Proceedings

HIGH ALTITUDE REVEGETATION WORKSHOP

NO. 19

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Edited by

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As editor and on behalf of the High Altitude Revegetation Committee, we wish to express our sincere appreciation to the "Society for Ecological Restoration CSU Student Guild" for their help in editing and formatting these proceedings.

PREFACE

The 19th biennial High Altitude Revegetation Workshop was held at the Hilton Fort Collins in Fort Collins, Colorado on March 2-4, 2010. The Workshop was organized by the High Altitude Revegetation (HAR) Committee in conjunction with the Departments of Soil and Crop Sciences and Forest, Rangeland and Watershed Stewardship at Colorado State University. The Workshop was well attended this year by 221 people from a broad spectrum of universities, government agencies, and private companies. Discussions centered on the revegetation of disturbed lands always seem to be of interest to many people as evidenced by the number in attendance this year at the Workshop. The HAR Workshop is somewhat unique in that it focuses on the practical, on-the-ground application of revegetation techniques. People come away from the Workshop with new information and new ideas that they can take home and apply directly to their specific situations.

This Workshop would never happen without the dedication and contributions from the many people on the HAR Committee. This is an all volunteer organization and everyone that contributed to this years Workshop is to be commended for their efforts.

As was done in 2008, the Committee solicited volunteer papers instead of inviting speakers as was done in past years. This approach worked well and we would like to thank all the people who took time to prepare not only a presentation or poster, but also a paper or abstract for inclusion in these proceedings. The proceedings consist of a schedule of the presentations, associated abstracts for both the oral and poster presentations, and 17 papers.

One of the highlights of this year's workshop was our keynote speaker, Dr. Richard J. Hobbs. Dr. Hobbs leads the Ecosystem Restoration Laboratory in the School of Plant Biology at the University of Western Australia. His particular interests are in vegetation dynamics and management, invasive species, ecosystem restoration, conservation biology, and landscape ecology. He was able to share his vast experiences and perspectives from his work dealing with restoration of Australian landscapes. His insights were enjoyed by all in attendance.

In addition to the papers and posters presented on March 3 and 4, a special Revegetation Equipment Demonstration Session was held on March 2 at The Ranch (Larimer County Fairgrounds). This session was well received and attended by over 80 people. Attendees had the opportunity to get up close and personal with some of the equipment commonly used in revegetation including disks, chisel plows, crimpers, various types of drills, and hydromulchers. Each piece of equipment was discussed with regards to what it does, how it works, and where it fits in the revegetation process, along with its associated pros and cons.

For current information on upcoming High Altitude Revegetation Committee events, visit our website at: www.highaltitudereveg.org.

Joe E. Brummer
Editor

NINETEENTH HIGH ALTITUDE REVEGETATION WORKSHOP

Conference Proceedings

March 2 -4 2010
Fort Collins, CO

Sponsored by:
Colorado State University
Departments of:
Soil and Crop Sciences
Forest, Rangeland, and Watershed Stewardship
and the
High Altitude Revegetation Committee

CONTENTS:

NINETEENTH BIENNIAL
HIGH ALTITUDE REVEGETATION WORKSHOP

Schedule and Abstracts

WEDNESDAY, MARCH 3

7:30 – 9:00 a.m. CONFERENCE CHECK-IN for preregistered participants and LATE REGISTRATION. Coffee available in Exhibit Area.

8:45 – 9:00 a.m. **WELCOME**: Randy Mandel, Chairman of the High Altitude Revegetation Committee.

➘➘**KEYNOTE SESSION:** Chair – David Buckner.

9:00 – 10:00 a.m. **KEYNOTE ADDRESS: Restoration in a Rapidly Changing World.** Dr. Richard J. Hobbs leads the Ecosystem Restoration Laboratory in the School of Plant Biology at the University of Western Australia. Originally from Scotland, he has been in Western Australia since 1984, working with CSIRO and at Murdoch University before joining UWA in 2009. His particular interests are in vegetation dynamics and management, invasive species, ecosystem restoration, conservation biology and landscape ecology. He is the author of over 300 scientific publications and author/editor of 18 books. He is currently Editor-in-Chief of the journal Restoration Ecology.

10:00 – 10:30 a.m. **Milltown Dam Riparian and Floodplain Revegetation**. Tom Parker, Principal Ecologist, Geum Environmental Consulting, Inc., Hamilton, Montana.

Milltown Dam, located at the confluence of the Blackfoot River and Clark Fork River in western Montana, was removed in stages between 2007 and 2009 as part of an integrated remediation/restoration project coordinated by the Environmental Protection Agency and the State of Montana. While the remedial work focuses on removing contaminated mining sediments that have accumulated behind the dam since 1908, the restoration design emphasizes restoring natural river and floodplain function in the context of a local community, and is driven by objectives that were developed collaboratively by the Site Natural Resource Trustees – State of Montana, US Fish and Wildlife Service, and the Confederated Salish and Kootenai Tribes. Revegetation is a significant component of this restoration effort. The revegetation plan focuses on creating conditions that will support riparian plant community development through natural river and floodplain processes. While the revegetation plan includes some planting and seeding, many surfaces are being designed to promote natural vegetation recruitment. This type of design was possible through a unique collaboration between engineers, hydrologists and ecologists. Rather than responding to a grading plan, ecologists helped develop grading criteria, and were able to include micro-swales, wetland features, and woody debris as components of the final graded floodplain surface. Revegetation activities include weed management, seeding, planting containerized plants and wetland plugs, installation of pre-vegetated coir mats and logs, bioengineering structures such as vegetated soil lifts and sod brush trenches along river banks, and variation of substrate and topography.

10:30 – 11:00 a.m. COFFEE BREAK in Exhibit Area.

➘➘**SESSION 2:** Chair – Mark Paschke.

11:00 – 11:30 a.m. **Millsap Project: Beyond Reclamation--Restoring Land and Rebuilding Lives**. Al Amundson, Professional Engineer and Project Manager, and Julie Annear, Realty Specialist and Project Manager, Colorado Division of Reclamation, Mining and Safety, Denver, Colorado.

The Millsap Mill Tailings are located just south of Victor, Colorado in the Cripple Creek Gold Mining District, in a relatively remote and arid environment where waterways are stressed by dewatering, intensive agriculture, urban use, and the impacts of over a hundred years of hardrock gold mining. This project brought together a diverse group of state, federal and local agencies, land owners, water rights holders, and non profit organizations, including over 20 partners. The Millsap Mill Tailings ponds were created from the 1900's to 1928's to hold tailings slurried from the Independence Gold Mill. The original dams held nearly two million cubic yards of tailings and were breached several decades ago allowing the tailings to erode downstream during storm events. This siltation has caused wild trout habitat to become significantly degraded in Four Mile Creek, and has eliminated the possibility of Millsap Creek being a fishery. During heavy rain events, this sediment also reached the Arkansas River. The goal of this project was to stop the massive erosion, reestablish native vegetation, and ultimately improve and protect the downstream wild trout habitat. Reclamation of the tailing serves to alleviate one of the major stresses on the stream system. This project is more than reclamation partnership; it is a cooperative effort that includes the State of Colorado Department of Corrections Vocational Training Program located in Buena Vista. The inmates become skilled in operating heavy construction equipment and in construction management as well as cooperation with co-workers and supervisors. The program is successful in training and developing life long skills which greatly reduce recidivism, easing the burden on the prison system. This program provides jobs to the inmates upon release and over 95% of the participants have employment opportunities when released.

11:30 a.m. – 12:00 p.m. **Use of Performance Standards in Assessment of Revegetation Success**. Carla Vik, ESCO Assoc., Boulder, Colorado.

Assessment of the success of revegetation projects in the Intermountain West and Great Plains of North America has moved from a largely qualitative basis in the early years to progressively more quantitative measures in more recent times. The prime example of the use of quantitative revegetation performance standards has resulted from the passage of the Surface Mine Control Reclamation Act (SMCRA) in 1977. This Act established law relative to coal mining reclamation that was sufficiently specific regarding revegetation that subsequent rules included requirements for quantitative assessment of several vegetation attributes, including percent ground cover, productivity of useable forage, density of trees and shrubs, and the diversity of species present. Thirty plus years of experience in the implementation of these standards have produced an understanding of the feasibility of making such numerical expectations a part of major energy extraction projects. Reasons underlying the choice of these quantitative standards will be explored along with practical observations on the gathering of requisite data in the field and the use of statistics in the testing of hypotheses regarding revegetation success.

12:00 p.m. – 12:30 p.m. **Case Study: The Pine Tree Wind Farm.** Ed Kleiner, Comstock Seed, Gardnerville, Nevada.

The Pine Tree Wind Farm is under construction on a ridge in the southern Sierra's 20 miles northwest of Mojave, California. Construction began in 2007 and is expected to be completed by summer 2010. The original project consists of 80, 1.5 megawatt turbines as well as 10 miles of transmission lines. The project also includes construction of 38 miles of roads, a 3.8 mile underground electrical collection system, and a 10 mile utility corridor. Seeded areas will approach 300 acres. Several new solar and wind power projects are currently planned for the Mojave Desert. The author will reveal the significant ―footprint" that this project creates. These green energy projects are becoming the target of increasing criticism due to their significant impacts to the Mojave ecoregion. Common ground must be found between green energy development, their environmental impacts, and appropriate mitigation.

12:30 – 1:30 p.m. LUNCHEON

➘➘ **SESSION 3:** Chair – Randy Mandel.

1:30 – 2:00 p.m. **Obliteration and Restoration of OHV Roads in Colorado: Tried and True Treatments**. John Giordanengo, Projects Director and Executive Director, Wildlands Restoration Volunteers (WRV), Fort Collins, Colorado; Alan Carpenter, Land Stewardship Consulting, Inc., Boulder, Colorado; and Ed Self, Executive Director, WRV, Boulder Colorado.

Wildlands Restoration Volunteers (WRV) engages members of the community to implement over 40 ecological restoration projects each year. Through an extensive training program of volunteers, and by engaging environmental consultants, WRV provides land management agencies with technically sound means of restoring drastically disturbed lands on moderate scales. Since 2004, WRV has completed restoration of over 20 miles of undesignated roads on public lands from the lower montane to the alpine zones of Colorado. A typical project involves the following: project planning in cooperation with agency staff; technical design; utilizing heavy equipment to recontour hillsides and decompact soils; and engaging volunteers to prepare a seedbed, spread seed, install erosion matting, construct erosion control structures, spread and secure mulch, and erect site protection barriers. Monitoring has provided essential feedback for the adaptive management process and has helped to define a well-integrated system of successful treatments. Results indicate that volunteers provide exceptionally high-quality work and high value for land management agencies. In addition to a presentation on general road obliteration and restoration techniques, results from a small trial evaluating the effects of Regreen and Biosol on establishment of desired plant species will be presented.

2:00 – 2:30 p.m. **Restoring a Montane Stream and Its Wetlands**. Andy Herb, Owner/Ecologist, AlpineEco, Denver, Colorado.

As a result of wetland impacts from the expansion of a local airport, the Federal Aviation Administration (FAA) and US Forest Service (USFS) became unlikely partners. The FAA needed to replace 2.3 acres of wetlands, but for safety reasons, could not use airport property. As a separate project, the USFS had their sights set on restoring a tributary to one of the largest rivers in the region that had been channelized nearly 100 years ago. The two came together under the auspices of the Clean Water Act to mitigate the impacts at the airport by restoring the creek and its wetlands. The now restored tributary and approximately 3.4 acres of new wetlands are situated at 8,000 feet above sea level in the San Juan Mountains of southern Colorado. The creek is fed almost exclusively by snowmelt and typically flows from April to July. The watershed is almost entirely within the federally protected Weminuche Wilderness Area, on the flanks of the 13,000-foot Pagosa Peak. After extreme drought, weed infestations, reseeding, replanting, and five years of monitoring, the site was considered officially –successful" in late 2008. The goals of the project were to restore/create approximately one mile of highly sinuous, low-gradient stream channel; establish wetland hydrology for 3.4 acres of adjacent habitats; and create more functional wildlife habitat. This presentation provides a summary of the project and specific details on the mitigation, seeding, and planting techniques employed to achieve the desired results.

2:30 – 3:00 p.m. **Kerber Creek Restoration Project, Saguache County, Colorado.** Kimberly Schott and Romana Sutton, MS Candidates, Colorado State University-Pueblo; Laura Archuleta USFWS, Saguache Colorado; Steve Sanchez, BLM, Saguache, Colorado; and Karl Ford, BLM, Division of Resource Services, National Operations Center, Denver, Colorado.

The Kerber Creek Restoration Project is a partnership with numerous stakeholders including, but not limited to the Bonanza Stakeholders Group, Trout Unlimited, Bureau of Land Management (BLM), Natural Resource Conservation Service, US Fish and Wildlife Service, US Forest Service, Americorp/Vista Western Hardrock Watershed Team, Environmental Protection Agency, Colorado Water Conservation Board, and Saguache County Sustainable Environment and Economic Development. The project involves removing and in-situ treatment (i.e. phytostabilization) of mine wastes, revegetation, in-stream habitat enhancements, stream bank stabilization, and grazing management. Mine wastes discharged into Kerber Creek between the 1890's and 1970's from several mining-related operations in the Bonanza Mining District were transported and redeposited downstream. Although remediation objectives for Voluntary Cleanup and Redevelopment Act work (1997-2003) in the upper watershed were met, mining wastes are still present and degraded stream channel conditions continue to persist along Kerber Creek for about 19 miles. Low pH and high metal concentrations prevent re-vegetation due to phytotoxic conditions; consequently, stream banks are not stable, in-stream habitat is impaired, and a proper functioning riparian corridor is not present in many areas. From 2005-2008, BLM characterized mining wastes covering approximately 60 acres of riparian and floodplain areas along 19 miles of Kerber Creek. The partnership began implementing restoration projects in 2008 and this presentation will discuss details of phytostabilization, stream bank stabilization, and revegetation work. Additionally, we will briefly discuss the partnership's collaborative efforts.

3:00 – 3:30 p.m. COFFEE BREAK in Exhibit Area.

➘➘**SESSION 4:** Co-chairs – Jody Nelson and Ray Sperger.

3:30 – 4:00 p.m. **Reclamation of a Sandstone and Clay Quarry with No Topsoil: Use of Filter Fines as Growth Medium**. David Buckner, Senior Plant Ecologist, ESCO Associates Inc., Boulder, Colorado, and Lynn Riedel, Plant Ecologist, City of Boulder Open Space and Mountain Parks, Boulder, Colorado.

Reclamation of a quarry used to produce sandstone aggregate and clay near Boulder, Colorado was undertaken in 1995 without the benefit of salvaged topsoil. Subsoil was generated from remaining clay (weathered Lykins formation shale). Top layer growth medium was created using filter fines from a City of Boulder water treatment plant. These materials were sediment load transported by water passing from a high mountain watershed down a steel pipeline to the treatment plant. Silt and coarser size particles had been separated by filtration; clay particles had been precipitated using alum. The resulting ―filter fines” had the appearance and sandy loam texture of topsoil with occasional aggregations of alum. Planting in this material in late 1994 was accomplished by broadcast and mulched with bonded fiber matrix or hydromulch. Plentiful rain in spring 1995 resulted in a very strong cover of the sown native grasses (mainly thickspike wheatgrass, *Elymus lanceolatus*, and western wheatgrass, *Pascopyrum smithii)*. Stands with initial highest plant cover were associated with the deeper soil thicknesses. Over time, stands on thinner soil cover, with lower initial cover values, had greater species density, as less competitive native species were able to slowly establish in the absence of heavy grass competition. Diffuse knapweed entered the site early from local sources as well as soil material and was removed by hand in large quantities. Very small and inadvertent early presence of domesticated cool season grasses has continued to grow through the twelve-year record and may pose a threat to dominance of the site by native species.

4:00 – 4:30 p.m. **Cheatgrass Seed Dispersal in Reclamation Areas**. Danielle Bilyeu Johnston, Research Scientist, Colorado Division of Wildlife, Grand Junction, Colorado.

Cheatgrass (*Bromus tectorum* L.) seed dispersal has been quantified for sagebrush ecosystems, but little is known about cheatgrass dispersal over the bare soils common in newly reclaimed areas. Recently, fluorescent seed marking has emerged as a useful tool to study seed dispersal. We used fluorescently marked cheatgrass seeds to quantify cheatgrass dispersal distances on simulated well pads in northwestern Colorado. A total of 1300 sterilized, marked seeds were released in groups of ~100 from 20-cm high platforms in three types of environments: a mesa top, a gulley, and a ridge top. Seeds were recovered at night using blacklights 4 times over 14 days, and the distance between each seed and its release platform was measured. At all sites, the majority of movement occurred within 2 days of release. Dispersal distance averaged 2.4 m and was highly variable, with 5% of seeds traveling further than 10.6 m. Differences in dispersal distance between sites occurred but did not coincide with measured differences in wind speed. Seed recovery was > 94% at the first time step, and fell to 60-70% after 14 d. The average distances reported here are seven-fold higher than those reported for intact sagebrush ecosystems, and imply that in the absence of impediments, cheatgrass seeds may penetrate the interior of reclamation areas. Fluorescent seed marking is a promising method to explore cheatgrass dispersal dynamics.

4:30 – 5:00 p.m. **The Economic Benefits of Implementing Reclamation Successfully the First Time for Oil and Gas Sites**. David Chenoweth, Owner/Soil Scientist, Western States Reclamation, Frederick, Colorado; David Holland, Environmental and Regulatory Manager, and Gerald Jacob, Environmental Advisor, Pioneer Natural Resources, Inc., Denver, Colorado; Lindsey Kruckenberg, Coordinator within Piceance Basin Surface Management Team, EnCana Oil & Gas; John Rizza, Arborist/Estimator, Western States Reclamation, Frederick, Colorado; and Brian Whiteley, Piceance Basin Surface Management Coordinator, EnCana Oil & Gas.

Environmental Managers employed by energy companies are often plagued with the lack of adequate cost data to support appropriate budgets for successful initial reclamation programs. Insufficient budgeting and improper initial reclamation for drill pads and access roads can result in higher overall operating cost and lower net profits over the life of the well. Pioneer Natural Resources and EnCana Oil and Gas Inc. have provided actual cost data for this case study and information from operations in the Piceance Basin and Raton Basin of Colorado. Minimizing reclamation and maintenance costs over the life of the well by properly budgeting and planning initial reclamation activities is essential to ensure cost savings. Reclamation failures can result in a 50% cost increase over initiating proper reclamation techniques from project implementation. The economic impacts associated with the direct costs of additional earthwork for sediment clean up and regrading, importing topsoil or applying soil amendments when poor soil conditions generate initial revegetation failures, re-seeding, re-installation of erosion control products, and weed control are significant. Operators can expect to spend upwards of $20,000 repairing sites where initial reclamation programs have failed. Additionally, hidden indirect costs, which are difficult to quantify, include administrative time to coordinate reclamation work that needs to be redone, potential agency fines for storm water management violations, and potential lost opportunity costs associated with delaying other projects. Developing more effective programs to track these reclamation and stormwater management costs would benefit operators in the long term. In addition, providing reasonable estimates for reclamation activities on sites to be capitalized up front would ensure resource protection.

5:00 – 6:00 p.m. **POSTER PAPER SESSION**: Presenters will be available at their posters for discussion.

Protecting the Parachute Penstemon during Clean-up and Closure of Oil Shale Operations. Richard Alward, Aridlands Natural Resources Consulting, Grand Junction, Colorado; Susan Hall and Ron Spears, URS Group, Inc., Denver, Colorado; and Carla DeYoung, Bureau of Land Management, Glenwood Springs Field Office, Glenwood Springs, Colorado.

Parachute penstemon (*Penstemon debilis*) is a candidate for listing as threatened or endangered by the U.S. Fish and Wildlife Service and is recognized as a Sensitive Species by the Bureau of Land Management Colorado State Director. Parachute penstemon habitat is limited to a specific geologic substrate: the steep white shale talus on the Mahogany Zone of the Parachute Creek Member of the Green River Formation. Of the four known locations, the largest occurrence on federal lands is at the Anvil Points Facility near Rifle, CO. The Anvil Points Facility was constructed to research and develop methods of oil shale mining and processing and has been inactive since 1983. Beginning in 2008 and continuing through 2009, a removal, clean up, and closure plan has been implemented to safely remediate and store waste shale and close the mine adits. Several steps were taken to protect individual Parachute penstemon that were located near adits slated for closing. All penstemon plants on the historic mine bench were inventoried, flagged and mapped. Plants growing on access routes to adits were protected in place with synthetic mats. Plants growing directly in front of adits were transplanted to safe locations up to 30 meters distant. Survivorship of transplants and plants protected in place were both in excess of 85%. This rate is comparable to natural over winter survival observed in inventoried plants that were not directly impacted by mine clean up actions. With these steps, a rare plant species growing in and around oil-bearing shale formations was successfully protected from impacts of activities associated with oil shale mine closures. These protective measures might be an appropriate mitigation measure during other development activities proposed for similar substrates.

Development of a Sagebrush Steppe Plant Community 32 Years after Disturbance. Brock Bowles, Graduate Research Assistant, and Mark W. Paschke, Associate Professor, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado.

In 1976, the Successional Study on Surface Disturbed Soils (SSSDS) was initiated to examine the effects of seed mixes and fertilizer treatments on a sagebrush steppe plant community in northwestern Colorado following disturbances associated with mining activities. With renewed interest in oil shale development of western Colorado, the Piceance study site has become a unique and valuable source of long-term data for restoration practices of semiarid ecosystems. The experiment is a split-plot design consisting of 54, 9 x 18 m subplots, with six seed mixtures comprising the main plots and three fertilizer treatments comprising the subplots. Native and introduced grass, forb, and shrub species were used in the seed mixtures. Preliminary results after one year of data collection (2008) suggest that native seed mixes have the greatest species diversity while introduced seed mixes have the lowest species diversity. However, native species were outcompeted by introduced, mainly due to the persistence and invasive qualities of *Agropyron cristatum*. Introduced seed mixes had a lower presence of annual species, such as *Bromus tectorum*, compared to native seed mixes. The initial fertilizer treatments increased plant biomass and have lasting effects on species composition. This project shows that native seed mixtures create a more diversely rich pant community while the introduced seed mixtures produce more biomass with less plant diversity.

Using Native Annual Plant Species to Suppress Weedy Invasive Species in Post-fire Habitats. Chris M. Herron, Graduate Research Assistant, and Mark W. Paschke, Associate Professor, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado.

Increasing rangeland fire frequencies and uncharacteristic fires are creating a need for improved restoration methods across the west. Traditional seed mixtures of perennial plant species may not be suitable for intensely burned sites. A devastating fire has the potential to return a site to early seral conditions where native annuals have the potential to be the most suitable species for competing with invasive plant species such as cheatgrass (*Bromus tectorum*). In addition, native perennial plant establishment may be increased by providing a means for a more natural succession toward a later-seral community. We are testing the idea that native annual plant species are better suited to post-fire restoration efforts, compared to perennial plant species that are commonly used in traditional seed mixtures, with four treatments (native annual seed mixture, standard perennial seed mixture, combination of annual and perennial, and a control). Results after one growing season suggest that the response of cheatgrass cover was decreased in plots seeded with the native annual plant species. However, this was only observed at two of four sites, possibly due to differences in precipitation between regions.

Long-Term Recovery of a Sagebrush Steppe Ecosystem in Northwest Colorado in Response to Nutrient Addition. Timothy B. Hoelzle, Graduate Research Assistant, and Mark W. Paschke, Associate Professor, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado.

Due to recent legislation, oil shale research and development has increased throughout the western US. The aim of this study is to investigate the long-term effects of various reclamation practices on ecosystem development associated with disturbed oil shale lands in the Piceance Basin of northwestern Colorado. In 1984, an experiment was established to examine the response of nitrogen (N) and phosphorus (P) addition on plant recovery and succession following a severe disturbance associated with energy development. We revisit these experiments 24 and 25 years after the initial disturbance to assess plant successional dynamics. Initial results help to support current successional theories. After five years of study, N was found to be the main factor controlling ecosystem succession, while P had no significant effect. Twenty years later, both N and P addition was found to promote the longevity of annual species, increase total aboveground production, and decreases species richness, slowing plant successional development relative to the undisturbed reference communities.

Surviving Lodgepole Pine Forest Structure at Early, Middle, and Late Stages of a Mountain Pine Beetle Eruption in Rocky Mountain National Park, CO. Kellen N. Nelson, Matt B. Diskin and Monique E. Rocca, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado.

