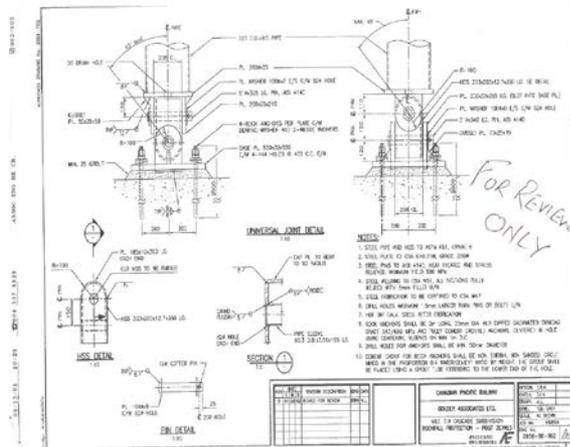
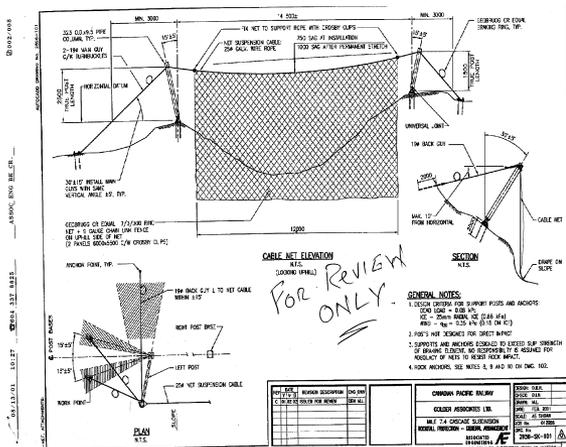
Feather River Canyon Hybrid Drapery System March 2004



