FIELD EXPERIENCE WITH WOOD-STRAND EROSION CONTROL MULCH ON MINE AND PIPELINE PROJECTS[1]

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Abstract. Soil erosion is a significant risk during and after grading operations on mine and pipeline sites. A range of materials are commercially available to reduce the erosive effects of wind and/or rainfall, including agricultural straw, hydraulic mulches, and rolled erosion blankets. Each of the conventional materials have limitations sufficient enough that federal agencies supported development of a new material beginning in 2002 that would be long-lasting, wind resistant, naturally weed-free, and could be transported and applied using conventional hay and straw methods. Three years of research and development resulted in a wood-strand material that is optimized for technical performance and ease of application. More than 15,000 tonnes of the wood-strand material has been used on a range of road, post-wildfire, watershed protection, streambank and other uses across federal, state, and private lands in the western United States. Among the federally sponsored projects have been many abandoned mine lands (AML) sites. When permitting or contracting new mine and pipeline projects, Federal land agencies including the Bureau of Land Management and the USDA Forest Service have recommended or specified the new material or specified that erosion control materials used must meet its technical performance. Since its commercial introduction in 2005, wood-strand erosion control mulch has been used on at least fifteen mine and pipeline projects in eight western states. This paper reviews the science and design process that led to the technical features of the wood-strand mulch. The paper reports results of a recent survey of land managers, project leaders, and erosion control contractors to assess performance versus design criteria for the material. Results of the survey indicate that engineered wood-strand mulches offer viable wind and water erosion control while providing additional benefits of being weed-free, long-lasting, and wind-resistant. Results of the survey are being used to improve the material and update guidelines for its specification and use for erosion control on mines, pipelines, and other severely disturbed areas.

Additional Key Words: soil, slope, wind, water, rainfall, sediment

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Introduction

Agricultural straw is widely used for erosion control in projects throughout the world, including mine sites, drill pads, pipelines and other disturbed landscapes. Straw is inexpensive, readily available and easy to spread by hand or machine. Recent events and new knowledge challenge the advantages believed to be held by agricultural straw, particularly when used in hillslope, mine, pipeline, highway, wildland and forest applications. Limitations associated with agricultural straw erosion control materials include:

- Agricultural straw has been implicated as a source of noxious weeds not already naturalized in a landscape (Associated General Contractors of Washington, 2002; Robichaud et al., 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 or months of exposure to the weather (Wishowski et al., 1998).
- During the critical first weeks after seeding and mulching, straw mats may absorb and trap most of short-duration rainfall events that re-evaporate to the air, thus reducing rainfall infiltration to support germination and early seedling growth (R. Foltz, Per Comm.)
- Wheat, barley and rice straw are easily blown off of sites exposed to wind (Copeland, 2007; Copeland et al., 2006; Copeland et al., 2009). Bare areas exposed by wind are subject to increased erosion and may be trigger points for rill formation and for sediment movement . Straw is documented to blow away at less than 6 m/s (13 mph) (Whicker et al., 2002).
- 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).

Forest Concepts was first approached in 1998 by a regional manager from the Washington State Department of Ecology and asked to develop a wood-based alternative to agricultural straw mulch for use in the Seattle watershed. Their objective was to reduce invasive weeds and herbicide residue leachates that were documented from use of wheat straw on road obliteration projects. A similar request was received from USDA Forest Service and USDI Bureau of Land Management erosion control specialists in 2001 as they faced uncontrollable invasive weed infestations after use of agricultural straw on road and post-wildfire projects. All three of these land management agencies wanted a material that was:

- Environmentally compatible with the soils and ecosystems where it was being applied both during its functional life and as it decayed into duff or soil organic matter
- Long-lasting with sufficient functional stability and performance life until seeded or natural revegetation provides at least 50 % soil cover and assume the natural roles of rainfall interception and surface water erosion control
- Inherently weed-free without need for sterilization, chemical treatment, or inspection.
- Baled and able to be applied with straw blowers so as to use proven and existing straw logistics and application systems

- Effective at high winds (defined by the USFS as 35 miles per hour at the surface)
- Effective from flat surfaces to at least 30% slope on highly erosive soils

The engineering team at Forest Concepts was selected by USDA to develop a new wood-based erosion control alternative to agricultural straw for use on public lands. Forest Concepts was known to have deep competencies in a) translating natural resources issues into engineering functional objectives (Dooley, 1994; Dooley, 2000), b) a development process that leads to innovative and effective solutions (Dooley and Fridley, 1996, 1998b), and c) experience designing new wood products and processing methods (Dooley and Fridley, 1998a; Dooley and Paulson, 1998). The USDA Small Business Innovative Research Program (Grant number # 2003-33610-13997) provided funding for Forest Concepts to work with the Forest Service and other specialists to design a wood-strand material that looks, applies, and performs like straw, BUT is naturally weed-free and ecologically compatible with forest soils. Additional programmatic funding was provided to the USDA Forest Service Rocky Mountain Research Station to support the Forest Concepts effort.

