South Fork of Dutch Creek Pilot Project Report

Photo Source: EcoFlight

ROARING FORK WATERSHED PLAN at work

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ROARING FORK CONSERVANCY

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

Contents

Acknowledgements

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On-the-ground photos for this report were provided by the U.S. Forest Service, White River National Forest. EcoFlight, of Aspen, Colorado, graciously flew over the project area on several occasions, and contributed the aerial photos which are included in this report.

Summary

Fifty years of large-scale coal mining activities occurred in Coal Basin, a western Colorado watershed characterized by naturally steep, unstable and highly erodible slopes. Today, erosion from the prior resource extraction and the landscape alteration caused by these activities, as well as sedimentation from naturally-occurring soil erosion and mass movements are degrading water quality and stream habitat in Coal Basin and contributing to sedimentation issues downstream in the Crystal River. In addition, Coal Creek Road (FSR 307) and 17 miles of historic mining roads are causing stream bank instability and sediment transport issues throughout the basin. Although the Colorado Division of Reclamation, Mining & Safety (CDRMS) completed a series of restoration projects in Coal Basin from 1994-2004, *nearly 650 acres of disturbed area directly connected to the Coal Creek stream system remains*.

Decommissioned mining road reclamation work was conducted on 10 acres in Coal Basin. This pilot effort was designed to assess the cost-effectiveness and utility of using soil amendments on disturbed soils (including compost and a compost/biochar mixture), coupled with drainage improvements to reduce the volume of surface runoff, improve the water and nutrient-holding capacity of the soils, reduce soil compaction and bulk density, and enhance the growth of native vegetation.

Project Background

Large-scale mining and associated activities (such as roads, wash plants, refuse piles, grazing, and logging) previously conducted on unstable, steep slopes, combined with major channel alterations at the mouth of Coal Creek, have severely impacted a large area within the Coal Basin watershed. The U.S. Forest Service (USFS) has identified over 645 acres of Connected Disturbed Areas (CDAs)[1] in Coal Basin that may benefit from restoration (*see* Figure 1). Noteworthy is the large area of natural clearings (approximately 6% of the watershed) that likely contribute high volumes of sediment to the stream channel.

The South Fork of Dutch Creek in Coal Basin (shown in Figure 2) is a good example of an impacted stream - the channel has a high width to depth ratio, lacks riparian vegetation, and excessive fines clog the channel. The 10-acre South Fork of Dutch Creek Pilot project was designed as a reclamation project for this severely-impacted area. The pilot project was also designed to study the costs and benefits of several different restoration techniques in order to determine the most favorable methods to be utilized in the planned landscape-scale restoration of Coal Basin.

The project is one of the first major initiatives developed under the 2012 *Roaring Fork Watershed Plan*, which identified as an *"Urgent Action"* the need to "[work] with landowners, resource experts, and other interested parties, [to] plan and implement riparian/ instream protection and restoration projects." Coal Basin, in the Crystal River Watershed, is at the top of the restoration project list.

[1] CDAs are disturbed clearings and roads that artificially intercept and combine natural channels, thereby increasing flows, erosion, and sediment transport.

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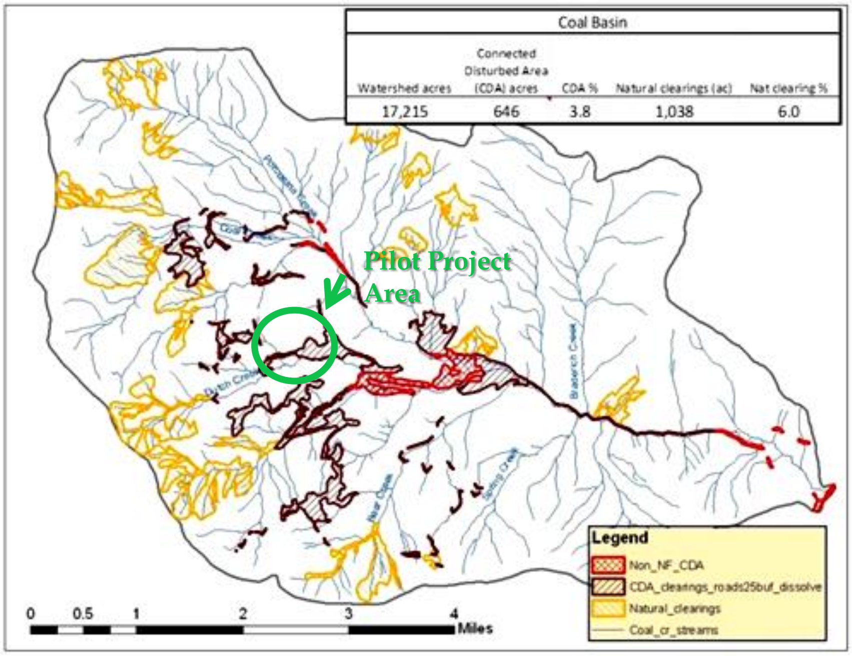

*Connected Disturbed Areas (CDAs) are disturbed clearings and roads that artificially intercept and combine natural channels increasing flows, erosion, and sediment transport.

Figure 1. Connected Disturbed Areas (CDAs) in Coal Basin; pilot project area is circled in green.

Figure 2. South Fork of Dutch Creek below the pilot project area.

To ensure that local residents, resource experts, and land owners and managers were informed about the project, extensive outreach was conducted by Roaring Fork Conservancy and the USFS beginning in May of 2011. This effort included presentations and field trips for numerous groups, ranging from local civic organizations to USFS White River National Forest (WRNF) leadership - almost 700 contacts. Coal Basin was chosen as a featured stop on the Colorado Foundation for Water Education's Upper Colorado River Basin Tour in June 2013, an event attended by the general public, state legislators and a local county commissioner. Press releases and articles in the RFC bi-annual newsletter provided additional exposure for the project.

A two-day *Coal Basin & Crystal River Area Restoration Workshop* was held in May of 2012 to develop strategies for continuing the critical restoration work undertaken by CDRMS in Coal Basin, and to discuss opportunities for improving the Coal Creek/Crystal River confluence area. The workshop brought nearly 50 hydrologists, soils scientists, geomorphologists, fish biologists, water quality analysts, plant ecologists and other technical experts together with highway engineers, mining reclamation experts, recreational planners, and other key stakeholders from multiple federal, state and local government entities, as well as local nonprofits and private interests (*see* Figure 3). Workshop participants identified seven near-term tasks, all of which built upon the "lessons learned" in the prior restoration efforts and utilized available information on the area's land use history, natural resources, and geomorphology.[2] One of the *near*-term (1-2 year) projects recommended by workshop participants was to: ***Support current USFS initiatives to rehabilitate sediment-producing mining-related disturbed areas with selected native plants in Coal Basin. Evaluate the efficacy of using biochar, or other soil-enhancing amendments, and selected native plant species as part of this restoration initiative*.** The pilot project tracks this recommendation.

Figure 3. May 2012 workshop participants.

[2] The full workshop report can be found at **www.roaringfork.org/coalbasin**.

Project Objectives

The South Fork of Dutch Creek Pilot Project is part of the larger Crystal River Assessment Project which has a goal of integrating and completing site-specific watershed projects to:

- Improve riparian area function/wildlife value,
- Reduce anthropogenic sedimentation,
- Improve upland vegetation to stabilize soils,
- Improve instream habitat and fisheries,
- Address water quality issues,
- Protect the Town of Redstone from flood flow damages, and
- Increase late summer stream flows.

