Field Performance of Long-Strand Wood Erosion Control Mulch and Agricultural Straw Under Natural Rainfall Events

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Abstract

Field plots were used to compare the performance of agricultural straw mulch with a new wood-based long strand erosion control material. Three studies were installed at two locations-western Washington and central California. Slopes ranged from 15% to over 50%. Soil types included gravelly sand and fine sandy loam. Each plot was approximately 5m wide by 30m long. The study ran continuously during the winter of 2004-2005. After three months, the long-strand wood erosion control mulch performed equal to agricultural straw mulch. Both materials reduced sediment delivery off the plot by more than 99 percent when compared to a bare soil plot at the California location. The relative performance of the mulches was also equal in the two studies in western Washington.

Background and Rationale

Agricultural straw is widely used for erosion control in projects throughout the world. Recent events and new knowledge challenge the advantages believed to be held by agricultural straw, particularly when used in hillslope, highway, wildland and forest applications. From an ecological perspective, erosion control mulches made from forest materials are more likely to support soil formation and health in forestlands than are mulches made from non-indigenous materials. Other limitations associated with agricultural straw erosion control materials include:

- Agricultural straw is recognized as having agronomic and ecological value when left on the field or plowed under, thus reducing the availability of straw as a crop residue (Kline 2000).
- Agricultural straw is considered a raw material for energy production, fiber panels and other potentially higher value uses, thus increasing its base cost (Bower and Stockmann 2001; Fife and Miller 1999).
- Agricultural straw has been implicated as a source of noxious weeds in forested watersheds (Associated General Contractors of Washington 2002; Robichaud, Beyers, and Neary 2000).
- Fine dust from shattered agricultural straw is a respiratory irritant and source of allergens to workers who are involved in spreading straw by hand or machine (Kullman et al. 2002).
- Straw decomposes rapidly, resulting in minimal effectiveness after a few weeks of exposure to the weather (Wishowski, Mamo, and Bubenzer 1998).
- Wheat, barley and rice straw are easily blown off of slopes exposed to wind (W. Elliott, pers. Comm.). Bare areas exposed by wind are subject to increased erosion and may be trigger points for rill formation.

Forest Concepts was approached in 1998 and asked to develop a wood-based alternative to agricultural straw mulch for use in the Seattle watershed. A similar request was received from USDA Forest Service and USDI Bureau of Land Management erosion control specialists in 2000. Preliminary research indicated that we could probably design an effective long-strand erosion control material made from wood. We further believed that we could make a product that was cost-competitive with certified weed-free straw.

Since 2000, we have worked to develop a precision wood mulch that has long strands much like agricultural straw, is easy to make and apply, and performs at least as well as straw when applied for erosion and sediment control. Early success led to funding from US Department of Agriculture and cooperative support from the US Forest Service Rocky Mountain Research Station. The core science to enable design of a long-strand wood mulch was completed in 2003 (Foltz and Dooley 2003), and optimization work continued through most of 2004. By the end of 2004, we had a wood-strand material and an efficient manufacturing process ready for pilot production. This report documents the first formal field trials with what is now called WoodStraw™ long-strand erosion control mulch.

Summary of Laboratory Results

Figure 1. Agricultural wheat straw at 70 percent cover

Figure 2. A "high storage" blend of WoodStraw™ material at 70 percent cover.

The final round of experiments using the rainfall simulator at the USFS lab in Moscow, Idaho was completed in 2004. Variables examined in a series of factorial experiments were: fiber length (160, 80, and 40mm), percent ground cover (0, 30, 50, and 70%), ground slope (15 and 30%), and soil type (decomposed granite and sandy loam). The figures below represent the effect of varying amounts of wood strand cover on runoff and sediment loss as determined from rainfall simulations. Test conditions included simulated rainfall at a rate of 50mm/hr plus two levels of added overland inflow beginning 15 minutes into the trial. Publications documenting the results of the second round of research are in preparation.

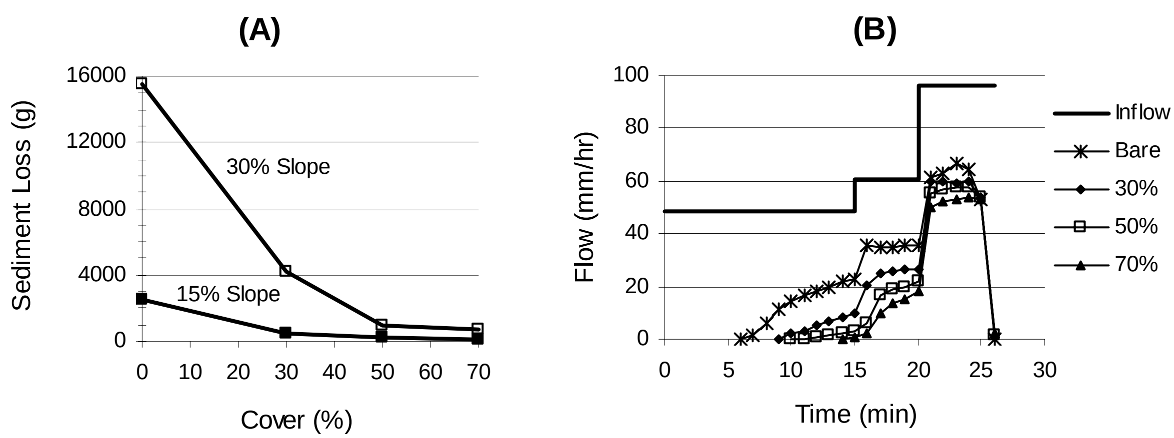

Figure 3: Sediment loss (A) and runoff hydrograph (B) for varying cover amounts of wood strands.