Feather River Canyon Hybrid Drapery System March 2004



Feather River Canyon Hybrid Drapery System Sample Specs from BC March 2004



The Narrows 2004

Emergency Opening Wildfires in San Bernardino County The Narrows – Curtains



Emergency Opening Wildfires in San Bernardino County The Narrows – Curtains



Emergency Opening Wildfires in San Bernardino County The Narrows – Curtains



Emergency Opening Wildfires in San Bernardino County The Narrows – Curtains



Emergency Opening Wildfires in San Bernardino County The Narrows – Curtains



Lower 18
2004

The Lower 18 2004



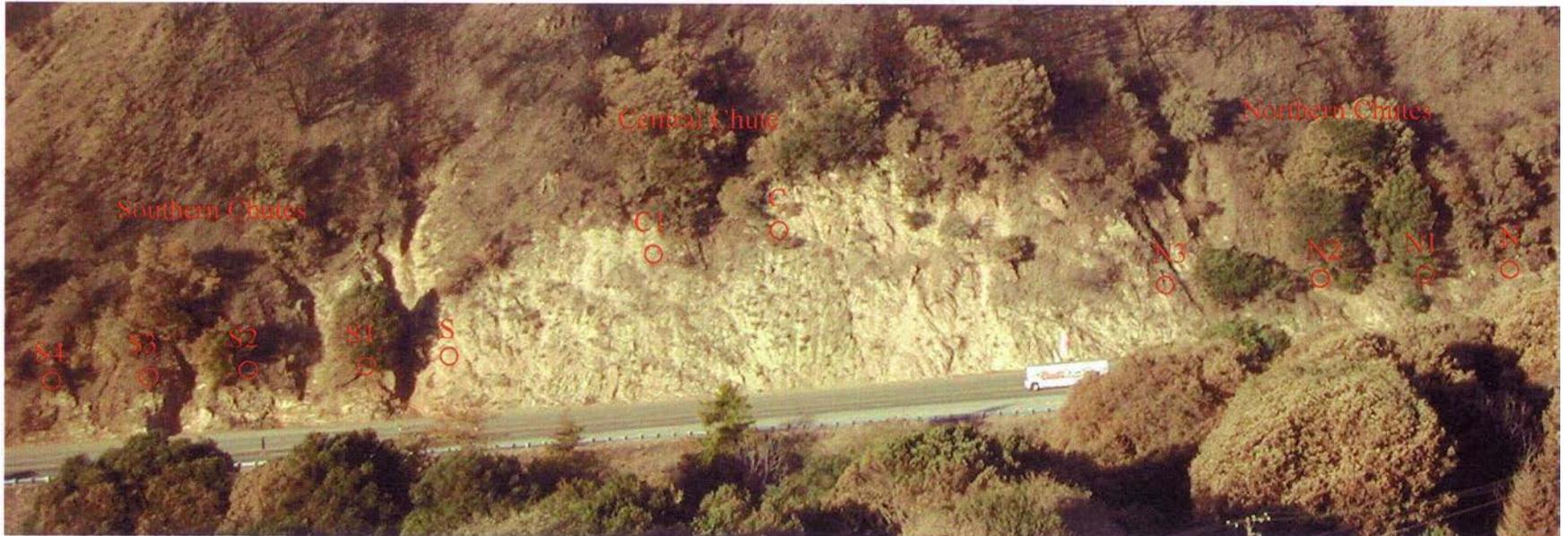
The Lower 18 2004



The Lower 18 2004



The Lower 18 2004



The Lower 18 2004



The Lower 18 2004



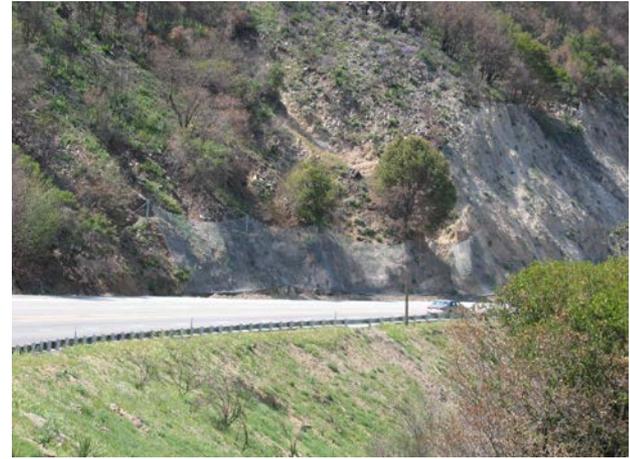
The Lower 18 2004



The Lower 18 2004



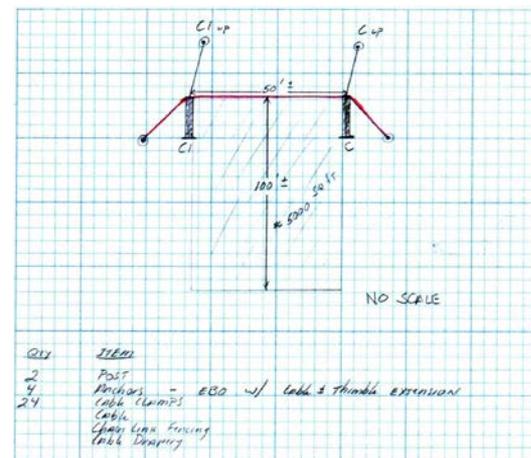
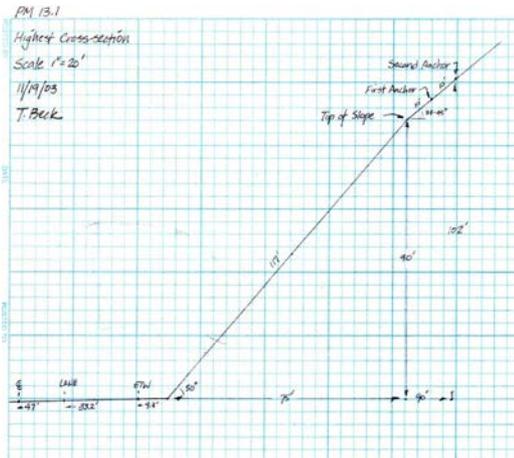
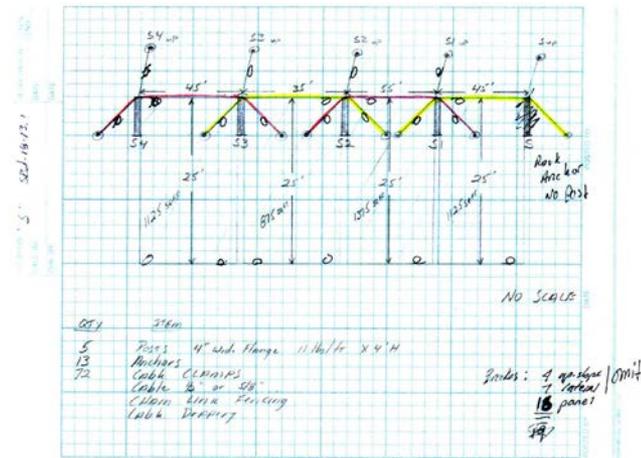
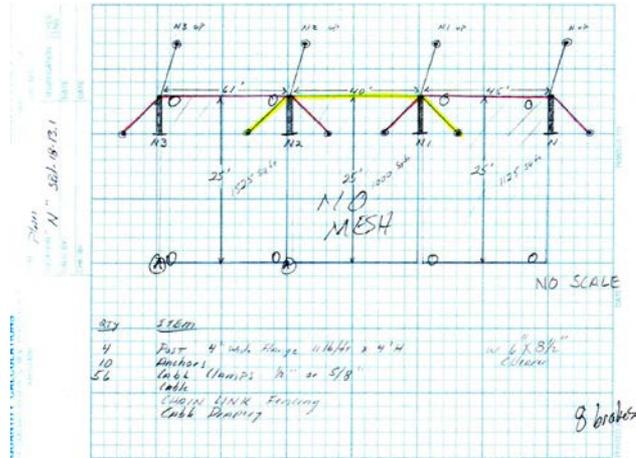
The Lower 18 2004