Problem Analysis

Engineers, together with technical and market specialists began the development effort by conducting a thorough problem analysis to understand the literature surrounding erosion control and to translate natural language needs expressed by land managers into actionable technical specifications.

Wind Erosion Problem

Wind erosion is a major ecological, social, and human health problem, with only limited means for its control. Wind erosion on construction sites, low volume roads, and bare-soil is a substantial source of particulate pollution and public outcry. Loss of soil from project sites due to wind erosion affects the health and quality of life in downwind neighborhoods and communities. Untreated mine tailings and mine site reclamation projects are also substantial sources of dust until such time as surface organic matter and vegetation develop to provide soil cover (McGinley, 2002). Additionally, large areas of forest and grasslands adjacent to neighborhoods and communities are burnt each year in wildfires. Post-wildfire wind erosion includes ash, cinders, and burnt mineral soil.

One recent study (Whicker et al., 2002) on the Los Alamos National Laboratory site concluded that wind erosion rates were significant at wind velocities above 6 m/s (13 mph). In this instance, suspension and resuspension of nuclear contaminants was a specific wind erosion control concern for Los Alamos. Field studies conducted near Lubbock, Texas by Stout (Stout, 2004) to validate a method for establishing the critical threshold for aeolian transport of soil also found that wind velocities in the range of 6 m/s resulted in the initiation of wind transport of soil particles. In the Columbia Basin of Washington State, wind velocities of 6 m/s have a two-day occurrence interval (Copeland et al., 2006).

There are many chemical wind-erosion and dust-control products on the market, but few that can be used on areas slated for revegetation. Dust control products (aka dust palliatives) fall into a number of types (Hare, 2007):

- Deliquescent salts - Calcium Chloride
- Lignosulfites - Lignite sulfide, pulp mill black liquor

- Resinous products
- Petroleum emulsions – asphalt emulsions
- Polymers – Acrylic co-polymer, Polyvinyl acetate, and similar adhesives
- Hydraulic short-fiber mulch – wood-fiber mulch, bonded fiber matrix
- Water – delivered by water trucks or sprinklers

Erosion control chemical sprays can prevent revegetation or produce ongoing soil problems (Raskin et al., 2005). Of the available materials, only hydraulic mulch and water are recommended for sites that will ever be revegetated. Water is only effective for a few hours at best, and its use is discouraged in areas where water-use restrictions are in effect. Thus, contractors in urban and suburban settings seek effective materials for those portions of their sites that are not amenable to chemical dust palliatives. Hydraulic mulch has a functional life of a few weeks, unless seed is added and irrigation or natural rainfall is sufficient to grow vegetative cover. Hydraulic mulch cannot be driven over at any time or the fragile matrix will tear and easily blow off of the treated area. Further, contractors working in forests and natural areas are typically unable to draw water from streams, ponds and rivers due to environmental protection regulations.

A new wind erosion control material was needed that: a) does not require mixing with water, b) is wind-stable on open graded areas, c) is compatible with future revegetation, d) can be applied over bare soil around trees, and around perennial vegetation, and e) is effective at reducing both rainfall soil erosion and dust emissions from bare soil.

Rainfall Erosion Problem

Soil erosion from disturbed areas and low-volume roads is a major source of water pollution in all areas of the United States (Dunne and Leopold, 1978). Water-related erosion is the movement of soil downslope due either to the splash of raindrops or overland flow of water. For unprotected soils associated with low-volume forest and agricultural roads or road construction and maintenance activities, the accelerated rate of soil erosion can produce negative effects downslope. Sediment that enters streams from upslope erosion is associated with the decline of salmonids in the Pacific Northwest (Bisson et al., 1997). Federal, state, and local water quality regulations prohibit discharge of sediments from construction activities into lakes, streams and rivers. Regulations also require contractors and agencies to use approved erosion prevention and sediment control methods.