The USFS data shows that very effective erosion control can be obtained at 50% groundcover. This is in contrast to similar performance of wheat and rice straw at 90% cover or higher (Burroughs and King

1989). Also, the figure shows a dramatic reduction in runoff from the plots covered with wood strands. Reduced runoff due to increased infiltration captures more rainfall to support plant growth and reduces the risk of downslope flooding.

Field Research Objectives

Our primary objective is to evaluate the functional performance of wood-strand erosion control mulch across a range of soils, slopes and climates. In addition to absolute performance, we would like to obtain comparative performance data for the wood-strand materials versus straw mulch.

Our aim is to test the hypothesis that wood-strand erosion control material is equal or better in sediment control than the standard straw mulch prescription.

We also would like to obtain observation data on the comparative performance with respect to wind stability, mobility on the slope due to overland flow, functional strand life, and rate of vegetation establishment.

Overview of Method

- Adjacent vertical strips of approximately 10 meters (30 ft) wide and 30 meters (100 ft) long will be treated with agricultural straw mulch and WoodStraw™ brand wood-strand mulch at generally recommended rates. The strips will be hand or machine mulched as specified by the cooperator.
    - We will not have a replicated experiment. Where replication is desired, there should be five plots of each technique (USFS guidelines). This first study does not warrant the space and expense of a five-rep experiment.
    - In most cases, we will not place an upper bound on the plots. If the plots are to be of defined length, then a ditch or edging must be installed at the top edge to divert overland flow around the plot area.
    - Where practical and the negative consequences to the site are small, we will include a bare soil treatment. If a bare soil treatment is included, the silt fence for that treatment must be stronger than for treated areas.
- A 5-meter (15 feet) wide silt fence sediment collector will be installed at the bottom of the treated strips. The silt fence collector will be similar to those specified by USDA Forest Service for evaluating hillslope erosion (Robichaud and Brown, RMRS-GTR-94, 2002). Our primary deviation will be to use a short (approximately 0.4m (16 inches)) fence height to reduce the visual impact of the sediment collector.

- A recording rain gauge will be installed between the two treated plots, or in near proximity.
- After each significant rainfall event or every month, the site will be visited to collect data and observations.
- Results will be analyzed and reported. We will use mixed units for ease of reading. Rainfall is reported in inches, while sediment is reported in kilograms.

Site Selection and Characteristics

We sought three sites for our initial field study. We wanted sites that included a wet and dry climate, shallow and steep slopes, and different soil types. The field trials are not intended to be a complete factorial design, rather a first indicator of field performance. If larger, more complex field trial experimental designs were indicated by the results of these trials, then appropriate sponsors and cooperators would be sought. As will be seen in the results, there are no anomalies in the results that would suggest a need for more extensive field experiments.

We recruited cooperators, and ultimately selected the Ernst Ranch in Paso Robles, CA and Pierce County Chambers Creek Properties as cooperators. The Ernst site is fairly steeply sloping farmland that was graded as part of a vineyard removal project. The Chambers Creek site is a former sand and gravel operation with many areas of uniform slope with various steepness.

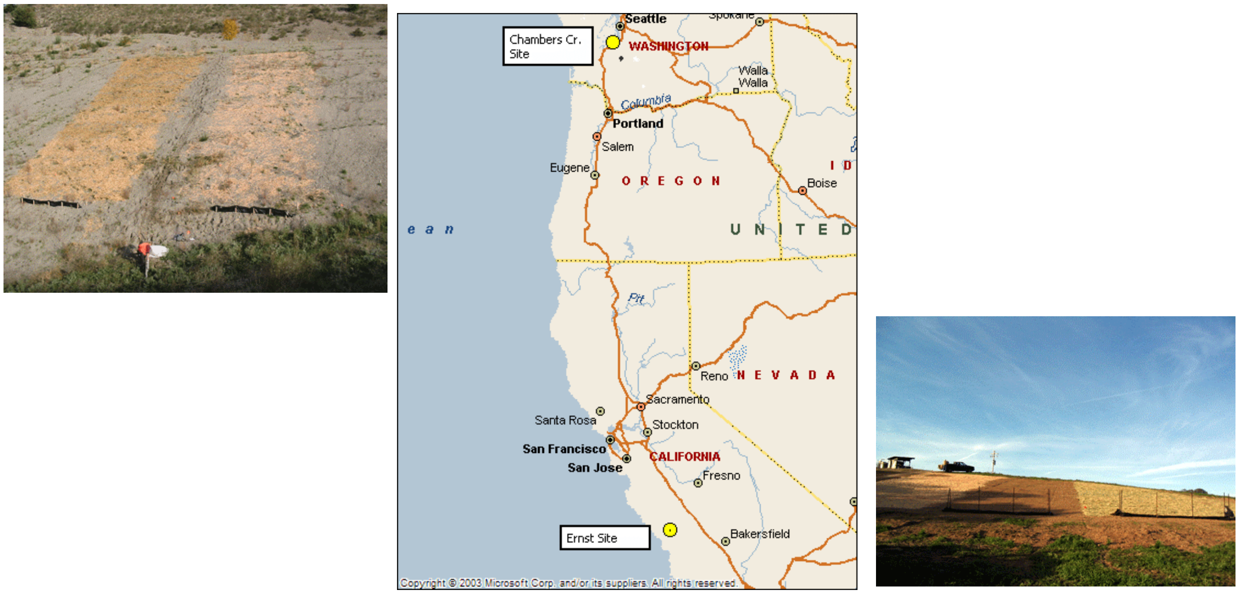

Figure 4: Field test site locations. Chambers Creek site is in Tacoma, WA and Ernst site is near Paso Robles, CA.

We expected the Chambers Creek site to be our wet site and the Ernst site to be the dry site; however, the winter of 2004-2005 proved to be exactly the opposite as California was pounded by many intense rain events from December through the end of the study period while the Puget Sound basin was in a drought.