The two objectives of the pilot project are:

1. **Successfully reclaim and reduce sediment-loading from more than 10 acres of the decommissioned road network in the former mining areas of Coal Basin, and**
2. **Assess the cost-effectiveness and utility of using biochar and other carbonaceous soil amendments in future large-scale reclamation efforts in Coal Basin and similar locations.**

Project Accomplishments

Reclamation Work

Based on 10 years of reclamation work in Coal Basin, CDRMS shared its major "lessons learned" at the *Coal Basin & Crystal River Area Restoration Workshop* :

1. Understand the environment at Coal Basin and work with its unique character;
2. Recognize that it is an exceptionally dynamic and mobile system;
3. Grazing should only be allowed after substantial maturity and diversity of vegetation have been established;
4. Build microclimates on site;
5. Disperse water at every opportunity on site; and
6. "Soils" and remnant refuse respond favorably to the addition of organic matter.

These "lessons learned" served as the cornerstone for the 10-acre road reclamation pilot project initiated by RFC and the USFS on the South Fork of Dutch Creek in September of 2012.

The South Fork of Dutch Creek study site was chosen in order to reclaim some of the highest sediment-producing portions of the decommissioned road network in the former mining areas of Coal Basin, and to assess the cost-effectiveness and utility of using carbonaceous soil amendments in this type of reclamation effort. Figures 4 and 5 and Table 1 identify the treatments and reclamation areas. The tasks involved in this project to-date have included:

1. Using the USFS CDAs analysis (*see* Figure 1) to select the pilot project reclamation site.
2. Reconnecting intermittent streams and ephemeral channels across old road prism using rocks for grade control and stability; eliminating headcuts; constructing water bars and cross-ripping road prism for water infiltration/routing, and soil deposition; placing wood perpendicular to

slopes on headcuts for stability and soil deposition; and constructing an intermittent stream alluvial fan.

3. Procuring biochar and compost and hauling these materials to the project site.
4. Amending soils in the pilot project area by incorporating a mix of biochar and compost.
5. Revegetating road prism and riparian areas adjacent to intermittent and ephemeral stream channels using ecotypic grass seed from the WRNF and USFS spruce seedlings.
6. Fencing the amended soil areas from livestock to allow for plant development.
7. Treating noxious weeds in the pilot project area.
8. Installing a soil moisture and temperature monitoring station on the project site.
9. Monitoring soil parameters and vegetation in the pilot project area.

Figure 4. Pilot project area with treatment areas outlined.

Figure 5. Pilot project area with work ongoing, September, 2012 (source: EcoFlight). Note the darkened surface at area 2c ("alluvial fan") area, where the largest volume of compost/biochar was applied.

Name of Treatment Area	Acres
1 Uppermost Treatment	0.14
Treatment 1 Shale	0.11
2a Upper Above Fan	0.1
3a Upper Control	0.06
4a Upper Switchback	0.14
2c Alluvial Fan	1.01
Road seeded and ripped	8.57
Total:	**10.13**

Table 1. Acreage for the pilot project treatment areas.

Site Modification

Site 2a in Figure 6 shows an intermittent stream channel failure associated with a road crossing. Some of the water from the channel was routed down the road, causing gullying and rilling and a head-cut where water exited the road prism. The area was rehabilitated by reconnecting and hardening the stream crossing, cross ripping the road prism adjacent to the stream channel, placing wood perpendicular to the slope at the head cut, amending the soils with biochar and compost, and seeding the entire area with locally-sourced ("ecotypic ") native grasses (*see* Figure 7).

Figure 6. Area 2a before restoration.

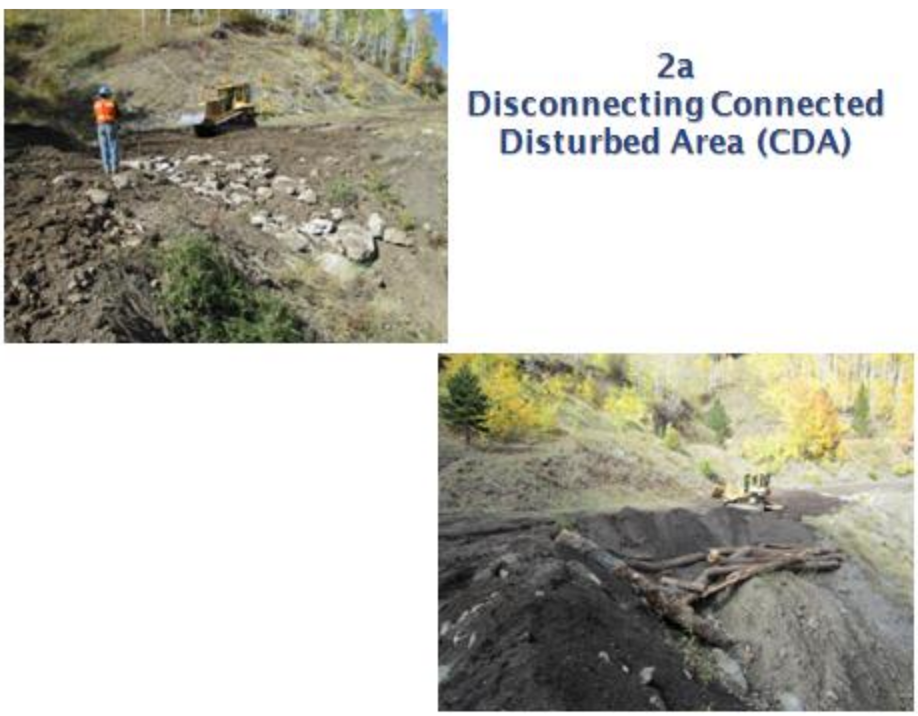

Figure 7. Area 2a during restoration.

Figures 8 and 9 show the road prism before and after reclamation. In Coal Basin there are approximately 17 miles of legacy mining roads that were built using the cut-and-fill method; these were in-sloped to convey water, which was subsequently routed through culverts under the road. The culverts contributed to channel degradation by increasing flows in channels not naturally designed to carry these flows. Part of the reclamation work done by CDRMS was to out-slope the road prism and remove the culverts. Additional work still needed to be done on the road prism to improve water routing, increase water infiltration and vegetative cover, and reduce soil losses by sheet flow and rill/gully erosion. To accomplish this, the road prism in the pilot project area was cross-ripped to a depth of 18”, water bars were constructed in-between the reconnected intermittent and ephemeral channels, and the entire road prism was broadcast-seeded in the fall of 2012. Selected areas were amended with compost and/or a compost-biochar mixture.

Figure 8. Road prism before treatment; road had minimal infiltration and excessive overland flow.

Figure 9. Cross-ripped road with compost/biochar soil amendment (above) and without soil amendment (below).

Figures 10-13 show the extensive work done on the intermittent stream channel (area 2c), road prism, and floodplain. The primary objective of this effort was to reduce overland flow and sediment delivery to the streams and to provide opportunities for water infiltration and sediment storage in the upland areas, all while increasing vegetative cover. Figure 10 shows the intermittent channel as it drops to the valley floor near the confluence with the South Fork of Dutch Creek. Low gradient areas and associated wide floodplains, such as this area, are where sediment is naturally stored. To attempt to mimic this natural function, restoration began upslope at site 2a and continued to the confluence area at site 2c. A natural alluvial fan located near the confluence of Braderich and Coal Creeks was used for reference during construction of the alluvial fan shown in Figures 12 and 13. Several things were done as part of this site reclamation: the stream road crossing was stabilized (as discussed above); the road prism was cross-ripped and soil amendments were added; a 1-acre alluvial fan was constructed; grade controls were installed at the downstream end of the fan/intermittent stream channel using logs; and the area was revegetated with a grass seed mix, spruce seedlings, and willow cuttings.

