Evaluation of Gully Erosion Control and Restoration Techniques in the North Crystal Creek Basin, Pikes Peak

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Abstract

Adequately addressing gullies created by stormwater runoff originating from high mountain roads and the resultant sedimentation of connected streams and wetlands has been a challenge for land managers across Colorado due to the impacted areas often being located in difficult to reach terrain. Remote streams and wetlands on Pikes Peak can be included among those most affected. Basins located on Pikes Peak have received an unusually excessive amount of sediment, up to eleven times the estimated natural erosion rate, due to uncontrolled runoff conveyed through erosion gullies emanating from the Pikes Peak Highway. Within the North Crystal Creek Basin on Pikes Peak, discharge of stormwater off the highway onto unprotected slopes has resulted in the development of thirteen long, deeply incised gullies located in difficult terrain. A 120 m long gully that was incised 1.0-2.5 m was selected from this set in order to ascertain the effectiveness of prescriptions implemented to reduce sediment transport into North Crystal Creek. Prescriptions included the placement of twelve loose-rock check dams and four different vegetation treatments randomly applied to areas upstream of each dam. To measure effectiveness, twelve 5 m x 3 m plots were installed upstream of each dam in the treated area. Cross-section transects to determine changes in gully morphology and line intercept transects to measure increases in vegetation cover were established in each plot. Two additional plots were established in a control gully to determine natural response rates. Effectiveness monitoring over a 5-year period (2006-10) shows that prescriptions were successful in stabilizing the gully channel through an increase in vegetation cover and a reduction in gully erosion. All vegetation treatments showed an increase in cover over natural rates and 9 out of the 12 plots had a reduction in cross-sectional area.

Introduction

Colorado's high sub-alpine and alpine regions have long been an attractive draw for those wishing to exploit these areas for their mineral deposits, wildlife, or scenic beauty. The result has been over 100 years of road construction within some of the most environmentally sensitive lands within the State. Many roads were constructed with little or no thought as to how stormwater would affect adjacent watersheds. Culverts, if any at all, were often placed in inappropriate locations and protection of the slope beyond the out fall was extremely rare. The legacy of many of Colorado's mountain roads is a degraded landscape characterized by gully scars and sediment laden streams. Pikes Peak (4,302 m), renowned as America's Mountain, is an extreme example of how the presence of an automobile route in combination with poor stormwater management can severely degrade a watershed.

Dominating the skyline just west of Colorado Springs, CO; Pikes Peak is one of the principal landmarks in the western United States and provided inspiration for the song “America the Beautiful.” The summit of Pikes Peak is accessible by the 19 mile long Pikes Peak Highway Toll Road. Constructed in 1915, the Pikes Peak Highway now supports over 300,000 visitors a year helping to establish Pikes Peak as the second most visited mountain in the world after Japan’s Mount Fuji. In addition to being a major tourist draw, Pikes Peak is also one of the most important natural areas in the region. The mountain provides critical habitat for a wide range of native flora and fauna including populations of the federally listed threatened Colorado greenback cutthroat trout. The Pikes Peak Watershed is the principal local source of water for the communities of Colorado Springs and Manitou Springs.

The Pikes Peak Highway has long been a center of controversy. Beginning as early as 1952, nearly a dozen reports and studies from several organizations and agencies have confirmed the environmental degradation caused by the road upon the surrounding landscape and the Pikes Peak Watershed. All of the reports agreed that the environmental impacts from the Pikes Peak Highway are a direct consequence of the highway being maintained as an unpaved road and that the lack of proper water control structures are a principal factor behind the degradation. The discharge of stormwater runoff from the highway unto unprotected slopes has resulted in the creation of over 120 gullies within the watershed. These gullies have facilitated the transport of road material and radically increased natural erosion rates (RMFI, 2003). Many of the gullies are over a quarter mile long, have developed on extremely steep terrain, and are located in difficult to reach areas.

In 1998, the Sierra Club filed suit in US District Court against the City of Colorado Springs and the USDA Forest Service alleging violations of the Clean Water Act in the management of the Pikes Peak Highway. In 2000, the Court ruled in favor of the Sierra Club and instructed the City of Colorado Springs and the Forest Service to address the erosion and sedimentation problems of the highway and to bring the road into compliance with the provisions of the Clean Water Act. The court set a timeline of 10 years for these improvements to be made and since that time approximately 9 miles of unpaved road has been surfaced with asphalt and erosion control structures put into place.