An ongoing mountain pine beetle (MPB) outbreak has been dramatically changing Colorado's lodgepole pine forests since 1996. Warmer climate trends and extensive old forests facilitated this widespread outbreak. We distributed 46 randomly located clusters of three plots across the west side of Rocky Mountain National Park to examine the influence of environmental and stand structure factors on lodgepole pine mortality patterns, and to assess changes to stand and landscape structures through three stages in the eruption. Across the landscape, mean stem mortality reached 47%; however, 71% of basal area was killed. Surviving stand structure experienced large decreases in diameter at breast height (17.4 to 11.0 cm), basal area (29.3 to 8.5 m^2 ha^{-1}), and density (1393 to 915 stems ha^{-1}). Environmental factors (elevation and moisture) and tree size greatly influenced which stands saw high levels of mortality during the early stage of the eruption. In contrast, later stages of the eruption showed stronger relationships with stand structure factors (tree size, basal area, proportion of non-host trees, density and stand age). Changes in forest heterogeneity depended on spatial scale. At the local scale, heterogeneity increased among subplots within clusters, while heterogeneity among clusters on the landscape declined over time. The current mountain pine beetle outbreak has caused extensive changes to the subalpine forest landscape, but high densities of surviving trees and increased stand-scale heterogeneity will allow forest recovery and increased resistance in the face of future outbreaks.

Nitrogen Dynamics of Actinorhizal Buffaloberry in Colorado Forests Affected by Mountain Pine Beetle. Zoe M. Miller, Graduate Research Assistant, and Mark W. Paschke, Associate Professor, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado.

Russet buffaloberry (*Shepherdia canadensis* (L.) Nutt.) is an actinorhizal shrub capable of forming a symbiotic relationship with the N_2-fixing soil actinomycetes *Frankia*. Russet buffaloberry is commonly found as a dominate understory species in lodgepole pine (*Pinus contorta* Douglas ex Louden) communities. The mountain pine beetle epidemic is currently responsible for large losses in lodgepole pine forests. As the overstory canopy of lodge pole pine communities dies off, there will be an increase in light availability in the understory. This study will investigate buffaloberry's response to two environmental factors, light and soil N availability, with a field study. We hypothesize that as light availability increases, the N_2 fixation will increase. With more light, buffaloberry will have more energy to expend in the energy intensive N_2 fixation process. We also hypothesize that as bioavailable soil N increases, the amount of N_2 fixation will decrease. If there is available N in the soil, the plant will usually use the soil available N rather than put energy into fixing N_2. The field study was a random survey of buffaloberry sites across north-central Colorado with buffaloberry foliage, soil samples, and light measurements for canopy cover collected at each site. The buffaloberry foliage will be analyzed and compared to local non-N_2 fixing reference shrubs found at each site using the ^{15}N natural abundance method with a mass spectrometer. The sites will be characterized by light availability and compared to the values of N_2 fixation determined by the comparison of buffaloberry to the local reference shrubs. Data for the field study was collected in July 2009. A total of 60 sites were sampled with varying levels of light and buffaloberry density. This information will allow us to examine the relationship between light availability and N_2 fixation, and ultimately provide a better understanding of how buffaloberry will respond to the changing lodgepole pine communities.

Restoring Sage Grouse Habitat in the Pinedale Anticline Gas Field, WY – Part II: An Update of the Shell/BLM Revegetation Project. Richard S. Carr, III, C-M Environmental Group, Inc., Pinedale, WY; Aimee Davison, Shell E&P Company, Pinedale, WY; H. James Sewell, Shell E&P Company, Denver, CO.

At the 18th High Altitude Revegetation Workshop in 2008, we presented the results of the Shell/BLM Pinedale Anticline Revegetation Pilot Project, initiated in 2004. The paper focused mainly on the reclaimed well-pad locations seeded in the original 2004 test and used monitoring transect data and observations collected through 2007. In 2008, a rigorous monitoring program of on-site/off-site vegetation transect pairs was carried out for all locations seeded in 2004 (4th growing season in 2008) and 2006 (2nd growing season in 2008). In 2009, onsite transects were repeated for the same reclaimed locations. Brief summaries of the 2008 transect data were presented previously in a paper given by the authors at the 2009 Society of Petroleum Engineers Americas E&P Environmental Conference in San Antonio, TX. This current poster presentation is an update on the original 2004 test locations since 2007, and a distillation of some lessons learned from various seeding trials and errors on well-pad locations and pipeline right-of-ways in the Pinedale Anticline from 2006 through 2009. Shrub: forb:grass ratios for sites seeded with the ―Shell Habitat Blend" (SHB) more closely mirror that of the adjacent reference (off-site) sites on most of the drill seeded and hydroseeded sites. For Overseed sites (SHB seeded into older grass-dominated sites), shrubs and forbs still lag significantly in diversity and frequency. Shrub diversity and frequency generally meet/exceed 5-Year expectations by BLM requirements. Forb diversity and frequency are lacking by new BLM requirements but are showing some improvement as forbs in adjacent, undisturbed areas seed into disturbed ground. This is especially true, and important, with mat-forming phlox and buckwheat species, the predominant native forbs in the reclaim area (seed usually unavailable commercially). Many forbs seeded in drought years have surprisingly emerged after 2-3 years. Most grasses seeded are established; one site was reseeded in 2008. Diversity of grass species is increasing as offsite species in adjacent, undisturbed areas seed into reclaim areas. Predominance of grasses on Overseed sites is still problematic; grass-heavy seed mixes are no longer used on newer reclaims and pipelines. Precipitation during the first growing season and soil conditions at the time of seeding, including the application of amendments, continue to be the most important factors for successful reclamation. The SHB is an evolving seed mix. Sub-dominant shrub species are now tailored to match specific sites; the number of grass species has been increased to four; number and type of forbs are controlled year to year by availability. The effectiveness of more site specific soil amendments has become clearer in subsequent year seedings, particularly in the case of a 2007 pipeline reclamation. Drill seeding with the Truax Rough Rider range drill is still the preferred method, although hydrdoseeding is considered a workable alternative when required by site constraints. Restoring frequency and diversity of native forbs (specifically phlox and buckwheat species) is the obvious current challenge for meeting the new requirements for interim and full reclamation.

5:30 – 7:00 p.m. **SOCIAL HOUR** in the Exhibit Area.

7:00 p.m. **CONFERENCE BANQUET.** After dinner, Ed Kleiner will present ―A Visual History of Reclamation at the Colloseum Mine" which is located southwest of Las Vegas in the Clark Mountains. Join Ed in this pictorial journey from active mining through reclamation and the associated vegetation changes over time. His presentation includes a compilation of three sets of photographs beginning with historic photos from the 1930's when the Colloseum mine was already in production. These photos and a series taken between 1987 and 1991 are presented with permission from Sally McLeod who was employed at Colloseum during this time. His photography covers the period from 1995 to 2009. Ed is with Comstock Seed out of Gardnerville, Nevada.

THURSDAY, MARCH 4

➘➘**SESSION 5:** Co-chairs – Mike Ellis and Wendell Hassell.

8:30 – 9:00 a.m. **Achieving Sustainable Forests**. Ann Walker, Forest and Rangeland Health Program Director, Western Governor's Association, Denver, Colorado.

American forests directly and positively influence the social, economic, and ecological conditions of the country. They sustain and enrich the well-being of individuals and communities. And in the West, they are a huge part of the identity of its citizens and communities. The threats our forests face and the inadequacy of our current response to these threats have caused concern as to whether the nation's forests are, in fact, sustainable. The values at risk are not trivial – clean and abundant water, clean air, stable employment, energy self-sufficiency, wildlife habitat, and access for recreation and spiritual renewal. The United States has the fourth largest forest estate of any nation, with 8 percent of the world's forests, exceeded only by the Russian Federation, Brazil and Canada. The total forestland in the United States is approximately 749 million acres — about one-third of the Nation's total land area. Further, there is a set of disturbing trends threatening these forest values across the country. Key to this vision of sustainability is that, across large areas, forests must be able to deliver a full and integrated set of economic, environmental and social values. Forests which generate economic value provide the means to fund environmental and social benefits. This is true on both public and private ownerships. At the same time, by protecting a forest's environmental values sustainable forestry maintains the basic soil, water and biological elements that underpin economic value. Equally important, is the need for forests to deliver a robust set of social values so that citizens ultimately have the emotional commitment to keep and nourish forests appropriately for all benefits. Our goal is to create a renewed commitment and social contract, both in the west and across the nation, to understand, enhance, and protect the health, productivity, and sustainability of America's forests. A fundamental policy discussion needs to occur on the national stage across all ownerships about the future of forests in the United States.

9:00 – 9:30 a.m. **Barrick Gold Corporation's Standardized Protocols for Reclamation Monitoring and Final Relinquishment.** Steve Viert, Senior Range/Wildlife Ecologist, and Jesse Dillon, Range Ecologist, Cedar Creek Associates, Inc., Fort Collins, Colorado.

Reclamation monitoring targets several mine closure elements including: vegetation establishment and development, soil quality, and soil surface stability; all critical to a productive post-mine land-use and final relinquishment. Most current programs have no real systemic link to operational mining processes, no feedback system for improved reclamation performance, and no functional link to a determination of success. Relinquishment addresses processes, regulatory mandates, and milestones that assure stakeholders that reclaimed land will not be problematic to the future ―well-being" of the environment. This protocol describes the soil surface and reclamation evaluation procedures to be used by Barrick held mines for monitoring and analysis of reclamation performance. Unless superseded by site-specific permitting requirements, these procedures support the process leading to effective financial guarantee or assurance release. Two important side-benefits are: 1) the timely detection of latent reclamation issues along with corrective action guidance, and 2) a standardized means of recording information that precludes loss due to staffing changes/turnover. This protocol is based on step-wise procedures developed in the United States and Australia that concentrate on: information control; evaluation of soils; evaluation of soil stability; performance of revegetation; consistent and meaningful reporting; and development of, and compliance with, release criteria to facilitate relinquishment of any regulatory mandated financial assurances and/or liability. Key to the success of these components is the fifth step (reporting) that provides an effective feedback loop conveying pertinent and/or corrective information to site managers or their successors. Once reclaimed surfaces have achieved satisfactory results, final relinquishment can be effected.

9:30 – 10:00 a.m. **Case Study: Peanut Mine Reclamation Project, Gunnison County, Colorado**. Steve Renner, Senior Environmental Protection Specialist, Colorado Division of Reclamation, Mining and Safety, Grand Junction, Colorado.

The Peanut Mine is located near the Town of Crested Butte in the central Colorado Rockies. The Peanut is an historic coal mine that was active in the late 1800's and early 1900's. Thousands of yards of anthracite coal waste materials, some of which displayed a propensity to spontaneously combust, were left at the site following abandonment. Following abandonment of the coal mine, a silver mill was constructed at the site. The silver mill, which processed ore transported to the site from throughout Gunnison County, operated sporadically through the mid 1970's. Acid generating silver mill tailings were stored in impoundments situated within and immediately adjacent to the Peanut Mine site. The Colorado Division of Reclamation, Mining and Safety; Inactive Mines Reclamation Program and Peanut Mine Inc, a non-profit corporation dedicated to preserving open space for public use, formed a partnership dedicated to reclaiming this mixed waste site. This unique partnership not only overcame significant environmental issues, but was able to design and construct this abandoned mine restoration project using innovative reclamation and revegetation techniques, while providing for federal, state and local involvement at all stages of project design and construction. The Inactive Mines Reclamation Program was presented with the Excellence in Abandoned Mine Land Reclamation National Award by the U.S. Office of Surface Mining in 2008 for its reclamation efforts at the Peanut.

10:00 – 10:30 a.m. COFFEE BREAK in Exhibit Area.

➘➘**SESSION 6:** Chair – Mindy Wheeler.

10:30 – 11:00 a.m. **Town of Minturn Eagle River Restoration Project.** David Blauch, Vice President and Senior Ecologist, and Troy Thompson, P.E., Ecological Resource Consultants, Inc., Evergreen, Colorado.

The Eagle River near Minturn, Colorado has been significantly impacted by mining and urban development. These activities have lead to an over-widened stream, degraded aquatic habitat, loss of riparian habitat and water quality impacts. Beginning in 2003, Ecological Resource Consultants, Inc. (ERC) initiated with the Town of Minturn, a restoration (enhancement) plan to improve over 2-miles of the River. The project was developed in two phases, Phase I was implemented in 2003-2004 and Phase II was implemented in 2008-2009. The objective of the project was to restore the natural function of the stream and adjacent riparian corridor, given current constraints. Restoration design included background assessment of stream hydrology, aquatic, riparian and geomorphologic conditions for this river system located at an elevation of approximately 8,000 feet. Designed channel geometries were defined based on fluvial hydraulic calculations and resulted in typical bankfull widths to match current flow conditions (impacted by diversions). The channel planform was adjusted to reintroduce stream sinuosity that had been lost during past encroachment and the channel profile was manipulated to mimic the natural stream type. Instream aquatic habitat was improved through the creation of varying habitat types including riffle, pool and glide sequences characteristic of the natural stream type. Riparian habitat improvements included re-vegetation of the created flood terraces as well as select historically disturbed areas along the riparian corridor. In total over 2-acres of riparian habitat was improved as part of the project.

11:00 – 11:30 a.m. **Overburden Revegetation with Low Seeding Rates and Minimal Soil Amendments at Tijeras Limestone Quarry, NM.** Robin Bay, Environmental Scientist, Ken Carlson, Principal Soil Scientist, and Wayne Erickson, Principal Environmental Scientist, Habitat Management, Inc., Englewood, Colorado.

Four soil amendment treatments, three broadcast seeding rates, and transplanting of woody species were evaluated to determine the best strategy to enhance reclamation efforts on redbed overburden materials used in lieu of salvaged topsoil for soil growth medium reconstruction at GCC Rio Grande, Inc's Tijeras Cement Plant and Limestone Quarry located in Tijeras, New Mexico. In 2008, after five years of monitoring, the different treatment combinations have all been successful at promoting increased vegetation cover, desirable species establishment, shrub densities, and species diversity. Additionally, soil parameters tested in 2008 were all within suitable limits and showed little difference between treatments or over time. Results of soil and vegetation data after five years suggest several conclusions: (1) Applying an organic amendment, such as the horse manure and stable waste used, was not cost effective; (2) The native hay mulch used on some plots was beneficial in reducing erosion, but the costs associated with this application and the introduction of undesirable plant species outweighed the benefit in this case; (3) All of the low broadcast seeding rates were effective at establishing cover and diversity with the 10 and 20 PLS/sq ft treatments providing the best overall vegetation results; and (4) While the transplants increased woody diversity and density, the added cost in materials and labor did not pay off in terms of overall cover, diversity, or production.

11:30 – 12:00 p.m. **Steamboat Ski Corp Base Area Regrade and Revegetation Project.** Lee Johnson, C.P.E.S.C., and Ron Whiteman, Bowman Construction Supply, Inc., Denver, Colorado; and Frank Case, Steamboat Ski Resort, Steamboat Springs, Colorado.

The lower part of the mountain where the beginner area is located had a design problem. The draws and double fall lines that Mother Nature provided had a tendency to bunch people together. As a result, the terrain was not conducive for teaching both skiing and snowboarding and they chose to regrade and reshape the contours of the Base Area. The project involved reshaping the lower 25 acres of the mountain terrain from the top of the Christy chair down to the base of the Gondola lift. No soil was removed nor was there any added. In their efforts to comply with Phase Two of the Clean Water Act, the Ski Corp employed over 25 employees full time for nearly three months to install berms, swales, check dams and Erosion Control BMP's to meet the obligations of their Stormwater Permit from the CDPHE. A Bonded Fiber Matrix was then applied over native seed and soil amendments last fall to revegetate the area. The end result was the successful germination and growth of vegetation on the site that allowed the area to close its permit with the state earlier this year, easily meeting the 70% requirement for revegetation.

12:00 – 12:30 p.m. **Salvaging a Seeded Native Grass Stand and Saving the Client Money.** Ron Dean, Business Development, Down to Earth Compliance, LLC, Denver, Colorado, and Tom Bowman, Division President, Bowman Construction Supply, Inc., Denver, Colorado.

Five sedimentation ponds, approximately 1.1 acre each in size, were situated in and around a housing development and golf course. The ponds were seeded, straw mulched, and blanketed fall of 2007. The ponds were inspected in early 2009 for construction compliance. It was determined that the native grass cover was inadequate for stability even though the slopes showed no signs of erosion. The grass cover was at best 1 plant per sq yd, and at worst, 1 plant per 5 sq yd. Recommendation was to remove the blanket, furnish and spread 6” of topsoil, reseed and blanket the sites. This method was estimated to cost $120,136, about $0.51 per sq ft. DTEC suggested an alternate treatment. Spread seed and soil amendment over the existing blanket. Use the existing plants and fill in with additional plants from seed. The soil in the ponds was sampled and tested, as well as the topsoil to be imported. While the potential imported topsoil was good, the soil in the ponds was not that much different. The decision was made to overseed and amend the project. The straw in the BioNet blanket had deteriorated, but the BioNet was still intact. Initially, a walk-behind slit seeder was used to apply seed; however, the slit seeder tore the BioNet. Therefore, the seed and amendment were applied over the netting with a hydroseeder. A standard native seed mix was used at double rate, 1800 lbs of Biosol per acre, 900 lbs of humate per acre, and 10 lbs of micorrhyzae per acre was sprayed over the blanketed areas, and the non-blanket area was drill seeded and straw mulched. This treatment also included some grading, weed control, and some straw BioNet blanket installation. This treatment cost approx. $41,140 or $0.15 per sq ft.

12:30 – 1:30 p.m. LUNCHEON.

➘➘**SESSION 7:** Chair – Ron Whiteman.

1:30 – 2:00 p.m. **Challenges of Native Seed Collection**. Bill Agnew, Granite Seed Company, Lehi, Utah.

The seed industry is in the business to provide the reclamation industry with the types of plant materials they demand regardless of their life-form (grasses, forbs and woody plants). Land reclamation is a very specialized industry and the seed required for the reclamation of those lands is also specialized and frequently in high demand and but short supply. The seed industry is able to meet demand only when seed merchants can successfully predict what the demand will be. To be successful in providing native plant materials, good planning addressing the type of plant materials that are needed may require preparation years in advance of the year in which we bring seed to market. The seed industry relies heavily on past history to know what to stock and the quantities of specific materials to keep in inventory. When seed is in short supply, the reason may be related to crop failure, unusual demand, or requests for material that the reclamation industry has not typically needed or wanted in the past. The price of seed can vary widely and is related to the amount of effort required to harvest particular species. Grasses are frequently the most affordable which relates to the mass cultivation in monoculture farm production fields. Typically, forbs and woody plants are more expensive because they must be hand collected from the wild. Seed collection is difficult work and requires the collector to be very familiar with plant communities and their environments across vast areas. Collectors must find stands that are large enough to be worth harvesting and free from invasive species. An ideal stand is one in which all your time can be spent collecting seed and very little time walking between plants looking for one ripe to harvest. The insistence of locally collected natives has presented a new challenge for the seed industry. If you must have site specific plant collections, success can only be achieved by planning with your seed supplier years in advance.

2:00 – 2:30 p.m. **Edwards Eagle River Restoration Project, Edwards, Colorado.** Julie Ash, P.E., Walsh Environmental Scientists and Engineers, LLC, Boulder, Colorado.

The Edwards Reach of the Eagle River completely lacks a mature riparian corridor and contains areas of poor quality aquatic habitat. These degraded conditions effectively disconnect high quality riparian and aquatic habitats that are present upstream and downstream. Channel conditions and aquatic habitat have been degraded by past agricultural land use practices coupled with increasing development linked with non-point source pollution supply. The most significant impacts are from fine sedimentation, livestock grazing and denuded riparian vegetation. In this lowest gradient reach of the Eagle River, where the valley abruptly widens and flattens, the channel has an extremely high width to depth ratio and an insufficient capacity to transport fine sediment at lower flows, which causes the fine sediment accumulations visible in sections of the river. The fine sediment accumulations have been identified as significant habitat for the tubifex worm (*Tubifex tubifex*), an organism associated with the occurrence of whirling disease (*Myxobolus cerebralis*) in trout. Further, the fine sediment accumulations choke the channel bed substrate, reducing insect populations and hiding cover and food supply for trout. High instream temperatures and low dissolved oxygen levels occur in the Edwards Reach during low flow periods and are detrimental to aquatic habitat. The overly high width to depth ratios in the reach contribute to poor aquatic habitat and the reach lacks both mature overhead canopy and Instream cover for shading and cooling. With the goal of improving habitat and function in the Edwards Reach and its floodplain, Walsh integrated stream health and function, aquatic, riparian and wildlife habitat, surface water quality, sediment control, land use management, education, and recreation into the design.

2:30 – 3:00 p.m. **Soil Heterogeneity of Abandoned Gas Well Sites in the Piceance Basin of Western Colorado.** Tamera Minnick, Physical and Environmental Sciences, Mesa State College, Grand Junction, Colorado; Richard Alward, Aridlands Natural Resources Consulting, Grand Junction, Colorado; and Mackenzie Gibson and Seth Wilson, Physical and Environmental Sciences, Mesa State College, Grand Junction, Colorado.

We are exploring the recovery of vegetation and soil resource patterns following oil and gas development in the Piceance Basin in western Colorado. Disturbed areas are generally characterized by a loss in heterogeneity in vegetation and soil structure and function. We identified eight abandoned well pads and two reference sites to compare soil and vegetation characteristics. All sites are located in Rio Blanco County, Colorado. The most recently abandoned site had only just had the topsoil replaced in the spring prior to sampling, while the oldest site was abandoned in 1967. At each site, we established a 9 m x 12 m sampling grid. We randomly located a point in each of 48, 1.5 m x 1.5 m grid areas. We also randomly located 4 subplots of 2 m x 2 m, and sampled 16 random locations within each subplot. We sampled a total of 112 points in each plot. Soil organic carbon and other chemical characteristics were determined for each sample. Geostatistical analyses of soil organic carbon indicates less heterogeneity in the disturbed sites in comparison to the two reference sites. With the exception of the recently recontoured site, the range of variation in soil organic carbon is linearly correlated with the age of abandonment and was lower than the two reference sites. These results suggest that even 40 years after abandonment, soil heterogeneity levels have not recovered. Practices that instill heterogeneity at the time of reclamation may aid in the reclamation of these sites.

3:00 – 3:30 p.m. COFFEE BREAK in Exhibit Area.

➘➘**SESSION 8:** Chair – Denise Arthur.

3:30 – 4:00 p.m. **Evaluating *Diorhabda carinulata* releases against *Tamarix* spp. in Coloroado**. Andrew Norton, Department of Bioagricultural Sciences and Pest Management, Colorado State University, Fort Collins, Colorado.

Diorhabda carinulata (formerly *D. elongata*) is a biological control agent specific to invasive *Tamarix* spp. Field releases of *D. carinulata* were first performed in Pueblo, CO in 2001, and approval for large-scale implementation releases was granted by USDA-APHIS in 2005. Colorado State University, in cooperation with the Colorado Department of Agriculture, USDA-APHIS and several partner organizations has made releases of the biocontrol agent at 8 sites in Colorado. As part of this release program, we have conducted evaluations to measure the establishment, population growth and spread of the beetle, and the impacts of *D. carinulata* on *Tamarix* performance. In addition, we have collected detailed data on the response of the associated plant communities at each release site. Results from these releases have been variable, ranging from explosive population growth and spread (2 sites), establishment and slower growth (1 site), persistence through 1 season (4 sites, but at two of these sites releases were first made in spring 2009) and no recoveries of the beetles following release (1 site). At the two sites with explosive population growth *Tamarix* have been substantially defoliated for three successive years and the live volume of focal *Tamarix* at these sites is now declining. In contrast, at sites where the biocontrol agent failed to persist or establish *Tamarix* volume has increased. The response of the associated plant communities at these sites has thus far been minimal, but there is no evidence that *Tamarix* is being replaced by other noxious species.

4:00 – 4:30 p.m. **Use of Landscape Fabric and Supplemental Irrigation to Enhance Survival and Growth of Woody Perennials Planted on Reclaimed Mine Lands.** Bob Musselman, USFS Rocky Mountain Research Station, Fort Collins, Colorado; Freeman Smith and Wayne Sheppard, Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship, Fort Collins, Colorado; and Lance Asherin, USFS Rocky Mountain Research Station, Fort Collins, Colorado.