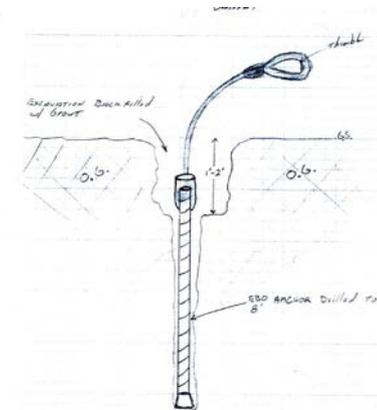
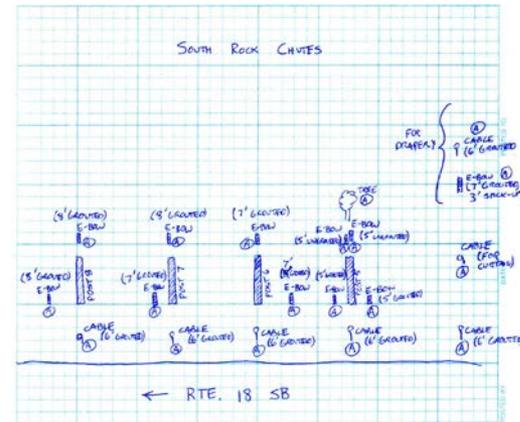
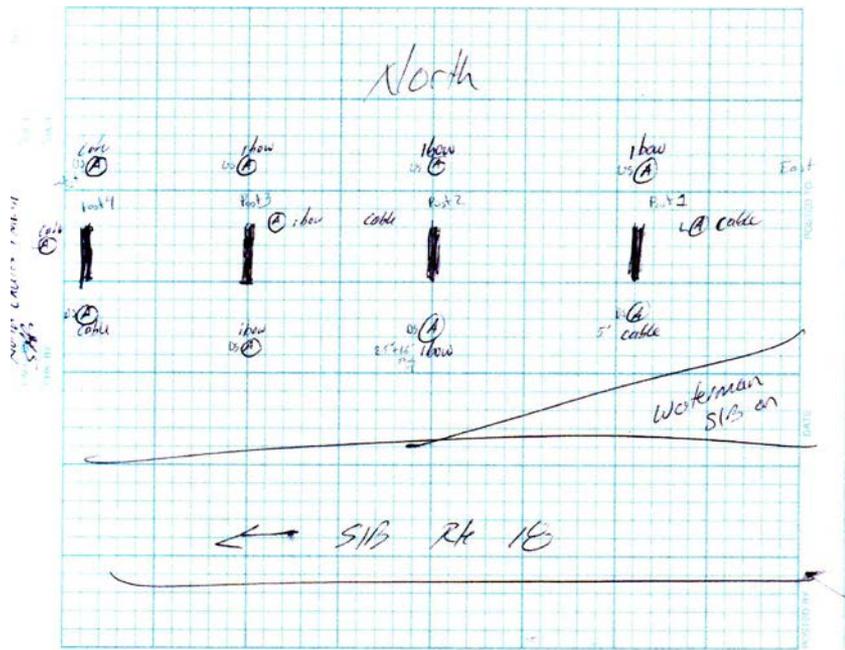
The Lower 18 2004