As the paving of the Pikes Peak Highway progresses, remediation and restoration of impacted areas within the watershed is being undertaken by the Rocky Mountain Field Institute. Addressing the numerous gullies and reducing their impact to streams and wetlands within the watershed is a primary goal of RMFI's *Pikes Peak Watershed Restoration Project*. A five-year effectiveness study of the erosion control prescriptions and vegetation techniques used to stabilize a 120 m long gully emanating from the Pikes Peak Highway in the North Crystal Creek Basin is presented.

Methods

Site Description

The North Crystal Creek Basin abuts the Pikes Peak Highway between mile markers 7 and 10 at an average elevation of 3000 m. Within the basin is North Crystal Creek, a small tributary stream to Crystal Creek. Crystal Creek is the main natural source of water flowing into Crystal

Reservoir within the Pikes Peak Watershed. This reservoir is a primary source of drinking water for the City of Colorado Springs.

Within the North Crystal Creek Basin, discharge of stormwater off the Pikes Peak Highway onto unprotected slopes has resulted in the development of thirteen deeply incised gullies. These gullies are highly unstable with active undercutting of the bankslopes occurring. Extensive alluvial deposits have formed at the gully outlets, spreading into the North Crystal Creek channel. Because of these factors, the North Crystal Creek Basin was identified as a priority for completing paving and erosion control on the Pikes Peak Highway. Road work completed in 2005 resulted in all culverts discharging stormwater from the highway into the North Crystal Creek Basin being either removed or closed, allowing stabilization and restoration work in the basin to begin.

The gully selected for effectiveness monitoring is approximately 112 m in length with a natural drainage area estimated to be 3.14 hectares. Previous runoff has resulted in an incised channel that averages 1.5 m deep and 3 m wide through most of its length with an average channel gradient of 12 percent. Prescriptions implemented within the gully included loose-rock check dams and four different vegetation treatments.

Loose-rock Check Dams

Loose-rock check dams have long been recognized as an effective way to provide gully control. Heede (1976) studied and quantified the effectiveness of several types of rock check dams along Colorado’s Front Range and the National Resource Conservation Service has been using check dams for gully control for decades. Loose rock check dams are easy to construct but can require a substantial amount of material depending upon the area and length of the gully to be controlled. General practice involves using heavy machinery to move the material into place. Due to the inaccessible nature of the gullies on Pikes Peak an alternate method to transport material to the project site was needed. The Rocky Mountain Field Institute has had good success in gully control and remediation in remote, difficult to access alpine areas using a Rock Tram system to transport large amounts of rock material to build check dams and retaining walls. This method involves setting up a tram tower at the material source and a second tower near the work site. The tram at the material source must be located above the work site. In general, a flat area of about 4 m^2 is required to provide enough space for the tram tower to be constructed. A rope pulley system is then rigged between the two towers that allow rock material to be transported through the air from the source pile to the work site. The system can be used to transport up to 160 Kgs (approximately 350lbs) of rock material in a large bucket or individual rocks up to 182 Kgs (400lbs) in a sling each trip (Figure 1 and 2). Distances of up to 120 m can be covered depending upon the steepness of the slope with steeper slopes allowing for longer distances.

Figure 1 and 2. Example of Rock Tram with bucket and rock sling

The system has many advantages over the use of heavy machinery. It is easily transportable and can be set up on extremely steep slopes, which is actually desirable due to the rope slack in the system which can cause the rock bucket or sling to drag on the ground if the slope is not steep enough. The system does not require any access roads to be constructed as generally the top tower will be placed on or near the existing road above the gully to be treated. The system allows material to be transported quickly and without disturbing the landscape under which the material is being carried. The main disadvantage to the system is that it is very labor intensive, requiring at least three persons to operate the top tram and load material from the source pile, and at least two persons to dump the material and ready the bucket or sling to be transported back to the top tram. Individuals wanting specific information on setting up the Rock Tram system should contact the Rocky Mountain Field Institute directly.

The Rock Tram system was applied in the construction of 12 loose-rock check dams within the project gully in the North Crystal Creek Basin. Position of the check dams was determined using the standard calculation;

$$D = (100 \times H) \div Z$$

Where: D = Distance between structures H = Height of proposed structure
Z = Percent grade of channel (Fifield, 2000)

Dams were constructed according to specifics outlined by Heede (1976) and Fifield (2000). Approximately 56 metric tons of granite rock 8 cm to 91 cm in diameter was utilized to construct the rock check dams. Sizes of the check dams ranged from 1.6 cubic meters to 23.7 cubic meters and averaged 1 meter high. The rock tram was utilized to transport the rock 24 m from the staging area off the Pikes Peak Highway down into the gully (Figure 3 and 4). From there a team of 11 workers filled painters' buckets with 18 to 23 Kgs of rock and hand carried the material to the dam site (Figure 5 and 6).