Figure 10. Area 2c alluvial fan before restoration (arrows show direction of flow).

Figure 11. Area 2c alluvial fan during restoration.

Figure 12. Area 2c alluvial fan during restoration.

Figure 13. Area 2c alluvial fan transporting water and dissipating sediment following restoration. May 13, 2013.

Soil Amendments

Figure 14 shows the application of soil amendments. The purpose of soil amendments is to reduce soil compaction/bulk density, increase soil moisture content, and provide nutrients for plants. Three treatment types were used: a control (no amendments); compost only; and compost with biochar. Compost was obtained from the South Canyon Landfill/Heartland Environmental Services and biochar from Biochar Reclamation, LLC. Table 2 lists the location of the different treatment options.

Figure 14. Application of biochar/compost and compost only soil amendments in treatment areas. Top left photo is a close up of biochar. Piles in photos are compost/biochar blend.

Treatment Polygon ID	Treatment Acreage	Soil Amendment Mix	Notes
1	0.14	several treatment types; two composts (South Canyon-Heartland and Mesa County-Mesa Magic), compost-char (Heartland), and control (no treatment)	uppermost treatment area
2a	0.21	.11 acre compost-char (near shale cliffs) and .10 acre compost-char (road prism) and Mesa Magic (on berm/large wood retention area)	two treatment polygons (.11 acre and .10 acre)
3a	0.06	compost-biochar (Heartland)	area around armored-ford; some patches of surface application (no ripping)
4a	0.14	compost only (Heartland)	1st switchback above alluvial fan
2c	1.01	compost-biochar (Heartland)	lowermost treatment area; alluvial fan. Soil moisture (OnSet/Hobo) station installation
Total:	**1.56**		

Table 2. Soil treatment types in the pilot project area.

Revegetation

To improve vegetative cover, thereby increasing water infiltration and decreasing erosion, the treatment areas were seeded and trees were planted. In the fall of 2012, approximately 1.5 miles of road constituting a CDA to the Dutch Creek drainage were ripped and crossed ripped, and then broadcast-seeded at 35 pure live seed (PLS)/acre with a genetically local (ecotypic) grass seed mix (*see* Figure 15). The seed mix was comprised of 60% WRNF mountain brome and 40% WRNF slender wheatgrass. Prior to this effort, the road had been revegetated with cultivar grasses, including both native and exotic perennial grass species. Additionally, a 1-acre alluvial fan reconstruction area was broadcast-seeded at 35 PLS/acre with a genetically local (ecotypic) grass seed (*see* Figure 16). The grass seed mix was comprised of 40% WRNF mountain brome, 35% WRNF slender wheatgrass and 25% WRNF blue wildrye. Prior to seeding, the native soil on this 1-acre site had been amended with 10% biochar/compost.

On June 3rd and 4th, 2013, 750 Engelmann spruce trees (provided by the USFS) were planted by USFS staff with the help of Colorado Parks and Wildlife and the brute strength of *"Aspen"*, a USFS mule(*see* Figure 17). Each tree was planted in a hole where the soil was amended to improve conditions at the micro-site level. Planting took place over approximately 4 acres within a 9,000'- long decommissioned road prism. Wet draws from the top to the alluvial fan and then down to the gate at the Lamphouse (an abandoned mining facility) were planted, in addition to all amended soil locations and other water bars that had visible water. The idea was to plant timber stringers up draws and mimic naturally-occurring features on such aspects. (Cottonwood sprouting out of cottonwood logs half buried on the upslope end of the fan was noted.)

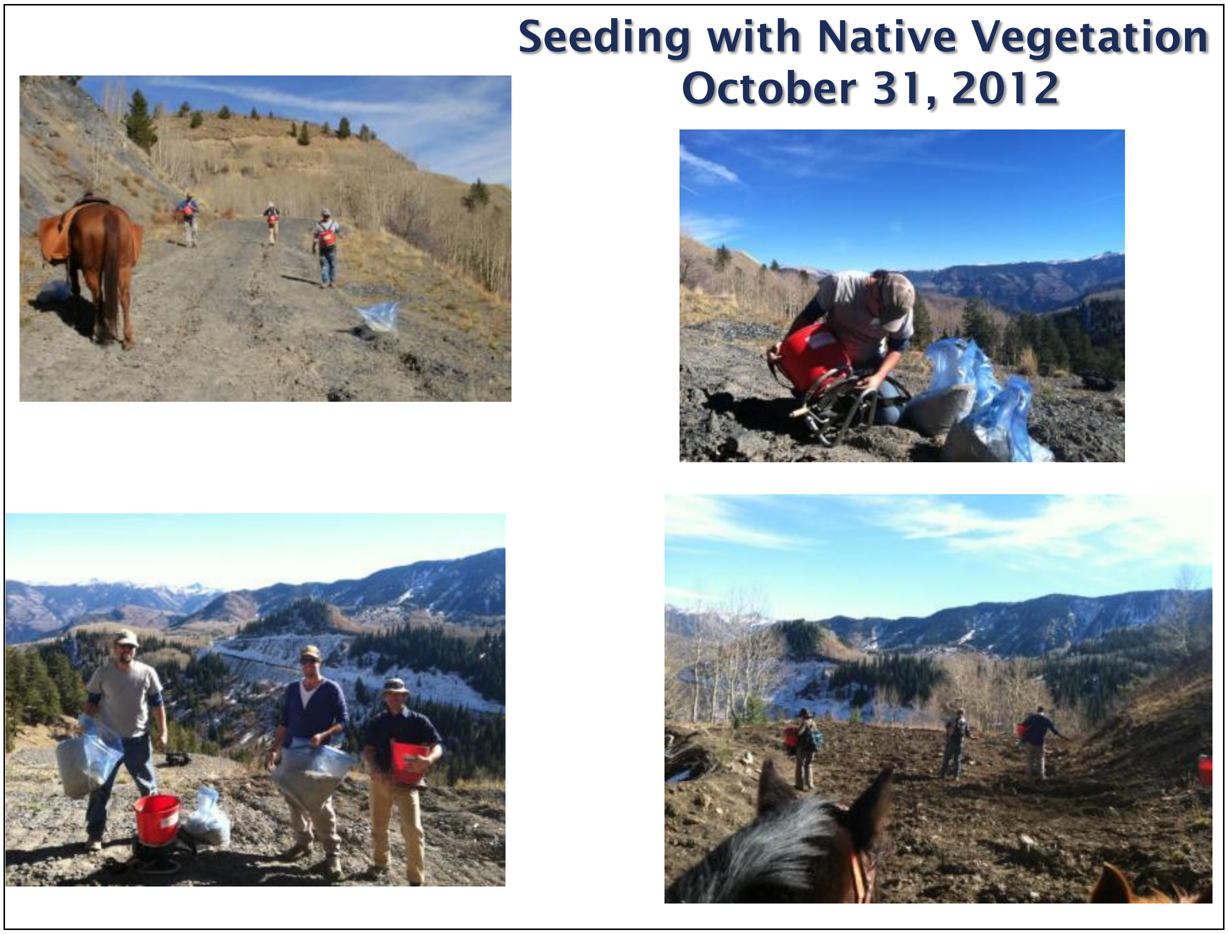

Figure 15. Seeding with native (ecotypic) WRNF grass seed mix.

Figure 16. Reconstructed alluvial fan seeded with WRNF mountain brome, slender wheatgrass and blue wildrye.