The causal mechanisms for rainfall-induced erosion include raindrop impact that dislodges soil particles and overland flow of water acting upon an unprotected or erosive soil. The rate of erosion is a function of soil type, slope, rainfall intensity and duration, soil cover, root strength and many other factors. For a given climate and site condition, the primary method of controlling the erosion rate on disturbed land is to manipulate soil cover through the addition of mulches, blankets, and the like. It is expected that vegetation will establish and grow to assume the cover function over time.

There are ongoing erosion control research programs across the United States and throughout the world. Interest and research activity are sufficient to support frequent international symposia, such as the recent Soil Erosion Research for the 21st Century conference in January 2001 (Ascough and Flanagan, 2001). Soil particle mobilization through raindrop impact has been studied extensively in the past (e.g., (Ellison, 1944; Thompson and James, 1985). The only effective method found to reduce raindrop impact is to provide soil cover with a material that absorbs the force of raindrops and protects soil aggregates from direct impact from raindrops.

As we designed an optimal wood-strand erosion control material, we sought to provide the dual functions of intercepting rainfall drops and increasing on-slope storage of water and sediment. We know that increasing cover should decrease the rate of raindrop-related sediment mobilization. We also know that increasing the surface roughness through higher material piece count and material thickness should decrease water velocity and increase depression storage. That is, ponding of overland flow above a wood strand reduces the velocity and provides an increased opportunity for infiltration. As predicted by the Random Roughness relationships for depression storage, the effect to reduce erosion and increase infiltration can be significant (Govers et al., 2000). With a veneer-based wood strand, we expect that the roughness effect will last for several growing seasons. This contrasts to the roughness effect of straw, which is generally lost within a few weeks to months (Wishowski et al., 1998).

Rainfall Absorption and Re-evaporation Problem

A portion of the leading edge of rainfall events is captured by erosion control mulch through a combination of matrix surface tension, adsorption, and absorption. This is an un-quantified side effect of using organic mulch for erosion control. In the case of thick mulches such as agricultural straw or adsorptive fibrous mulches such as hydraulic mulch, capture of rainfall from short duration, low intensity events may effectively preclude soil infiltration needed for soil organisms, seed germination, and plant growth. However, capture of the leading edge of short duration high intensity events (e.g., thunderstorms) may preclude soil erosion, rill formation, and downslope flash floods. Tradeoffs between concurrent objectives of erosion control and maximizing infiltration require that managers have access to data on rainfall capture by alternative mulch materials.

Since no data existed in the literature, Forest Concepts conducted a rainfall simulator experiment to quantify rainfall interception and storage by straw mulch applied at BMP (best management practices) rates and an early version of the wood-strand mulch being developed for federal agencies. Both materials were evaluated in small plots on a sloped-table rainfall simulator. Simulated rainfall was applied for up to 25 minutes at 54 mm/hr with large droplets typical of summer rains in the interior Northwest. Over the entire 25-minute event, the wheat straw captured 3.5 times the rainfall (2782 g/kg vs. 796 g/kg) that was captured by the wood-strand material when both were applied at a rate of 4.5 Mg/ha. In just the first three minutes of a simulated high intensity event, the wheat straw captured 2.9 times the rainfall (2131 g/kg vs. 734 g/kg) versus the wood strand material. When the results are allocated to a treatment area basis, the wheat straw mulch at an application rate of 4.5 Mg/ha will capture approximately 1 mm of rainfall in the first five minutes of a high intensity event and approximately 1.25 mm over the first 25 minutes. In contrast, the wood strands captured 0.33 mm in the first five minutes and little more over the remaining time periods.

We concluded that both wheat straw mulch and wood-strand mulch capture most of their potential water holding capacity in a very short time after the onset of high intensity rainfall. We also concluded that large differences exist in the amount of rainfall captured by wheat straw and wood strands. Therefore, if the primary management objective is to increase rainfall infiltration opportunity while achieving good erosion control, then the wood-strand material will be a preferred option. However, if the primary objective is to delay the onset of runoff from hydrophobic or low-infiltration-rate soils, then the wheat straw mulch may be a preferred option.

Discussion with agency erosion control and revegetation specialists encouraged us to emphasize the increased infiltration objective since that applies to most site conditions.