Table 1. Site Characteristics

	Chambers Cr. Steep	Chambers Cr. Shallow	Ernst Ranch
GPS Location	47.2023N 122.5719W	47.2000N 122.5719W	35.6413N 120.6203W
Date Installed	Nov. 4, 2004	Nov. 3, 2004	Dec. 6, 2004
Slope	45 – 70%	14 – 17 %	16 – 19%
Soil Type	gravelly sand glacial outwash	gravelly sand glacial outwash	Arbuckle fine sandy loam over decomposed granite
Aspect	West	West	South
Elevation	100 ft.	50 ft	900 ft.
Climate	Puget Sound Maritime	Puget Sound Maritime	Semi-arid (< 10 in. / year)

Plot Installation

Chambers Creek: The Chambers Creek study was installed by a Forest Concepts crew on November 3-4, 2004. The site had been graded at least a year prior to the study, and no further site preparation was done.

Silt fence sediment collectors were installed and the corners of each plot were marked with pin flags. Photo points were established with 1x2 stakes, slopes were measured and the rain gauge was installed.

Erosion control wheat straw was from a local feed store source that is a current supplier to Pierce County. WoodStraw^{TM} mulch was provided by Forest Concepts. The product designator is LS64-125. The material included a 50:50 by area blend of strands that were 160mm and 64mm long. Material thickness was 3.2mm (1/8 in) and strand width was 4.7mm (3/16 in).

All materials were hand-spread to a target ground cover. The wheat straw mulch was applied to a target cover of 90%, and the WoodStraw^{TM} mulch was applied to a target cover of 50%. These application rates are consistent with generally accepted practice for straw mulch, and the laboratory-based optimum for WoodStraw^{TM} mulch on minimally erosive soils (high infiltration rate).

On the shallow slope area of the Chambers Creek site, we installed a third silt fence sediment collector on an untreated plot. Unfortunately, a bare soil plot was not practical on the steep slope area. However, the results indicate that little sediment moved on any of the plots due to the extremely high infiltration rate of the soil and low rainfall during the winter of 2004-2005.

The Chambers Creek site has been allowed to revegetate naturally during the study. We were not permitted to control weeds and vegetation during the study. By the end of the third month, both the steep and shallow wheat straw plots show some (unquantified) vegetation cover. The wood-strand plots have occasional tufts of grass, as does the bare soil plot.

Ernst Site: The site had been tilled and graded during 2004 when a vineyard was removed from the property. Immediately prior to installing the plots, the site was re-graded by a tractor/scraper to remove all vegetation, smooth the surface, and bring fresh topsoil to the surface. The study area was large enough to include three test areas – wood-strands, bare soil, and straw mulch. The remainder of the field below the plots was previously planted with pasture grass, thus providing a buffer for excess sediment that may be released by the bare soil plot.

Silt fence sediment collectors were installed and the corners of each plot were marked with pin flags. Photo points were established , slopes were measured and the rain gauge was installed. Erosion control barley straw was from bales made by the Ernst Ranch cooperator on another part of their property. WoodStraw^{TM} mulch was provided by Forest Concepts. The product designator is LS64-125. The material included a 50:50 by area blend of strands that were 160mm and 64mm long. Material thickness was 3.2mm (1/8 in) and strand width was 4.7mm (3/16 in).

All materials were hand-spread to a target ground cover. The barley straw mulch was applied to a target cover of 90%, and the WoodStraw^{TM} mulch was applied to a target cover of 70%. These application rates are consistent with generally accepted practice for straw mulch, and the laboratory-based optimum for WoodStraw^{TM} mulch on highly erosive granitic soils.

The test plots were sprayed with a broad spectrum herbicide (Roundup) one week after the plots were installed, and monthly since that time. Herbicide applications ensure that the results are not confounded by the development of vegetative cover and root mass.

Ernst Site Results

The experiment was installed on December 6, 2004 and continued through the end of February 2005. The landowner/cooperator will continue to monitor the site through spring of 2005. The site was dry until approximately December 27, when a series of major storms moved across southern California. Figure 5 shows the cumulative rainfall for the study period. In addition to cumulative rainfall, we were able to calculate instantaneous intensity for each tip of the rain gauge (0.01 in). Rainfall intensity is well understood to be a more important driver of soil erosion than cumulative rainfall. As long as the intensity is below the rate of infiltration, no runoff will occur. When intensity exceeds infiltration, then the amount of runoff is a function the excess rainfall.

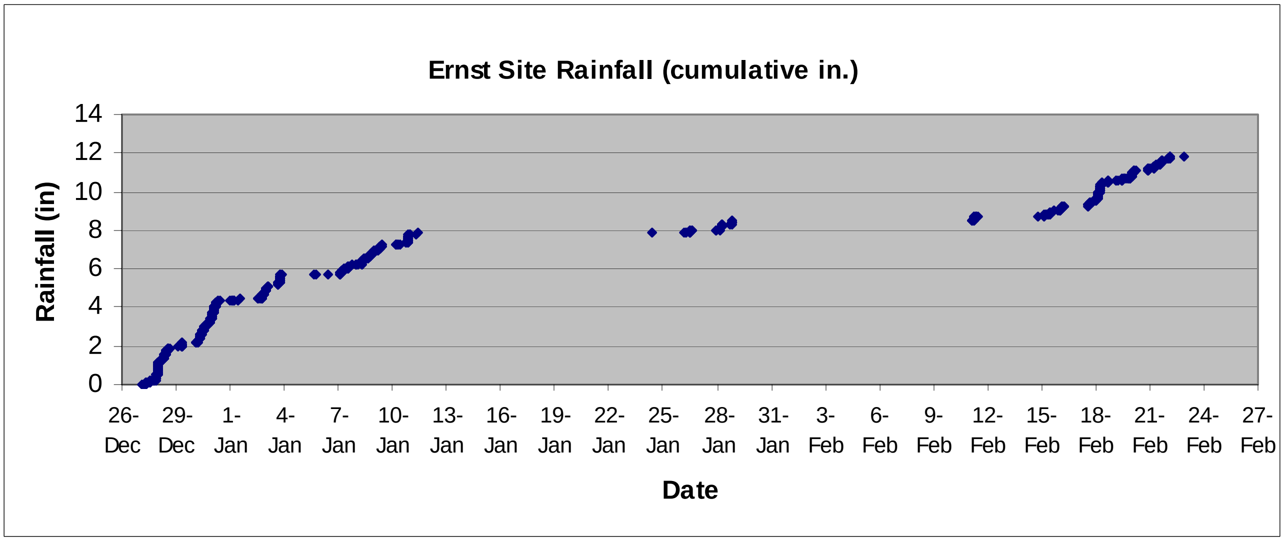

Figure 5. Cumulative rainfall record at Ernst site from December 26, 2004 through February 28, 2005.