Figure 17. Engelmann spruce tree planting, June 2013.
Note the improvement of conditions at the micro-site level.

To protect the vegetation in the project area from cattle grazing, an electrical fence was installed by USFS personnel before cattle were turned out in the USFS grazing allotments (*see* Figure 18). Mules and horses were used to haul fencing material to the project site. This fence was taken down after the cattle were removed and stored for the winter. It will be put back up in the spring of 2014.

Figure 18. Electric fence in alluvial fan area.

Weed Treatment

Due to the amount of ground disturbed from coal mining and associated activities (such as roads, wash plants, and refuse piles), there are large areas of Coal Basin significantly impacted by noxious weeds (notably, plumeless thistle, hounds tongue, oxeye daisy, and Canada thistle[3]). The ground disturbance associated with the pilot project only compounded the problem. While addressing this added infestation was outside the purview of the USFS annual weed spraying program, USFS personnel played an essential role in the design and implementation of a successful program to treat the pilot project area. USFS expertise was used to identify potential applicators, most effective timing, application rates, chemicals, and methods. Sixteen acres of ground within and adjacent to the pilot project area were treated for noxious weeds during the week of June 18-21, 2013 (*see* Figure 19). Subsequent hand treatments (pulling) followed throughout the growing season when resource specialists were at the site for monitoring events.

Figure 19. Spot spraying for weeds (June 2013) in the treatment areas.

Soil Monitoring

Continuous soil monitoring probes were installed at the project site to collect data to facilitate the comparison of the effectiveness of a biochar/compost mix, compost, and no soil amendments for improving soil moisture (*see* Figures 20 and 21). The system consists of a tipping bucket for precipitation data, a photovoltaic panel and battery for solar power, and soil moisture and temperature probes installed within the rooting zone for local vegetation (*see* Figure 22). Probes were located at 2”, 8”, and 20" depths, following protocols established by Natural Resources Conservation Service (Soil Climate Analysis Network) stations and in a manner compatible with local soil moisture data being collected

[3] All are List B species on Colorado’s noxious weed list.

under the auspices of the Aspen Global Climate Initiative (AGCI). Data were collected from August 21 to November 1, 2013.

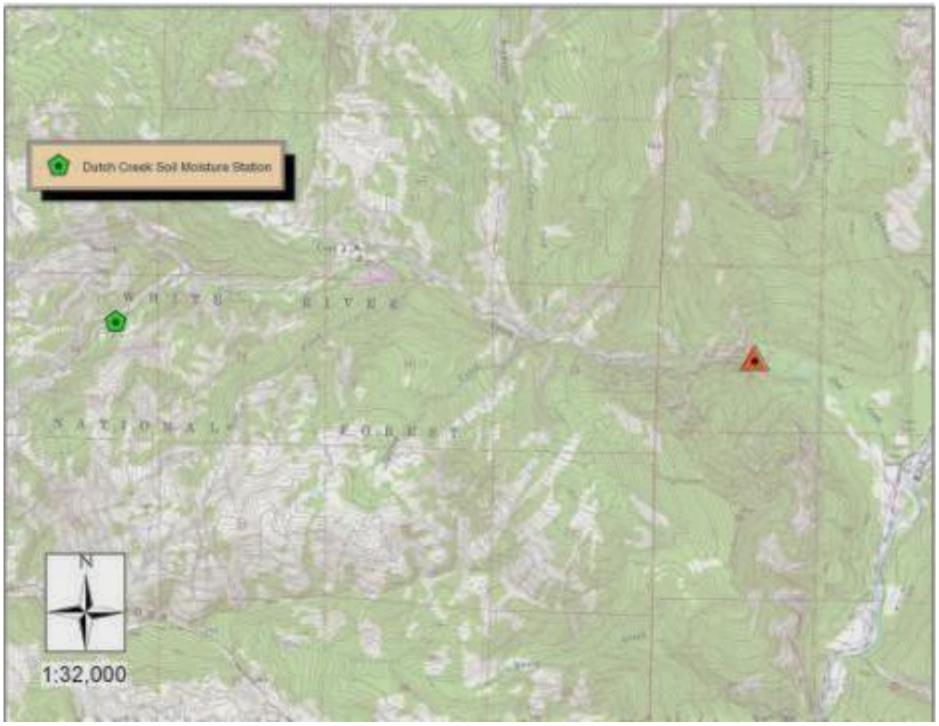

Figure 20. Location of the soil moisture monitoring station in Coal Basin.

Figure 21. Location of the soil moisture monitoring station in the pilot project area.

A summary of the mean, minimum, and maximum soil moisture contents by soil treatment is provided in Tables 3 - 5; these values cover the first four months of data collected following installation in August of 2013.[4] Soil amendments (compost-biochar blend and compost only) increased soil moisture content by 4-5% at the 8” depth (the heart of the plant rooting zone) relative to the control; this, along with increased nutrient content and more favorable soil structure from the soil amendments, likely accounts for the stark contrast in plant establishment and vigor in areas of the pilot project that were ripped with soil amendments, as opposed to just being ripped/decompacted.

	Water Content, Control @ 2"	Water Content, Compost Char @ 2"	Water Content, Compost @ 2"
Mean	0.23	0.21	0.20
Min.	0.09	0.13	0.11
Max.	0.33	0.26	0.29

Table 3. Mean/minimum/maximum soil moisture content at 2” depth.

	Water Content, Control @ 8"	Water Content, Compost Char @ 8"	Water Content, Compost @ 8"
Mean	0.17	0.20	0.21
Min.	0.11	0.15	0.17
Max.	0.24	0.23	0.25

Table 4. Mean/minimum/maximum soil moisture content at 8” depth.

[4] It is important to note that these are absolute values. To express a figure as a percentage, the number needs to be multiplied by 100. For example, the minimum soil moisture content in the control area at a 2” depth was 0.09; this translates to 9% volumetric soil moisture content.

	Water Content, Compost Char @ 20"
Mean	0.18
Min.	0.15
Max.	0.21

Table 5. Mean/minimum/maximum soil moisture content at 20" depth. Data logger for the system could not handle any more inputs as configured.

Figure 22. Soil moisture monitoring station. August 2013.