A study was conducted to determine the effectiveness of landscape fabric and supplemental irrigation for increasing survival and growth of the woody perennials aspen and serviceberry planted on reclaimed surface coal mine lands at a high elevation site in Colorado. The study compared growth and survival of 1-gallon potted aspen and 10 cu. in. potted serviceberry planted with or without landscape fabric for control of competing vegetation, and with or without biweekly supplemental irrigation during the first growing season. First year response of aspen indicated that the landscape fabric was particularly crucial in survival and growth on sites with heavy competing vegetative cover. Supplemental irrigation provided only limited advantage compared to the landscape fabric. Photosynthesis and pre-dawn moisture stress measurements on the aspen indicated that they were more stressed without landscape fabric. Soil moisture was higher under the landscape fabric. There was no survival or growth response of the smaller serviceberry plants to landscape fabric or to irrigation during the first growing season.

4:30 p.m. CLOSING REMARKS. Randy Mandel, Chairman, High Altitude Revegetation Committee.

MILLTOWN DAM RIPARIAN AND FLOODPLAIN REVEGETATION

Tom Parker[1], Amy Sacry[2], Sarah Flynn[3], Erin Belmont[4], and Jesse Wallace[5]

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ABSTRACT

Milltown Dam, located at the confluence of the Blackfoot River and Clark Fork River in western Montana, was removed in stages between 2007 and 2009 as part of an integrated remediation and restoration project coordinated by the Environmental Protection Agency and the State of Montana. While the remedial work focuses on removing contaminated mining sediments that have accumulated behind the dam since 1908, the restoration design emphasizes restoring natural river and floodplain function in the context of a local community, and is driven by objectives that were developed collaboratively by the Site Natural Resource Trustees – State of Montana, US Fish and Wildlife Service, and the Confederated Salish and Kootenai Tribes. Revegetation is a significant component of this restoration effort. The revegetation plan focuses on creating conditions that will support riparian plant community development through natural river and floodplain processes. While the revegetation plan includes some planting and seeding, many surfaces are being designed to promote natural vegetation recruitment. This type of design was possible through a unique collaboration between engineers, hydrologists and ecologists. Rather than responding to a grading plan, ecologists helped develop grading criteria, and were able to include micro-swales, wetland features, and woody debris as components of the final graded floodplain surface. Revegetation activities include weed management, seeding, planting containerized plants and wetland plugs, installation of pre-vegetated coir mats and logs, bioengineering structures such as vegetated soil lifts and sod brush trenches along river banks, and variation of substrate and topography.

PROJECT BACKGROUND

Construction of Milltown Dam was completed in 1907 at the confluence of the Blackfoot and Clark Fork Rivers approximately four miles upstream from Missoula, Montana. The 1908 flood of record filled the reservoir with sediments containing mining and milling wastes from upstream mining operations in Butte and Anaconda, Montana. The Milltown Reservoir was designated as a National Priorities List (NPL) Site in 1983.

Figure 1. 1908 flood photograph at left, 1935 flood photograph on right.

Conditions within the reservoir behind the dam contributed to the formation of a plume of arsenic-contaminated groundwater that impacted the drinking water supply of the nearby community of Milltown. Concentrations of copper, other metals and arsenic in the reservoir sediments represented a chronic and sometimes acute hazard to aquatic life within the reservoir and immediately downstream, particularly when contaminated reservoir sediments were scoured during dam operations, elevated flood events, and periodic ice scour.

In addition to the threat of contaminated sediments to public health and aquatic life, the location of the dam also limited upstream migration of fluvial fish into both the Blackfoot River and Clark Fork River (Schmetterling, 2003). Selective fish passage at the dam was initiated in the late 1990s to evaluate fish movement upstream of the reservoir, but manual fish passage was costly and time-consuming.

To address these issues, the Environmental Protection Agency (EPA) and the State of Montana elected to remove Milltown Dam and the most highly contaminated sediments stored behind the dam. Remedial activities began at the Milltown Reservoir in 2007. The State of Montana and the other Site Natural Resource Trustees (U.S. Fish and Wildlife Service and the Confederated Salish and Kootenai Tribes) initiated restoration planning for the two rivers in 2003 and restoration activities began at the site in 2008. Restoration activities aim to restore natural river and floodplain functions by reconstructing the channel in some locations and re-grading and revegetating the floodplain surface at the former Milltown Dam and Reservoir locations. The EPA and State of Montana worked together to coordinate and integrate remediation and restoration activities. The Montana Department of Justice, Natural Resource Damage Program (NRDP) has funded and directed the restoration effort.

SUMMARY OF RESTORATION DESIGN

The restoration design for the Milltown restoration area (Figure 2) emphasizes restoring natural river and floodplain functions in the context of a local community, and is driven by objectives that were developed collaboratively by the Site Natural Resource Trustees (Trustees) – State of Montana, US Fish and Wildlife Service, and the Confederated Salish and Kootenai Tribes. The restoration area includes the former location of Milltown Dam and its reservoir along with portions of the Clark Fork and Blackfoot Rivers upstream of the former Milltown Dam location.

Figure 2 below shows the general location of the restoration area and reaches assigned within the restoration area for planning and implementation purposes.

The State of Montana assembled an interdisciplinary team of hydrologists, engineers, geomorphologists, ecologists and biologists to develop a restoration plan for the Milltown Dam restoration area. The team includes River Design Group, Inc. of Whitefish, Montana; WestWater Consultants of Corvallis, Montana; and Geum Environmental Consulting, Inc. of Hamilton, Montana. The team produced the final restoration document *Restoration Plan for the Clark Fork River and Blackfoot River near Milltown Dam* (State of Montana, 2008a). The NRDP and Montana Department of Fish, Wildlife and Parks also participated as technical team members and provided leadership that made the interdisciplinary approach possible.

Implementation of the restoration plan began in summer 2008, and restoration work will continue through 2012. A monitoring plan was also developed to evaluate the effectiveness of restoration actions. Monitoring began in 2009 and will continue for several years.

Restoration Goals and Objectives

The overall project goal set forth by the Trustees is to restore the confluence of the Blackfoot and Clark Fork Rivers to a naturally functioning, stable system. Specific goals include: (1) Maintain water quality by reducing the erosion of contaminated sediments; (2) Provide channel and floodplains that will accommodate sediment transport and channel dynamics appropriate for the geomorphic setting; (3) Provide high quality habitat for all native fishes and other trout species, including continuous upstream and downstream migration while minimizing habitats that will promote undesirable fish species; (4) Provide functional wetlands and riparian communities, where feasible. These communities will also provide improved riparian and wildlife habitat within the restored area; (5) Improve visual and aesthetic values through natural channel design, revegetation and the use of native plants and materials; and (6) Provide safe recreational opportunities compatible with other restoration goals, such as channel and floodplain stability, sediment transport, and fish habitat.

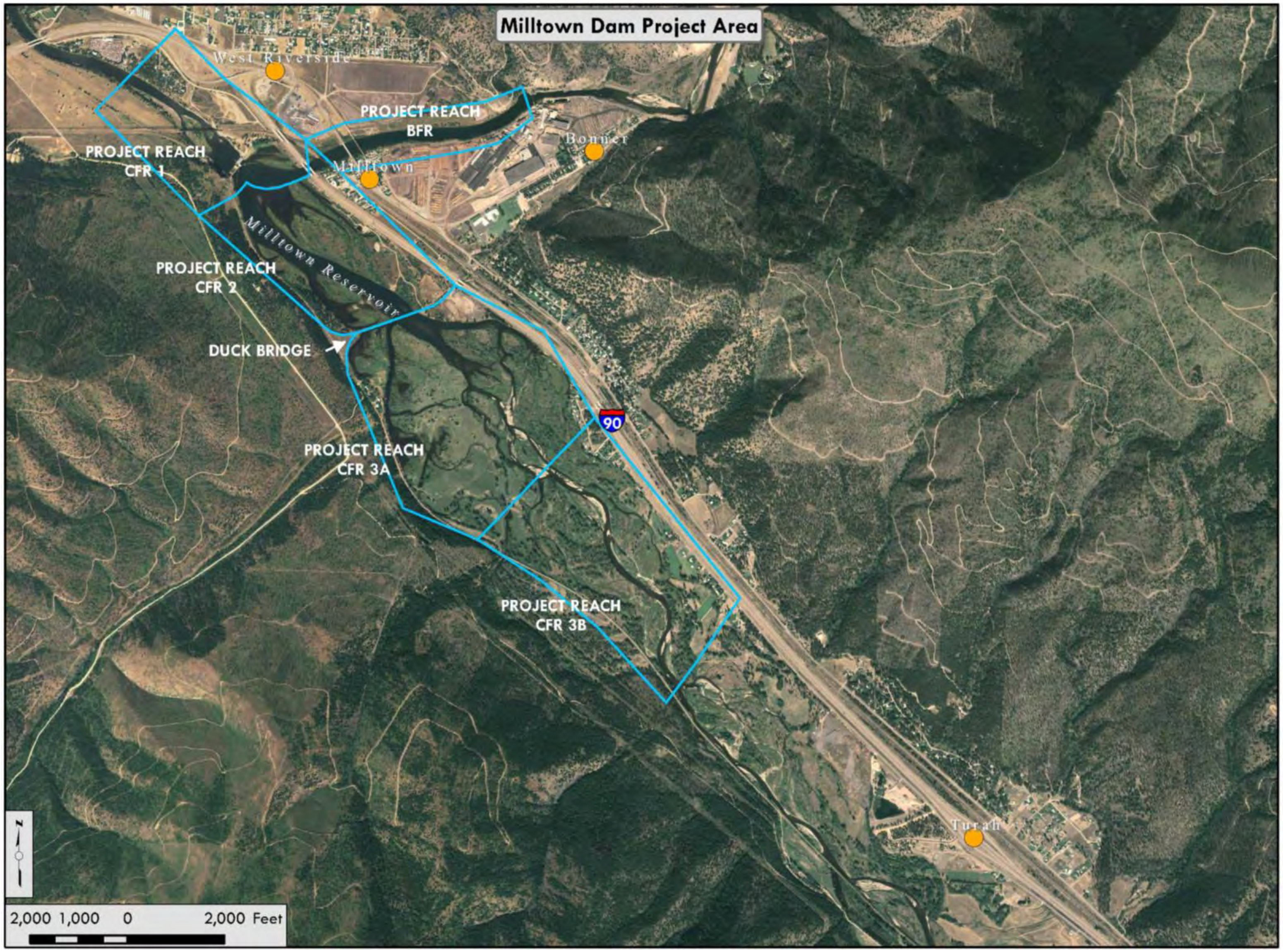


Figure 2. Overview figure showing the Milltown restoration area and project reach breaks.

FLOODPLAIN AND STREAMBANK REVEGETATION DESIGN

The following sections focus on the revegetation portion of a comprehensive restoration program developed for the Clark Fork and Blackfoot Rivers near the Milltown Dam site. Restoration activities address the river channel, side channels, floodplain, off-channel wetlands, riparian plant communities, and portions of adjacent uplands. The restoration approach described here was developed through a collaborative, interdisciplinary process that closely integrated revegetation designs with engineering designs described in the restoration plan. Because riparian plant community composition and distribution is related to geomorphic position in the floodplain, substrate texture and thickness, hydrology and hydraulics; the desired future condition for these plant communities is linked to a hydrogeomorphic framework that considers all these factors (Hauer and others, 2002). This section describes desired future condition cover types that guide restoration activities, and specific revegetation treatments aimed at restoring these cover types.

Desired Future Condition

The desired future condition for the riparian and floodplain environment within the restoration area is a dynamic, succession driven mosaic of plant communities capable of supporting a wide range of floodplain ecosystem functions. This type of environment is present in many undisturbed riparian communities in western Montana and was likely present in the restoration area prior to the construction of Milltown Dam. To successfully create and maintain a diverse mosaic of plant communities in the restoration area requires acknowledging the role that fluvial processes play in determining plant community structure. Geomorphic and other disturbance processes will affect the development of the riparian and floodplain ecosystem, ultimately determining the spatial pattern and successional development of riparian vegetation communities.

Vegetation Assessment Methods

In early 2005, initial assessments were completed to evaluate historical and existing vegetation conditions in the vicinity of the restoration area. Vegetation data were collected in the field with the goal of identifying a range of desired plant communities for the restoration area. Data collection and analysis included: (1) completing a detailed map of vegetation communities present within the restoration area, and (2) cross-referencing these vegetation communities with existing riparian plant community and hydrogeomorphic classification schemes that are specific to the western Rocky Mountains in Montana (Hansen and others, 1995; Hauer and others, 2002). Results from analyzing these data are reported in *Milltown Revegetation Data Summary Report* (Data Summary Report) (State of Montana, 2006).

Based on review of spatial data and field observations, the following criteria were determined to be the most important factors in determining occurrence of desired vegetation cover types:

- Elevation relative to bankfull (as a surrogate for hydrology),
- Soil texture,
- Depth of soil based on soil profile data or the depth to alluvium.

These criteria were used to plan the location and distribution of desired cover types that represent the desired future condition related to floodplain and streambank environment within the restoration area and determine treatments necessary to achieve these desired cover types (Table 1).

Desired cover types include the following surfaces and vegetation communities: exposed depositional; colonizing depositional; other shrub; emergent wetland; pole cottonwood and aspen; mature cottonwood and conifer; riparian conifer; and upland. Figures 3 and 4 below show the desired distribution and location of these cover types as designed. Each cover type is described in more detail below.

Exposed Depositional

The exposed depositional cover type includes recently formed point bars and other recent depositional areas in the floodplain where riparian plant communities will establish. These surfaces are composed of exposed alluvial sand, gravel and cobble; and initially support mostly scattered annual vegetation and groups of cottonwood and willow seedlings. Because of their position within or adjacent to the bankfull channel, these surfaces are subject to frequent scour and reshaping. The combination of sparse vegetation and exposed mineral substrate makes exposed depositional features ideal surfaces for cottonwood and willow recruitment.

Colonizing Depositional

The colonizing depositional cover type includes depositional surfaces that are becoming more stable, such as the portion of point bars and other depositional areas at or above bankfull elevation, or depositional areas where the river alignment has shifted away, leaving the area less prone to scour and re-sorting. This cover type is characterized by young willow, cottonwood or early successional mixed annual and perennial herbaceous species. These surfaces are formed from recently deposited sediments, so they are composed mostly of exposed alluvial material. Because these surfaces are older than exposed depositional surfaces, they may also include areas of finer-textured sediment such as fine sand and silt that have settled out due to friction from seedlings and woody debris accumulations. Because of their position near the bankfull channel, these surfaces are subject to some scour and reshaping; however, they are typically stable enough to support perennial vegetation in places. While vegetative cover can be high on these surfaces, they may still support some cottonwood and willow germination.

Other Shrub

The other shrub cover type includes areas that consist primarily of shrubs located along secondary channels, near off-channel wetland features and along outer banks. Within the other shrub cover type, the hydroperiod has low variability (soils are saturated during a significant portion of the growing season), and soils may be deeper than in other areas of the floodplain. In most cases, the other shrub cover type is a transitional cover type between either emergent wetland or open water, and tree-dominated vegetation cover types. Most other shrub cover type areas are expected to develop and maintain wetland characteristics.

Table 1. Floodplain design criteria for restoration cover types for the Milltown Dam restoration project. Design criteria include elevation, soil depth and soil texture criteria. This table also provides proportional abundance of desired floodplain cover types that currently occur in the restoration area and the desired distribution of cover types both short term (5-15 years) and long term (15-25 years).

Cover type *	**Existing (% canopy cover)**	**Short Term 5-15 yrs (% canopy cover)**	**Long Term 15-25 yrs (% canopy cover)**	**Elevation relative to bankfull ****	**Soil texture *****	**Soil depth *******
Main channel water surface at base flow	8	5-8	5-8	N/A	N/A	N/A
Off channel water surface at base flow	6	2-5	2-5	N/A	N/A	N/A
Exposed depositional areas at base flow	2	5-15	5-10	-2 to 0 feet	Sand-cobble	0-1 inches to alluvium
Depositional areas with colonizing willows and cottonwoods	1	10-25	5-15	-1.5 to +0 feet	Sand-cobble	0 to 6 inches to alluvium
Other shrub wetland communities	22	5-15	10-20	-1.5 to +3 feet	Silt loam/sand (soil profile data)	0 to 12 inches along the channel to alluvium, 27 inches at a point bar (soil profile depth)
Herbaceous wetland communities	10	10-20	5-15	-3 to 0 feet	Loamy sand, silt loam, loam (soil profile data)	0 to 36 inches (soil profile depth), 108 inches to alluvium
Pole cottonwood and aspen 2 to 6 meters in height	1	5-10	10-20	+1.3 feet (only one data point)	Sand/gravel/cobble with some silt on surface	0 to 12 inches alluvium depth
Mixed conifer/cottonwood and aspen > 6 meters in height	7	10-20	20-40	+2 feet	Silt loam, sandy loam, loamy sand (soil profile data)	1 foot (soil profile depth), alluvium depth is 36 to 37 inches
Conifer (ponderosa pine and Douglas-fir)	5	5-10	10-20	+3 feet	Sandy loam	No data available
Agricultural field	38	To be determined by post-restoration land use plan	To be determined by post-restoration land use plan	N/A	N/A	N/A
Developed, including buildings/roads/trails/recreational facilities	0	0-5	0-5	N/A	N/A	N/A

*Restoration cover types and desired proportional distributions are adapted from Hauer and others (2002). Long term and short term proportional distribution ranges are adapted from Hauer and others (2002) and adjusted to match expected belt widths within the Clark Fork River floodplain.
**'Elevation relative to bankfull ranges are based on sub-sampling cross-sections elevations.
***Table cells that include 'soil profile data' are actual textures recorded in soil pits. All other cells were extrapolated based on experience on similar rivers.
****Soil depth refers to the depth observed in a soil pit, not necessarily actual depth of mineral soil.

Emergent Wetland

This cover type includes areas of emergent wetland associated with off-channel wetland and open water features. This cover type may also occur in small areas along the main channel and secondary channels. These areas will have highly variable, but generally longer, hydroperiods and will likely be submerged during flows above bankfull. Emergent wetlands will function as a transition between open water and shrub or cottonwood cover types within off-channel wetlands and open water features.

Pole Cottonwood and Aspen

The pole cottonwood and aspen cover type represents five to fifteen year-old age class cottonwoods and willows that develop as a result of depositional bar formation associated with a particular flood event or series of flood events. This cover type is the next successional stage after the colonizing depositional cover type and occurs throughout the floodplain at surfaces that generally correspond with the bankfull elevation. In cases where these surfaces remain in place (where they are not washed away by floods and re-set to the exposed depositional cover type), this cover type will transition to the mature cottonwood and conifer or the riparian conifer cover type over time as sediment accumulates on the floodplain and/or the river shifts its location.

Mature Cottonwood and Conifer

The mature cottonwood and conifer cover type includes mature conifer, cottonwood and aspen stands. This cover type occurs in areas corresponding to the existing low terrace elevation observed in the restoration area, where floods would occur at frequencies of ten years or greater. The time frame for developing mature vegetation on this surface is 15 to 25 years after floodplain construction. In general, this cover type will not support wetlands although small areas of wetland may persist in low elevation swales.

Riparian Conifer

This cover type includes mature conifer communities with a mix of riparian shrubs and upland shrubs such as chokecherry, mockorange, and serviceberry. The riparian conifer cover type, located between two and three feet above the bankfull elevation, is unlikely to be altered by flood events that occur at frequencies of 20 years or greater. Within this cover type, the dominant disturbance processes are less likely to be flood-related, and more likely to be caused by wind, fire, insects or disease. The time frame for developing mature conifers on this surface is 30 to 50 years after floodplain construction.

Upland

This cover type includes areas where the desired long-term plant community includes upland grassland or conifer communities within the restoration area. This cover type occurs on landform positions higher than those occupied by the riparian conifer cover type.

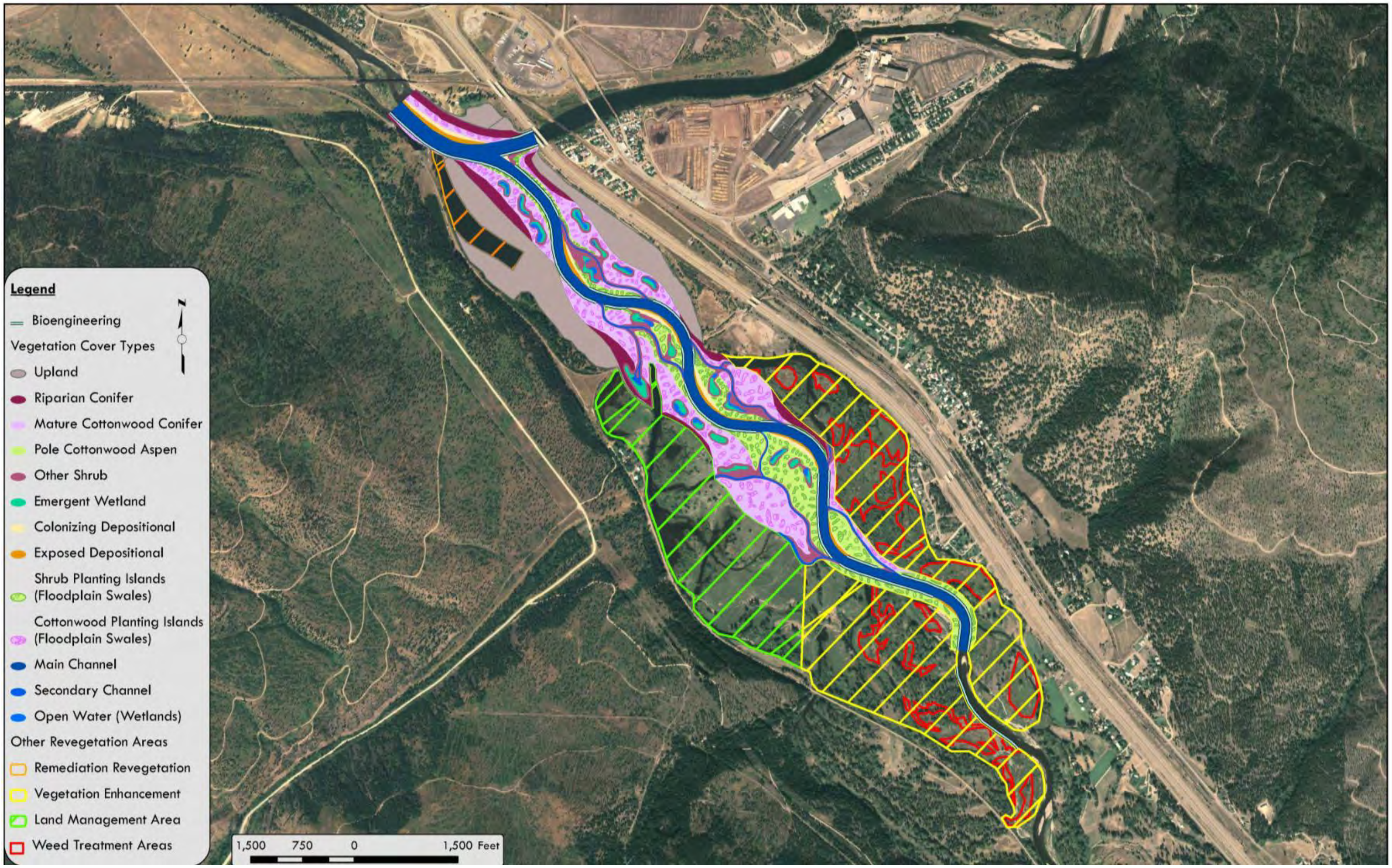


Figure 3. Design floodplain vegetation cover types and restoration areas for the Clark Fork River near Milltown Dam.