The Lower 18 2004



The Lower 18 2004



Gaviota

October 2004

Gaviota

October 2004



Gaviota

October 2004



Gaviota

October 2004



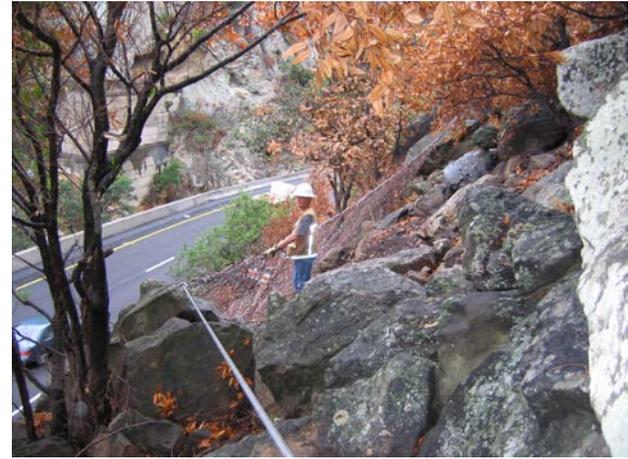
Gaviota

October 2004



Gaviota

October 2004



San Bernardino
March 2006

San Bernardino Hybrid August 2004



San Bernardino Hybrid March 2006



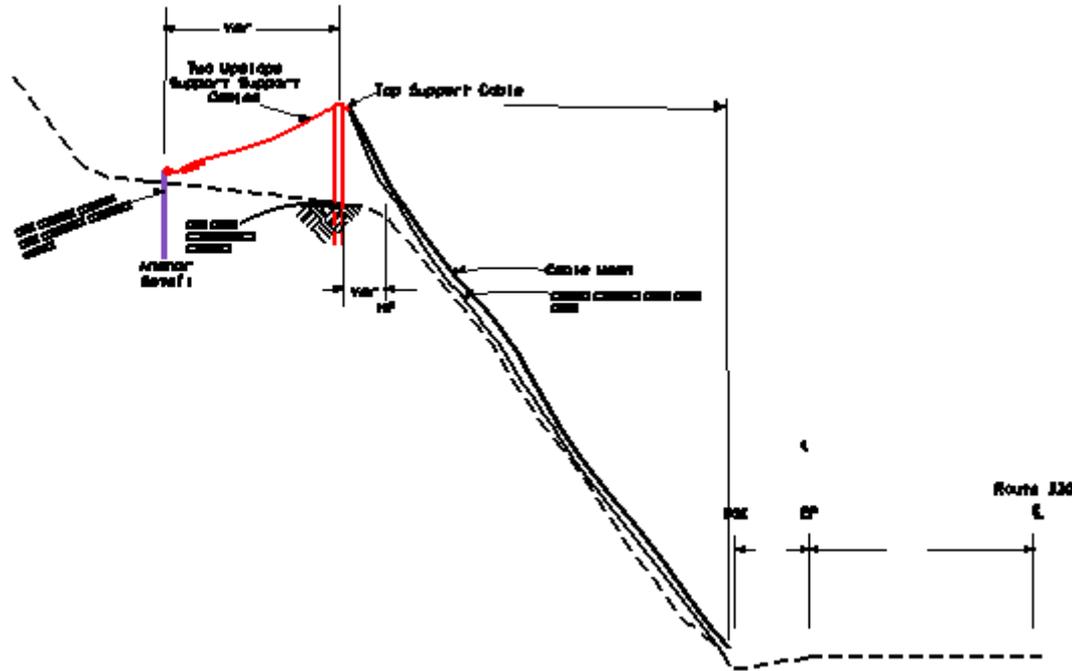