Herbicide Carryover Problem

Occasional revegetation failures on straw-mulched sites could not be explained by lack of rainfall, poor seed viability, or other plausible factors. Questions have been raised as to whether revegetation issues, particularly those where grasses emerge well and broadleaf plants are suppressed or missing could be caused by herbicide carryover in agricultural straw mulches. Although issues with herbicide carryover from grain crops to sites mulched with straw have been well documented for urban gardens and organic farms, formal studies of herbicide issues on public land erosion control products had not been conducted. We have been unable to find any peer reviewed or general literature studies of how herbicide residues in erosion control straw products and revegetation straw mulch affect broadleaf species abundance and richness on construction sites or disturbed land. This is not surprising in one sense because such use of baled residue from herbicide treated crops is prohibited by the herbicide label (Dow AgroSciences, 2008) and neither buyers or sellers are likely to admit to using an unpermitted material. However, anecdotal reports suggest that baled straw mulch from treated fields is widely available in the commercial market.

The herbicide clopyralid has been registered for use in the United States since 1987 (Cox, 1998). The chemical is used alone or in combination with other herbicides (Dow AgroSciences, 2002). Clopyralid and the related picloram compound are synthetic plant hormones that have been proven to be particularly effective to control broadleaf weeds in grain crops. Clopyralid containing products were first registered in California in 1997 (de la Fuente, 2002) and across the western US at about the same time. Immediately thereafter, reports began to emerge about apparent herbicide damage in gardens and crops where straw-based and lawn-grass composts and mulches had been applied (de la Fuente, 2002; Gaolach; Granatstein, 2001; Washington State University and Washington State Dept. of Ecology, 2002). As a result, the use of clopyralid and picloram in residential consumer weed killers was stopped, while agricultural use continued.

Both of these materials, clopyralid and picloram, are reported by the manufacturer, Dow AgroSciences, to bio-accumulate in the stalks of grain crops and affect the germination and growth of non-grass species when the straw is used as a mulch (Dow AgroSciences, 2002, 2007, 2008). The labels for both herbicides specifically warn: “Do not use straw from treated crops for composting or mulching on susceptible broadleaf crops.”

Unfortunately, in spite of label warnings, crop residue from herbicide treated fields is reported to be routinely baled and sold for erosion control mulch. Such use may be inadvertently encouraged by Extension publications that recommend spraying of hay and grain fields destined for “certified weed-free feed” with clopyralid and similar herbicides (de la Fuente, 2002). At this time there are neither state nor federal requirements to test for clopyralid residues in straw, compost, or mulches. As a result, herbicide containing straw may be unknowingly used in straw erosion control blankets, straw-based hydraulic mulches, and in baled straw erosion control and revegetation materials. Note that we are using the term “herbicide containing straw” rather than “herbicide contaminated straw” since the presence of the herbicide would be a result of planned cultural practices and not accidental or unintentional.

One of the earliest operational uses of wood-strand erosion control mulch was by the USDI BLM Boise District on the Snake One fire (B19E) near Weiser, ID in the fall of 2005.

BLM technical specialist Cindy Fritz monitored the application of seed, straw, and wood-strands during the initial application and for the following three seasons. Aerial seeding was prescribed on 5,790 ha (14,300 acres) and included a grass/forbs mixture. Drainage areas with high erosion potential were helimulched either with agricultural straw or WoodStraw® wood-strand mulch. Her *Third-Year Closeout ESR Monitoring Report* (Fritz, 2008) reported that overall revegetation success was high in the mulched areas and marginal where seeding was not followed by mulching. Total vegetative cover in years one, two, and three was higher in the wood-strand treated areas than in the agricultural straw treated areas. The plant community in both treatments was about evenly divided between native grass, perennial forbs, and seeded annual grass. Shrub species were only apparent in the wood-strand plots and not present in the straw mulched plots. One potential explanation for the increase of shrub species in the wood-strand mulched areas could be related to persistent herbicide residues in wheat straw used on the project. Unfortunately, there was no way to trace the straw back to the grower or farming practices, so the herbicide connection was speculative.

The issue was subsequently discussed at a national wildland fire burned area response meeting. There was support for some level of herbicide testing, but cost and logistics issues precluded any serious movement toward a policy solution to require testing or certification of straw mulches. The final consensus was that new erosion control materials that are not based on crop residue would make the herbicide carryover issue moot.