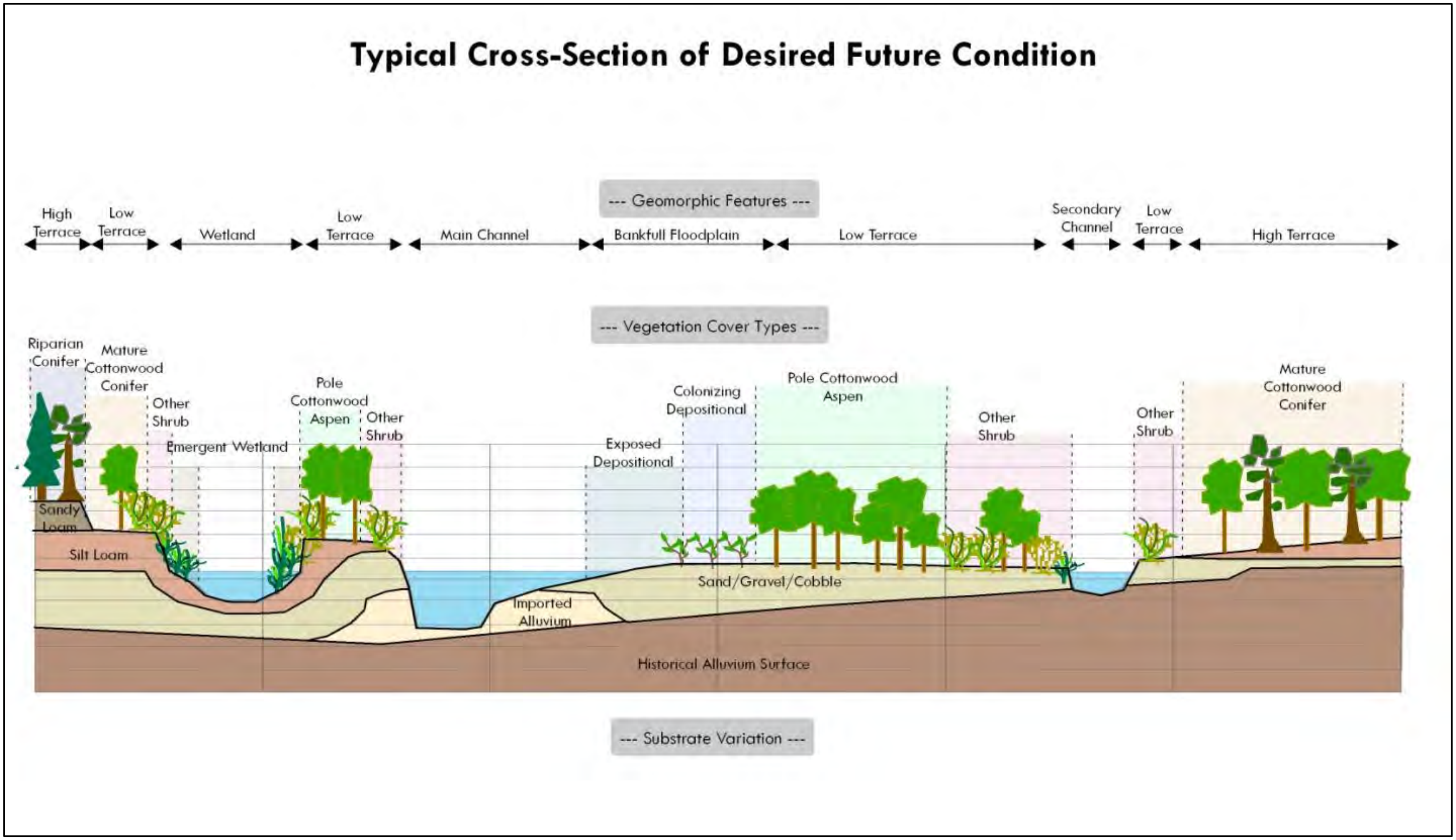


Figure 4. Typical cross section of the desired future condition for vegetation in relation to geomorphic features and substrates.

FLOODPLAIN AND STREAMBANK REVEGETATION TREATMENTS

The revegetation plan for the Milltown Dam restoration area focuses on creating conditions that will support riparian plant community development through natural river and floodplain processes. Active revegetation treatments include floodplain grading and substrate variation, plant salvage and transplant, bioengineering, seeding, containerized planting, browse protection, and weed management. These revegetation treatments are described below, and because revegetation activities began in 2009, some references are made to modifications that were made during construction, in addition to discussion of how treatments were originally designed.

Floodplain Grading and Substrate Variation

Floodplain grading is intended to create geomorphic surfaces such as bankfull floodplain, low terrace, high terrace, and uplands that naturally occur along an alluvial river system in western Montana. In addition, topographical diversity including lower elevation shrub and cottonwood planting island depressions (swales), combined with surface roughening and wood placement results in protected microsites where plants can become established (Figures 4, 5 and 6). Diverse microtopography is intended to reduce competition from invasive species, which thrive on simple, uniform surfaces. In addition, adding roughness to floodplain surfaces increases the ability of these surfaces to trap cottonwood and willow seeds that naturally colonize on exposed alluvial material.

Original designs presented in the restoration plan for floodplain grading and substrate variation were modified once construction activities began and the historical floodplain surface was revealed in places. As floodplain excavation continued, stumps and floodplain soils were exposed and in some of these locations, native vegetation was colonizing historical floodplain surfaces. Grading plans were modified and criteria were developed as a result of these findings to guide excavation so that the historical floodplain surface was preserved where feasible to take advantage of the existing substrate and potential for vegetation colonization.

In other locations, existing substrate is excavated or material is placed to meet the original design grading plan. In these cases, growth media (soil that can support plant growth) is placed according to texture and depth criteria (Table 1 above), with some modifications driven by either construction constraints or availability of material. Figure 8 below shows a plan view of how substrate criteria are associated with vegetated cover types in the floodplain.

Figure 5. Large constructed floodplain swales serve as planting islands. The left photo shows a swale after excavation. The right photo shows a swale after large and coarse woody has been added and the surface has been roughened to create microsites for plants to establish.

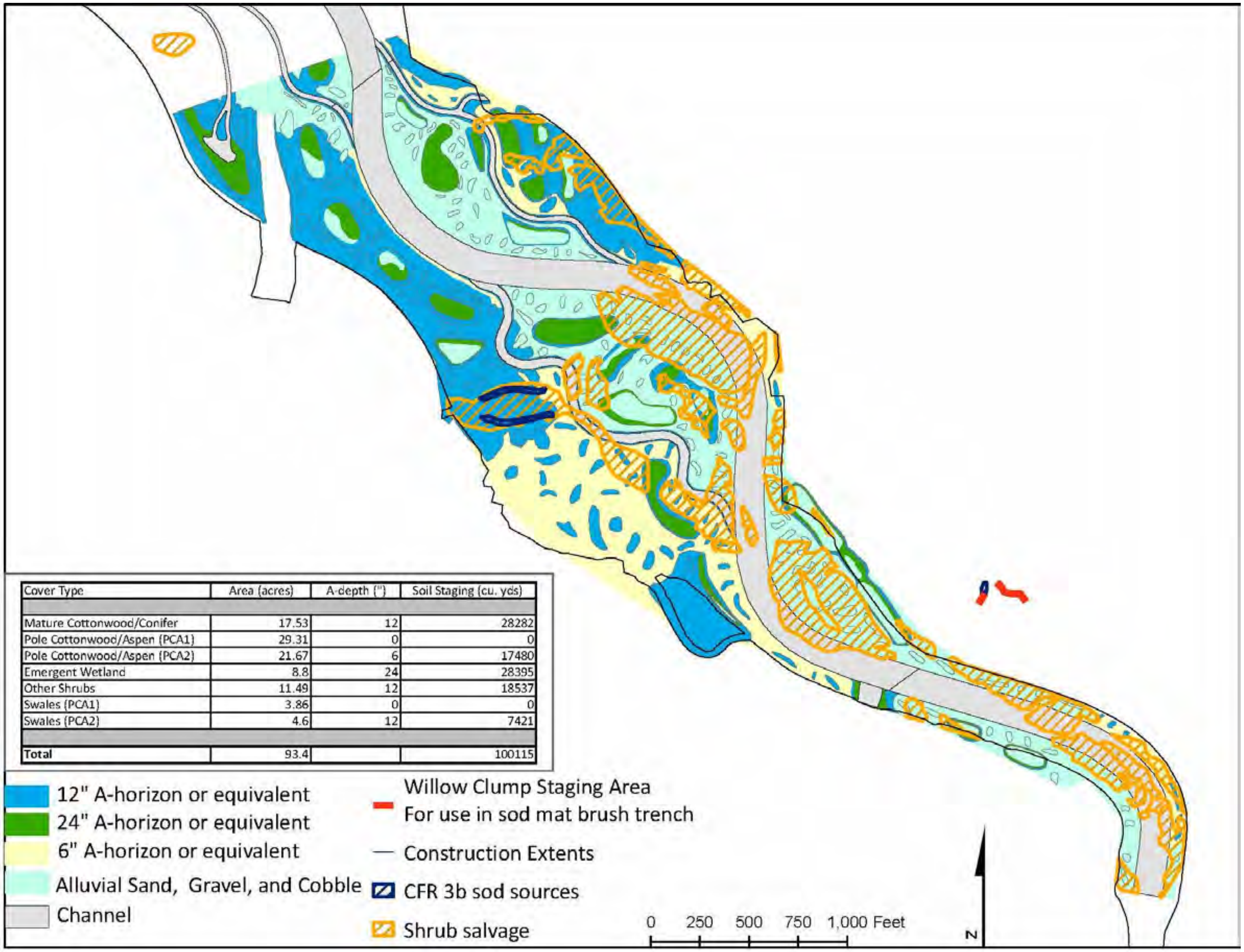
 

Figure 6. Constructed floodplain swales that have trapped debris and fine sediment transported during a flood event. Swale features also trap seeds and other plant propagules and provide microsites for installed container plants and natural recruitment.

Figure 7. Large and coarse wood that is partially buried in floodplain swales creates protected microsites for planted and seeded shrubs, trees, forbs, and grasses to establish and grow.

Plant Salvage and Transplant

Mature native shrubs and sod were salvaged from within construction limits for use in various revegetation techniques. Salvaged plants have the advantage of being adapted to site conditions, having mature and extensive root systems, and are mature enough to quickly add natural vegetation function to streambanks and floodplains once transplanted. Areas within construction limits with native sedge sod or willows were delineated for salvage. Figure 8 provides examples of plant salvage areas based on the vegetation community mapping completed during revegetation planning. Figure 8 also shows the substrate criteria for each cover type for a portion of the restoration area. Shrubs were salvaged from within construction limits both prior to construction and during construction. Prior to construction, shrubs were salvaged while dormant and staged out of the way of construction until they could be transplanted or incorporated as part of revegetation techniques such as sod brush trenches or planted on bankfull benches behind bioengineering structures (described below). Shrubs salvaged during construction were immediately transplanted into newly constructed wetlands and streambanks. Approximately two acres of wetland sod were salvaged and placed in a staging area for use in later project phases (Figure 9).



Cover Type	Area (acres)	A-depth (")	Soil Staging (cu. yds)
Mature Cottonwood/Conifer	17.53	12	28282
Pole Cottonwood/Aspen (PCA1)	29.31	0	0
Pole Cottonwood/Aspen (PCA2)	21.67	6	17480
Emergent Wetland	8.8	24	28395
Other Shrubs	11.49	12	18537
Swales (PCA1)	3.86	0	0
Swales (PCA2)	4.6	12	7421
Total	93.4		100115

Figure 8. Shrub and sod salvage, staging areas, and substrate distribution.

Figure 9. Photos of sod (left) and shrub (right) salvage staging areas.

Bioengineering

Five bioengineering techniques are being used in the restoration area: vegetated soil lifts, wrapped coir logs, vegetated brush trench, pre-vegetated coir mats, and pre-vegetated coir logs. Bioengineering is used in areas where erosion forces may be slightly greater, such as directly along streambanks, to reinforce the soil to allow woody vegetation to establish. Most of the bioengineering techniques use biodegradable coconut (coir) fabric. Coir is used for bioengineering because it stores water for long periods of time, and its durable fibers trap sediment and mimic soil matrices formed by living roots. Each bioengineering technique is described in more detail below.

Vegetated Soil Lifts

Vegetated soil lifts (Figures 11 and 12) are a revegetation and bank construction technique that combines layers of dormant willow cuttings with fabric-wrapped soil to revegetate and temporarily stabilize streambanks. Soil is wrapped within two layers of biodegradable coconut fiber (coir) fabric, to hold the soil in place while vegetation becomes established in the relatively high stress land/water interface. The purpose of this treatment is to create site conditions directly along the channel that are suitable for growing riparian vegetation. While vegetated soils lifts provide some degree of bank stabilization, they are primarily a revegetation technique. They are installed on a wood and cobble toe, between woody debris jams, that together reduce bank undercutting and move the highest velocity flows away from the bank. Over a five to seven year period, the fabric will decompose and be replaced by dense, woody vegetation that will provide rooting strength sufficient to maintain low bank erosion rates.

Figure 10. Photo series from left to right and top to bottom showing the construction of a vegetated soil lift.

Figure 11. Photo showing a completed vegetated soil lift with a woody debris jam in the foreground and a log toe.

Wrapped Coir log

Coir logs are densely packed, cylindrical bales of coir (coconut fiber) encased in a synthetic (polyethylene) or natural (coir) mesh. The intent of the wrapped coir log treatment (Figure 13) is to provide temporary physical protection for the streambank, along moderate stress portions of outer meander bends (lower stress areas than where soil lifts are used), while vegetation becomes established and ultimately provides deep, binding root mass.

Figure 12. Construction of a wrapped coir log.

Vegetated Brush Trench

The vegetated brush trench (Figure 14) is a revegetation technique used in association with placed sod along riffle and run features as they transition into inside meander bends. This treatment uses dormant willow cuttings to establish a dense row of vegetation along newly constructed streambanks. In addition, non-living brush materials incorporated into the brush trench provide floodplain roughness near streambanks to slow over bank flows and prevent erosion. During high flows, densely branching willows in the trench will trap sediments and native seed, and provide an environment for natural vegetation recruitment.

Figure 13. Construction of a vegetated brush trench.

Pre-Vegetated Coir Mats

Pre-vegetated coir (coconut fiber) mats are a type of nursery grown wetland sod that will be used to provide immediate revegetation and erosion control for floodplain wetland features. These mats are made of biodegradable coir fiber pillows that have been pre-planted in the nursery with native wetland vegetation. Pre-vegetated coir mats will be installed at the break between the emergent wetland and other shrub cover types at the upstream and downstream extents of each floodplain wetland feature.

Pre-Vegetated Coir Logs

Coir logs are densely packed, cylindrical bales of coir (coconut fiber) encased in a natural (coir) mesh. Pre-vegetated coir logs (Figure 15) are pre-planted with at least 30 willow, dogwood, or alder seedlings for each 10 foot length. The purpose of this treatment is to provide a stable, moist growing medium with mature roots, as a way to establish mature shrubs quickly in floodplain areas that might be susceptible to head cutting, within shrub establishment zones in wetland features, and along streambanks.

Figure 14. Photo showing pre-vegetated coir logs at the nursery during the first growing season.

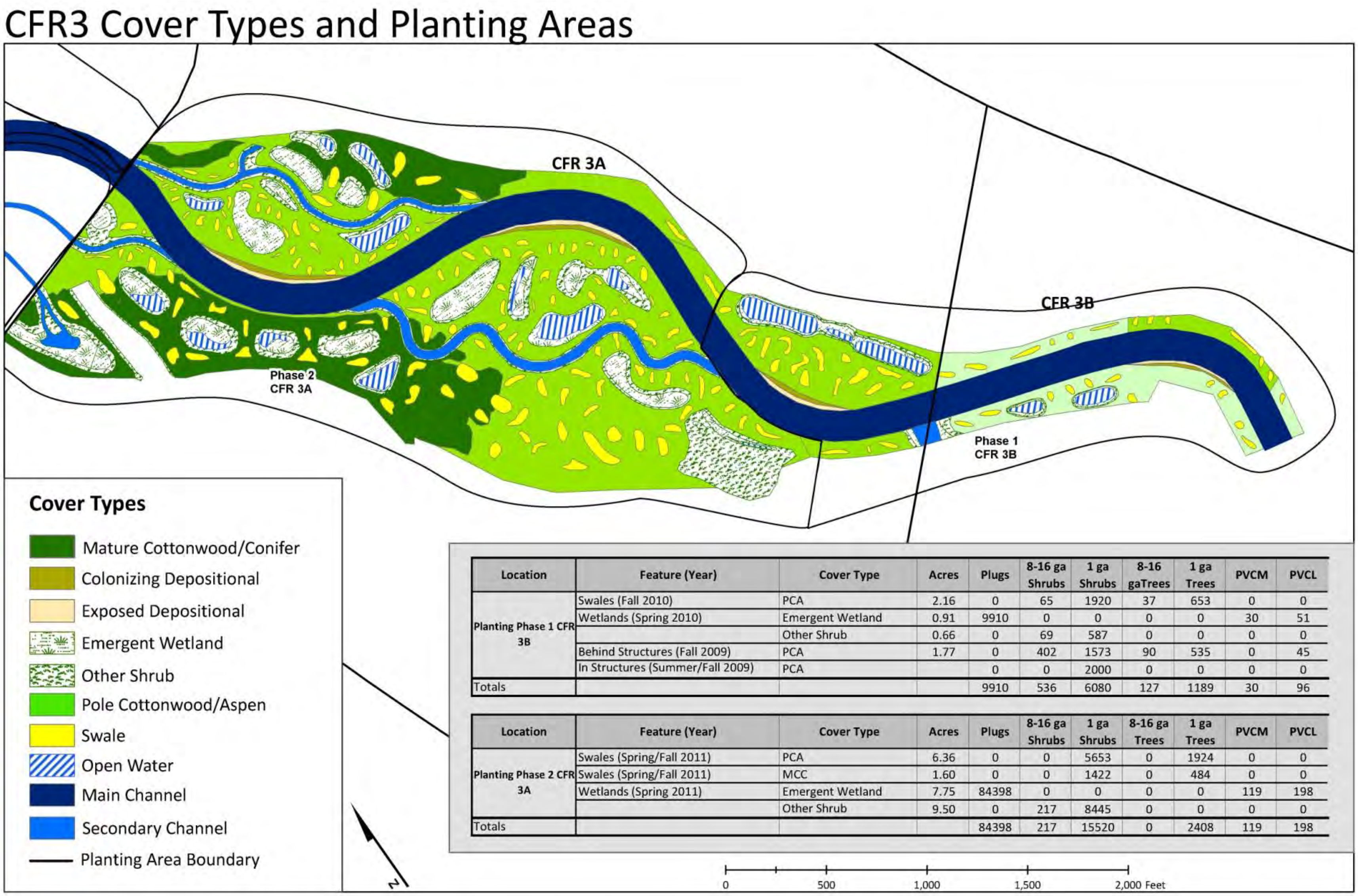
Seeding

Quickly establishing vegetative cover on the newly created floodplain is necessary to maintain soil stability and limit weed infestation. Floodplain planting (described below) is being used to establish native shrubs, trees and wetland communities in portions of the floodplain, but seeding is the primary mechanism for quickly establishing desired vegetation on bare soil. In general, a three-stage seed mix is being used for the project. This mix includes: (1) a mix of quick germinating species that will provide immediate cover to limit erosion and colonization by invasive species, (2) a mix of native herbaceous species that require a stratification period, and (3) a mix of species with long-lasting seeds to supplement the seed bank that will germinate over time as site conditions allow. Seed mixes are linked to specific vegetation cover types. Seeding methods include drill seeding, broadcast seeding, and terraseeding.

Containerized planting

Trees and shrubs will be planted in small clusters and in microtopography features throughout the floodplain (Figure 16). In mature cottonwood conifer and pole cottonwood and aspen vegetation cover types, planting will be concentrated in excavated swale features. In general, plant mixes include a mix of early-successional species, such as willows, alder, snowberry and rose, that may be better suited for the high light environment of the newly constructed floodplain surface. Species mixes also include some later-successional species, such as red-osier dogwood and Douglas-fir, in anticipation of the time when site conditions will favor these species. Plants are being grown in container sizes ranging from slightly less than one gallon to 16 gallon grow bags for trees and shrubs; and 10 cubic inch containers for herbaceous wetland species. Figure 17 shows the distribution of cover types and the quantity and type of plants for each planting area in the upstream portion of the restoration area.

Figure 15. Containerized plants in browse protectors (upper left), and in grow bags (upper right)



Location	Feature (Year)	Cover Type	Acres	Plugs	8-16 ga Shrubs	1 ga Shrubs	8-16 gaTrees	1 ga Trees	PVCM	PVCL
Planting Phase 1 CFR 3B	Swales (Fall 2010)	PCA	2.16	0	65	1920	37	653	0	0
	Wetlands (Spring 2010)	Emergent Wetland	0.91	9910	0	0	0	0	30	51
		Other Shrub	0.66	0	69	587	0	0	0	0
	Behind Structures (Fall 2009)	PCA	1.77	0	402	1573	90	535	0	45
	In Structures (Summer/Fall 2009)	PCA		0	0	2000	0	0	0	0
Totals				9910	536	6080	127	1189	30	96

Location	Feature (Year)	Cover Type	Acres	Plugs	8-16 ga Shrubs	1 ga Shrubs	8-16 ga Trees	1 ga Trees	PVCM	PVCL
Planting Phase 2 CFR 3A	Swales (Spring/Fall 2011)	PCA	6.36	0	0	5653	0	1924	0	0
	Swales (Spring/Fall 2011)	MCC	1.60	0	0	1422	0	484	0	0
	Wetlands (Spring 2011)	Emergent Wetland	7.75	84398	0	0	0	0	119	198
		Other Shrub	9.50	0	217	8445	0	0	0	0
Totals				84398	217	15520	0	2408	119	198

Figure 16. Design cover types and example planting plan for the upstream portion of the restoration area (PCA=Pole Cottonwood/Aspen cover type and MCC=Mature Cottonwood/Conifer cover type.

Browse Protection

Elk, deer, beaver and other mammals are common in the restoration area and these animals may preferentially browse new shoots on planted material. In addition to installing containerized plants within swales where access by wildlife is more difficult; individual browse protectors and fences around planting polygons were used to protect plants from wildlife browse. Individual browse protectors made from rigid plastic mesh were secured around some plants and staked into the ground. Exclosures (8 ft tall) were constructed around selected groups of plants (Figure 18).

Figure 17. Photos showing examples of browse protection. Individual browse protectors (left) and planting area exclosures (right) were used in different areas depending on the planting unit size and location within the floodplain.

Weed Management

A weed management plan was prepared for the project that addresses areas within and outside of construction limits (State of Montana, 2007). Within construction limits, pre-construction treatments focus on reducing existing weed densities to limit spread during construction and reduce potential constraints on revegetation. Post construction treatments focus on limiting the spread and abundance of weeds and promoting the success of revegetation activities by limiting competition to planted material. The weed management plan addresses areas outside of the construction limits to sustain a buffer around the restored area. Weed management was initiated in 2006 and will continue for several years.

MONITORING AND NEXT STEPS

An integrated monitoring program was developed to ensure that restoration goals and objectives are achieved (State of Montana, 2008b). The Milltown Dam revegetation plan is being implemented as part of an interdisciplinary restoration project whose goal is to restore riverine and floodplain ecological floodplain processes. Work began in 2009 and will extend through 2011 or 2012. Maintenance and monitoring will continue for several years after initial construction activities have been completed. Project progress can be followed at http://www.clarkfork.org and http://www.doj.mt.gov/lands/naturalresource/milltowndam.asp.

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MILLSAP MILL TAILINGS RE-GRADING PROJECT

Community Cooperation and Inmate Rehabilitation

Presented at the 30th annual National Association of Abandoned Mine Land Programs Conference,
October 26 – 29, 2008; Durango Colorado

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ABSTRACT

The Millsap Mill Tailings are located just south of Victor, Colorado in the Cripple Creek Gold Mining District, in a relatively remote and arid environment where waterways are stressed by dewatering, intensive agriculture, urban use, and the impacts of over a hundred years of hard rock gold mining. This project brought together a diverse group of state, federal and local agencies, land owners, water rights holders, and non profit organizations, including over 20 partners.

The Millsap Mill Tailings ponds were created from the 1900's to 1928's to hold tailings slurried from the Independence Gold Mill. The original dams held nearly two million cubic yards of tailings and were breached several decades ago allowing the tailings to erode downstream during storm events. This siltation has caused wild trout habitat to become significantly degraded in Four Mile Creek, and has eliminated the possibility of Millsap Creek being a fishery. During heavy rain events, this sediment also reached the Arkansas River. The goal of this project was to stop the massive erosion, reestablish native vegetation, and ultimately improve and protect the downstream wild trout habitat. Reclamation of the tailing serves to alleviate one of the major stresses on the stream system.

This project was more than reclamation partnership; it was a cooperative effort that included the State of Colorado Department of Corrections Vocational Training Program located in Buena Vista. While participating in the vocational training program, the inmates become skilled in operating heavy construction equipment and in construction management. The program is successful in training and developing life skills which greatly reduce recidivism, easing the burden on the prison system. The program also helps inmates with the job search process and over 95% of the participants have employment opportunities when they are released.

INTRODUCTION

The Millsap Mill Tailings Project involved reclamation of 45 acres of mill tailings that were being eroded down Millsap Creek into Four Mile Creek, tributary to the Arkansas River. The site consisted of mill tailings deposited in the headwaters of Millsap Creek, shown in Figure 1.