Figure 3 and 4. Examples of unloading the bucket from the tram set up.

Figure 5 and 6. Examples of building the check dams.

Cross-section baseline measurements were recorded for each rock check dam after completion in 2006 using a CST/berger LM700 Laser Level. Subsequent surveys were conducted each summer through 2010. Cross-sections were located 250 cm upstream from the check dams' center line and were delineated by rebar pins. Analysis of cross-sectional data was completed using WinXSPRO v3.0 Channel Cross Section Analyzer software (USDA, 2005). WinXSPRO allows for the calculation of the Gini coefficient. The Gini coefficient describes the channel cross sectional shape of the gully area by examining the distribution of channel depth measurements. Using the Gini coefficient for cross section data acquired over time allows for any change in channel shape to be quantified. An increase in the Gini coefficient indicates the channel is becoming deeper and narrower, and thus continuing to actively erode due to fluvial processes. Conversely, a decrease indicates the channel is becoming flatter and wider indicating that the channel is filling and that mass wasting is the primary process of erosion. An analysis of the Gini coefficient was completed to ascertain changes in cross-sectional area over the 5 year monitoring period.

Vegetation Prescriptions

Four different vegetation treatments were applied to randomly selected plots within the gully to assess their ability to increase vegetation cover within the gully channel. Twelve monitoring plots (5 m x 3 m) were established; each upstream of a check dam. Four plots each were located in the upper, middle, and lower sections of the gully (Table 1). One of the following four prescriptions were randomly selected to be applied to a plot within each section:

- Seeding, soil amendment, erosion control matting, and bank shaping
- Seeding, soil amendment, and erosion control matting
- Seeding and soil amendment
- Seeding only

Breakdown of the plots was as follows:

Plot treatment

Upper Section	
12	Seeding and soil amendment
11	Seeding, soil amendment, erosion control matting, and bank shaping
10	Seeding, soil amendment, and erosion control matting
9	Seeding only
Middle Section	
8	Seeding, soil amendment, and erosion control matting
7	Seeding only
6	Seeding, soil amendment, erosion control matting, and bank shaping
5	Seeding and soil amendment
Lower Section	
4	Seeding, soil amendment, erosion control matting, and bank shaping
3	Seeding only
2	Seeding and soil amendment
1	Seeding, soil amendment, and erosion control matting

Table 1. Plot Treatment Description

The seed mix used within each plot was comprised of the following:

Species/ Common Name/ PLS lbs-acre/ % of Seed Mix
Elymus Canadensis/ Canada Wildrye / 9.00 / 48.6
Festuca arizonica / Arizona Fescue/ 6.00/ 32.4
Trisetum spicatum/ Spike Trisetum / 3.00 / 16.2
Achillea millefolium/ Common Yarrow / 0.10 / 0.5
Chrysopsis villosa / Golden Aster/ 0.20/ 1.1
Penstemon virgatus/ Palmer's Penstemon / 0.20/ 1.1

The soil amendment used was commercially available BioSol. BioSol is an organic mycelium-based fertilizer with a 6-1-3 nitrogen-phosphorous-potassium ratio and is widely used in restoration projects. The erosion control matting applied consisted of certified 100% California Straw and Coir, with 2 natural biodegradable nets.

As Bonham (1989) states, measuring an increase in vegetation cover from monitoring plots is useful for monitoring plant responses to various vegetation treatments. To establish percent cover for the plot, six transects were randomly placed along the 3 m length of the side of the plot running parallel to the gully bank. A random number generator was used to choose the locations. Cover was then measured using the line intercept method as described by Elzinga et al., (1998). Samples from the six transects were aggregated and a percent cover for the entire plot was calculated. Each transect was also broken down into upper left bank, left bank, channel, right bank, and upper right bank. Samples from the six transects were aggregated and a percent cover for the each subsection was calculated. Vegetative cover in the channel, and on the gully left and right banks, were used to determine effectiveness of vegetation treatments as these subsections were highly disturbed and, in the case of the channel bottom, were devoid of vegetation. The upper left and upper right banks of each plot were assumed to represent undisturbed conditions. These subsections were used as a reference for expected natural vegetation cover. Control data was collected in a gully of similar slope, aspect, and severity upstream of the treated gully. Two control plots were established in the control gully to assess natural changes in vegetation cover from an untreated site and compare to the treated sites in the project gully.