San Bernardino Hybrid March 2006



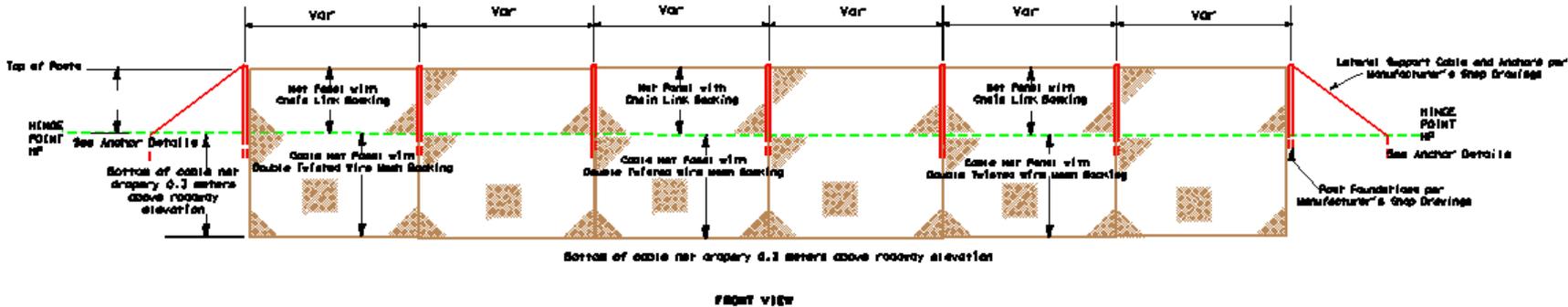
San Bernardino Hybrid March 2006



San Bernardino Hybrid March 2006



San Bernardino Hybrid March 2006



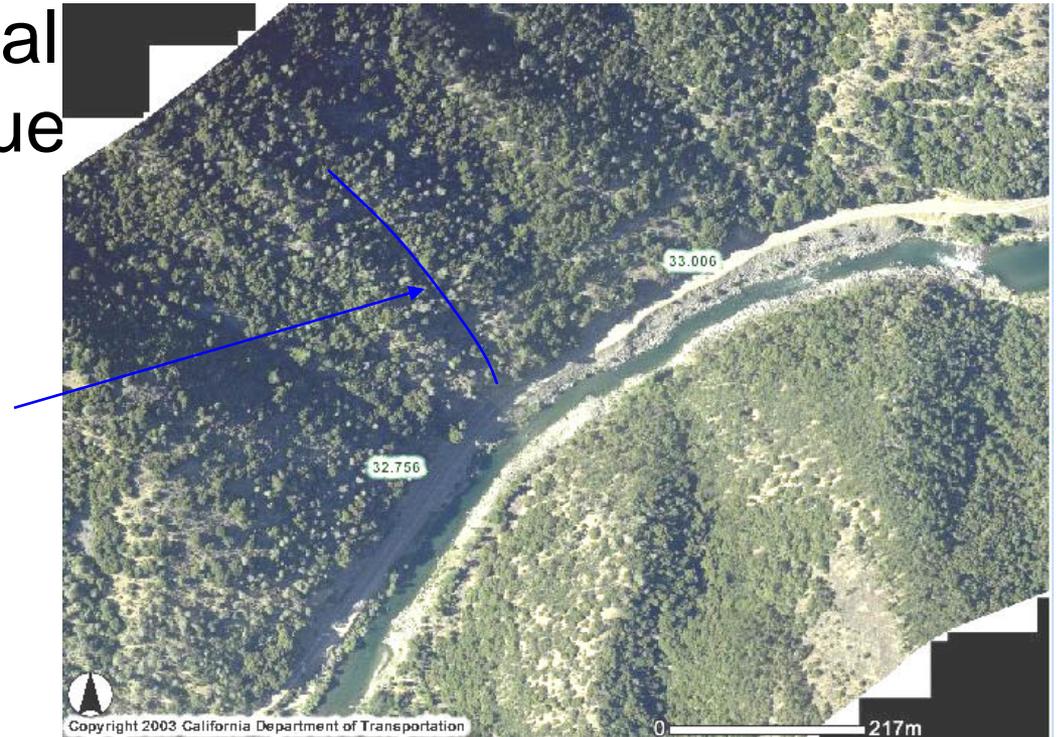
San Bernardino Hybrid November 2004



Trinity 299
April 2007

02-Tri-299-PM32 Hybrid Barrier

- Approximate location and extent of rockfall chute shown by blue line.