There are over one million cubic yards of fine, sandy tailings on the site, which were being eroded by both wind and storm water. The tailings resulted from the processing of telluride gold ores from the turn of the century mining in the Cripple Creek-Victor gold-mining district. They contain very little sulfides or acid forming materials, and would support vegetation, except for their unstable surface, high permeability and lack of organic material. The tailings were creating a sedimentation problem in the stream, and created wind-blown dust that were depositing on lands down-wind from the site. The site contained vertical highwalls up to 60 feet high, which created a hazard to people and livestock. The aerial photo below (Figure 1,) shows the area as it appeared at the start of the project. This project was designed and managed by Colorado Division of Reclamation, Mining and Safety, (CDRMS).

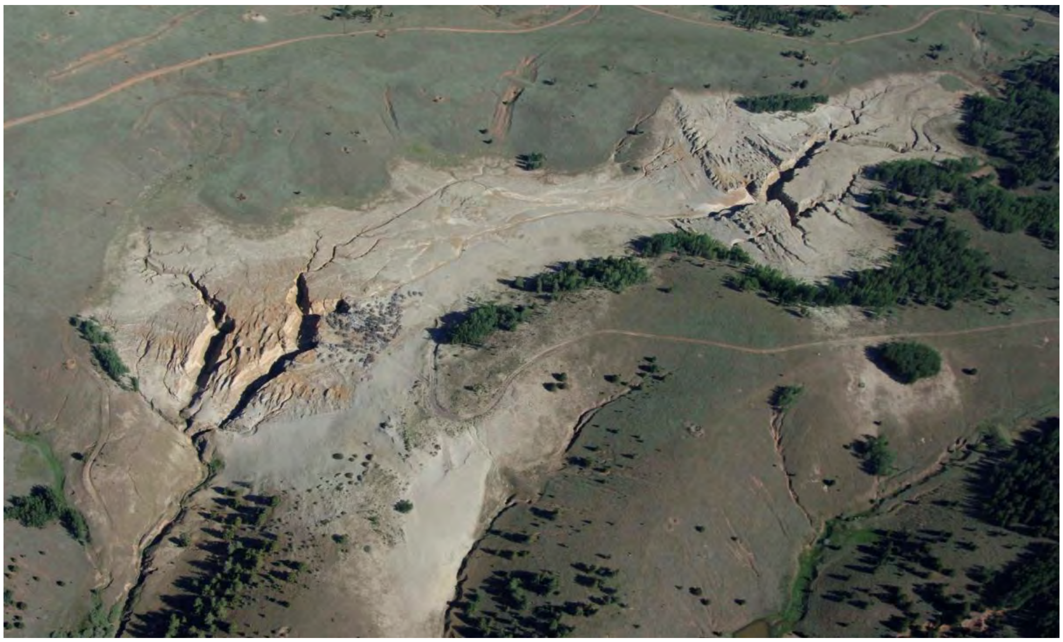

Figure 1 Aerial view of Millsap Mill Tailings July 14, 2006

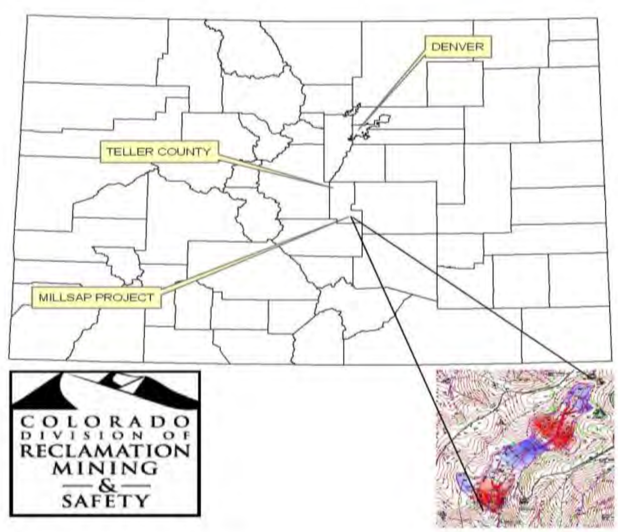

Figure 2, Location of Millsap Mill Tailings, CO. Cut and Fill Map, Red is cut, and Blue is Fill

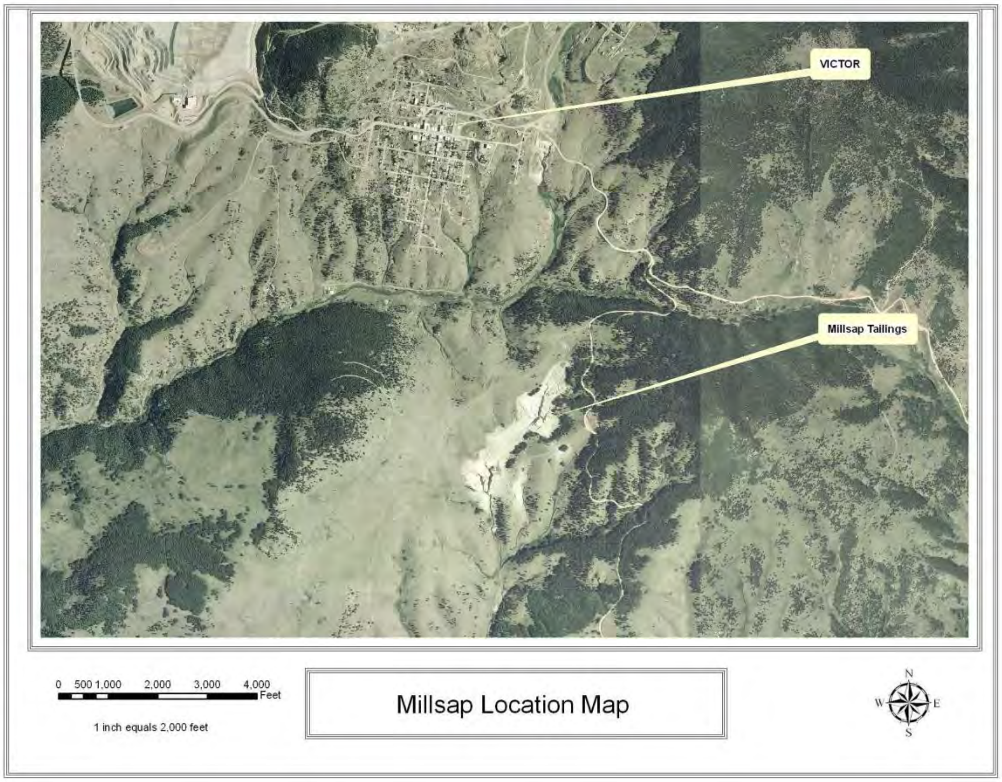

Figure 3, Millsap Mill Tailings located relative to Victor Colorado

HISTORY

The Millsap Mill Tailings were deposited as slurry behind two tailings dams, constructed of coarse tailings. The tailings material formed a flat, mostly-dry desert of fine sand. After about 40 years, the decant pipes (constructed of timber) failed, and in that process the dams failed, washing fine tailings downstream and creating deep gullies. The tailings continued to erode and wash downstream with each precipitation event, choking downstream irrigation structures and sterilizing Millsap Creek. The resultant damage to a downstream landowner's fields and irrigation structures caused him to bring this situation to the attention of CDRMS.

The site was used as a dump and contained 200 to 300 tree stumps and became popular with motorcycles ATV's and 4x4 trucks. The presence of the 60 foot high cliffs was a safety concern to land-owners and law enforcement.

Partners in Reclamation

This project was more than a reclamation project. It was a cooperative effort that included the State of Colorado Dept. of Corrections Vocational Training Program and numerous government agencies and businesses. See Figure 4. The Vocational Training program provides inmates with basic employment skills. The inmates become skilled in operating heavy construction equipment and in construction management as well as cooperation with co-workers and supervisors. The program is successful in training and developing life long skills which greatly reduces recidivism; easing the burden on the prison system. This program provides jobs to the inmates upon release and over 95% of the participants have employment opportunities when they are released.

Figure 4, Julie Annear (foreground) with Tom Bowen and Tom Foreman of DOC, with the crew. This project would not have been possible without our partners, many of whom have been involved since 2000. Partners included; The Bureau of Land Management, The Office of Surface Mining, Cripple Creek and Victor Gold Mining Co., Teller County Commissioners, Teller County Soil Conservation District, The Army Corps of Engineers, The Colorado Soil Conservation Board, Co. Dept. Public Health & Environment, The City of Victor, Trout Unlimited, Bob Shoemaker, Victor Fire Department, Woodland Park Sanitation, Kessler Reclamation, Wagner Equipment Rental, Fremont County Commissioners, Plainview Ventures, The Department of Corrections Facilities, Canon City, Envirotech Services, Inc, and American Civil Constructors, Inc.

Cripple Creek and Victor Gold Mining Company (CC &V) completed a reclamation project on a portion of the tailings located on their property concurrently with the Millsap project. " CC & V was a great partner" said Julie Annear. "They were always there to provide support to us, whether it was storing seed for us or providing water" CC&V initially provided the CDRMS with a topographic map in digital format which allowed CDRMS to design the final contours of the reclaimed site and estimate the quantities of material for the project. They also donated approximately 50,000 cubic yards of overburden material with some soil in it to use as erosion control cover and growth medium.

Construction

Construction started on May 29, 2007 and was completed November 3rd, 2007. As is the case with all large construction projects, there is a start-up period of time required for the contractors. In the case of the Vocational Training program, this process took a little longer because most of the inmates had never operated heavy equipment. Following a couple of weeks of training, the project began to progress at a steady pace. However, other challenges were encountered during the project including variable soil conditions and a greater than anticipated quantity of materials. These changed field conditions necessitated modifications in the original design of the project. However, the final outcome of this phase of the project was positive.

Following completion of the grading and contouring of the site, the entire area was covered with 1 to 2 feet of rocky overburden, 50,000 cubic yards, salvaged from the nearby mining operation. The overburden did not contain any "topsoil" or conventional growth medium. However, it stabilized the fine sandy tailings and provided an excellent "microclimate" for seed growth.

Revegetation

The original revegetation plan for Millsap was based on the plan for the Climax Molybdenum Mine in Lake County, Colorado. The design specified the application of hay and biosolids to amend the rocky cover and provide nutrients for seed germination and growth. Specifically, the rate of application was 2 tons per acre of hay and 45 cubic yards class A biosolids per acre. The biosolids and hay are ripped to a depth of 6 inches and seed is hand broadcast.

Although some biosolids were applied at the Millsap, the majority of the site received a BIOSOL® application due to delivery and trucking problems with the biosolids. The rate of application for BIOSOL®- 2000 lbs per acre. Due to additional delivery problems, only a portion of the site did receive an application of hay at a rate of 2 tons per acre. The shortage of hay was compensated for with an application of hydromulch at a rate of 2000 lbs per acre. The hay was incorporated into the cover material with a dozer. Following this process, BIOSOL®, seed and hydromulch were applied over the entire site in one application. The seed was applied at a rate of 25 pls/lbs./acre. The seed was a custom mix provided by the Colorado DRMS and based on the seed mix used by CC &V for their active mining operation.

Revegetation of Millsap was completed on November 12th, 2007. Precipitation for the winter of 2007-2008 was slightly below normal. However, vegetation began to become established in the furrows and between the large rocks.

By the spring of 2009 the vegetative cover was complete on over 75% of the site. Precipitation was above normal in the summer of 2009 and by the fall, over 90% of the site had good vegetative cover. There is no significant weed control problem at the site and minimal erosion.

Awards

The cooperation of all the partners resulted in the Millsap Mill Tailings Project being awarded a Cooperative Conservation Award by the Department of Interior, a Certificate of Merit by the Colorado Mining Association and a national reclamation award from the Office of Surface Mining.

SUMMARY

The Millsap Project involved the cooperation of over 20 participants. The reward of working with so many partners is the sense of community and of pride that it engenders among all of the participants.

The experience of working with the inmates was rewarding both in cost savings to CDRMS and also in participating in the process of the inmates rehabilitation. The inmates became wonderful partners in the project and learned valuable life skills as well as skills in equipment operation.

The success of the revegetation has been excellent. More than 90% of the project area has very good vegetative cover. There are very few weeds and minimal erosion problems. The DRMS continues to monitor the success of the project and address any maintenance issues.

Figure 6, Millsap Mill Tailings **BEFORE**, March 7, 2007

Figure 7, Millsap Mill Tailings **AFTER**, November 13, 2007

USE OF PERFORMANCE STANDARDS IN ASSESSMENT OF REVEGETATION SUCCESS

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ABSTRACT

Assessment of the success of revegetation projects in the Intermountain West and Great Plains of North America has moved from a largely qualitative basis in the early years to progressively more quantitative measures in more recent times. Passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977 established law relative to coal mining reclamation that was sufficiently specific regarding revegetation that subsequent rules included requirements for quantitative assessment of several vegetation attributes. Thirty plus years of experience in the implementation of these standards have produced an understanding of the feasibility of making such numerical expectations a part of major energy extraction projects. Reasons underlying the choice of these quantitative standards will be explored along with practical observations on the gathering of requisite data in the field and the use of statistics in the test of hypotheses regarding revegetation success.

INTRODUCTION

The concept of revegetation is relatively new, having arisen in the late 1890s and early 1900s out of an extended period of overgrazing and drought in the western United States as well as the Dust Bowl of the 1930s and 1940s. Over a century later, the use of performance standards on large scale projects such as coal mine reclamation is not widespread. The advancement from the stage of merely assessing "is it green enough?" to the use of actual specific quantitative standards with statistical control has been slow and is still not commonplace.

At the largest (federal) scale, only SMCRA currently makes extensive use of revegetation performance standards. Although the law and pursuant regulations have been in place for over thirty years (since 1977), the surface disturbances caused by other major extractive industries such as oil and gas are not officially subject to any federal standards close to the coal standards and even state mandated regulations such as the Oil and Gas Conservation Act of the State of Colorado are not as strict as those outlined in SMCRA.

As coal mine land reclamation tends to take place almost completely out of the public eye, the extensive experience with quantitative revegetation performance standards in that realm tends to be unknown to restoration practitioners in other fields. The goal of this paper is to make available this information and experience on a general level.

PERFORMANCE STANDARDS

It is important to first note that in the absence of specific performance standards, the judgment of revegetation adequacy (if any judgment is required) is often accomplished simply by a qualitative assessment and ensuing consensual agreement between the regulator and industry representative. Whether the adequacy of the qualitative standard used is sufficient is questionable as is the difficulty in documenting the nature of the qualitative standard for use by third parties.

Revegetation Performance Standard Anatomy

An underlying reason for establishing a revegetation performance standard is a constituency whose interests are served by assurance that restored vegetation is in some particular way "complete" and "functional." Under SMCRA, the four main revegetation performance standards are related to four different constituencies.

Ground Cover

The mediation of soil erosion control is the basis for the importance of sufficiently extensive ground cover, which is most commonly calculated as a combination of litter, rock, vegetation cover and standing dead as all of these can contribute to erosion control.

Biomass Production

In the late 1960s and early 1970s, ranchers of the high plains and intermountain west of Wyoming and Montana were fundamental in convincing legislators that the protection of their lifestyle and economic productivity was important in the face of proposed new surface coal mining. Current livestock forage production standards reflect this need for livestock producers to be able to continue the use of mined and reclaimed lands after coal extraction is complete.

Woody Plant Density

In most western U.S. coal mining areas, the habitat structure and foraging opportunities offered by tress and shrubs has been deemed critical to the use of areas by a wide variety of economically important game species, such as antelope, as well as sensitive species such as Sage grouse. Woody plant density standards are directly related to concerns about wildlife habitat.

Species Diversity

General ecological concerns regarding the quality of restored plant communities on coal mined lands were addressed through the establishment of the species diversity standards. These take various forms varying widely in approach, including assessments of total species diversity, native species diversity and the similarity of species diversity to unmined areas.

Another important part of the anatomy of a revegetation performance standard is the method of measurement, which can vary widely across parameters as well as among those conducting the measurements.

Also important in the anatomy of a revegetation performance standard are the circumstances under which valid measures can be made for assessment of compliance such as liability periods, supplemental husbandry actions and grazing demonstrations. For example, under SMCRA (and for areas with less than 26 inches of annual precipitation), a minimum of ten years must pass before reclamation can be approved for final bond release.

LESSON LEARNED

The Fighting Pairs – Cover/biomass production vs. woody plants / spp. diversity

Revegetation success for cover and biomass production were easily achieved in the early years using domesticated forage grasses such a smooth brome (*Bromus inermis*), orchardgrass (*Dactylis glomerata*), or intermediate wheatgrass (*Thinopyrum intermedium*). However, the vigorous herbaceous growth provided by these plants crowded the ecological "space" needed for other important life forms such as shrubs, trees and forbs.

Clearly, the domesticated forage grasses were incompatible with achievement of woody plant density and species diversity standards, especially where the climate prompted the proliferation of these domestic forage grasses. i.e. semi-arid or moister climates.

A solution was to substitute less aggressive native grasses to allow forb, shrub and tree development, although the competition from certain native grasses can also be great. Reduced seeding rates of native grasses have been used in conjunction with forb and shrub seedings to attempt to achieve woody plant and forb establishment for species diversity.

It is important to note that when grass competition is reduced for the benefits of increasing woody plants and species diversity (as forbs), opportunists may often arise in the form of weeds. In addition, another important lesson to be learned is that [nitrogen] fertilization can do much more damage in the form of encouraging nitrophilous weeds than is gained in the (usually limited) response of the native seeded species.

REFERENCE AREAS VS. TECHNICAL STANDARDS

A numeric goal must be set for the various performance standards of cover, biomass production, woody plant density and species diversity when quantitative assessments of revegetation success are used. These numeric goals are most often obtained from either reference area data or specific technical standards.

Reference areas are communities used as models to which reclaimed areas are compared to evaluate revegetation success. Technical standards are usually numeric or descriptive performance standards derived from a variety of sources such as historical data or USDA ecological site information. Although technical standards have the advantage and appeal of simplicity, they fail to take into account annual variation in the amount and type of vegetative growth in reclaimed or native plant communities in response to environmental factors such as precipitation and temperature.

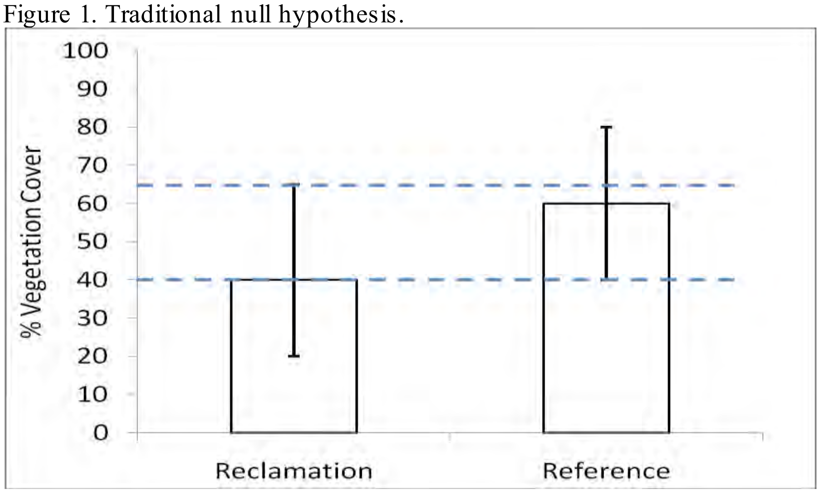
Regression-based "floating" or "adjusted" technical standards for cover and production are feasible but only after collection of an adequate historical record. New Mexico, for example, is one of the few western states to specify a minimum number of years (i.e., 5 years) of data collection to underlie and document a technical standard (19.8 ATTACHMENT 1, (per the New Mexico Administrative Code (NMAC, 1999))). If a regression model is used to allow historical record data to predict levels of cover or production, it is serendipitous if the period of years included in the historical record have a large range of climate conditions included. This provides the model with the broadest base of input and response data allowing it to be the "smartest."

USE OF STATISTICS

Statistical hypothesis testing has frequently been used in assessing revegetation success via performance standards with the purpose being to maximize objectivity pursued through the use of numerical standards. Statistics provide the a priori rules that resolve potential conflicts regarding being "close enough" to a performance standard.

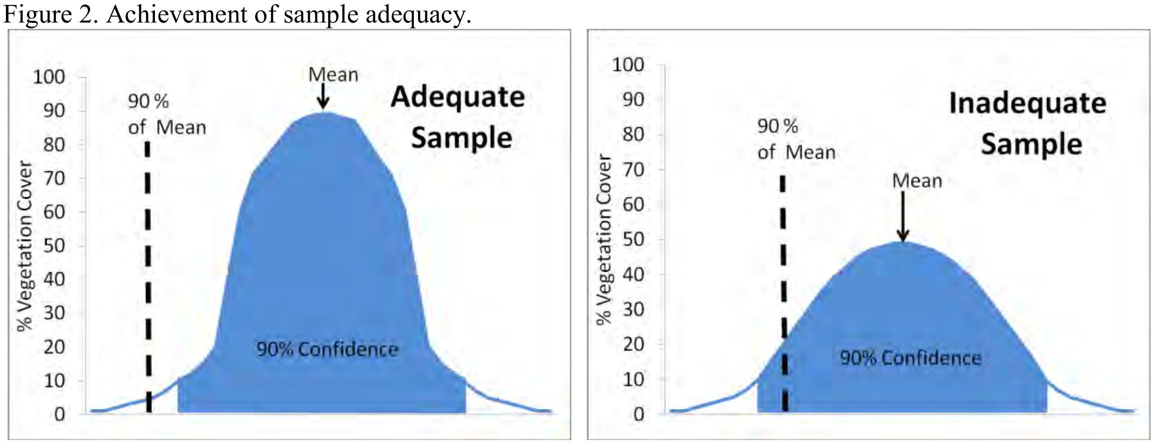
Since the federal and various state regulatory programs were assembled, the statistical tests envisioned for use were mostly in the form of simple parametric statistics based on Students t-test and the "traditional" null hypothesis, i.e., a simple assessment of the confidence intervals of the reclaimed and reference areas (Figure 1).

Figure 1. Traditional null hypothesis.



From the beginning of regulatory use, this simple form of testing was to be done only after accumulation of sufficient data so that (usually) a reduction in the mean of ten percent could be detected with ninety percent confidence. In visual terms this means that the presumably bell-shaped curve formed by the collected data should have a height to width ratio sufficiently large that the 90% lower tail does not extend beyond 90% of the mean (Figure 2).

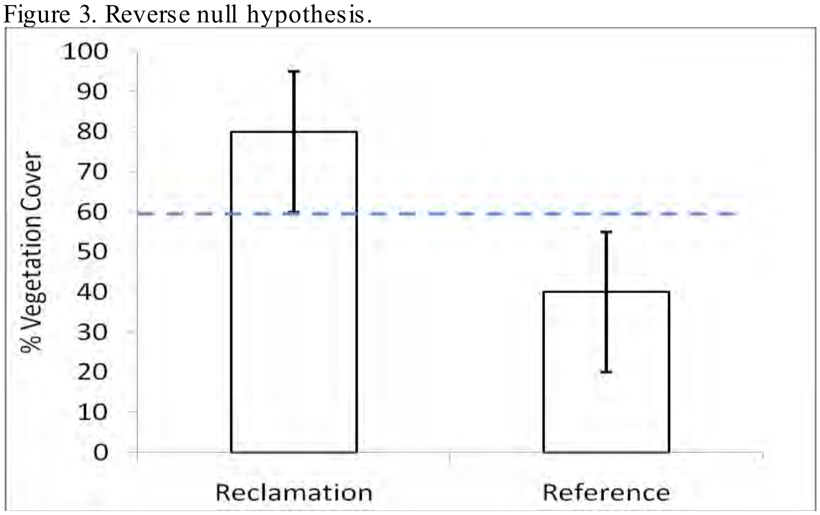
Figure 2. Achievement of sample adequacy.



The accumulation of sample size adequate to meet this criterion is known as achievement of "sample adequacy."

More recently, use of what in some places is referred to as the "reverse" null hypothesis has come into use and has been incorporated into regulatory packages. This approach is useful when the mean of a reclaimed site is greater than the mean from the reference area (or the technical standard). In this case, statistical testing seeks to evaluate whether the mean of reclamation area samples and specifically the lower edge of 90% confidence lies above the standard or not. Inasmuch as the absence of sample adequacy only makes it more difficult to pass this test, sample adequacy is not required (Figure 3).

Figure 3. Reverse null hypothesis.



Use of the reverse null hypothesis lends itself to use of non-parametric statistics also, and this approach has proven to be very useful at the practical level during hypothesis testing associated with assessment of revegetation success.

For a full review of pertinent statistics and a very useful flow-chart that guides the user thorough various alternative tests, the reader is directed to the draft statistics section of Wyoming Department of Environmental Quality, Land Quality Division coal regulations (WDEQ, 2008).