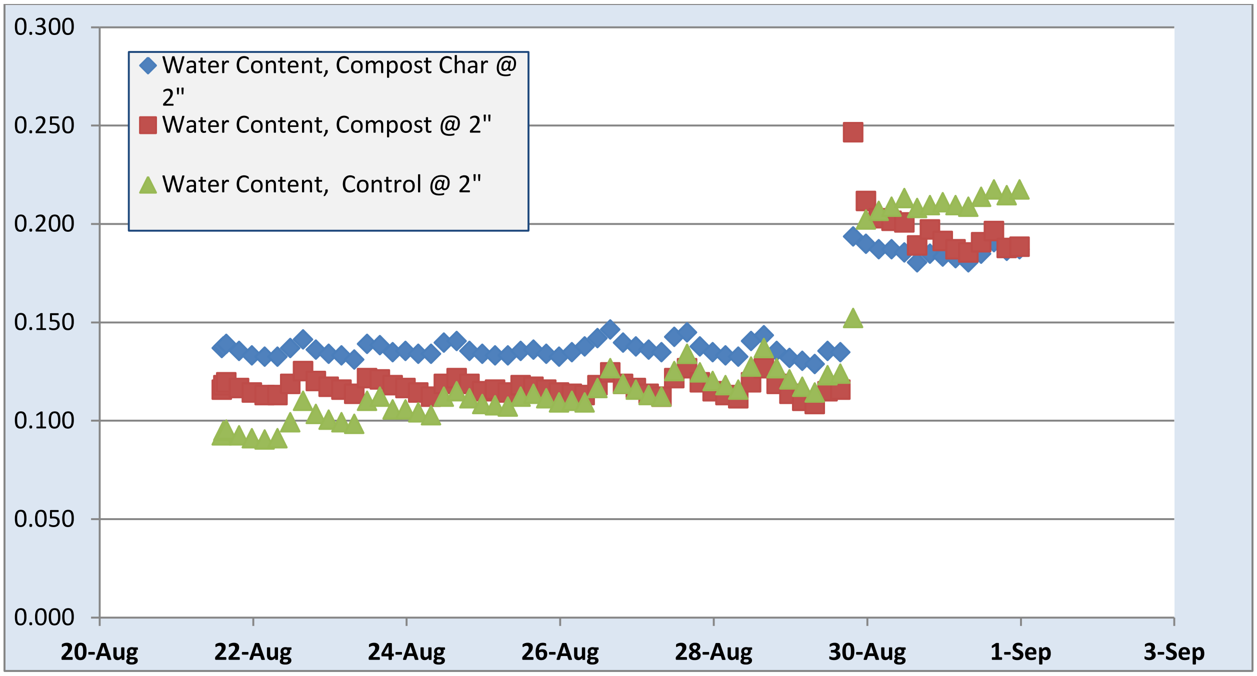

Figure 23. Results of the soil moisture monitoring at the 2" depth.

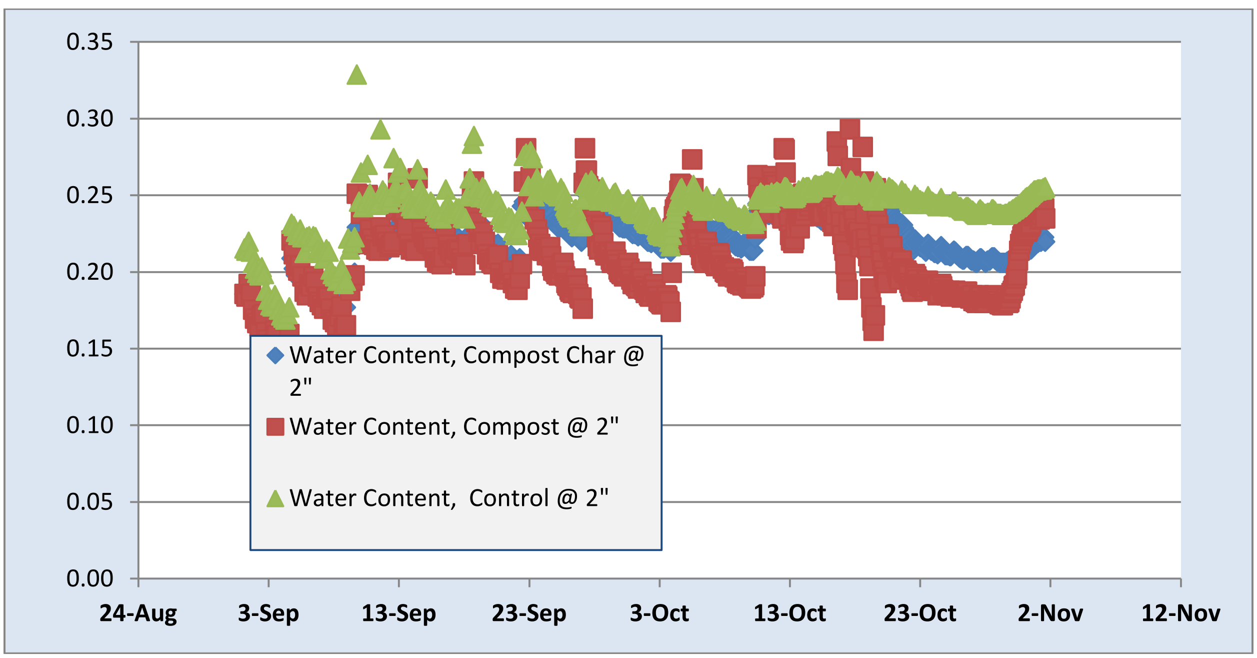

Figure 24. Results of the soil moisture monitoring at the 2" depth.

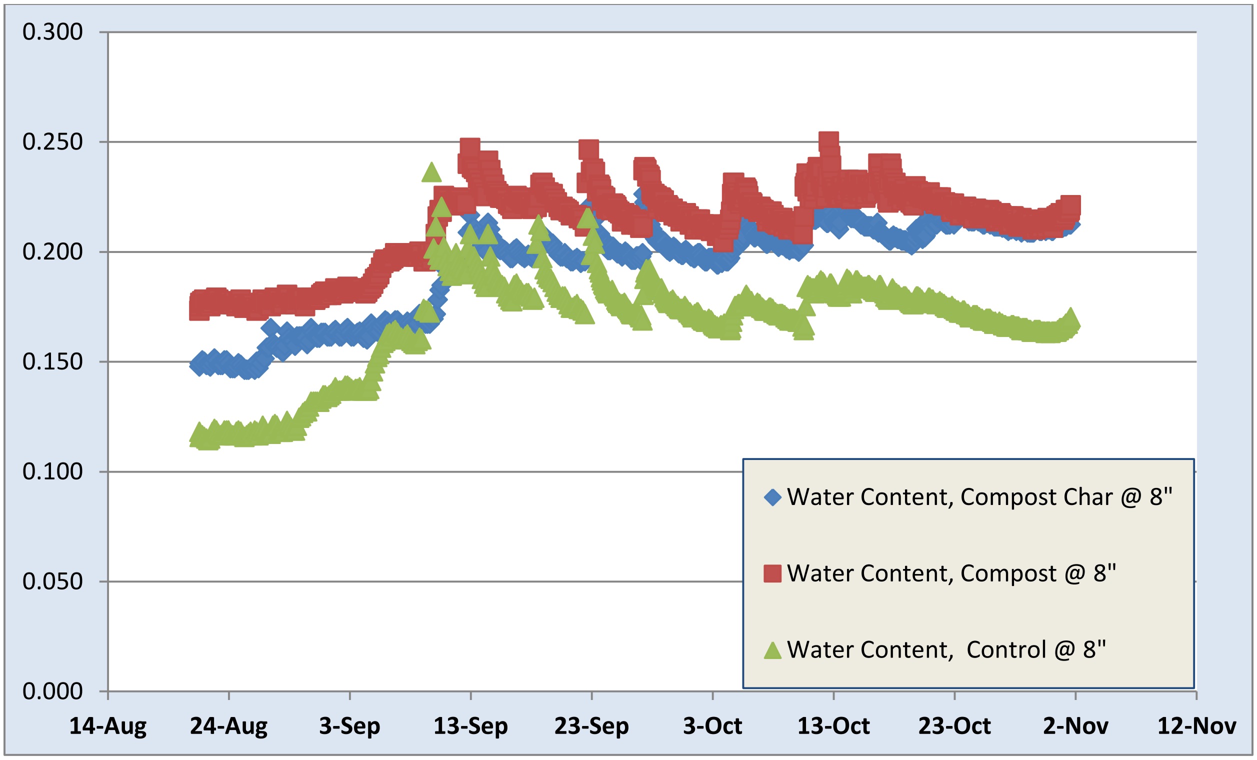

Figure 25. Results of the soil moisture monitoring at the 8” depth.