02-Tri-299-PM32
Hybrid Barrier
9-18-06



02-Tri-299-PM32
Hybrid Barrier
April 2007



02-Tri-299-PM32

Hybrid Barrier

April 2007



02-Tri-299-PM32

Hybrid Barrier

April 2007



02-Tri-299-PM32

Hybrid Barrier

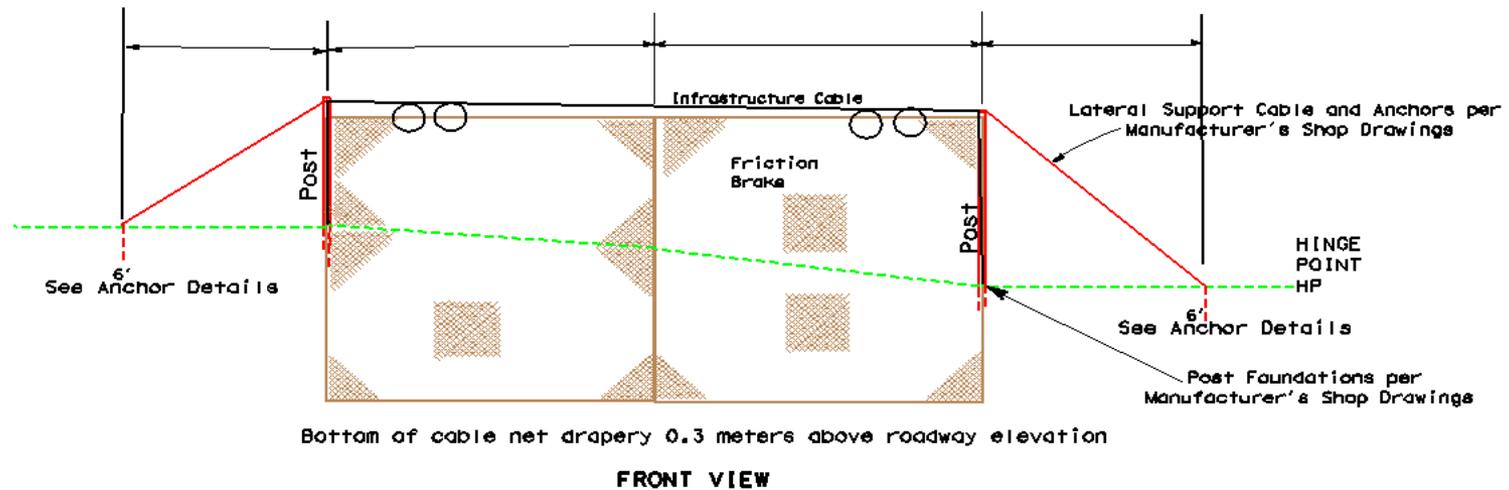
April 2007



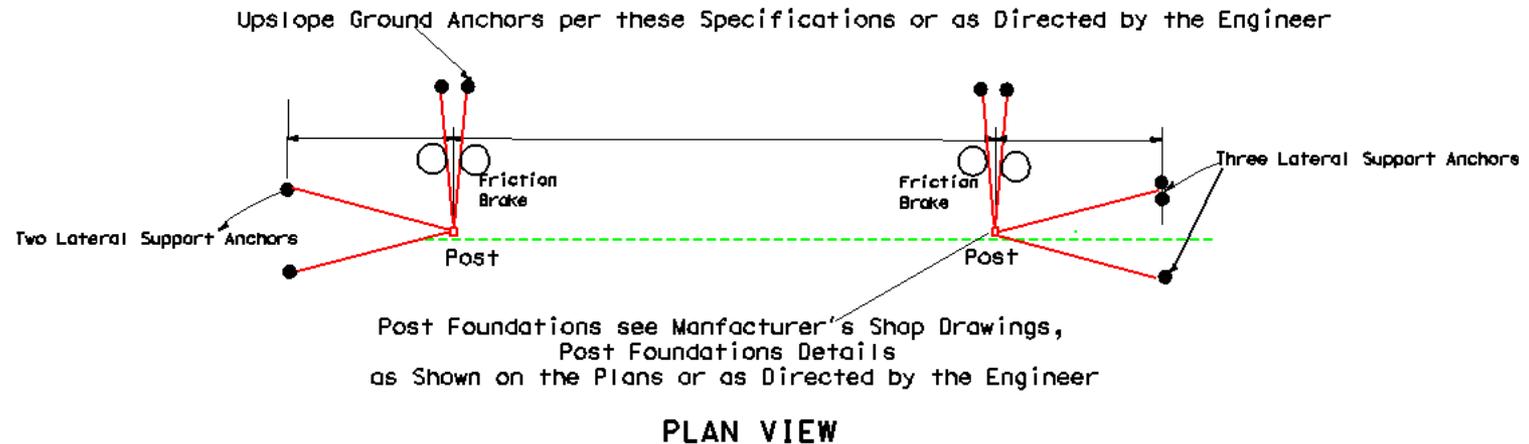
02-Tri-299-PM32

Hybrid Barrier

April 2007



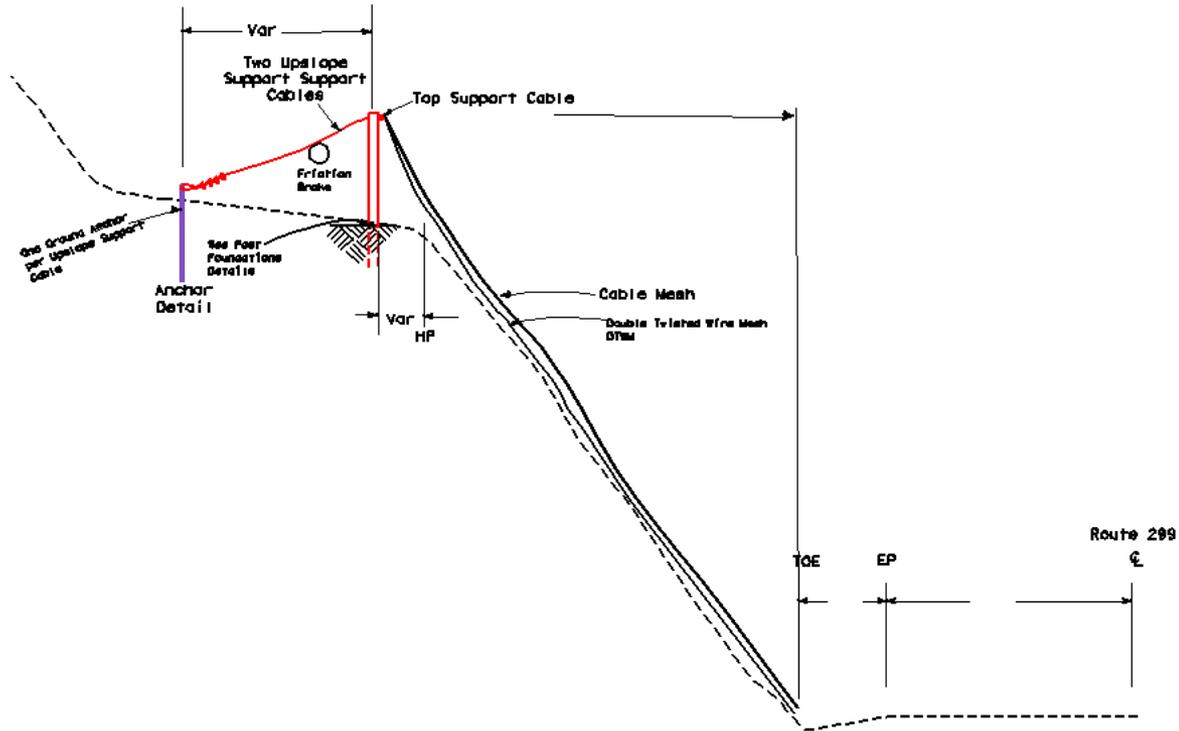
02-Tri-299-PM32 Hybrid Barrier April 2007