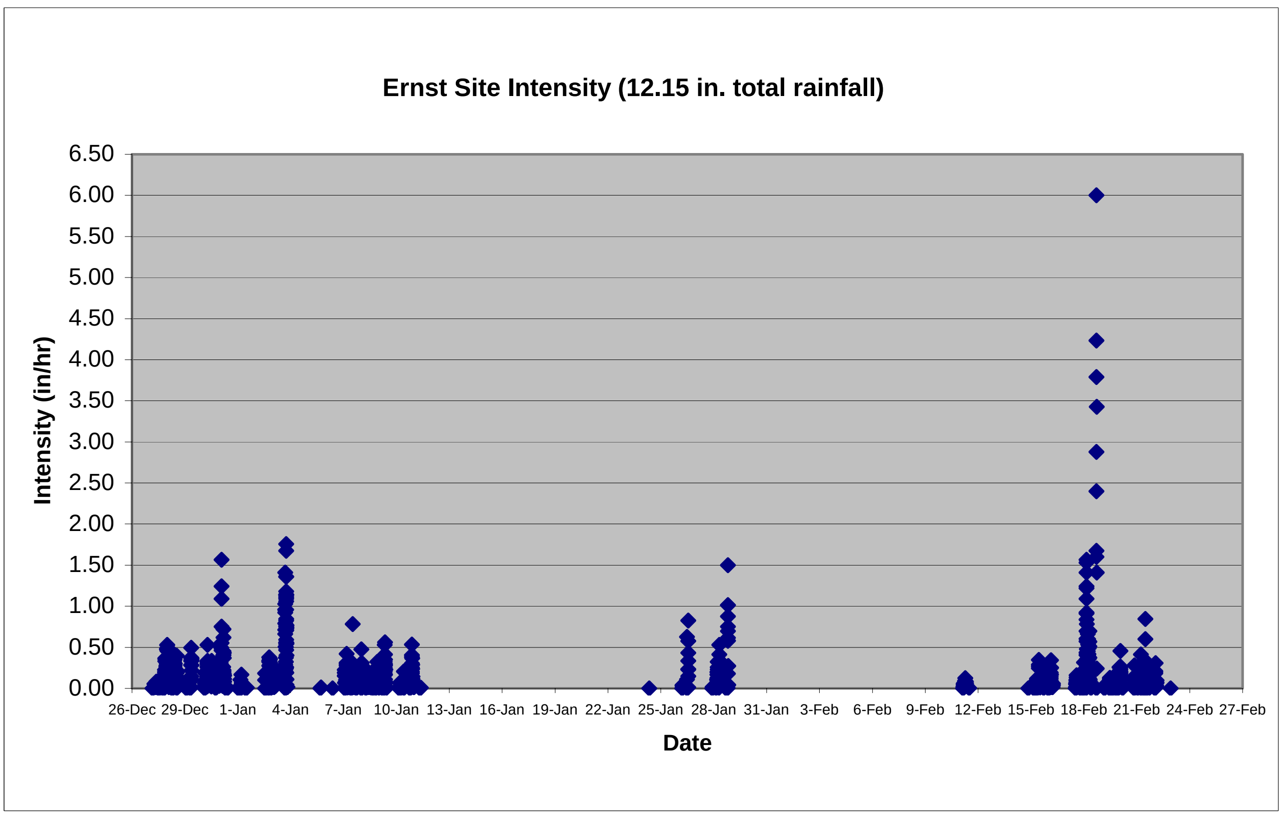

Figure 6. Rainfall intensity at Ernst site from December 26, 2004 through February 28, 2005.

The intensity graph in Figure 6 shows that the site was subject to five short duration events where the intensity exceeded one inch per hour. There were approximately sixteen events where the rainfall intensity exceeded the landowner’s one-half inch per hour estimate of soil infiltration rate.