RESULTS

Loose-Rock Check Dams

WinXSPRO v3.0 Channel Cross Section Analyzer software was utilized to quantify changes in gully morphology upstream of the dam sites using the Gini coefficient (USDA, 2005). The evaluation of the cross-sectional area measurements found that 9 of the 12 plots showed a reduction in cross-sectional area between the initial treatment in 2006 and 2010 indicating. Three of the plots (4,6, and 11) showed an increased in cross-sectional area (Table 2). The Gini coefficient value for all cross-sectional areas was substantially less than the maximum attainable values of =/- 1.0 indicating that very little change in gully morphology had occurred between the initial treatment in 2006 to 2010.

Cross-section area change from 2006-2010 for North Crystal Creek Gully1		
Plot #	Negative	Positive
1	-0.0338	
2	-0.09799	
3	-0.004	
4		0.01337
5	-0.01174	
6		0.00223
7	-0.08251	
8	-0.08633	
9	-0.02362	
10	-0.03167	
11		0.01021
12	-0.04006	

Table 2. Cross-section area change using the calculated Gini coefficient. A positive value indicates the channel is becoming deeper and wider. A negative value indicates the channel is becoming flatter and wider.

Vegetation Treatments

Vegetation surveys conducted over the monitoring period (2006-10) showed that all four vegetation treatments were successful in increasing vegetation cover within the study plots by the end of the monitoring period and that vegetation cover was greater than that observed in the untreated control plots (Figure 7). The combination of Seed/BioSol/Erosion Control Matting (ECM) was the most effective resulting in a 5th year vegetative cover of 46.24%. In comparison, aggregated vegetation cover in the untreated control plots was 24.5%. The combination of Seed/BioSol/ECM/Bank Shaping was the second most effective treatment with a 5th year vegetation cover of 40.96%. Treatment with only seed, or seed and BioSol, were less effective with vegetation cover percentages of 29.33 and 36.15, respectively.

Analysis of the percent change in vegetation cover from the initial year in 2006 to 2010 by gully morphology also shows that Seed/BioSol/ECM was the most effective, with an increase from 0% to 78.9 percent cover in the channel, 14.43% to 21.74% on the left bank, and 8.5% to 37.24% on the right bank (Figure 8). Applying seed only was the least effective treatment, however an increase in vegetative cover from 0% to 36.78% in the channel, 10.81% to 26.67% on the left bank, and from 11.93% to 25.62% on the right bank was observed. Results for the untreated control plots were mixed. In 2006, aggregated vegetation cover for the control plots was 14.53% in the channel, 58.33% on the left bank, and 32.77% on the right bank. By 2008, these numbers had dropped to 0, 0, and 4 percent, respectively. However by 2010, the aggregated vegetation cover for the control plots was 20.78% in the channel, 42.86% on the left bank, and 31.25% on the right. These results are comparable to the seed only treatment but are significantly less than the other treatments.