Development and Testing of Wood-Strand Erosion Control Material

The USDA SBIR Phase I activities included disciplined engineering design and experimentation to specify physical properties for a straw analog that meets or exceeds the performance of certified agricultural straw. More than 35 experimental runs were completed on the Forest Concepts rainfall simulator in Federal Way, Washington. Research quantities of wood-based strands of designated lengths and widths were produced for laboratory testing by the U.S. Forest Service Rocky Mountain Research Station (RMRS). Twelve additional experimental rainfall simulator runs were completed by Dr. Randy Foltz in a carefully designed experiment at the Rocky Mountain Research Station in Moscow, Idaho. Results of the RMRS experiments determined that a blend of wood-strands performed as well as agricultural straw in controlling erosion from a granitic soil. Two different wood-strand blends achieved 97 – 98 percent reduction in sediment delivery on a 30% slope at high rainfall rates (Foltz and Dooley, 2003).

Relying on the success of laboratory tests, the USFS requested that we make approximately one ton of a "July 2002 best solution" wood-strand mulch for field trials in Colorado. The material was delivered to Dr. Peter Robichaud in mid-July and deployed in early August 2002 at a field experiment on the Hayman Fire site in Colorado. Robichaud's FY2004 progress report suggested that the wood-strand material plots had significantly lower sediment output than straw mulched plots on the Hayman fire site (Robichaud and Wagenbrenner, 2005).

Mathematical modeling of surface water hydrology at the millimeter scale and physical prototyping by Forest Concepts suggested that it might be possible to substantially exceed the functional performance of agricultural straw and other commercially available mulch products with an engineered wood-strand material. It appeared that physical properties such as strand shape and thickness, as well as blends of components with diverse physical properties could be optimized for particular slope, soil, and climatic conditions.

Figure 1. Agricultural wheat straw at 70% soil cover.

Figure 2. A "high storage" 2002 prototype blend of engineered wood-strand material at 70% soil cover.

Following modifications in wood-strand design, a second round of experiments at the USFS lab was completed in 2003-2004 to further evaluate the effects of wood-strand properties. Variables examined in a series of factorial experiments were: strand length (160, 80, and 40 mm), 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 50 mm/hr plus two levels of added overland inflow beginning 15 minutes into the trial.

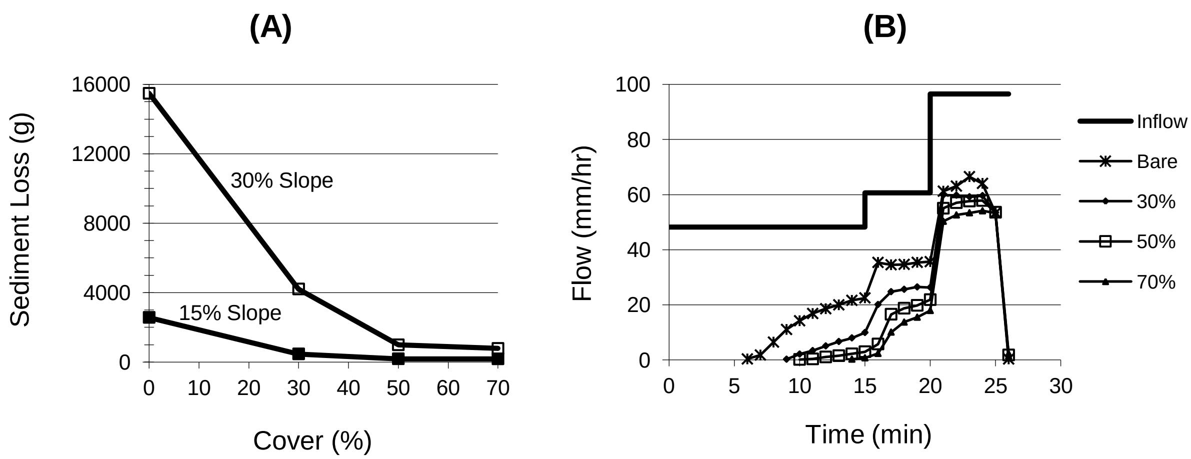


Figure 3. Sediment loss (A) and runoff hydrograph (B) for varying cover amounts of wood strands (Yanosek et al., 2006).

The USFS data (Yanosek et al., 2006) shows that very effective erosion control can be obtained at 50% ground cover. This compares favorably to equivalent 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.

The wood-based material is designed to perform the erosion control function as well as wheat or rice straw without being a potential source of non-native weeds, agricultural pesticide residues, and other foreign materials in pristine forest areas (Foltz and Dooley, 2003). While the functional performance of the wood-strand material has been demonstrated to be equivalent to wheat straw, other factors were observed that may cause secondary-effect differences. For example, equivalent sediment control is attained by the wood-strands at substantially lower ground cover rates than for wheat straw mulch. Increased open areas may encourage native plant emergence, and may increase raindrop impact on the soil surface with resulting increases in soil crusting.