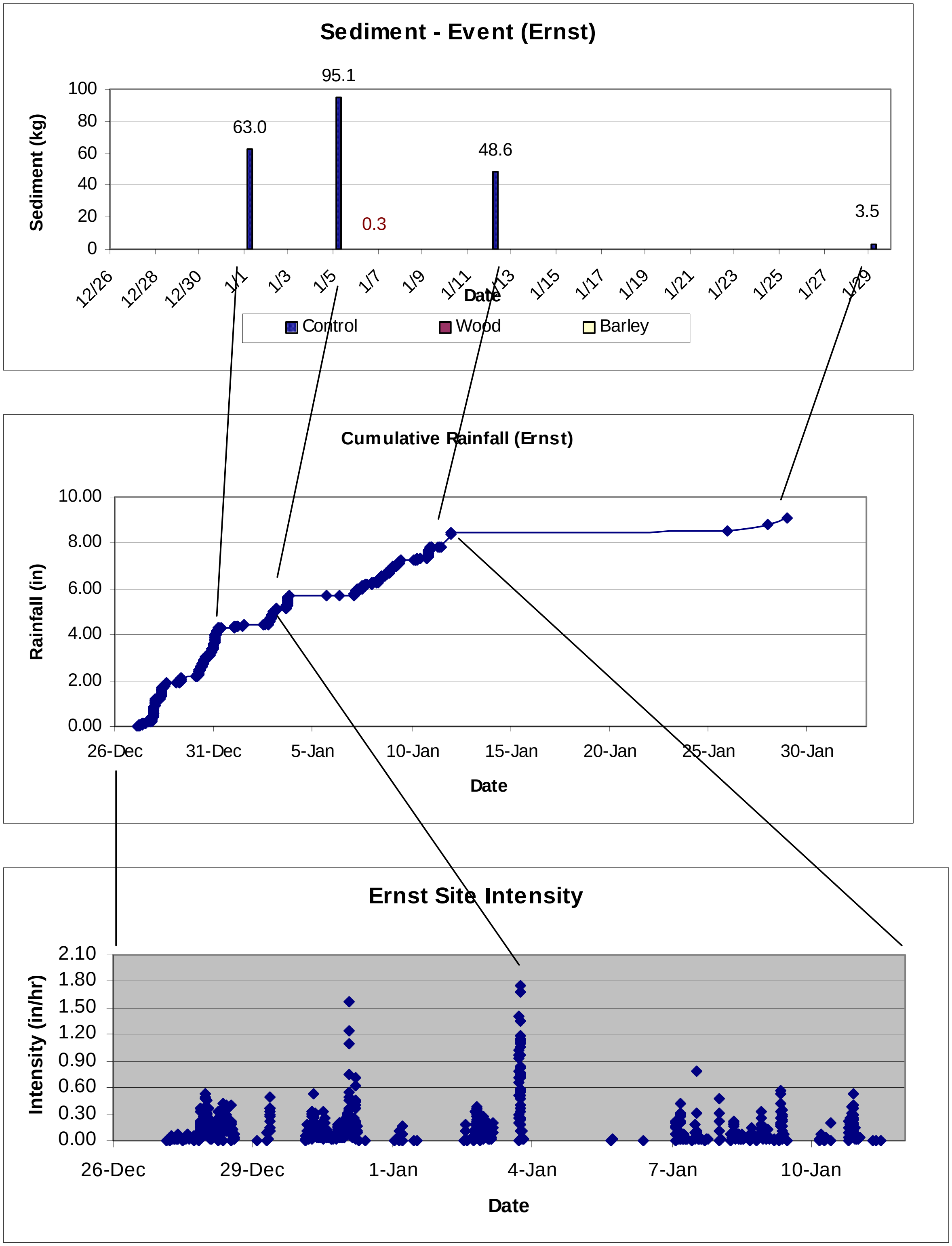

Figure 7. Linked graphs from Ernst Site for the period December 26, 2004 through January 30, 2005.

If we consider the first series of storms that occurred after installing the plots, we can show the relationship between rain intensity and sediment delivery from the site. The landowner collected sediment at the first day after each storm when he could get to the site. The first rain event on December 28-29 did not produce runoff from any of the plots. However, the December 30-31 event produced runoff from the bare soil plot. A total of 63kg (139 lb) (dry weight) of sediment was removed from the bare soil plot and nothing was recovered from the straw or wood-strand plots.

A larger rainfall event on January 3-4 resulted in 95kg (209 lb) of additional sediment from the bare soil plot, 0.3 kg (10 ounces) of sediment from the wood-strand plot and still no sediment from the straw plot. As can be seen from the figure, additional runoff and sediment occurred on the bare soil plot at each major event, but no additional sediment was delivered from either the straw or wood-strand plots.

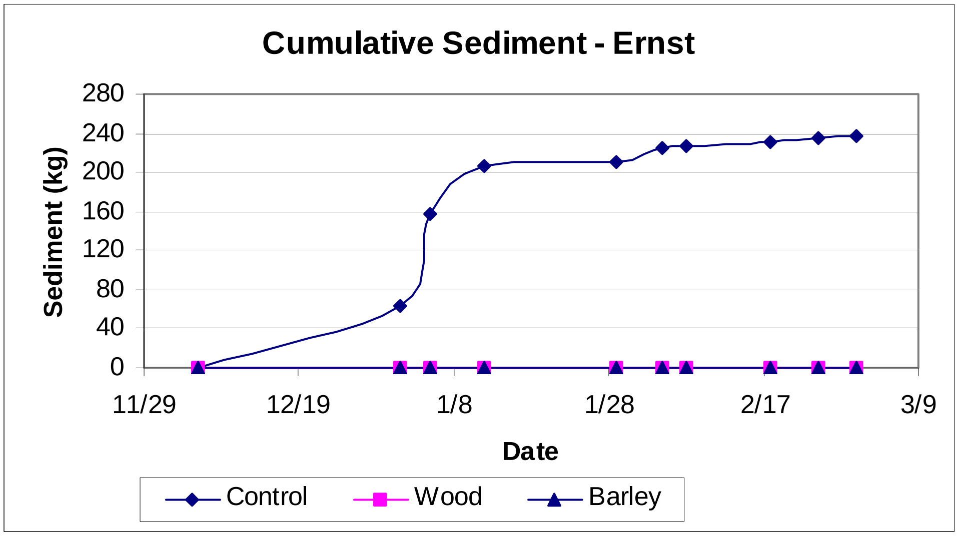

Figure 8. Cumulative sediment for treatments at Ernst site. As of February 28, the cumulative amount for bare soil plot was 238kg, the wood-strand plot was 0.3kg and 0.0kg for barley straw plot.