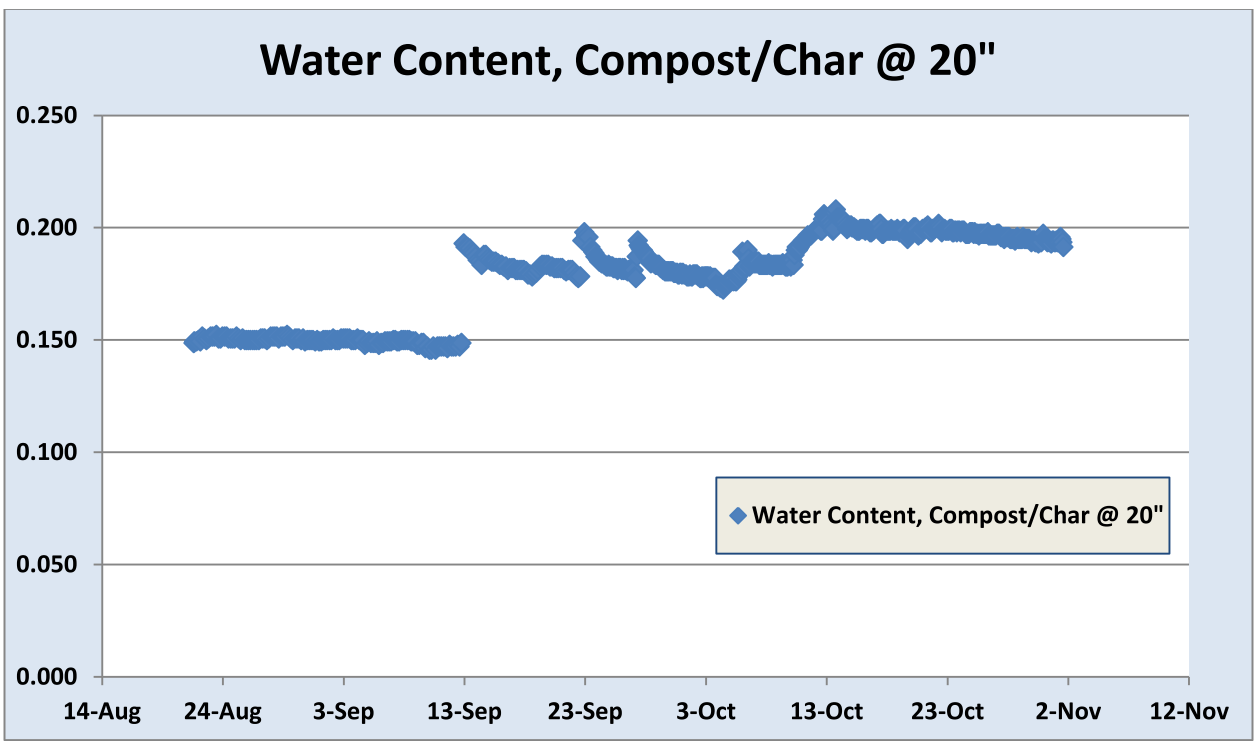

Figure 26. Results of the soil moisture monitoring at the 20” depth.

Data captured during the 2014 growing season will help elucidate trends and differences between soil treatment types. While further analysis of the data collected to-date is needed, the following observations can be made from the first 3 months of data collection:

1) Late August showed a significant increase in soil moisture, as evidenced by the spike in moisture content following a summer monsoon event that never significantly dissipated in the fall. There is also an interesting shift in relative moisture content between the treatments (control, compost, and compost/char) (*see* Figure 22). Figures 23 and 24 show that the control had higher moisture at 2" following the wet conditions, but at 8" (the plant rooting zone), compost and compost/char had significantly more moisture over time.

2) There was only one soil moisture probe at 20" depth (*see* Figure 25). At 20% moisture content, we would not expect much or any return flow to groundwater (and hence, the streams). The moisture is being held nicely in the root/vadose[5] zone (0-10 ", most likely).

3) There may be opportunities to improve the setup for 2014 (such as the need to reconfigure/adapt the setup to add probes for compost and control at the 20" depth).

Vegetation Monitoring

South Fork of Dutch Creek Road Decommissioning

On September 23rd, 2013, data was collected from one cover frequency transect (Dutch Creek #1) to determine source performance of the ecotypic seed sources utilized as well as the first year success of that revegetation effort (*see* Figures 27 and 28). Plans to measure two additional transects along this 1.5 mile stretch of road were interrupted by the government furlough. No additional transects associated with the Dutch Creek road decommissioning were measured in 2013.

Figure 27. Dutch Creek transect # 1.

Figure 28. Dutch Creek transect # 1.

Cover Frequency Index (CFI) is calculated to measure, display and compare the density of a plant species within and between monitoring transects (*see* Figure 29). Within Dutch Creek transect #1, WRNF slender

[5] The vadose zone extends from the top of the ground surface to the water table. The water contained in the vadose zone is termed soil moisture.

wheatgrass[6] had the greatest plant density with a CFI of 190. While WRNF mountain brome[7] was not observed at the time this transect was read, good germination was noted earlier in the spring. Douglas knotweed - a native dichotomous forb - was found in trace amounts. Cultivar grass species which were either present in the seed bank or already established from a previous seeding effort included: orchard grass, tall blue grass, and sheep fescue. Invasive species observed included trace amounts of hounds tongue.

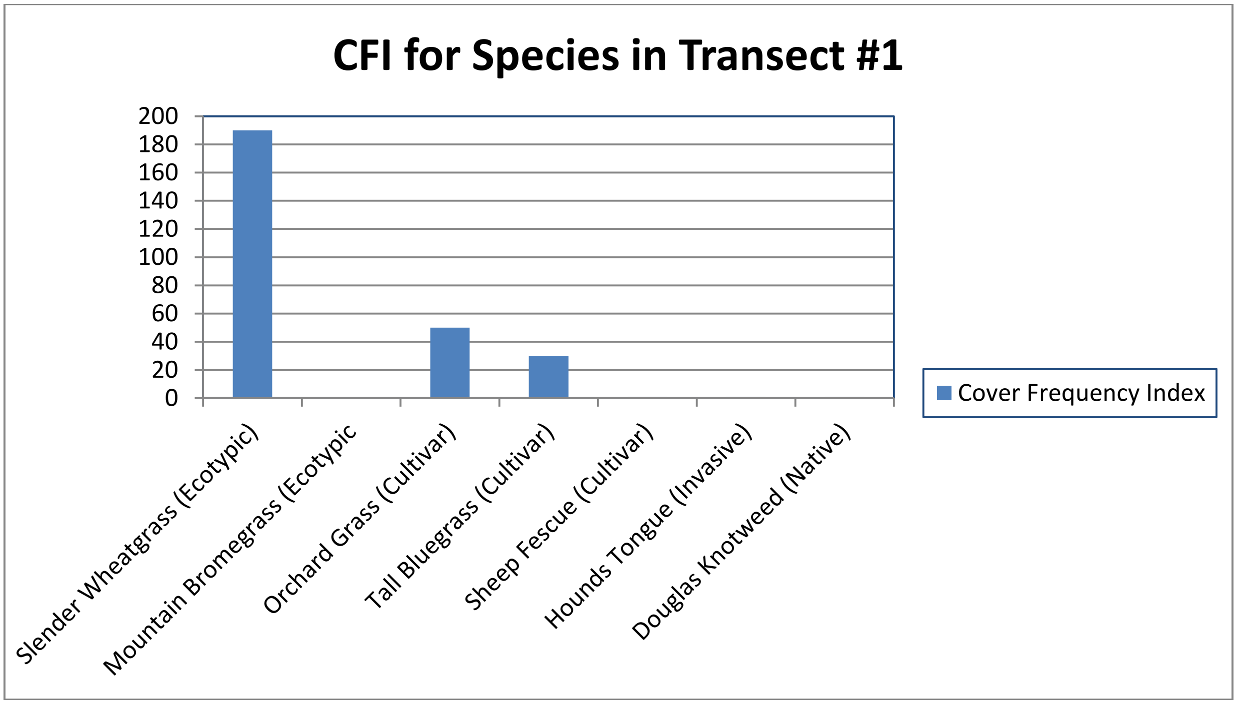

Figure 29. Cover Frequency Index for Dutch Creek transect #1 read in the fall of 2013.