SUMMARY

It is beneficial to all parties involved to have good revegetation or restoration and to be able to agree via pre-established rules whether restoration is "good enough." Performance standards serve the purpose of solidifying and making tangible the vision of what an acceptable restored/revegetated landscape looks like and how it measures. Furthermore, performance standards allow parties with differing ideas to resolve and document these varying ideas and goals, usually before restoration/revegetation begins. With the passage of time, documented performance standards allow a realistic view of what was sought and what was delivered in a restored area.

ACKNOWLEDGEMENTS

The author wishes to thank David Buckner of ESCO Associates, Inc. for his comments and suggestions.

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CASE STUDY: THE PINE TREE WIND FARM RECLAMATION IN THE SOUTHERN SIERRAS

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ABSTRACT

The Pine Tree Wind Farm is under construction on a ridge in the southern Sierra's 20 miles northwest of Mojave, California. Construction began in 2007 and is expected to be completed by summer 2010. The original project consists of 80 1.5 megawatt turbines as well as 10 miles of transmission lines. The project also includes construction of 38 miles of roads, a 3.8 mile underground electrical collection system, and a 10 mile utility corridor. Seeded areas will approach 300 acres.

Several new solar and wind power projects are currently planned for the Mojave Desert (BLM 1980). The author will show a series of photographs documenting the construction and initial reclamation efforts at Pine Tree. "Green" energy projects are becoming the target of increasing criticism due to their significant impacts to the Mojave ecoregion. Common ground must be found between green energy development, their environmental impacts, and appropriate mitigation.

INTRODUCTION

This presentation begins with a botanical characterization of the disturbed areas created by the Pine Tree wind farm. This is followed by a brief presentation on the wind farm construction which will give the audience a sense of the scope and the footprint of this type of energy project. This is important since so many solar projects are currently being planned for the Mojave region. The final section delineates the reclamation procedures that followed construction.

Botanical background

The eastern Sierra front is generally characterized by extreme changes in relief over short distance. This feature tends to compress the life zones into narrow bands with transitional overlaps that result in much diversity in flora and fauna. This is the case at the Pine Tree wind farm. Access roads to the farm, and the utility corridor carrying electricity from the farm begin at the eastern base of the southern Sierras at 2000' and climb to the wind turbines at 4000'. The eastern low elevation plant community is predominantly creosote, either in the washes or on the alluvial fans outside of the canyons. Progressing east and climbing, the creosote gives way to *Atriplex polycarpa* and *Ericameria linearifolia* until the broad washes terminate into steep ravines at about 3000'. Above 3000', the foothills are dominated by *Coleogyne, Juniper, Cowania, Ericameria, Eriogonum,* and *Ephedra*. *Achnatherum speciosum* is the most common herbaceous perennial. I suspect that the areas dominated by the herbaceous species have been impacted by grazing and fire and were historically *Coleogyne*. Likewise, much of the open areas at the upper elevations have been reduced to broadleaf weeds, predominantly *Centaurea sp*. Most of the construction of wind turbines and access roads occurred in this Blackbrush zone. At the western and highest elevations of the wind farm, the Juniper gives way to *Pinus jefferyi* with occasional islands of *Quercus kelloggii*. Reclamation planning acknowledged these distinct floristic communities and set a goal to reproduce them post construction.

Construction

From its base to the tip of its rotor, the GE 1.5 megawatt wind turbine is 380 feet tall. Each rotor blade is 122 feet tall. Each turbine weighs 450,000 lbs and requires 6 to 8 semi's to deliver to the construction site (Thompson 2010). Most of the construction footprint occurred with road building to gain access to the windmill pads. In the southern Sierras, wind farm construction occurs on the foothills and ridgelines, creating larger foot prints than wind farms on flatter lands in the Midwest (Gipe 2000).

Reclamation

The steep terrain at Pine Tree resulted in relatively large areas of disturbance created by the cut and fill slopes. Due to steepness in the majority of the reclamation areas, hydroseeding was chosen as the optimal technique for applying materials to the cut and fill slopes. Hydroseeding has occurred primarily during fall, winter, and early spring to take advantage of winter moisture. Even summer applications have been discussed as a mitigation measure to guard against erosion in the event of summer precipitation events which have the potential to cause extreme erosion on unprotected surfaces. A landscape contractor (Diversified Landscaping, Winchester California) applied the following list of nutrients, stabilizers and seed to these slopes with the exception of exposed bedrock areas.

Wood fiber mulch - 3000#/acre Provides erosion control and moisture retention
Organic Tackifier – 300#/acre Bonds fiber to the soil surface
Compost – 4 cubic yards/acre Provides organic matter and nutrients
Synthetic fiber – 10#/acre Improves tenacity and bonding of fiber mulch
Copolymer gel – 20#/acre Stores water and nutrients; retains moisture for seed germination and lessens rainfall impact, thereby reducing erosion
Seed – 3 different blends per specifications

All materials were applied with FINN T-330 hydroseeders. At the above application rate, a tank load covered .4 acres. With over 300 acres, the project required 750 tank loads of material. The T330 hydroseeder has a 3000 gallon working capacity, thus total water used totaled 2.25 million gallons.

The three seed blends include Mojave Wash, Blackbrush, and Oak grassland. The species are listed in the following tables: (The seed blends were designed based on several criteria including baseline data, commercial availability, and colonizing potential.)

MOJAVE WASH SEED BLEND

SPECIES	PLS #/ACRE
Hymenoclea salsola	.75
Atriplex canescens	4.00
Atriplex polycarpa	4.00
Encelia farinosa	.25
Encelia actonii	1.00
Ericameria lineriafolia	.75
Larrea tridentata	3.00
Ambrosia dumosa	1.00
Achnatherum hymenoides	3.50
Eriogonum fasciculatum	1.00
Eschscholtzia californica	.25
Total PLS #/acre:	19.50

BLACKBRUSH SEED BLEND

SPECIES	PLS #/ACRE
Ericameria nauseosus	.80
Coleogyne ramosissima	2.77
Encelia farinosa	.35
Encelia actonii	.90
Hymenoclea salsola	.70
Ephedra viridus	3.00
Larrea tridentata	2.00
Eriogonum fasciculatum	1.00
Eschscholtzia californica	2.25
Lupinus exubitus	.30
Ericameria lineriafolia	.18
Achnatherum speciosus	1.00
Atriplex polycarpa	3.15
Cowania mexicana	.60
Total PLS#/acre:	19.00

OAK GRASSLAND SEED BLEND

SPECIES	PLS #/ACRE
Ericameria nauseosus	.75
Ephedra viridus	3.25
Eriogonum fasciculatum	3.00
Eschscholtzia californica	3.50
Lupinus exubitus	.50
Achnatherum speciosus	2.15
Atriplex polycarpa	3.25
Cowania mexicana	.60
Total PLS #/acre:	17.00

CONCLUSION

Dryland reclamation in the desert regions requires patience. Optimal weather conditions include intermittent but consistent precipitation during the winter months but most importantly, moisture in the soil as soil temperatures and daylight hours increase in the spring. Seed needs to be firmly embedded in the soil to imbibe moisture. Once the above conditions stimulate metabolic activity within the seed, we hope that the soil conditions allow the germinating plants to develop healthy root systems such that annuals will hopefully flush out, producing vegetative matter and seed, and improve the soil for later seral succession. Perennials need to develop healthy root systems to allow the young plants to survive their first summer. With such steep terrain, hydroseeding may be the only practical way to distribute seed and materials onto the disturbed slopes, but it may not be optimal compared to seed that is set into the soil. The winter of 2009-10 has included rain, snow, and freezing conditions that may assist the seed in becoming bonded with the soil. Time and the elements will tell us much. In poor soils, if seed does germinate, annuals may flush out without producing seed and perennials can be dwarfed for years relative to their equivalents in undisturbed soil conditions. Initial assessments have included some repair of the hydroseeded surfaces due to soil instability or disruption by cattle. Pine Tree is not fenced.

Pine Tree is a relatively small project compared to some green energy projects being proposed for the Mojave Desert. Some of the Photovoltaic and Thermal projects in current BLM proposals exceed 4000 acres and will destroy the earth where the energy systems are installed. This environmental externalities of green energy can be somewhat mitigated by also pursuing Distributed Energy Production options. These systems are decentralized and are built at the point of consumption, thus eliminating utility corridors and the inefficiencies associated with energy distribution. Germany has a progressive distributed energy program that encourages systems that can be incorporated into commercial and residential architecture or installed on the ground where space allows (World Class Initiative 2009).

On one of my winter visits to Pine Tree, the wind was blowing fairly strong. I was impressed and awed by the quietness and speed of the spinning turbines. I roughly calculated their speed to be 18 mph at the tip on this particular visit. It was late afternoon and the shadows created by the spinning blades were dizzying at ground level as they raced by in multiple directions.

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KERBER CREEK RESTORATION PROJECT, SAGUACHE COUNTY, COLORADO

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ABSTRACT

The Kerber Creek Restoration Project is a partnership with numerous stakeholders including, but not limited to the Bonanza Stakeholders Group, Trout Unlimited (TU), Bureau of Land Management (BLM), Natural Resource Conservation Service (NRCS), US Fish and Wildlife Service (FWS), US Forest Service (USFS), Americorp/Vista Western Hardrock Watershed Team, Environmental Protection Agency (EPA), Colorado Water Conservation Board, and Saguache County Sustainable Environment and Economic Development. The project involves removing and in-situ treatment (i.e.phytostablilization) of mine wastes, revegetation, in-stream habitat enhancements, stream bank stabilization, and grazing management.

Mine wastes discharged into Kerber Creek between the 1890's and 1970's from several mining-related operations in the Bonanza Mining District were transported and re-deposited downstream. Although remediation objectives for Voluntary Cleanup and Redevelopment Act work (1993-2003) in the upper watershed were met, mining wastes are still present and degraded stream channel conditions continue to persist along Kerber Creek for about 19 miles. Low pH and high metal concentrations prevent re-vegetation due to phytotoxic conditions; consequently, stream banks are not stable, in-stream habitat is impaired, and a proper functioning riparian corridor is not present in many areas.

From 2005-2008, BLM characterized mining wastes covering approximately 60 acres of riparian and floodplain areas along 19 miles of Kerber Creek. The partnership began implementing restoration projects in 2008 and this presentation will discuss details of phytostabilization, stream bank stabilization, and revegetation work. Additionally, we will briefly discuss the partnership's collaborative efforts.

INTRODUCTION

Description of area

Kerber Creek is located in the northeastern San Juan Mountains in Saguache County, Colorado (Figure 1). It flows through the towns of Bonanza (elevation 9,465 feet) and Villa Grove (elevation 7,986 feet) before confluencing with San Luis Creek. The watershed is part of the Rio Grande closed basin and recharges the Rio Grande River through sub-surface waters; its 5th level watershed HUC designation is 1301000302. Kerber Creek possesses multiple tributaries including Rawley Gulch and Brewery Creek (Figure 2). The entire Kerber Creek watershed encompasses 64,323 acres; Kerber Creek is 25-miles long from origin to its confluence with San Luis Creek.

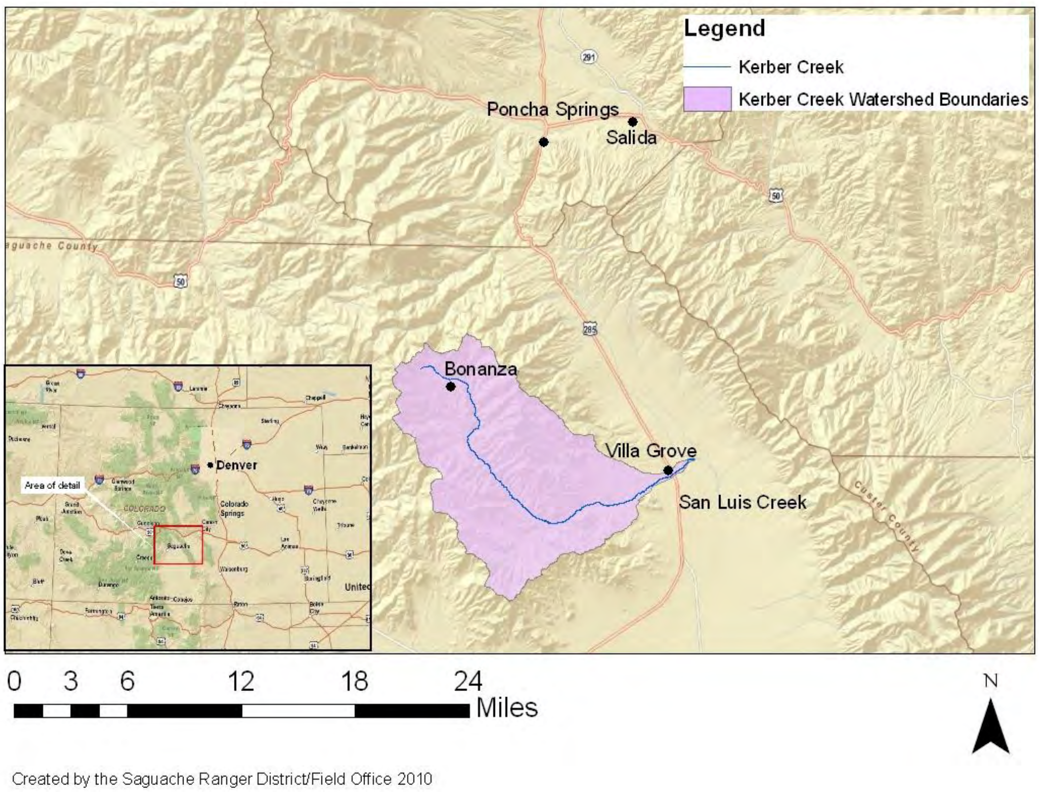

Figure 1: Kerber Creek Vicinity Map

Hydrologic Setting

Streamflow in the Kerber Creek watershed is typical of mountain streams throughout the southern Rocky Mountains. Streamflow is dominated by snowmelt runoff, which typically occurs between April and July. Snowmelt runoff is augmented by rain during the summer months and peak flows occur in May or June. Baseflow conditions are typical from late August to March. Summer monsoons (typically July-August) can cause increased streamflow in the watershed.

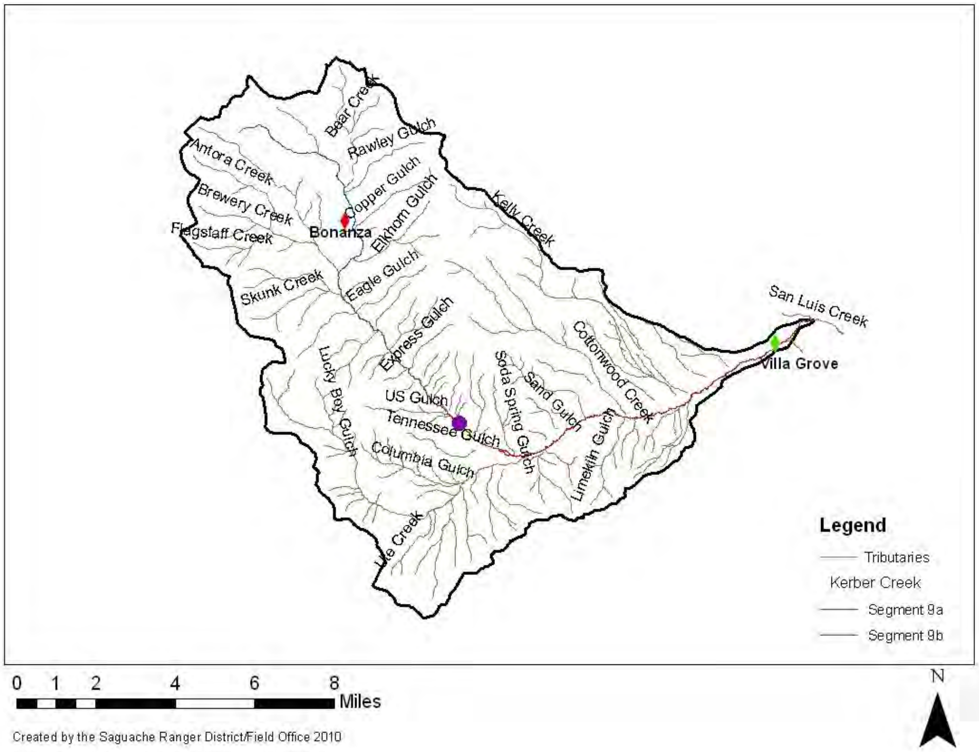

Figure 2: Kerber Creek Watershed

The two-year flow event is approximately 95 cfs and the 100-year event 434 cfs. The highest flow on record is 363 cfs in 1941 (CDSS, 2010). Average high flows occur between May and June and are about 60 cfs while average baseflows occur between September and March and are about 4 cfs (CDWR, 2009) (Figure 3). Permitted water diversions occur within the watershed and influence flow, especially in lower reaches of the creek.

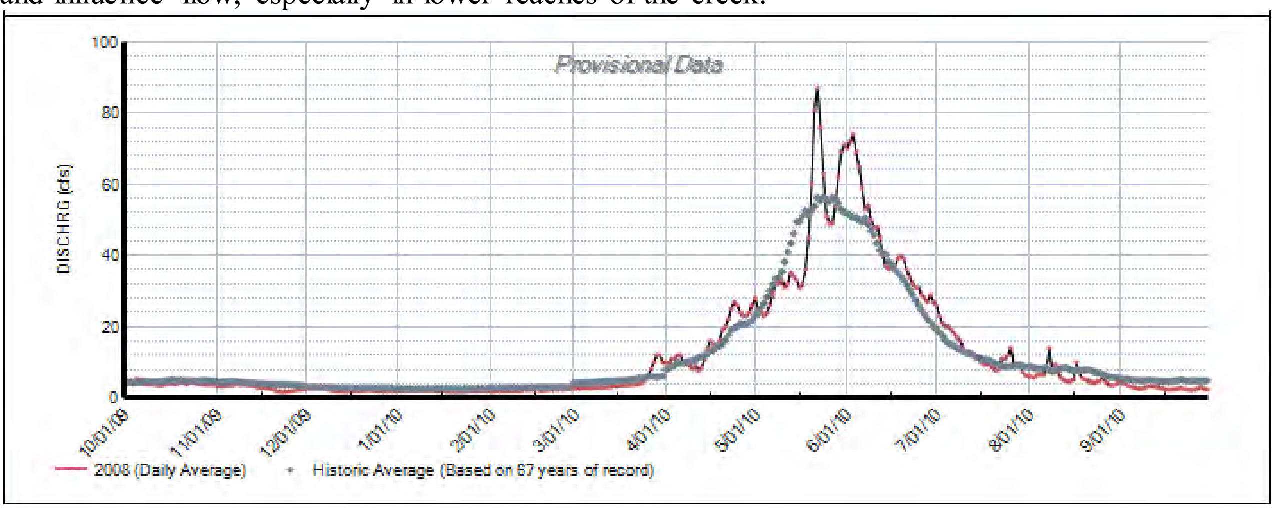

Figure 3: Historic Daily and 2008 Daily Mean Streamflow of Kerber Creek.

Historic Mining Activity

The majority of the lands surrounding Kerber Creek's 25-mile stretch are privately owned, and the BLM and USFS manage the remaining lands within the watershed. The town of Bonanza, which houses several inactive mines in the Bonanza mining district, is located upstream of the Kerber Creek and Brewery Creek confluence (Figure 2).

Ore was discovered in the Bonanza vein in 1880 and mining occurred from the early 1890s thru the 1970s. Approximately 1500 prospect holes and mines were opened by 1900, and tens of thousands of tons of metals were extracted from mines in the district (CSCVA, 2008). Crushed waste rock, from this point forward referred to as *tailings*, was highly acidic and contained metals including copper, zinc, silver, and lead.

During periods of high production, large amounts of tailings were produced. In response, multiple dams were built along Kerber Creek to contain waste materials. At times, high flow events caused some of these dams to overflow and fail (CDPHE, 2008). Additionally, ranchers destroyed the dams in the 1960s and 1970s to increase the water quantity for irrigation use (pers.comm. Jim Coleman, 2008). High flows and the destruction of tailings dams caused mine wastes to be deposited downstream of the mining district for about 19 miles. Some of these tailings were deposited behind beaver dams. When natural processes caused the beaver dams to fail, tailings were deposited further downstream. The tailings impaired water quality, aquatic invertebrate communities, fishery, and upland vegetation.

Degraded conditions along the creek contribute to erosion of the creek channel, leading to increased width to depth ratios of the creek. Jim Coleman (pers. comm. 2008) also remembers that by the 1970s, Kerber Creek flowed orange and was void of riparian vegetation and aquatic life.

Clean-up Activities

The American Smelting and Refining Company (ASARCO), BLM, USFS, EPA and the Colorado Department of Public Health and Environment (CDPHE) organized the first clean-up of the watershed in 1993. Over $10 million was spent in clean-up efforts focused on the upper watershed. Major aspects of the project include a bulkhead installation at the Rawley 12 tunnel and relocating tons of tailings into an on-site repository. In addition, numerous revegetation projects, stream relocations, and safety closures were part of the project. The project ended in 2003 and water quality has gradually improved in Kerber Creek (CDPHE, 2008). However, several sites in the upper watershed continue to impact water quality and degraded watershed conditions persist in the lower watershed.

In 2005, the BLM initiated a second clean-up effort to address degraded watershed conditions in the lower watershed along a 19-mile stretch of Kerber Creek. By 2007, a new partnership had formed between the BLM, TU, USFS, FWS, EPA, and NRCS. As the project gained recognition and momentum, additional partners joined the restoration efforts. Today, the project has many partners (not all are listed) and each brings unique expertise to the project (Table 1).

Table 1: Kerber Creek Partners and Contributions

Partner	Contribution
AmericCorps: VISTA and Saguache Methodist	Contributed 5 volunteers for capacity building, volunteer coordination, organization, and office support.
Bonanza Stakeholder's Group	Contributed > $250,000 in cash and in-kind matches, hosted work days, allowed access to their properties, and agreed to temporary covenants
BLM/USFS	Technical assistance, project support, and $135,000
Colorado Division of Wildlife	Technical Assistance
CDPHE	319 Grant oversight; technical support; funding
Colorado Water Conservation Board	Financial support
EPA: Federal Facilities and Region 8 lab	Technical support; analytical support
Fish and Wildlife Service	Technical assistance; monitoring
TU: National and Collegiate Peak Anglers Chapter	Fiscal agent, awarded $413,000 319 Non-Point Source grant. Provided additional funding to the project, as well as technical assistance, grant writing, and a field employee. The Chapter installed > 1.5 miles of wattles prior to 2009 work.

PHYTOSTABILIZATION

Historically, the standard method for mine waste restoration was to excavate the wastes and put them in a repository, which is then capped with soil and vegetated. However, this method can be expensive. *In situ* treatment of mine wastes and contaminated soils can be performed using a variety of strategies including soil amendments and vegetation, and has been researched since the 1940s. Phytostabilization, which we define as in-place treatment of mine wastes using amendments of limestone ($CaCO_3$), lime ($Ca(OH)_2$), and compost followed by re-vegetation, uses soil amendments to immobilize metals and vegetation to stabilize sites and prevent erosion. This process reduces the mobility of metals by altering them into less soluble, mobile, or toxic forms, prevents migration to surface or ground water, prevents airborne spread through dust, and reduces bioavailability for entry into the food chain through aquatic life or vegetation (USEPA, 1999; Neuman et al., 2006). Along Kerber Creek, phystostabilization was used to restore metals contaminated soils within the floodplain.

Multiple tailing sites along Kerber Creek were sampled for metals using an x-ray fluoresence device (XRF). XRF results showed elevated concentrations of metals in soils and soil paste pH was also measured and ranged from 2.9- 4.3 (Table 2). The low soil pH causes increased solubility of metals (Neuman et al., 2006) and these soluble metals levels, coupled with the low pH, most likely represent phytotoxic conditions (Munshower 1994, Adriano 1986) for all but the most tolerant plant species.

Soil Amendments

The soil amendments used were limestone ($CaCO_3$, calcium carbonate), lime ($Ca(OH)_2$, calcium hydroxide) and compost. Weed seed free straw was used for mulch and triple super phosphate was used for fertilizer. Limestone is for reducing the potential acidity over many years as sulfides are weathered to sulfuric acid. Lime is for treating the immediate acidity of the soil (Neuman et al., 2006). Compost was used to provide organic matter. The fertilizer was used to stimulate growth.

Acid-Base accounting of the tailings material was used to determine how much alkaline material was required to neutralize their active and potential acidity. The total lime requirement was determined by the modified Sobek method (Sobek et al., 1978, RRU, 1997) and the SMP buffer method (ASA 1982, Method 12-3). Analytical results were applied to Equation 1 to calculate the total lime requirement.