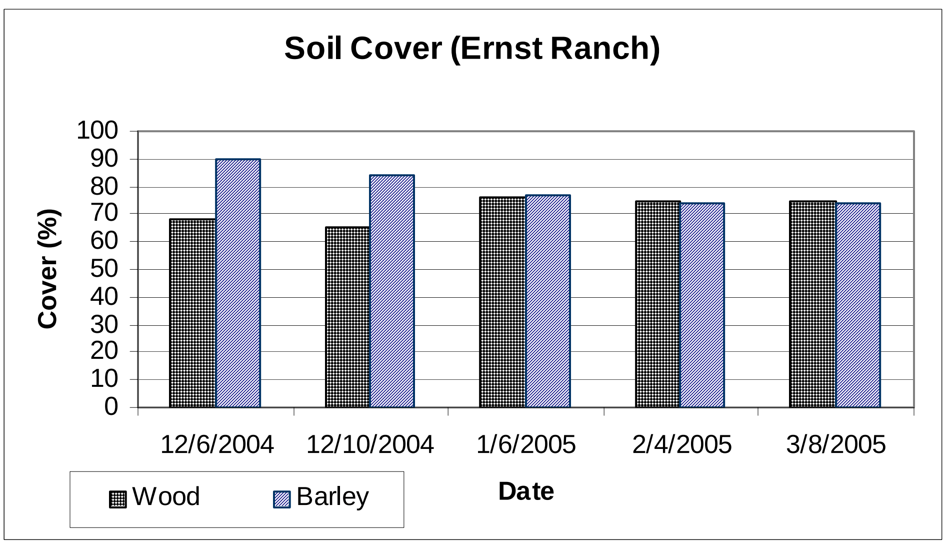

Figure 9. Measured soil cover for wood-strand mulch and barley straw mulch.

As noted earlier, the target application rate for barley straw was 90 percent and for wood-strands was 70 percent. Measurements of mulch coverage were taken using a point-intercept grid on a clear acrylic sheet. The square grid had 64 points spaced 40 mm apart. The grid was placed at twelve semi-random locations on the upper, middle, and lower sections of the plot. Points directly above functional mulch pieces were considered "hits." Total hits as a percentage of total points were used to determine the percent cover.

Over the three months from December 6 through March 8, the wood-strand cover continued to be approximately 70 percent. Variation from observation-to-observation is visible in Figure 9; however, the cover differences are not significant. The cover for barley straw has declined from an initial 90 percent to a March 8 cover of approximately 70 percent. By observation the reduction is due to loss of leaf area as the leafy component decays. The current cover is primarily due to stalk material.

Ernst Site Conclusions

The Ernst site near Paso Robles, California received nearly 12 inches of rainfall during the three-month study period. Rainfall included approximately sixteen events where the intensity exceeded infiltration, and six events where the intensity exceeded 1.5 inches per hour. More than 230 kg of sediment eroded from the bare soil control plot, while only 0.3 kg eroded from the wood-strand plot and none eroded from the straw mulch plot. In agronomic terms, the bare plot eroded at a rate of 7.3 tons per acre.

Both erosion control materials performed flawlessly, and reduced sediment by more than 99 percent compared to the bare soil plot. During the first three months after application, there was no difference in performance between wood-strand mulch and barley straw mulch when applied at the tested rates of 70 percent cover for the wood-strands and 90 percent cover for the barley straw.

Figure 10: Ernst site on January 3, 2005 with wood-strand plot on the left, bare soil in the center, and barley straw plot on the right. As of this date, neither of the treated plots showed any signs of rill erosion.

Chambers Creek Results

The Chambers Creek experiment was installed on November 3-4, 2004 and continued through the end of February 2005. The experiment will continue informally until the site is graded later in 2005. Figure 11 shows the cumulative rainfall for the study period. In addition to cumulative rainfall, we were able to calculate instantaneous intensity for each tip of the rain gauge (0.01 in) as shown in Figure 12.

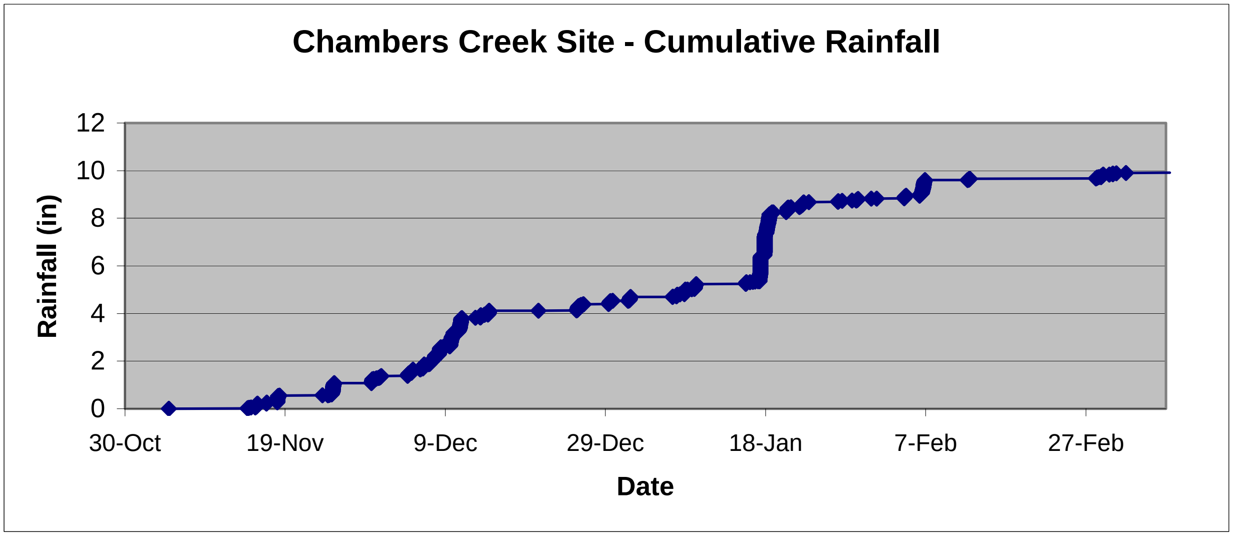

Figure 11. Cumulative rainfall for Chambers Creek site.