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[6] Slender wheatgrass is a cool season perennial tufted bunchgrass species with very short rhizomes (NRCS 2002). It is native to the mountain and intermountain areas of the western United States where it grows at elevations ranging between 4,500'-12,000'. Slender wheatgrass prefers loams and sandy loams in areas receiving at least 14" of annual precipitation. It grows on moist to dry sites and has moderate to good tolerance of alkaline conditions (pH = 8.8). Salinity tolerance ranges from 1-16 mmhos/cm depending on environmental conditions and ecotype. It does not tolerate excessive soil moisture. It is shade tolerant. Considerable genetic variability is present in slender wheatgrass populations and some ecotypes may be rather specific to their original sites due to self-pollination.

[7] Mountain brome is a short-lived, perennial, cool season bunch grass native to the mountain and intermountain regions of Western North America (NRCS 2006). Plants develop from a shallow, non-rhizomatous root system. Mountain brome is well adapted to the foothills and mountains of the Intermountain West in areas with $\geq$16" annual precipitation. It can be found naturally at elevations ranging 5,000' to 10,500'. It prefers deep, fertile, mesic soils of medium to fine textures, but also survives on thin, dry or coarse soils, resulting in lower levels of production. Mountain brome does not tolerate flooding or high water tables, but can tolerate very mild salinity. It is winter hardy and has good shade tolerance.

While good germination of both slender wheatgrass and mountain brome was observed in June of 2013, slender wheatgrass was the only species to persist.

Slender wheatgrass had moderately successful first year establishment because it is able to develop short rhizomes - making it more efficient at extracting water and nutrients from compacted soils and allowing it to better tolerate the extended dry period that occurred between May and July. It is unclear if alkalinity or salinity were factors in its performance.

Mountain brome had unsuccessful first year establishment in transect #1. This was likely due to the fact that it develops from a shallow root system which does not have rhizomes, and the fact that it prefers deep, fertile, mesic soils. This species root system is not well adapted to grow in compacted soils. The site conditions on Dutch Creek road were shallow, compacted, infertile, and experienced an extended dry period.

When contemplating source performance of the seed sources, utilized species biology and ecology must be considered in relation to the site preparation conditions they were seeded in. The Dutch Creek Road was historically utilized as a haul road to extract coal from the mine shafts and adits from the slopes above. Moreover, cattle have used, and will likely continue to utilize this road to graze and to trail to/from various pastures. Finally, the Dutch Creek Road has and will continue to be utilized by foot and horse traffic. Prior to seeding the road was ripped and cross ripped, but segments of this road still remained in a highly-compacted condition. Moreover, the soils in transect #1 were not amended. Finally, while the revegetation site experienced good spring and monsoonal moisture, an extended warm and dry period occurred from late May until middle July.

South Fork of Dutch Creek Alluvial Fan Reconstruction

On September 23rd, 2013, data was collected from one cover frequency transect (Dutch Creek #2) to determine performance of the seed sources utilized in relation to the soil amendments, and to determine the overall success of the revegetation effort(*see* Figures 30 and 31). Within Dutch Creek transect #2, WRNF mountain brome had the greatest plant density and excellent first year establishment, WRNF blue wildrye had excellent first year establishment, and WRNF slender wheatgrass had moderate first year establishment. WRNF mountain brome had a CFI of 850, WRNF blue wildrye[8] had a CFI of 760 and WRNF slender wheatgrass had a CFI of 180 (*see* Figure 32).

Native forb species that were observed in transect #2 included: Douglas knotweed, scorpion weed and willow herb. Invasive plants observed in transect #2 included: kochia and sweet clover. Cultivars utilized in previous revegetation efforts were noted in the treated area but outside of transect #2, including: stream bank wheatgrass, orchard grass, western wheatgrass, tall bluegrass, yarrow flower and Rocky Mountain beardtongue.

Invasive plants observed in transect #2 included: kochia and sweet clover. It is unclear if they were introduced by the equipment utilized, the compost that was brought in to the project site, the seeds that were broadcast on-site, or if they were already present.

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[8] Blue wildrye is a large perennial bunchgrass found from California to Alaska and also the Great Plains and northern Mexico (NRCS 2005). In the southern Rocky Mountains, blue wildrye prefers mesic aspen stands which receive filtered light. It grows well in both disturbed and undisturbed areas and is a good competitor. It tolerates wide variations in soil and weather conditions, though grows best in good soils. It prefers moisture, but tolerates drought. Some ecotypes are adapted to sunny grassland habitats.

As previously noted, when contemplating source performance of the seed sources utilized in revegetation, species biology and ecology must be considered in relation to the site preparation conditions they were seeded in. The soil amendments were the key to the successful revegetation of this 1-acre alluvial fan reconstruction site (*see* Figure 33). Prior to seeding, the native soil had been amended with a 10% biochar/compost mix. The revegetation site experienced good spring and monsoonal moisture but also had an extended warm and dry period occurred from late May until middle July. Figures 34 to 36 show the revegetation progression from May through July. The water holding capacity of the compost and biochar were critical in maintaining soil moisture and water availability to the establishing seedlings during the long dry period. The planting medium allowed the seedlings to obtain optimal root development and ultimately to establish and persist. The compost and biochar also provided nutrients (in the compost) and the ability to retain them (in the biochar), fertilizing the emergent vegetation and increasing the short- and long-term fertility of the growth medium.

While the WRNF blue wildrye did very well in the amended soils of the study area, it may also be a good candidate for any future seeding that may be required along Dutch Creek Road. WRNF blue wildrye seed is expected to be available for purchase from SW Seed in the fall of 2015. It is also possible that enough breeder stock seed will be produced by Lucky Peak Nursery during the 2014 field season to accomplish this task.

It is likely that the WRNF mountain brome had excellent establishment in transect #2 because of its preference for deep, fertile, mesic soils; the amended soils on the alluvial fan reconstruction site provided these conditions.

WRNF slender wheatgrass performed similarly in the amended soils of the alluvial fan reconstruction (CFI of 180) and the un-amended soils of Dutch Creek Road (CFI of 190). It is likely that the slender wheatgrass experienced some competition for resources (space, light, water, nutrients) in transect #2, where mountain brome and blue wildrye established well. The WRNF slender wheatgrass appears to have broad ecologic amplitude and may be suitable for utilization in a variety of situations.