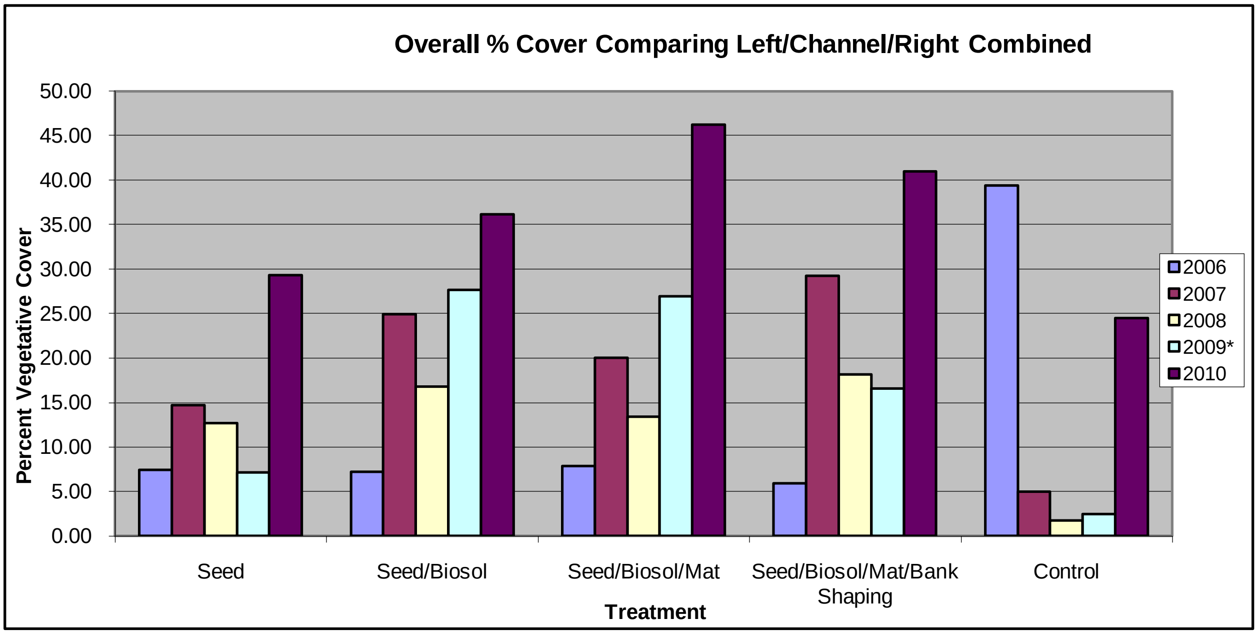

Figure 7: Overall Percent Cover of Left Bank, Channel, and Right Bank combined, by year.
* 2009 data is incomplete and shown for comparison purposes only

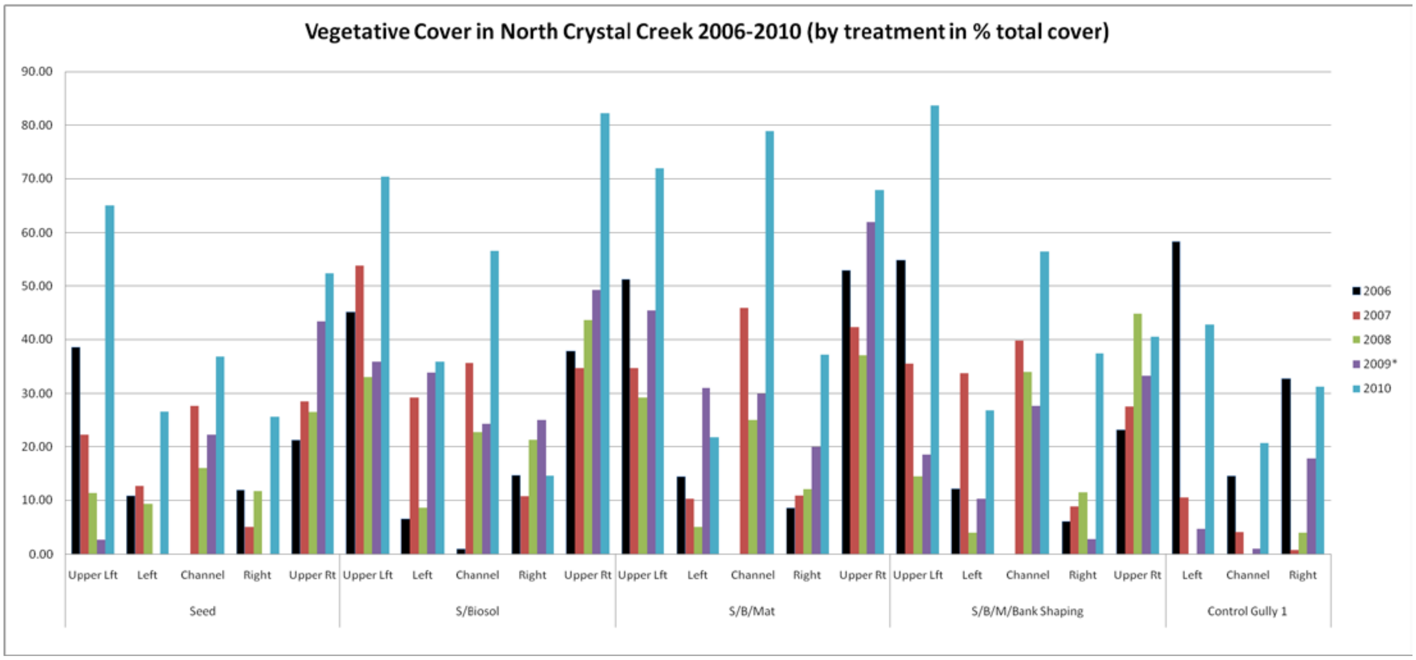

Figure 8: Comparison of % Vegetation Cover by Treatment Type and Gully Morphology.
* 2009 data is incomplete and shown for comparison purposes only