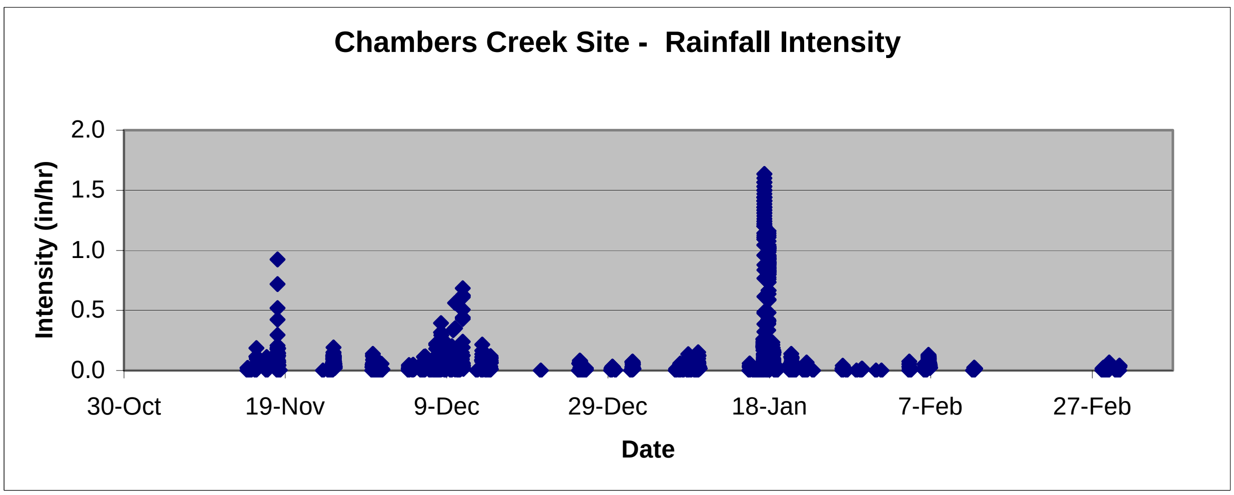

Figure 12. Rainfall intensity for the Chambers Creek site.

The Chambers Creek site received nearly ten inches of rainfall during the three-month study period. This is approximately half of what is expected in a normal winter. The site did not receive any snow. Three events included rainfall intensity above one-half inch per hour. Only one event exceeded one inch per hour. Surprisingly, the event on January 18 did not result in an increase in sediment. We suspect that the event, though intense, did not exceed the infiltration capacity of the glacial sand soil. Inspection of the plots indicated that water did pond on the surface and move some sediment short distances (less than 0.5 m) within both the wood-strand and wheat straw plots.

Sediment collection aprons were cleaned approximately monthly by Forest Concepts, beginning on November 4 when the plots were installed and continuing through March 14. Sediment on the apron consisted of three fractions. One fraction was sandy material that was deposited either from rainfall or wind action. A mulch fraction consisted of strands of either wheat straw or wood-strands. A stone/gravel fraction consisted of larger (greater than 6mm) stones and gravel that were likely deposited from dry ravel. For purposes of presentation and discussion, we are only displaying the sand fraction.

Table 2. Measured sediment from Chambers Creek plots vs. date.

Sediment Collected - sand only (kg)				
	Ag 1	WS 2	Ag 3	WS 4
4-Nov	0.00	0.00	0.00	0.00
20-Dec	2.04	1.28	1.17	0.56
4-Jan	0.38	0.17	0.50	0.31
8-Feb	0.00	0.00	0.09	0.10
14-Mar	0.00	0.00	0.01	0.02

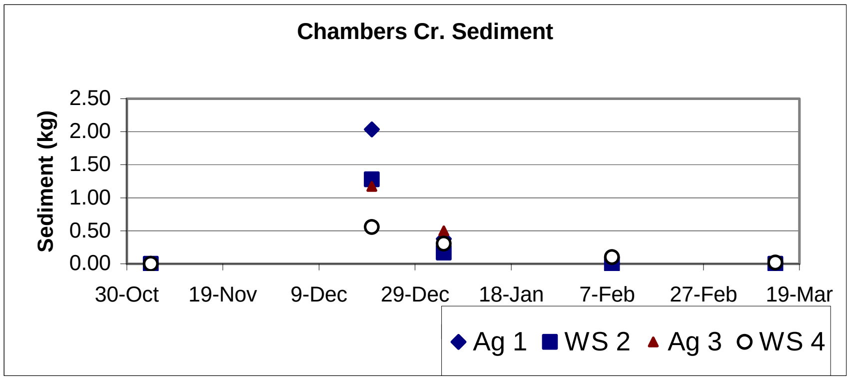

Figure 13. Measured sand sediment from Chambers Creek plots versus date. Additional large stones from dry ravel is not included.

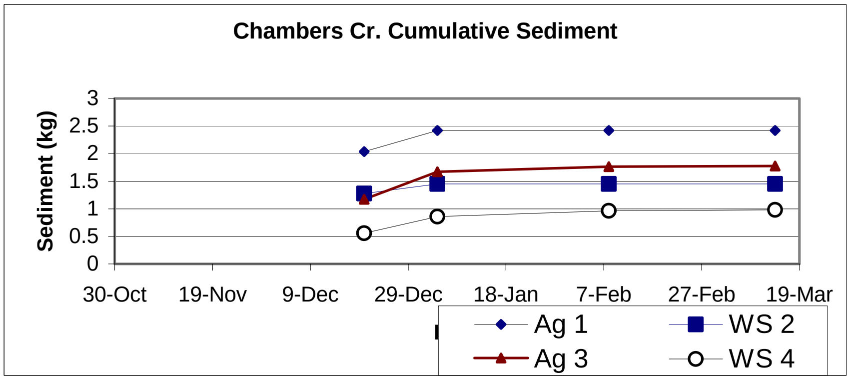

Figure 14. Cumulative sand sediment from Chambers Creek plots versus date.