Tons CaCO3 /1000 tons soil = (% HNO3 extractable S + % Residual S) 31.25 + 23.44(% HCl extractable S) + SMP Lime Requirement, tons CaCO3/1000 tons soil (Equation 1)

Both Ca(OH)2 and CaCO3 were applied according to the application rate based on calcium carbonate equivalence (CCE) (ASA 1965, Method 91-4.2), percent of oversize (> 0.25 mm) particles determined by dry sieving, and gravimetric water content. Sufficient calcium hydroxide (Ca(OH)2) was added to meet the requirement for the SMP active acidity, while CaCO3 was added to satisfy the potential acidity values. A 25 percent safety factor was used with the total lime requirement determined by Equation 1. Application rates of amendments are presented in Table 3.

Composted organic matter was incorporated into the upper 8 inches of the amended plots and fertilizer (N-P-K of 34-0-0) was applied to each test plot based on medium application rate of 60 lb/acre of N.

The lime and limestone amendments were incorporated to a minimum depth of 18" to maximize the area restored and to reach the lower root zone area. After incorporating the lime and limestone amendments into soils by making multiple perpendicular passes with machinery, the compost was then added to the surface and incorporated to a maximum depth of 8". Sites were seeded with a mix formulated for Kerber Creek.

Table 2: Kerber Creek Phytostabilization Sites: XRF Metal Concentrations (parts per million) and Paste pH.

Sample	Date	Pb	As	Zn	Cu	Ni	Fe	Mn	Paste pH
KC01	5/20/2007	1739	138	1789	287	nd	23795	1210	4.3
KC02	5/20/2007	693	nd	1220	193	1650	40192	nd	3.7
KC03	5/20/2007	763	nd	1070	164	nd	27597	nd	3.5
KC04	5/20/2007	990	nd	1040	354	354	39680	nd	3.3
KC05	5/20/2007	1400	92	1859	196	157	30182	nd	3.2
KC06A-1	5/20/2007	1250	nd	1920	158	nd	22490	nd	3.2
KC6-1	5/20/2007	720	55	1170	145	nd	32589	nd	2.9
KC07	5/20/2007	1020	69	1120	140	nd	23590	nd	3.4
KC08	5/20/2007	1080	nd	780	114	161	28698	nd	3.3
KC09	5/20/2007	1150	nd	1659	nd	nd	21491	nd	3.6
KC09a	5/20/2007	1180	nd	1640	110	nd	27187	nd	3.6
KC09deep	5/20/2007	2059	nd	1779	340	nd	17190	nd	4.3
KC10	5/20/2007	1480	nd	1699	126	166	24998	nd	3.7
KC11	5/20/2007	554	nd	1300	133	nd	25190	nd	3.1
KC12b	5/20/2007	302	42	656	nd	nd	25690	nd	3.5
KC12a	5/20/2007	887	nd	1420	349	nd	29184	nd	3.9
KC13	5/21/2007	445	nd	636	121	209	29696	nd	3.4
KC14	5/20/2007	432	nd	494	173	nd	23296	nd	3.6
KC15	5/20/2007	2610	154	902	349	nd	27392	1180	4.1
KC16all	5/20/2007	446	nd	732	115	263	30899	nd	3.5
BLK	5/20/2007	nd	nd	nd	nd	nd	nd	nd	-
2709	5/20/2007	nd	nd	72	nd	nd	27776	nd	-
2710	5/20/2007	1110	79	272	nd	nd	21888	nd	-

nd = non-detect (below detection limit of instrument)

REVEGETATION

Species Selection

The immediate project area surrounding Kerber Creek contains diverse communities of vegetation that have been grouped into ecological range sites. Each range site is expected to contain a potential natural community (PNC) of vegetation, meaning species that occur naturally in an unaltered range site. PNCs can be used as a guide in range site management. When assessing the vegetation in a particular site, the composition of PNC vegetation expected for each range site present is used as a reference. As a vegetative community is degraded, the PNC may be altered as non-native species replace PNC vegetation. PNCs in the Kerber Creek watershed in sites unaffected by tailings will serve as general revegetation reference sites. For example, PNC in a Wet Meadows range site may include western wheatgrass (*Pascopyrum smithii*), slender

Table 3: Kerber Creek Phytostabilization Sites: Soil Amendment Application Rates

		buffer	$CaCO_3$[2]	$Ca(OH)_2$[3]	Compost[4]	Fertilizer	Phosphate
Site	**Acres**	**pH**	**pH 7.0**				
			18" depth	**16" depth**	**wet/tons**	**lb N/ac**	**lb TSP/ac[5]**
KC01	0.6	5.9	23.3	11.6	75.6	60	27
KC02	0.26	4.9	10.1	9.5	15.1	60	27
KC03	1.2	5	50.8	43.7	40.8	60	27
KC04	0.79	4.5	33.5	35.2	45.8	60	27
KC05	0.43	5	17.1	15.7	54.2	60	27
KC06	1.48	4.7	58.5	62.2	186.5	60	27
KC07	1.22	5.1	44.5		70.8	60	27
KC08	1.52	5.4	55.4	42.2	51.7	60	27
KC09	1.51	5.2	56.9	43.8	87.6	60	27
KC09a	0.5	5.3	19.8	49.2	29	60	27
KC09d	0.3	6.3	8.9	15.4	37.8	60	27
KC10	2.75	5.2	119.9	3.5	346.5	60	27
KC11	1.25	4.6	54	89.7	42.5	60	27
KC12a	0.07	4.9	2.9	54.8	2.4	60	27
KC12b	0.05	5.6	2.1	2.7	2.9	60	27
KC13	0.36	4.9	14.2	1.2	12.2	60	27
KC14	0.27	5.3	11.3	13.8	9.2	60	27
KC15	0.57	5.6	22.2	8.3	71.8	60	27
KC16	2.78	5.5	108.7	14.1	94.5	60	27

[2] Total tons/parcel limestone @Colorado Lime $CaCO_3$ equivalence

[3] Total tons/parcel slaked lime per parcel (=actual required tons/ac x total acres)

[4] Tons/parcel based on % moisture and organic matter content determined by CSU Soils Laboratory

[5] TSP is triple super phosphate

wheatgrass (*Elymus trachycaulus*), tufted hairgrass (*Deschampsia caespitosa*), bluejoint reedgrass (*Calamagrostis canadensis*), Baltic rush (*Juncus balticus*), and Nebraska sedge (*Carex nebrascensis*) (SCS, 1984).

Species selected for revegetation (Table 4) were chosen because they were present in the area, were readily available, and were shown to be relatively metals-tolerant in studies performed by Neuman, et al. (2005) and Neuman and Ford (2006), and through previous project work performed in the area by the BLM. Amended sites were revegetated by drilling (1 site) or broadcasting seed. Straw, which was used as mulch, was then crimped into amended and seeded soils using dozer tracks or disks. Triple super phosphate fertilizer was added at .69 pounds per acre and nitrogen at 60 pounds per acre. PNCs of vegetation in the Kerber Creek watershed are highly variable because multiple range sites are present; therefore, the seed mix does not contain all PNC vegetation for each revegetation site. However, it is expected that vegetation will shift towards its PNC at each site over time, as vegetation establishes itself through increased root mass and deposition of organic matter.

Table 4: Kerber Creek Seed Mix

% Seed Mix	Scientific Name	Common Name
57.34	*Pascopyrum smithii*	Western Wheatgrass
41.72	*Elymus trachycaulus*	Slender Wheatgrass
0.57	*Poa spp.*	Bluegrass
0.20	*Helianthus annus*	Sunflower
0.18	*Artemisia frigida*	Fringed Sagebrush

Vegetation Monitoring

Revegetated sites were monitored using modified Daubenmire assessments. The data collected using these assessments were used to determine trends in vegetation. This determination was based on Cover Frequency Index (CFI) of vegetative cover, as well as the composition of PNC species present. CFI is the product of the total percent of species-specific vegetative cover including overhead cover for each species, and frequency index, which is the number of plots per transect a species occurs divided by the total number of total plots in the transect. It is the most commonly used method vegetative inventory for the Rocky Mountain Region (USFS, 1996), and is more accurate than using canopy cover or frequency index alone (Uresk, 1990). As vegetation in reclamation sites reestablishes itself over time, the CFI of non-native species are expected to decrease as the CFI of PNC species increases.

In 2009, prior to phytostabilization and revegetation, two sites (KC04, KCD) were selected for baseline vegetation data collection. In addition, a site (KC06) that was phytostabilized in 2008 was monitored. One transect was established at each site. Baseline monitoring was not completed in 2008, so quantitative comparisons cannot be made for KC06. However, comparison of before and after photographs of KC06 show that revegetation appears promising (Figures 6, 7) and future monitoring will help make this determination.

Vegetation Monitoring Methods

Establishment of Transects

One 50’ by 100’ transect was established at three monitoring sites. Transects were marked with stakes, and their locations were recorded using a GPS.

Determination of Cover

Measurements of species-specific vegetative cover were taken at 5 foot intervals along two 100 foot reaches located 50 feet apart using a 7.9 by 19.7 inch Daubenmire frame, for a total of 40 frame readings per transect. Vegetative cover, which included ground cover and canopy cover, bare soil, small rock (< 1.18 inch), large rock (> 1.18 inch), and litter (non-living organic matter) were measured and assigned a value using canopy cover class codes. Cover is three dimensional in that it includes the column above the plot (canopy cover). For this reason, the total measured value exceeded 100 percent cover in many cases.

Determination of Frequency

Species-specific frequency was calculated by determining the number of plots (Daubenmire frame) in which each species was present, and dividing this number by the total number of plots in the transect (40).

Determination of CFI

CFI indices were then calculated for each species by multiplying cover by frequency.

Revegetation Results

Prior to phytostabilization in fall 2009, Site KC04 lacked live vegetation, and contained only metals-laden soil, litter (non-living organic matter) and rock (Figure 4). It was phytostabilized in 2009, but results will not be evident until the spring of 2010, when new growth is expected to occur.

Figure 4: Site KC04 in 2009 Prior to Phytostabilization

Site KCD had minimal amounts of false equisetum (*Equisetum* species) and willow (*Salix* species) (Figure 5). A comparison of the vegetation present with PNC vegetation (SCS, 1984) shows that the vegetation present is not part of the potential natural community of its range site. This site was phytostabilized in 2009. Results are not expected until the spring of 2010, when new growth is likely to occur.

Figure 5: Site KCD in 2009 Prior to Phytostabilization

The final site monitored for CFI, site KC06, illustrated the improvements in cover that can occur in one year. Though CFIs were not measured in 2008, Steve Sanchez, BLM Natural Resources Specialist (pers. comm.), states that the site contained no vegetation before stabilization (Figure 6). This site was phytostabilized in 2008, and by September 2009 vegetative cover had greatly increased (Figure 7). Slender wheatgrass (*Elymus trachycaulus),* Baltic rush (*Juncus balticus),* goosefoot (*Chenopodium species*), barley (*Hordeum vulgar*) and Russian thistle (*Salsola kali*) were present in the area, and the CFI of bare ground had decreased.

Figure 6: Site KC06 in 2008 Prior to Phytostabilization

Figure 7: Site KC06 in 2009 Following Phytostabilization

STREAM CHANNEL MORPHOLOGY

Channel morphology determines fluvial processes. While there are many channel types, lotic waterways share the common function of transport and deposition of sediment. Channel structure differs by degree of entrenchment, width-to-depth ratio, sinuosity, and slope.

Using the Rosgen (1996) classification system, Kerber Creek was identified as a degraded type C channel. Historically, it likely possessed such features as a well-developed flood plain (land surrounding the stream that is regularly inundated with water as a result of flooding), well-developed point bars (the convex side of a meander bend where sediment is deposited), moderate width-to-depth ratios, and a pattern of sinuosity. A healthy type C channel is able to maintain stability even in natural lateral migration, through lateral accretion and point bar deposition (Rosgen, 1996). Tailing deposition along Kerber Creek resulted in a loss of vegetation, which negatively impacted bank stability, width-to-depth ratios, and sinuosity. Without the tenacious root systems of riparian vegetation to act as a buffer against erosion, the stream channel was unable to maintain balance.

Channel width-to-depth ratio is defined as, "the ratio of bankfull surface width to the mean depth of the bankfull channel" (Rosgen, 1996). A type C channel with a low width-to-depth ratio is able to transport higher sediment loads than a type C channel with a high with-to-depth ratio. As the width-to-depth ratio of a channel increases (the channel becomes wider and shallower), increased stress is placed along bank regions and erosion is accelerated (Rosgen, 1996).

Sinuosity describes the natural meandering pattern a stream develops over time (Figure 8). It dissipates the kinetic energy contained in flows.

Figure 8: A Highly Sinuous Stretch of Kerber Creek

When natural patterns of sinuosity are altered (e.g. through erosion), instability occurs. If the sediment load is too large for the amount of energy contained in flow, stream congestion and reduced flow can occur (Figure 9). If the kinetic energy contained in flow is too high for the sediment load, sinuosity will decrease as erosion of streambanks lead to increased widths (Rosgen, 1996). Riparian vegetation and in-stream flow directing structures were used to improve channel morphology.

Figure 9: Excessive Sediment Deposition in Kerber Creek

Riparian Vegetation

Riparian vegetation plays an important part in protecting streambanks because tenacious root systems of riparian vegetation shelter them from erosion. Both willows and sedges possess extensive root systems and can provide support. The stream channel was stabilized using root wads, dormant willows, and sedge mat transplants.

In 2008, approximately 800 dormant willow stem bundles were planted along a 17 mile stretch of the stream corridor. Willows selected for transplantation were shrub-like, mature, healthy, and had multiple stems emerging from the root crown. Species used were native, non-invasive, or have multiple beneficial values including wildlife habitat, forage value, aesthetics, biomass, limited water uptake, and root mass to stabilize stream banks. Coyote willow (*Salix exigua*) is the most common willow type in the watershed, and it is one of the species recommended for use in bank stabilization projects (Kittel, 2003; NRCS, 2004).

Sedge mats were transplanted in 2008 and 2009 at sites where phytostabilization occurred. Native sedges (*Carex nebrascensis*) were clumped together to form sedge mats. The density of sedge mat transplantation determines their rate of coverage. Actively eroding sites and sites where the rate of sedge mat survival is expected to be low generally require higher densities of transplantation. For streambank protection, mats were placed along the entire radius of the inside or outside curves, at and slightly above the high water mark of the stream.

Riparian Vegetation Stream Channel Stabilization Methods

Species Selection

All necessary permissions were obtained prior to riparian plant removal. Plants were collected from areas that would have been destroyed by construction activities, or from "donor sites". Donor sites were located close to restoration sites at a similar altitude, and contain similar soils and hydrology. Plants were harvested from the edge of the patch of sedges or willows to minimize damage to other plants. Only a few willows or sedge mats were taken from each donor site to disperse the impact. No more than ¼ of the overall donor patch was collected. Sites that were vulnerable to weed infestation or that contained noxious weeds were not used as donor sites to avoid spreading the weeds to the transplant sites, and to avoid weed establishment at the donor sites were the soils were disturbed.

Willow Transplantation

Root Wads

Dead willows and other large woody vegetation were harvested from the root by using heavy machinery. The plant or plants were then placed root side up into eroding banks to act as a protective barrier against erosion.

Willow Cuttings

Cuttings were selected that possessed leaf buds near the top of each cut line, and that had branches ½ to 2 inches in diameter and at least 2 to 3 feet long. The bottom end was cut at a 45˚ angle. Cuttings were stored between 31°F to 40°F in water with root stimulator.

Willows were staked into the soil vertically and angled with the slope of the bank. If the top of the willow was damaged during staking, it was removed. To prevent moisture loss and possible washing away due to high water flow, dormant cuttings were anchored deep in the soil from the toe of the eroding bank to the highest point where moisture was available. Willow cuttings were set deep enough to maintain contact with moist soil from the water table but not completely submerged in water year-round. Minimum planting density was one willow stake every 3 feet.

Sedge Mat Transplantation

The transplant area was prepared prior to sedge collection from the donor site by creating a depression in the soil to accommodate the dimensions of the transplanted sedge mat(s). The depression was lightly scarified and soils were loosened to a depth of 6 to 18 inches. Large soil clumps were broken up, and any rocks, roots, or other debris that might create air pockets were removed. Excavation continued until the depression was filled with water and the mats were installed in water depths of 1 to 4 inches.

Mats were excavated using a front end loader and were generally no smaller than 2.5 by 2.5 feet in size. They were dug out deep enough (generally18 inches) to ensure a majority of the root system remained intact. Mats were handled gently to keep as much of the soil surrounding the root system attached as possible. The donor sites were than rehabilitated by filling in the hole with soil and smoothing the area to the natural grade.

Mats were planted directly after harvest, and were not left to dry out. The excavated sedge mat was placed in the prepared depression so that the top of the soil was flush with the surrounding ground. The depression was filled and the mat was reset as needed. The edges were filled with soil to protect the roots from air exposure. The mat was lightly tamped using the back side of the excavator bucket so that it was in direct contact with the soil. The transplant sites were watered using the excavator bucket to further eliminate air pockets. Sedge mats were likely securely rooted within 4 to 5 weeks of transplantation.

Instream Structures

J-Hook Vanes and Cross-Vanes are in-stream rock structures designed to redirect a stream's energy toward the center of the stream to relieve pressure on eroding banks and create pool habitats. Redirecting energy helps decrease bank erosion by reducing near bank slope, velocity, stream power, and shear stress, and can lead to a reduction of the channel width and increase the depth of the of the stream channel. The decrease in energy along the streambank allows planted material to take root and mature, which will increase long term stability of the streambanks. In addition, these structures promote pool formation which enhances aquatic habitat.

J-Hook Vanes are placed on the outside of stream bends where strong downwelling and upwelling currents, high boundary stress, and high velocity gradients generate stress in the near-bank region (Rosgen, 2006). Cross Vanes are grade control structures that decreases near-bank shear stress, velocity and stream power, and focus energy to the center of the channel (Rosgen, 2006).

Instream Structure Installation Methods

For both J-Hook Vanes (Figure 10) and Cross Vanes (Figure 11), banks were reshaped to a 2:1 or flatter slope prior to rock placement. A pool was excavated downstream of each structure to a depth of approximately 2 feet with 2:1 side slopes and 4:1 slopes on upstream and downstream sides. Angular rocks were selected for use and placed in the stream channel at a 4-7% slope using a backhoe with an opposing thumb. The rocks were positioned so that the flatter portion of the rock was facing up. Footer rocks and top rocks were placed in contact with adjoining rocks. The rocks were then keyed together with equipment to ensure that all rocks were stable and in contact with each other. J-Hook Vanes do not span the channel; their end rocks were blended into a gravel bar to form a J shape. Cross-Vanes span the entire channel.

Stream Channel Morphological Data

In September 2009 baseline channel width, depth, and sinuosity data were collected from three monitoring sites in Kerber Creek (Table 5). It is hoped that width to depth ratios will decrease over time as riparian vegetation closes in on the stream and protects the channel from erosion. To gather width and depth data, cross-sections were surveyed using the rod and level surveying technique (USFS, 2005) with an LB-10 laser beacon to measure width and depth across the channel. Sinuosity is the ratio of the valley length to the length of the stream channel, and was calculated using information gleaned from aerial photography.

Table 5: Stream Channel Morphological Data

Site	Date	Width to Depth Ratio	Sinuosity
KCD	09/01/2009	6.32	1.232
KC04	09/01/2009	10.84	1.192
KC06	09/01/2009	5.27	1.124

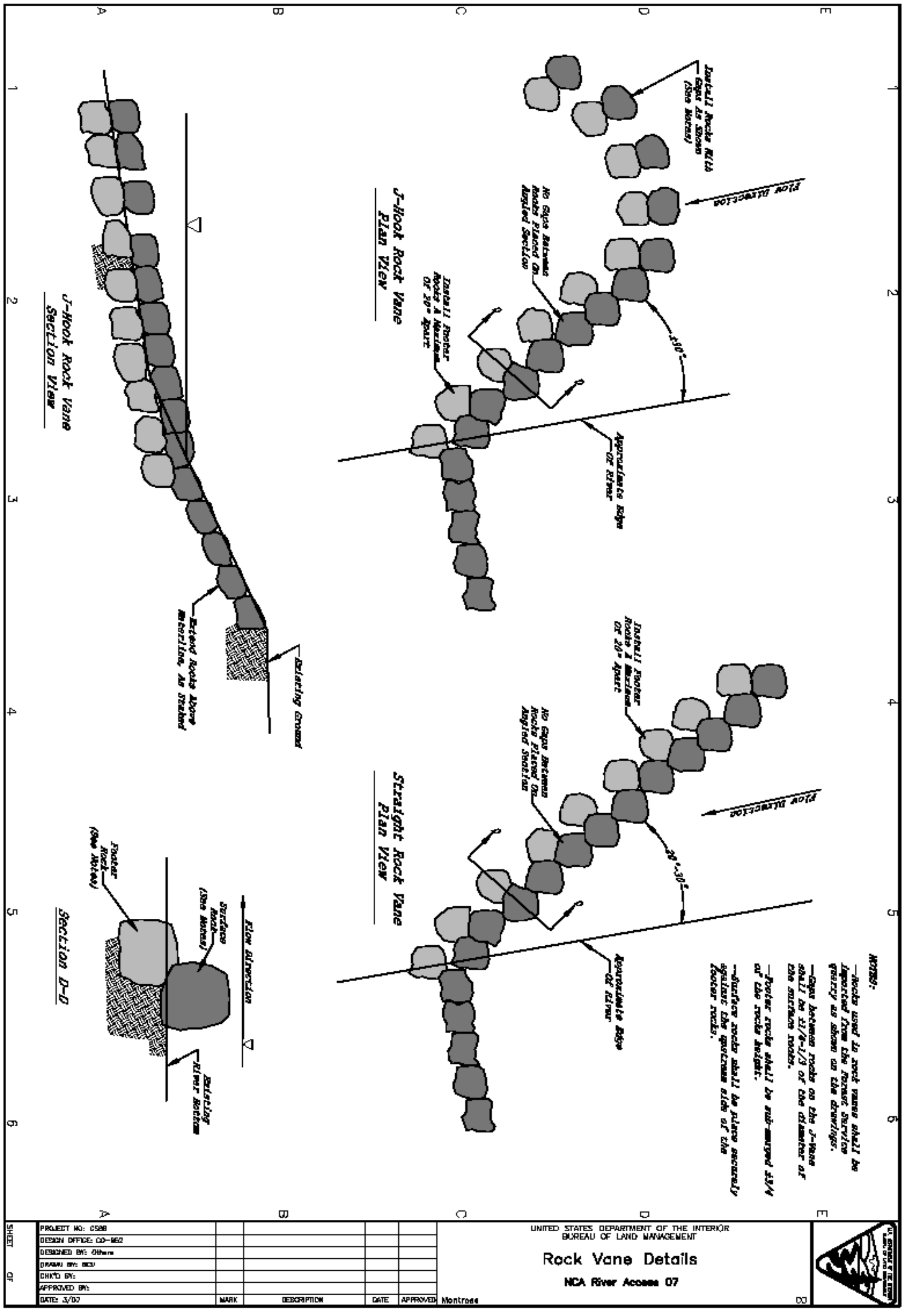

Figure 10: Specifications for J-Hook Vane Structures (Rosgen, 2006)

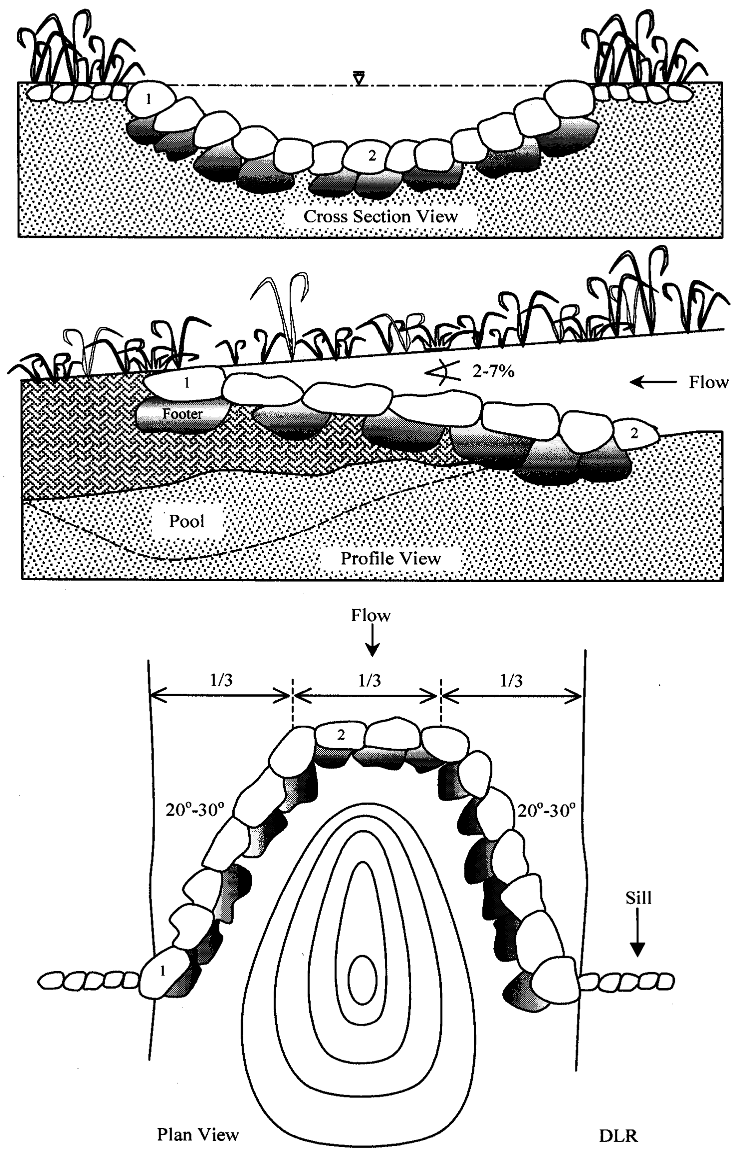

Figure 3. Cross section, profile and plan view of a Cross-Vane

Figure 11: Specification for Cross-Vane Structures (Rosgen, 2006)

Grazing Management

In general, forage selectivity varies by animal species, palatability of vegetation, and preference. Livestock typically favor green seedlings over better established, course plants and select for them (Wyman, et al., 2006). If overgrazing of livestock on seedlings occurs before the plant can store an adequate supply of nonstructual carbohydrates, which are collectively referred to as total available carbohydrates (TAC) through photosynthesis, the plant is particularly susceptible to degradation and death (Vallentine, 1990). Unmanaged grazing can negatively affect emerging vegetation by decreasing leaf biomass, which leads to a decrease in root system biomass and health (Vallentine, 1990), reduced cessation of elongation (Crider, 1955), reducing root numbers and branching (Vallentine, 1990), and reduced depth of soil penetration (Ruby and Young, 1953). In addition, seedlings are particularly susceptible to being pulled out of the ground by grazing animals before their root systems are fully developed (Vallentine, 1990). The negative physical changes of overgrazing can have long-term effects, including species composition shifts (Tomanek and Albertson, 1957), reduced infiltration, and increased erosion and runoff (NRCS, 2001).