A first proof of concept study for the wind erosion control potential of wood strands was conducted during the 2005-06 academic year at the USDA ARS laboratory in Pullman, WA. Dr. Joan Wu and Dr. Brenton Sharratt guided a graduate student (Ms. Natalie Copeland) to test the efficacy of wood-strand materials under laboratory wind tunnel conditions.

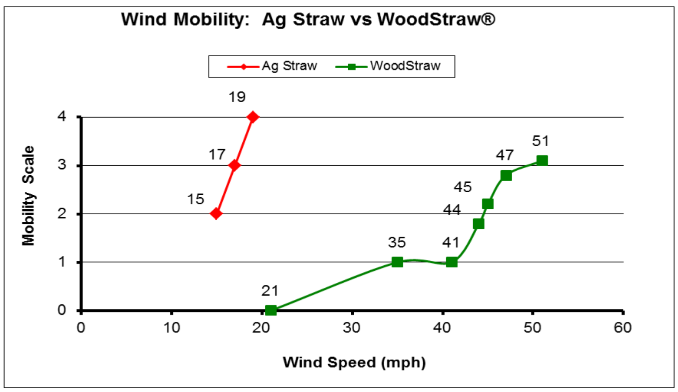
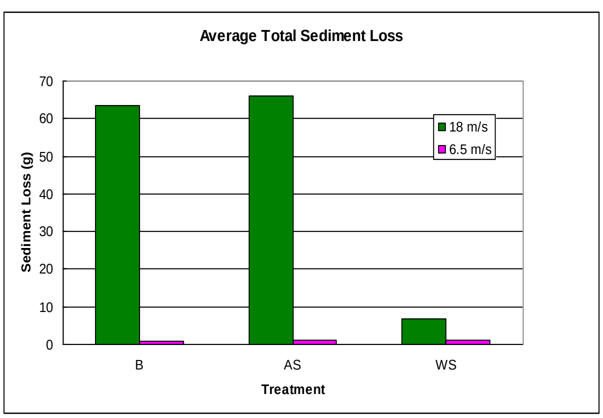
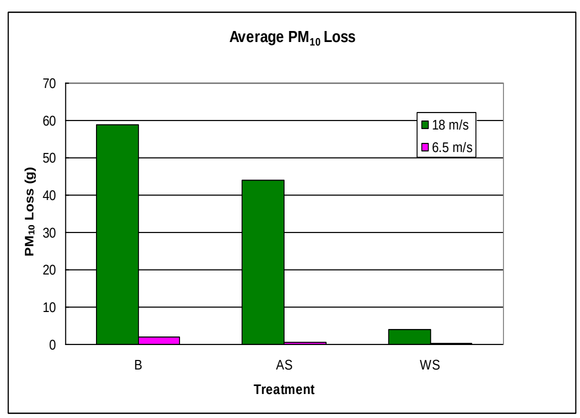


Figure 4. Results of an experiment at USDA ARS laboratory in Pullman, WA showing the threshold velocity for wheat straw versus one wood-strand blend under wind tunnel conditions (Copeland et al., 2006). At a movement score of 3, mass mobilization of the material begins, and at score of 4 all material is lost from the plot.





Figures 5 and 6. Results of wind tunnel experiments comparing bare soil (B) to mulches demonstrate that wood strands (WS) of the type tested are more effective than straw mulch (AS) for controlling both total sediment and fine PM_{10} dust emissions (Copeland et al., 2006).

The charts above clearly demonstrate the potential for wood-strand wind erosion control materials to effectively reduce wind erosion from graded soil. As discussed earlier, the effectiveness of any mulch material is determined by its mobility at target wind velocities. The charts above show that at low 6.5 m/s wind speed (2 day occurrence event in central Washington) the straw mulch stayed in place and performed well. However, at the 18 m/s wind speed (2 year occurrence under central Washington conditions) the agricultural straw mulch treatment actually increased total sediment. This was attributed to the straw acting as a soil surface abrader when it blew off of the plot. This finding reinforces the need to develop wind erosion control mulch materials that are wind-stable at target wind speeds.