The amount of sediment captured at the Chambers Creek site was a fraction of the amount that we expected. Although inspection of Figures 13 and 14 suggests that the wood-strand plots had consistently less sediment than the wheat straw plots, the differences are probably not significant. Adjacent to the shallow slope plots, we installed a silt collector on an open area as a bare soil control. To date, there has been no sediment delivered from the bare soil plot.

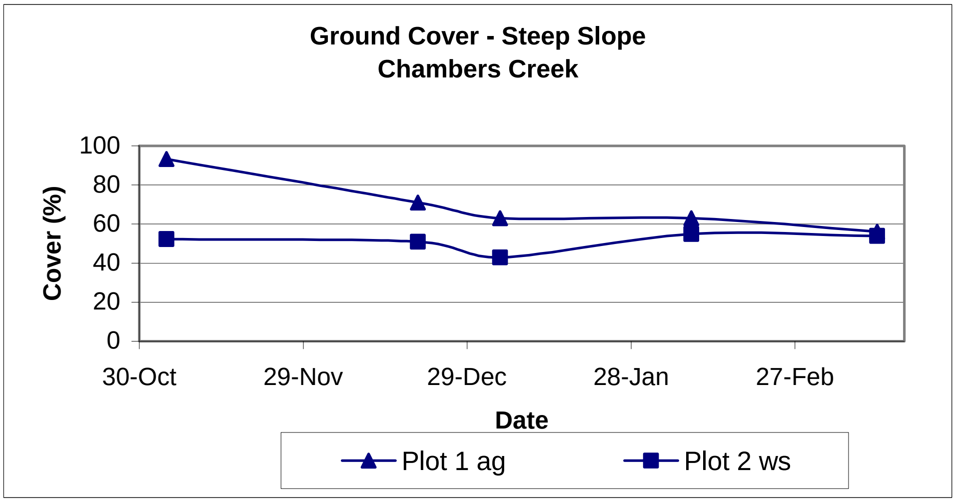

Figure 15. Measured ground cover over time for the Chambers Creek steep slope plots.

The initial application rates for wheat straw and wood strands were 90% and 50% respectively. The wood-strand material has maintained a constant soil cover throughout the study period. Variance from observation to observation are not significant. As was expected, the wheat straw lost leafy material over the first 6-8 weeks, leaving the more persistent stalks at a cover of 55 – 60 percent.

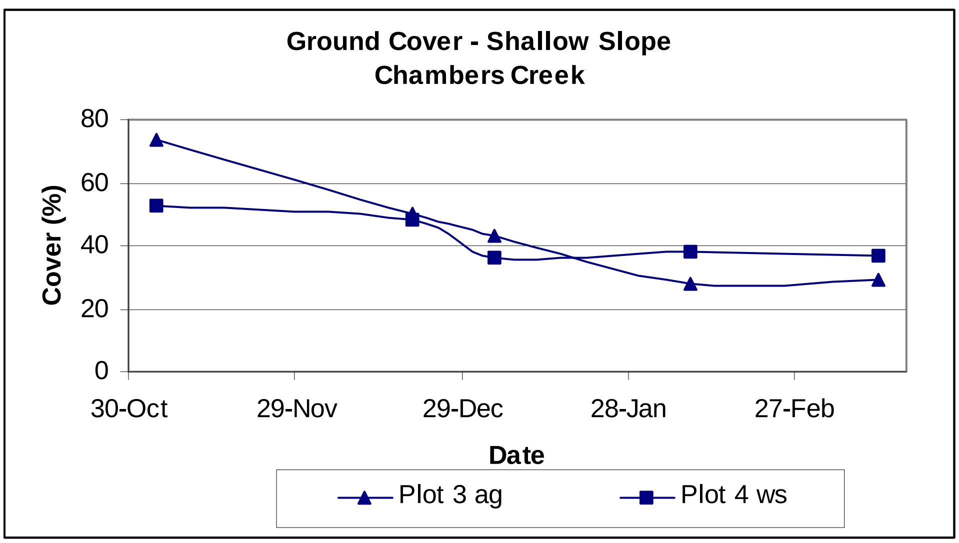

Figure 16. Measured ground cover over time for the Chambers Creek shallow slope plots.

Although the target initial cover for wheat straw on the shallow slope plot (ag 1) was 90 percent, the actual measured initial cover was 74%. Initial cover for the wood-strands was 53%. The coverage of both materials has declined over time to where the current coverage is 29% and 37% for the straw and wood-strands respectively. We do not have a ready-explanation for the loss of wood strands, and the more extreme loss of wheat straw cover. The site is in an open area, and there is ample sign of birds including eagles, other raptors, seagulls, and smaller birds using the site. The most likely explanation is that birds and small mammals are collecting the straw materials and removing them from the plots.

We were concerned that the Chambers Creek site would be affected by normally high winds that blow off of Puget Sound. We observed some clumping of both the wood-strands and wheat straw on the steep plots, but cannot attribute that to wind. There was no apparent wind-related movement of materials on the shallow slope plots.

Chambers Creek Conclusions

The Chambers Creek site received just under ten inches of rainfall during the four month study period. Only two rainfall events included intensity above one-half inch per hour. Neither the shallow slope nor steep slope plots produced more than minimal sediment, probably due to a combination of low rainfall and high infiltration rates of the soil. During the first four months after application, there was no difference in performance between wood-strand mulch and wheat straw mulch when applied at the tested rates of 50 percent cover for the wood-strands and 75 - 90 percent cover for the wheat straw.

(A) (B)

Figure 17. Overview of Chambers Creek plots. Shallow slope (A) and steep slope (B).

Acknowledgements

The Chambers Creek study was installed in cooperation with Pierce County Public Works and Utilities. Anne-marie Marshall-Dody provided project coordination.

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