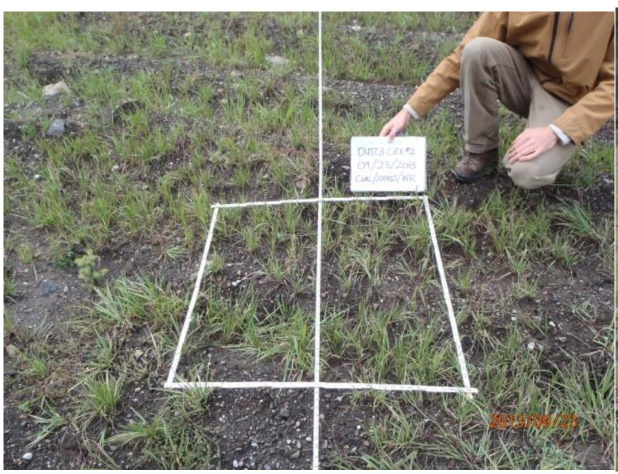

Figure 30. Slender wheatgrass in transect #2.

Figure 31. Transect #2.

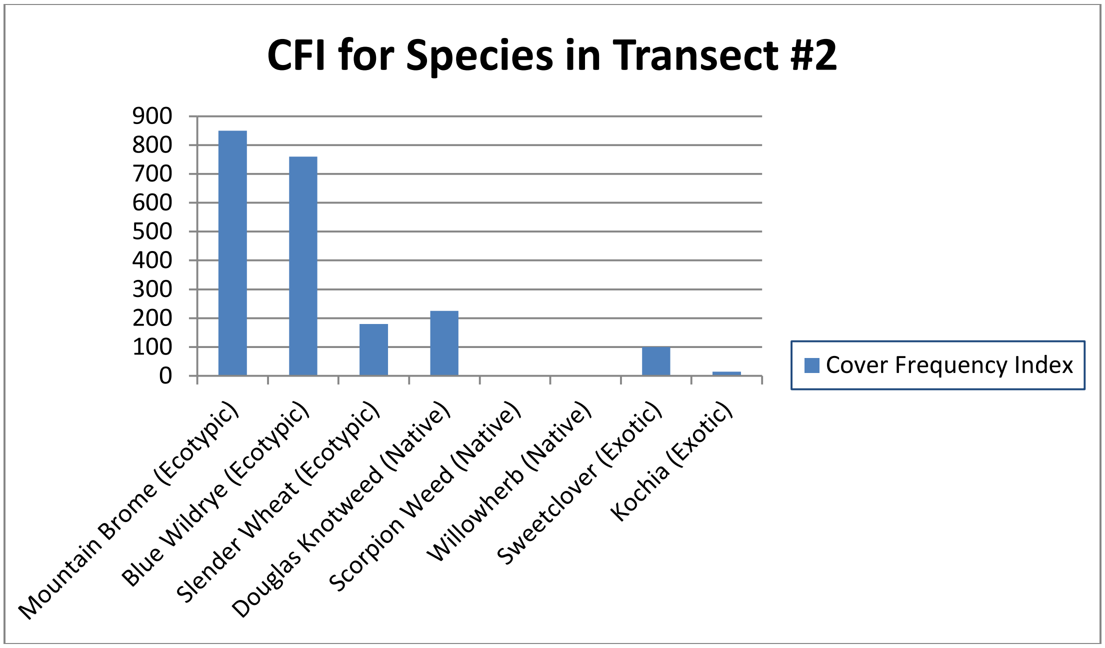

Figure 32. Cover Frequency Index for Dutch Creek transect #2 read in the fall of 2013.

Figure 33. Contrast between alluvial fan area amended with compost-biochar (left of red line) and without (control-right of red line). September 24, 2013.

Figure 34. Alluvial fan. May 13, 2013.

Figure 35. Alluvial fan. June 10, 2013.

Figure 36. Alluvial fan. July 10, 2013.

For comparison purposes, we had planned to record cover frequency data from the soil treatments to determine: a) vegetative success among soils amended with compost, b) vegetative success among soils amended with compost/biochar, and c) vegetative success where soils were not amended. Due to the U.S. Government shutdown in the fall of 2013, we were not able to record data among soils amended with only compost. This task will be completed in the fall of 2014 when we revisit and record data from the two established cover frequency transects (transect #1 and transect #2).

The data collected in 2013 did allow us to compare vegetative success among soils amended with compost/biochar to vegetative success where soils were not amended (Table 7).

Species Seeded	Compost Amendment	Compost / Biochar	No Amendments
Mountain Brome (BRMA4)	NA	Excellent 1st year Establishment	No 1st year Establishment
Slender Wheatgrass (ELTR7)	NA	Good 1st year Establishment	Good 1st year Establishment
Blue Wildrye (ELGL)	NA	Excellent 1st year Establishment	NA

Table 7. Comparison of first year (2013) vegetative success between soil treatments.

The following conclusions may be drawn from the 2013 transect data and ocular observations:

- WRNF mountain brome did not persist in areas of un-amended and/or compacted soils and may not be suitable for future use under these conditions.
- WRNF mountain brome displayed excellent first year establishment in areas where soils were amended with compost/biochar and is recommended for future use under these conditions.
- WRNF slender wheatgrass has broad ecologic amplitude and is suitable for future use in areas of un-amended and/or compacted soils within the Dutch Creek area.
- WRNF slender wheatgrass displayed good first year establishment in areas where soils were amended with compost/biochar and is recommended for future use under these conditions.
- WRNF blue wildrye was not evaluated in areas of un-amended and compacted soils.
- WRNF blue wildrye displayed excellent first year establishment in areas where soils were amended with compost/biochar and is recommended for future use under these conditions.

Next Steps

In 2014 several activities will occur in the pilot project area. We will reinstall the electric fence to exclude cattle from the pilot project area. The need for additional weed treatment and reseeding will be assessed and carried out as necessary. Soil moisture and vegetation monitoring will continue. If the soil moisture station is able to be retrofitted to allow for additional data inputs, soil moisture probes will be installed at the 20" depth to allow for measurement of the compost only and control treatments and comparison with the existing compost/biochar probe at this depth. Soil temperature probes would be installed at all sampling depths as well, pending a review of the additional data input capability of the data logger. Although the soil moisture monitoring showed slight soil moisture increases in the compost treatment compared to the compost/biochar treatment, this may reverse over time as the compost breaks downs and the biochar retains its ability to retain moisture. However, several additional years of soil moisture comparisons are needed to determine if this is true. We will record cover frequency data from the soil treatments to determine vegetative success among: a) soils amended with compost, b) soils amended with compost/biochar, and c) where soils were not amended.

Bibliography

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http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmcpg6081.pdf.

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https://plants.usda.gov/factsheet/pdf/fs_eltr7.pdf.

Appendix

Vegetation Monitoring Transect Data

Transect #1 Data

ELTR7		t	1	t	t	t	1	t	t	t	t	1	1	1	1	1	1	1	1	1	
BRMA4																					
DAGL	1			T							3				1	1					
POAM	2				T								2								
FEOV											1										
CYOF			1																		
PODO							T						T								

Transect #2 Data

ELGL	2	2	1	1		1	1	2	2	2	3	2	1	1	1	1	1	T	T	T	0
ELTR7	1	1		1	1	1	T	T	2	T	T	T	T	T	1	2		2	1		190
BRMA4	1			2	2	2	1	1	T	2	1	2	2	2	2		3		2	2	
DAGL																					50

Common Name	**Scientific Name**	**Abbreviation**
Slender wheatgrass	Elymus trachycaulus	ELTR7
Mountain bromegrass	Bromus marginatus	BRMA4
Orchard grass	Dactylis glomerata L.	DAGL
Tall bluegrass	Poa ampla	POAM
Sheep fescue	Festuca ovina	FEOV
Hounds tongue	Cynoglossum officinale	CYOF
Douglas knotweed	Polygonum douglassii	PODO
Blue wildrye	Elymus glaucus	ELGL