Resulting Wood-Strand Mulch

The resulting wood-strand erosion control material incorporates functionality and composition that address the known limitations of agricultural straw and meets the functional requirements of public agency cooperators:

- Manufactured from clean wood to be ecologically compatible with forested and brush covered landscapes, be inherently weed-free, and free of pesticide residues
- Designed as a multi-part blend of strands that are stable at design cased winds of 18 m/s as well as stable on hillslopes subjected to overland flow.
- Demonstrated to prevent or minimize rill formation and propagation.
- Demonstrated to reduce sediment loss by at least 85% on highly erosive soils.
- Packaged in bale form to be compatible with straw bale infrastructure and straw blowers.
- Can be applied or blown at high moisture to minimize dust creation.

Early in 2005, product engineers and business managers at Forest Concepts, as well as advisors from the USDA Forest Service and BLM, concluded that the new wood-strand erosion control mulch had achieved all design objectives and performance criteria. The material was approved by the interagency Burned Area Emergency Response (BAER) national program leader for use as a post-wildfire erosion control material beginning with the 2005 fire season.

Commercial Use of Wood-Strand Mulches

Engineered wood-strand erosion control mulch was first commercially produced and marketed in 2005 under the WoodStraw® trademark. It is now manufactured in Colorado under the Blue-Straw™ brand name. Wood-strand erosion control mulch (US Patent 6,729,068) is increasingly a preferred alternative to agricultural straw mulch as well as the more expensive rolled erosion control blankets for both water and wind erosion control on many high-value sites. More than 15,000 Mg (metric tons) of material have been applied to approximately 300 projects on public and private lands of the United States. Among the early uses are active mine sites, restoration of abandoned mine lands, pipeline construction, and utility corridor construction. In the past few years, wood-strand mulch has been used on more than fifteen significant mining and energy related projects, with positive results.

In some cases, production and sales staff at Forest Concepts do not know the end-user or use of wood-strand mulch that is shipped through dealers or distributors. However, mine and pipeline projects known to have used wood-strand erosion control mulches include:

Mines

- Crandall Canyon Mine – UT – Scamp Excavation
- Midas Gold – ID – Midas Gold, Inc.
- Barrick Mines – NV – BLM/Barrick Mines
- Swastika Mine – NM - Eight 14 Solutions
- Mayflower Mine – OR – Cascade Earth Sciences
- Metaline AML – WA - – Cascade Earth Sciences
- Freeport McMoran – AZ
- Livingstone Mine – ID – JR Thornton
- Champion Mine – OR – PSC
- Rio Puerco Mine – NM – Grants Ridge Reclamation
- Whiteoak Mine - UT – Skyline Reclamation
- Smelter Flats Mine – ID – JR Thornton
- Sugarite Mine – NM - Samcon

Pipelines

- Williams Pipeline – CO – Mt. West
- Ruby Pipeline – NV - BLM

Now that the wood-strand erosion control material has been in use for up to seven years and many specifiers, applicators, and land managers are repeat users, Forest Concepts chose to conduct a survey of specifiers, applicators, and land managers to measure their satisfaction with this relatively new material, how well the current product delivers on the functional design specifications that guided its development, and how to improve the material for future projects.

Materials and Methods

We designed a web-based survey and provided links via an invitation email to persons who have had first-hand involvement in erosion control projects using the wood-strand mulch over the past seven years. The two principal authors of this paper have experience with survey design and administration in the past. The design of the survey and analysis were guided by the works of Dillman (Dillman, 1975, 2000). The survey was executed using an online, web-based survey provider. The software automatically summarized results and aggregated comments. A copy of the survey questions is included as an appendix.

The invitation to potential survey participants clearly stated that participation was voluntary, responses would be aggregated in ways that would render anonymity to participants, and provided a contact to call or email with questions or concerns.

Results of Survey

Invitations were emailed to twenty persons. There were six complete responses for a thirty-percent response rate.

One-half of the respondents were project managers, while others were technical specialists or contractors. Two-thirds of the projects were on federal lands and one-third of the projects were on behalf of state agencies. Mines and pipelines represented two-thirds of the project types, while the rest were classified as watershed protection projects. All of the projects were less than 50 ha (100 acres) with most of them having 1-10 acres of treated area.

Site conditions for the reported projects included mostly mixed slopes (50% of sites) or moderate slopes (one-third of sites). Soils were judged to be moderately or highly erosive. The most common application rate was 50% soil cover with one site being covered at 70% due to steep slopes. Two-thirds of the applications were completed by hand crews. Others used straw blowers to apply the wood strand mulch.