02-Tri-299-PM32

Hybrid Barrier

April 2007



Hwy 299

Hwy 299



Hwy 299



Testing Italy

Testing Italy

- I spoke with Francesco Sassudelli early this week regarding the Hybrid testing. He and the folks at Igor have been planning the test and have asked for our input/comments on what they have planned thus far.
-
- Location - uphill from the barrier testing (above the roadway) - This yields a better location for the drape portion and impact velocities of around 25m/sec.
- The Hybrid will be based on their SF200 system (latest certified Igor 2000 kJ barrier);
- Up to 3 tests can be done in one day if all goes well - They are currently planning on a 1 tonne rock and a 2.5 tonne rock - if time remains and the hybrid is in good shape a 3rd rock could be done (potentially to destruction);
- Currently no braking elements are planned in the barrier section of the hybrid - Tom, you have noted in the past these are a maintenance headache - perhaps in the final design version we could put in "fuse brakes" that would actuate only under a "hail Mary" hit and protect the system - this may be a topic for more discussion.
- The current plan is to have the rock impact the ground surface directly in front of the hybrid and bounce into the barrier - this will impart angular momentum into the boulder (Ty - I think you and others have expressed an interest in adding this component to the testing) - we can direct the hit to occur in the center of the barrier panel or lower as desired.
- Please let me know what your thoughts are on the proposed testing program. I have included a couple of photos so you can recall or get a feel for the uphill portion of the test facility.
-
- All the best,
- Pete

Testing Italy

- Pete,
- Thanks for sending this information. The test location and the proposal to have angular momentum seem good. My opinion is that if we can identify the capacity of the sweet spot/zone, then design modifications can be made to favor hits this area. I don't yet have a sense of how well a simple drapery can attenuate the energies, but avoiding braking elements (that would get actuated) or re-tensioning of the system should be a design objective.
-
- My opinion is that the boundary conditions are one of the the most important aspects to understanding how these systems function and to optimize their design. I attached two drawings of typical applications that I think would behave differently, both being strongly influenced by how much dead load is acting on impact area. Some of the design analysis may best be done with numerical modeling (which is currently in the works with Washington State University). You don't mention what/where/how the system loads will be measured. If possible, I think it would be worthwhile to instrument the sides and bottom somehow to help understand the boundary effects.
-
- Fence and drapery orientation relative to the impact direction may also be a factor to consider
-
- That's all I can think of for now. Looking forward to seeing these systems in action.
- *Tom*

Testing Italy

- Good ideas Tom - The arrangement in Hawaii is like your arrangement A. The rocks rolled into it as a "field test" never reached the bottom and the braking elements were not engaged. I don't have a photo of the completed barrier yet - should get one from Pierre soon but one near completion is attached.
-
- The measurements on the barriers done to date have load cells placed in line with the cables forming the top/bottom longitudinal ropes, anchors and braking elements. As you would imagine, instrumenting rings is impractical as the loads dissipate rather than concentrate there. I have attached two photos showing load cells - the first is of a pair of load cells on the end anchor ropes; the second (if enlarged a bit) shows the load cells on the uphill anchors resting on the slope soil. I am not sure which of the wire ropes Francesco has planned for measurements. If shortened lower ropes are used to allow rocks to drop through and under the drape - those may be the critical points to measure. I agree braking elements should be avoided if possible - some increase in stiffness (of components like cables & posts) or heavier rings may be warranted in the uppermost barrier section to eliminate the need for braking elements.
-
- All the best,
- Pete

Testing Italy



Hawaii

Hawaii



Hawaii