Lastly, an analysis of year to year change in percent vegetation coverage by treatment was completed (Table 3). All treatments except for the control showed an increase in cover during the first year of growth from 2006 to 2007. All treatments, including the untreated control, then declined in the second year from 2007 to 2008. Vegetation growth from 2008 to 2009 was mixed with some treatments showing increases and others declining. Percent cover change for all treatment types, including the control, increased significantly from 2009 to 2010 with increases upwards of 24%. This analysis again shows that the combination of Seed/Biosol/ECM was the most effective treatment with the highest cumulative percent cover change from year to year of 38.39%. The control plots showed an overall decline at the end of the study period, with percent cover 14.92% less than the initial baseline cover recorded in 2006.

Difference in Percent Total Cover					
	Seed	Seed/Biosol	Seed/Biosol/Mat	Seed/Biosol/Mat/Bank Shaping	Control
2006	Baseline	Baseline	baseline	Baseline	Baseline
2007	7.29	17.71	12.21	23.34	-34.45
2008	-2.05	-8.10	-6.66	-11.06	-3.27
2009	-5.51	10.87	13.57	-1.64	0.74
2010	22.19	8.46	19.28	24.41	22.06
Cumulative	21.91	28.94	38.39	35.05	-14.92

Table 2: Comparison of % Total Cover Change from Year to Year by Treatment.

* 2009 data is incomplete and shown for comparison purposes only

CONCLUSION

Effectiveness monitoring over a 5-year period (2006-10) shows that vegetation prescriptions were successful in stabilizing the gully channel through an increase in vegetation. All vegetation treatments showed an increase in cover over natural rates with the combination of Seed/BioSol/ECM being the most effective followed by the combinations of Seed/BioSol/ECM/Bank Shaping and Seed/BioSol respectively. The results show the importance of using a natural fertilizer, such as BioSol, and erosion control matting to effectively promote vegetation growth in nutrient poor soils such as those derived from Pikes Peak Granite. These results support a study by Grismer et al. (2008) that showed Biosol and the use of amendments (in this case; compost, wood chips) increased overall cover in plots with granitic soil in the Lake Tahoe area. However a note of caution was expressed by the authors in the use of BioSol; the majority of new plant cover was by less-desirable annual species rather than native perennials. Species diversity was not calculated in the North Crystal Creek plots though this would aid in assessing the true effectiveness of restoring the plots to a natural state.

Analysis of the Gini coefficient of the cross-sectional area measurements indicates that the presence of loose rock check dams was effective in stabilizing the gully channel by attenuating runoff and trapping sediment. It is interesting to note that the 3 plots that showed a small positive value were those treated with the combination of Seed/BioSol/ECM/Bank Shaping. A significant portion of the gully banks were reshaped in these plots and deposited on the channel floor behind the dam. This material was easily transported and resulted in a rill developing through the deposited material in subsequent years after treatment. However, the magnitude of change for these plots was significantly less than the maximum value of + 1.0 indicating significant deepening and narrowing of the channel. In fact, all plots showed values significantly less than the maximum value of +/- 1.0 indicating that gully morphology within the plots had changed little over the course of the study after treatment.

LITERATURE CITED

Bonham, C. 1989. Measurements for Terrestrial Vegetation. John Wiley & Sons. New York.

Elzinga, C., Salzer, D., Willoughby, J. 1998. Measuring & Monitoring Plant Populations. U.S Department of the Interior, Burue of Land Management. Report # BLM/RS/ST-98/005+1730

Fifield, J. 2000. Installing Check Structures in Small Drainage Channels. *Erosion Control*. < http://www.forester.net/ec_0004_installing.html > (01 July 2005)

Heede, B. 1976. Gully Development and Control: The Status of Our Knowledge. USDA Forest Service Research Paper RM-169. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO.

Grismer, M. E., Schnurrenberger, C., Artst, R., Hogan, M. Integrated Monitoring and Assessment of Soil Restoration Treatments in the Lake Tahoe Basin. Environmental Monitoring Assessments. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18483773.

Rocky Mountain Field Institute. 2003. Sedimentation Survey of Drainages off the Pikes Peak Highway. Unpublished report prepared for the Sierra Club.