Respondents reported that wood-strand mulch was used on their project predominantly because of expectations about its erosion control performance (38% of responses). Other reasons to uses wood-strand mulch included its resistance to high winds (13%), long life compared to other treatments (13%), durability (13%), and avoidance of the risk to introduce invasive species had straw been used (13%).

During the design of the projects, respondents reported they considered agricultural straw (50%), hydroseed (17%), rolled erosion blankets (17%), and wood chips (17%) as alternative erosion control materials.

Compared to other erosion control methods, baled wood-strand mulch was judged to be somewhat difficult to handle and apply by half of the respondents, easy to apply (17%), moderately easy to apply (33%), and none reported the material to be difficult to handle and apply. These responses may be related to the fact that a majority of the sites reported the material was applied by hand crews without mechanical assistance from blowers, etc.

Overall performance considering all project objectives was considered excellent (50%) or good (17 %). One project is still too new to judge performance, and one project was reported having moderate overall performance for the wood-strand mulch. No projects were reported as having poor or “not-good” performance. In all cases but one, the wood-strand mulch was judged to be worth the cost.

Discussion and Conclusions

In spite of limited sample size for this first survey of wood-strand mulch users, valuable insights were obtained that reinforce many of the design objectives and identify at least one area for further investigation.

This area for further investigation is to explore methods for handling and application that are easier for application crews. Design specifications from our USDA Forest Service partners included baling the wood-strands so they can be handled just like straw mulch, but to reduce the bale weight to approximately 25 kg (55 pounds) to make baled wood-strands much easier to carry than hay bales that weight 40-50 kg (85-110 lb). There obviously is more to gain in ease of handling and application.

As expected, respondents considered agricultural straw as the most-often compared alternative product, with hydromulch, wood chips, and rolled erosion blankets as other alternatives. Wood-strand mulch is more expensive than agricultural crop residue straw and “free” wood chips. When compared to hydromulch, the limiting factor is often access to water for the hydromulch. Wood-strands are also known to be a fraction of the applied cost in comparison to rolled erosion blankets that must be carefully applied and pinned to the soil.

The results of the survey indicate that wood-strand mulches of the type developed by Forest Concepts in cooperation with the USDA, US Forest Service, Bureau of Land Management, and others offer viable erosion control while providing additional benefits of being weed-free, long-lasting, and wind-resistant. The technical staff and management of Forest Concepts plan to apply lessons learned from this survey, and to repeat the survey in the future as the installed-base grows.

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Appendix

Survey Questions

1. My background is a:
    - Project Manager
    - Technical Specialist
    - Land Manager
    - Soil Scientist
    - Hydrologist
    - Wildlife Biologist
    - Other:
2. The project was for:
    - The forest service
    - The BLM
    - The DNR
    - The DOT
    - A contractor
    - Other
3. Project Type:
    - Wildfire rehab
    - Mine reclamation
    - Pipeline
    - Road project
    - Watershed
    - Other
4. Project size (approximate acreage):
    - Less than 1 acre
    - 1-10 acres
    - 11-100 acres
    - 100+ acres
    - Other
5. WoodStraw® application rate:
    - 40%
    - 50%
    - 70%
    - Other
6. Slopes treated were:
    - Shallow/Flat
    - Moderate
    - Steep

Mixed
Other

7. Soil Types were:
    Not very erosive
    Mildly erosive
    Highly erosive
    Other

8. Primary reason WoodStraw® was used:
    Effective erosion control
    No invasive species
    Resistant to high winds
    Long lasting
    Durable
    Animals will not eat it
    "It's just wood"
    Required in specifications
    Other

9. WoodStraw® application method
    By hand
    Straw blower
    Heli-mulched
    Mixed methods
    Other

10. Additional materials considered:
    Agricultural straw
    Hydromulch
    Hydroseed
    Bonded fiber matrix
    Rolled erosion blankets
    Wattles
    PAM 12
    Other

11. How easy was WoodStraw® to handle and apply?
    Easy
    Moderate
    Somewhat difficult
    Difficult
    Other

12. How did WoodStraw® perform on your project?
    - Excellent
    - Good
    - Moderate
    - Not good
    - Other
13. Was WoodStraw® performance/benefits worth the cost?
    - Yes
    - No
    - If no, why?
14. Would you use WoodStraw® again for a project?
    - Yes
    - No
    - If no, why?
15. Would you recommend WoodStraw® to others?
    - Yes
    - No
    - If no, why?