While unmanaged grazing can be detrimental to plant communities, managed grazing can benefit riparian areas. For example, grazing enhances the nutritive value of available herbage by increasing the ratio of new growth to old growth. In addition, soil treading by grazing animals may benefit newly seeded sites because it works the seed into the soil surface and compacts the soil around the seed (Vallentine, 1990). To limit degradation of vegetation on amended soils and to maximize benefits associated with grazing, NRCS has worked with stakeholders along Kerber Creek to develop grazing management plans for each landowner's property. Rotation plans were developed for established pastures to minimize impact. Wildlife-friendly fencing materials, provided in part through Wildlife Habitat Incentives Program's (WHIP) cost share program, will be used to manage grazing on stabilized sites. Landowners will rest restored sites from livestock grazing during the vegetative recovery period, which varies with site-specific conditions. NRCS, in concurrence with the local biologist and/or FWS representative, will determine when the recovery has been reached. After the resting period, phytostabilized sites will be grazed in accordance with NRCS recommendations, which are based on productivity and location.

CONCLUSIONS

While much work was completed in 2008-2009, more will be in done in the future. Monitoring of phytostablization sites will continue to determine success of restoration and to determine if vegetation is moving toward PNCs. Stream channel morphological data will also be collected to determine if width depth ratios decrease and sinuosity increases. Other monitoring, including water quality and biological (fish and invertebrates), will also be conducted to determine changes through time.

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RECLAMATION OF A SANDSTONE AND CLAY QUARRY WITH NO TOPSOIL: USE OF FILTER FINES AS GROWTH MEDIUM

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ABSTRACT

Reclamation of a quarry used to produce sandstone aggregate and clay near Boulder, Colorado was undertaken in 1995 without the benefit of salvaged topsoil. Subsoil was generated from remaining clay (weathered Lykins formation shale). Top layer growth medium was created using filter fines from a City of Boulder water treatment plant. These materials were sediment load transported by water passing from a high mountain watershed down a steel pipeline to the treatment plant. Silt and coarser size particles had been separated by filtration; clay particles had been precipitated using alum. The resulting "filter fines" had the appearance and sandy loam texture of topsoil with occasional aggregations of alum. Planting in this material in late 1994 was accomplished by broadcast and mulched with bonded fiber matrix or hydromulch. Plentiful rain in spring 1995 resulted in a very strong cover of the sown native grasses (mainly thickspike wheatgrass and western wheatgrass, *Elymus lanceolatus* and *Pascopyrum smithii)*. Stands with initial highest plant cover were associated with the deeper soil thicknesses. Over time stands on thinner soil cover, with lower initial cover values, were possessed of the greater species density, as less competitive native species were able to slowly establish in the absence of heavy grass competition. Diffuse knapweed entered the site early from local sources as well as soil material and was removed by hand in large quantities. Very small and inadvertent early presence of domesticated cool season grasses has continued to grow through the twelve-year record and may pose a threat to dominance of the site by native species.

INTRODUCTION

An expansion of a small but long-term aggregate and clay (shale) quarry near Eldorado Springs, CO was proposed in 1984 on land managed by the Colorado State Land Board. This proposal was received with substantial public opposition. After a State of Colorado mine permit application was rejected by Boulder County (as per the review/approval process pursuant to Colorado mining reclamation laws), a land exchange was accomplished whereby lands including the quarry came into fee ownership by City of Boulder. Reclamation including revegetation of the quarry fell to the City as the new owner of a permitted mining operation.

METHODS – DESIGN AND IMPLEMENTATION OF RESTORATION

Identification of Practical Alternatives for Surface Grading

Like quarries in general, this one had extracted aggregate and clay for construction, industrial and transportation undertakings off-site, leaving a large void. Reconfiguration of approximate original contour thus would require import of a very large amount of material. Expenses for acquisition and haulage of the volume of material required for restoration of approximate original contour was excessive. Short of this step, the main priority was considered to be stabilization of features whose failure would comprise a hazard to public safety. Besides Lykins shale, the mining process had exploited intact Lyons sandstone; in part of the area pursuit of this sandstone had resulted in removal of the toe of a talus slope, leaving unstable coarse rock debris upslope. The consequent random rockfall hazard was deemed sufficiently great to make its stabilization the main object in the recontouring process. Reworking of the quarry working bench would be directed toward rebuilding of the talus toe-slope.

Revegetation Alternatives – Growth Medium

Topsoil had not been saved for restoration. If salvaged at all it had doubtless been a saleable item. The existing reclamation plan on file called for the use of the weathered near-surface materials associated with the Lykins shale, a deep-red material that had been mined probably for use in brick production. Weathering of Lykins shale produces a clay substrate that would likely be a suitable rooting medium, but which would, as with all un-aggregated clays, comprise a poor surface medium because of very low moisture permeability. Thus a coarser material to use as a topdressing over the clay as a subsoil was sought.

The City of Boulder is among few U.S. municipalities with a major portion of its water supply available through gravity flow. In the process of flow from watersheds at very high elevations (>10,000 feet) down to water treatment facilities near Boulder (approximately 6,000 feet), particles of soil were routinely entrained and transported through the pipes. At the water treatment plant, such particles were removed (sieved and flocculated with alum) and slowly built up there as an unneeded material that was termed "filter fines." Laboratory analysis of this material showed that it was of sandy loam texture, had approximately 3% organic matter, but was without structure. In appearance it was very similar to sandy loam surface soils often present in middle and higher elevation sites in the Front Range. However, because these filter fines are produced by an industrial process (preparation of potable water), they fall into a category of potentially hazardous material that cannot be transported and used for any purpose without proper permitting from the Colorado Department of Health and Environment. Following submittal of analytical data and adequate documentation of its proposed use, the necessary permit for use of filter fines as a plant growth medium was obtained.

Identification of Revegetation Alternatives – Plant Materials

The lands in question were under management of City of Boulder Open Space Department. It was the conclusion of staff plant ecologists at the time (1993) that a stabilizing cover of primarily cool season grasses would serve the dual needs of surface stabilization and wildlife forage production. The seed mix in Table 1 was settled on as suitable to initiate the process of recovery. All species were native but some of the grasses were acquired from commercial sources; all forb and shrub seed as well as some the grass seed (as indicated) was obtained from local collections.

Table 1. Seed Mix

Species	Common Name – Variety	Seeds per sq. ft.	Percent of Grass Mix	PLS lb/ac
GRASSES				
Andropogon gerardii	Big bluestem - Champ	6.6	4	2.0
Bouteloua curtipendula	Side-oats grama - Vaughn	5.1	3	1.4
Bouteloua gracilis	Blue grama – Hachita	30.3	20	1.6
Elymus lanceolatus	Thickspike wheatgrass – Critana	5.7	4	1.6
Hesperostipa comata	Needleandthread - VNS	11.7	8	3.7
Koeleria macrantha	Junegrass - VNS	6.4	4	0.12
Nasella viridula	Green needlegrass – Lodorm/ Local (54/46)	5.4	4	1.4
Panicum virgatum	Switchgrass – Blackwell/ Local (75/25)	8.0	5	0.9
Pascopyrum smithii	Western wheatgrass - Rosanna	60.1	39	23.8
Poa agassizensis	Agassiz bluegrass - Local	13.8	9	0.3
*FORBS**			% of Forb Mix	
Achillea lanulosa	Western yarrow - Local	1.9	18	0.03
Aster laevis	Smooth aster – Local	2	19	0.17
Lupinus argenteus	Common lupine – Local	0.2	22	0.5
Monarda fistulosa	Bee-balm – Local	2.1	2	0.06
Penstemon secundiflorus	One-sided penstemon – Local	1.1	10	0.08
Penstemon virens	Green Penstemon- Local	1.2	11	0.09
Ratibida columnifera	Prairie coneflower - Local	2.0	19	0.07
SHRUBS (sown only in rocky ridges)*				
Cercocarpus montanus	True mountain mahogany	0.7	33	0.7
Rhus glabra	Smooth sumac	0.9	33	0.9
Rhus trilobata	Skunkbush sumac	2.1	33	2.1

* Collected from local sources

Planting

In December of 1994 the area was seeded by hand. Seeding was preceded by raking and was followed immediately by raking. The steepest area (the talus slope buttress slope at 2(h):1(v)) was covered with Weyerhauser Soil Guard ® at the rate of 3500 lb/ac. Less steep portions were hydromulched with virgin wood fiber at 1600 lb/ac.

In April 1996, 200 shrubs as one-gallon nursery stock including mountain mahogany (*Cercocarpus montanus*), three-leaf sumac (*Rhus trilobata*), red-stem hawthorn (*Crataegus erythropoda*), golden currant (*Ribes aureum*), and wild rose (*Rosa woodsii*) were planted in the west-central portion of the area. It was deemed necessary to assure survival to provide each with a square yard of landscape fabric that was then covered with shredded wood mulch and to construct a cylindrical cage of 2 inch x 4 inch 14 gauge welded wire anchored with #3 rebar stakes. The landscape fabric was intended to reduce competition from grasses, and the cages were to prevent excessive browsing by deer.

Monitoring

The plant cover of the restored area was monitored at seven locations scattered through the 7 ac area. At each a transect 50 m in length was permanently established along which cover and species diversity data were collected in1996 (second growing season after seeding), 1997, 1998, 1999, 2005 and 2006.

RESULTS

Vegetation of the Restored Area

During the first two growing seasons, a planted area in most parts of the plains and lower mountainous regions that had been newly seeded with a perennial mix would usually experience strong development by annual and biennial plant species of the mustard (*Brassicaceae*) and goosefoot (*Chenopodiaceae*) families. The filter fine materials used for topdressing on this project may have had fewer seeds of mustards and goosefoot plants than substrates at most revegetation sites. No real annual/biennial explosion was noted, though the development of diffuse knapweed (that had colonized the filter fine stockpile at the water treatment plant) was notable and some growth of yellow-blossom sweetclover (*Melilotus officinalis*) was seen. In the most sheltered areas (steeply north-facing) plant dominance proceeded directly to cool season grass (mostly western wheatgrass) immediately. In 1996, monitoring transects in these moist sheltered sites showed cool season grass cover in the range of about 20 to 35% absolute cover while knapweed was 3 to 13% absolute cover. Knapweed may have been the only annual/biennial with significant amount of seed present in the filter fines and in effect had the stage to itself, but its performance as an opportunist was muted.

Total vegetation cover on the deep soil sites (including the undisturbed site) has declined over the ten years of monitoring likely in response to progressively drier conditions. (Figure 1). On the sites with shallower soil (sites with only 1 to 2 inches of topdressing), total vegetation cover has increased, converging on or even exceeding the values from the sites with deeper soil. This may reflect the oft-observed trend for plants on droughty sites to extend roots deeper, in this case preparing them for dry years more fully than plants growing on more (initially) favorable sites.

Weed control

The downside of using the filter fines as topsoil was the fact that during their storage near the water treatment plant, the stockpile had experienced invasion by diffuse knapweed (*Centaurea diffusa*). Consequently, early results included substantial presence of diffuse knapweed which was removed by hand mostly by exceedingly dedicated work by volunteers from the nearby community of Eldorado Springs (People for Eldorado Mountain – the initial organizers of public opposition to the initially-proposed quarry expansion). Several tons of knapweed were removed over the period of 1996 to 1998. The period of 1995 to 1999 was particularly wet and knapweed growth was favored. Beginning in 2000, conditions were on average much drier; PEM removal was important and the subsequent less favorable moisture has kept knapweed growth minimal. The maturation of the perennial cover has likely also elevated competitive interaction which also diminishes the success of knapweed. Diffuse knapweed is a weak competitor.

DISCUSSION

Topsoil Creation

There are many restoration sites on which salvaged (or salvageable) topsoil does not exist. One of the critical considerations in approaching the construction of growth medium in semi-arid sites is provision of both a lower moisture-holding layer of the root zone as well as a "moisture-acceptance" layer at the top. An upper layer that allows incident moisture to penetrate into the soil rather than running off is clearly important. But less obvious is the importance of that upper "acceptance layer" as a "waiting room" in which accepted moisture can linger as an often more clay rich subsoil slowly accepts downward moving moisture.

During the first spring (1995), the obvious risk of the soil construction strategy described above was manifested. The "waiting room" became saturated during May a month with 9.6 inches of precipitation. On the steep 2(h):1(v) slope the saturated surface layer did experience some slippage over the clay subsoil. The extent of damage was small enough that subsequent down-slope particle movement evened out the thickness. Resulting discontinuities in the vegetation cover did not linger past the first year.

Seed Lot Purity

A problem that has made itself an important factor at many other restoration sites and may be beginning to here is the lingering effect of probably a very few seeds of agricultural "super-plants" present in the seed lots of native species purchased and sown. These plants including smooth brome (*Bromus inermis*), tall fescue (*Schedonorus arundinacea*) , and intermediate wheatgrass (*Thinopyrum intermedium*) and are not listed noxious weeds are thus not prohibited from presence as minor components (less than 1%) under Colorado seed law. However, as the extremely aggressive plants that they are, a very few seeds can produce a very few mature plants that, especially for rhizomatous species like these, can spread to dominance.

General Vegetation

The revegetation on this site was expressly directed toward heavy native cool season grass dominance. From the beginning, which coincided with an extremely wet spring and was aided by lack of significant annual/biennial competition, this goal was achieved. Over the first dozen years, monitoring data show that dominance of cool season grasses has continued, but native warm season grasses, especially switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*) have made themselves large components of the cover on the sites that are more sheltered or have deeper topdressing. The progress of advance of non-native cool season grasses (smooth brome and tall fescue on the moister portions, intermediate wheatgrass on the dry extreme) merits careful watching, though no active intervention is thought to be needed at this time.

The bulk of the initial native cool season grass cover was western wheatgrass (*Pascopyrum smithii*), which as can be seen in Table 1, was the major component of the seed mix. Thickspike wheatgrass (*Elymus lanceolatus*) performed in accordance with a minor position in seed abundance. Green needlegrass (*Nasella viridula*) was likewise a minor component but through time up to year 12 has advanced considerably.

Photo 1. Monitoring Transect C1, 1996

Photo 2. Monitoring Transect C1, 2005

Photo 3. Monitoring Transect C1, 2006

CHEATGRASS SEED DISPERSAL IN RECLAMATION AREAS

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ABSTRACT

Cheatgrass (*Bromus tectorum* L.) seed dispersal has been quantified for sagebrush ecosystems, but little is known about cheatgrass dispersal over the bare soils common in newly reclaimed areas. Recently, fluorescent seed marking has emerged as a useful tool to study seed dispersal. We used fluorescently marked seeds to quantify cheatgrass dispersal distances on simulated well pads in northwestern Colorado. A total of 1300 sterilized, marked seeds were released in groups of ~100 from 20-cm high platforms in three types of environments: a mesa top, a gulley, and a ridge top. Seeds were recovered at night using blacklights 4 times over 14 days, and the distance between each seed and its release platform was measured. At all sites, the majority of movement occurred within 2 days of release. Dispersal distance averaged 2.4 m and was highly variable, with 5% of seeds traveling further than 10.6 m. Differences in dispersal distance between sites occurred but did not coincide with measured differences in wind speed. Seed recovery was > 94% at the first time step, and fell to 60-70% after 14d. The average distance reported here is seven-fold higher than the maximum distance recorded for an intact sagebrush ecosystem, and implies that in the absence of impediments, cheatgrass seeds may penetrate the interior of reclamation areas. Fluorescent seed marking is a promising method to explore cheatgrass dispersal dynamics.

INTRODUCTION

The expansion of cheatgrass (*Bromus tectorum* L.) in the intermountain west has caused dramatic declines in the productivity, diversity, and habitat quality of invaded lands (Leopold 1949, Knapp 1992). Reducing the dominance of cheatgrass and preventing its further expansion are goals common to land managers, wildlife managers, ranchers, and farmers (DiTomaso 2000).

Disturbances can allow cheatgrass to expand into new areas (Bradford and Lauenroth 2006), but may also afford opportunities to replace cheatgrass stands with more desirable vegetation. In restoring disturbed areas, the presence or absence of cheatgrass has a large impact on reclamation success (Pilkington and Redente 2006), and good choices of reclamation materials and methods depend on whether or not cheatgrass competition will be present. Predicting the likelihood of cheatgrass competition is not always simple, however, because our understanding of how cheatgrass seeds disperse is incomplete.

While long-distance dispersal of cheatgrass seeds by animal vectors has long been discussed (Leopold 1949, Mack 1981), very little attention has been given to how cheatgrass disperses over shorter distances. In a unique study, Kelrick (1991) used seed traps to quantify wind deposition of cheatgrass seeds in a sagebrush steppe environment. He found that secondary dispersal was common, with only 45% of seeds landing in a particular location remaining in that location (Kelrick 1991). He also found that litter and shrub cover were important in retaining cheatgrass seeds (Kelrick 1991). In a study of seeds similar to those of cheatgrass in that they contained awns (long, thin appendages which increase the seed's surface area) Chambers (2000) found that final seed distribution is greatly affected by the type of substrate over which the seed travels (Chambers 2000). How cheatgrass seeds travel over the bare substrates common in early reclamation has not yet been studied.

Recently, the use of fluorescent powder has emerged as a promising method for tracking seed movements (Lemke et al. 2009). In this study, we examine the usefulness of fluorescently marked seeds for studying cheatgrass dispersal, and use the method to quantify cheatgrass dispersal distances over bare soils for three locations in northwestern Colorado.

METHODS

Study area

Study locations were within the geological Piceance Basin, which is currently under intensive development for the extraction of natural gas. Cheatgrass prevalence in the Piceance Basin is extreme in lower elevation gullies, moderate on slopes and mesas, and constrained to roadsides and disturbed areas at higher elevations. The Grand Valley Mesa site (GVM; 5451 ft.) lies atop a small mesa near Parachute, CO, on Potts-Idlefonso soils. The Ryan Gulch site (RYG; 6835 ft) lies within one of the many gullies which drain to Piceance Creek, is bordered by steep slopes, and is on Glendive fine sandy loam soils. The Wagon Road Ridge site (WRR; 7268 ft) lies on a ridge on Piceance fine sandy loam soils. Slopes of all study sites were less than 5%.

A simulated well pad disturbance was created in all study locations by clearing all vegetation, stripping the top 20 cm, and then cutting and filling the subsoil to create a level surface. This work was completed between August 20th and September 10, 2008. The simulated well pad surface was kept weed-free through the 2009 growing season by repeated hand-spraying of emerging plants with 2% (v/v) glyphosate. The seed dispersal study was conducted on the bare soil of the simulated well pad surface.

Cheatgrass seed preparation

We collected cheatgrass seed from our study sites using hand clippers. Fully formed seeds without any sign of fungal infection were selected. Spikes were air dried until the seeds fell apart from the spike at the touch. Seeds were killed by allowing the seeds to imbibe water from moist paper towels for 5 hours, microwaving the seeds for 55 seconds on high power, and then oven-drying for at least 12 hours. To verify that this method achieved complete seed kill, we compared germination percentages of treated and untreated after-ripened seeds collected the prior year. This method killed seeds completely and did not alter seed dispersal appendages. Seed was counted into bundles of 100. In precise terms, the counted units were not seeds, but propagules, as sometimes two seeds or one seed plus the awned glumes did not easily shatter apart at the touch. These were left together to better approximate natural dispersal units. 2.5% of propagules contained two seeds, and the remainder contained one seed. For simplicity, we will hereafter refer to these simply as seeds. Seeds were coated in green fluorescent powder (DayGlo® Color Corporation, Cleveland OH) by gently shaking them in a plastic bag containing powder, and then gently shaking propagules in a 1mm sieve to remove excess powder. The weight addition due to the powder was quantified by weighing 3 large batches of seeds before and after coating. Coating with fluorescent powder added 10% to the weight of the seed.

Seed release and tracking

Four (4) groups of seeds were released at each site. Seeds were released from 8cm-diameter posterboard platforms tacked to the top of wooden stakes. Release platforms were 20-25 cm from the ground surface, a height similar to that of cheatgrass in the study area in the 2009 season. Release platforms were separated by at least 14m from each other and at least 7m from the edge of the simulated well pad. Well pads were bare or nearly bare of vegetation during the course of the study.

Average wind speed and wind gust data were collected at each site beginning at the time of release using a WindSmart sensor and MicroStation (Onset® Computer Corporation, Bourne, MA) mounted 30 cm from the ground surface. Rain data was collected at GVM and at a monitoring location approximately 27 km from the WRR and RYG sites using an RG3 datalogging rain gauge (Onset® Computer Corporation, Bourne, MA).

Upon release, wind almost immediately blew all seeds from release platforms, and seeds were informally noted to have landed within 1.5 m of the release platform upon initial contact with the ground. Seeds were relocated at night using blacklights, and polar coordinates from the release platform were taken using a tape measure and compass for all located seeds. In a few cases, seeds traveled so far that it was difficult to determine which platform was the release platform. In those cases, polar coordinates were taken from the nearest platform. Seeds were relocated four (4) times at each site: 1-2 days, 3-4 days, 7-8 days, and 13-14 days following release.

Analysis

The effect of time since release on dispersal distance was analyzed separately for each site using analysis of variance (ANOVA) in SAS PROC GLM with the number of days since release as a categorical variable. Differences between dispersal distance for consecutive measurement intervals were calculated using ESTIMATE statements. Differences between sites in dispersal distance for the final time step was determined using ANOVA in SAS PROC GLM. Means are reported with standard errors.

RESULTS

Over the course of the study, wind speed averaged 0.53 ± 0.07 m/sec at GVM, 0.05 ± 0.05 m/sec at RYG, and 0.55 ± 0.05 m/sec at WRR (Figure 1a). Average daily maximum gust speed was 6.3 ± 0.35 m/sec at GVM, 3.8 ± 0.24 m/sec at RYG, and 6.6 ± 0.27 m/sec at WRR (Figure 1b). A rain event of 3.2 mm occurred at GVM on July 29, and no additional rain fell during the course of the study. At the rain monitoring location closest to WRR and GVM, the Jul 29 rain event was 1.6 mm, and a second rain event of 0.8 mm occurred on August 6.

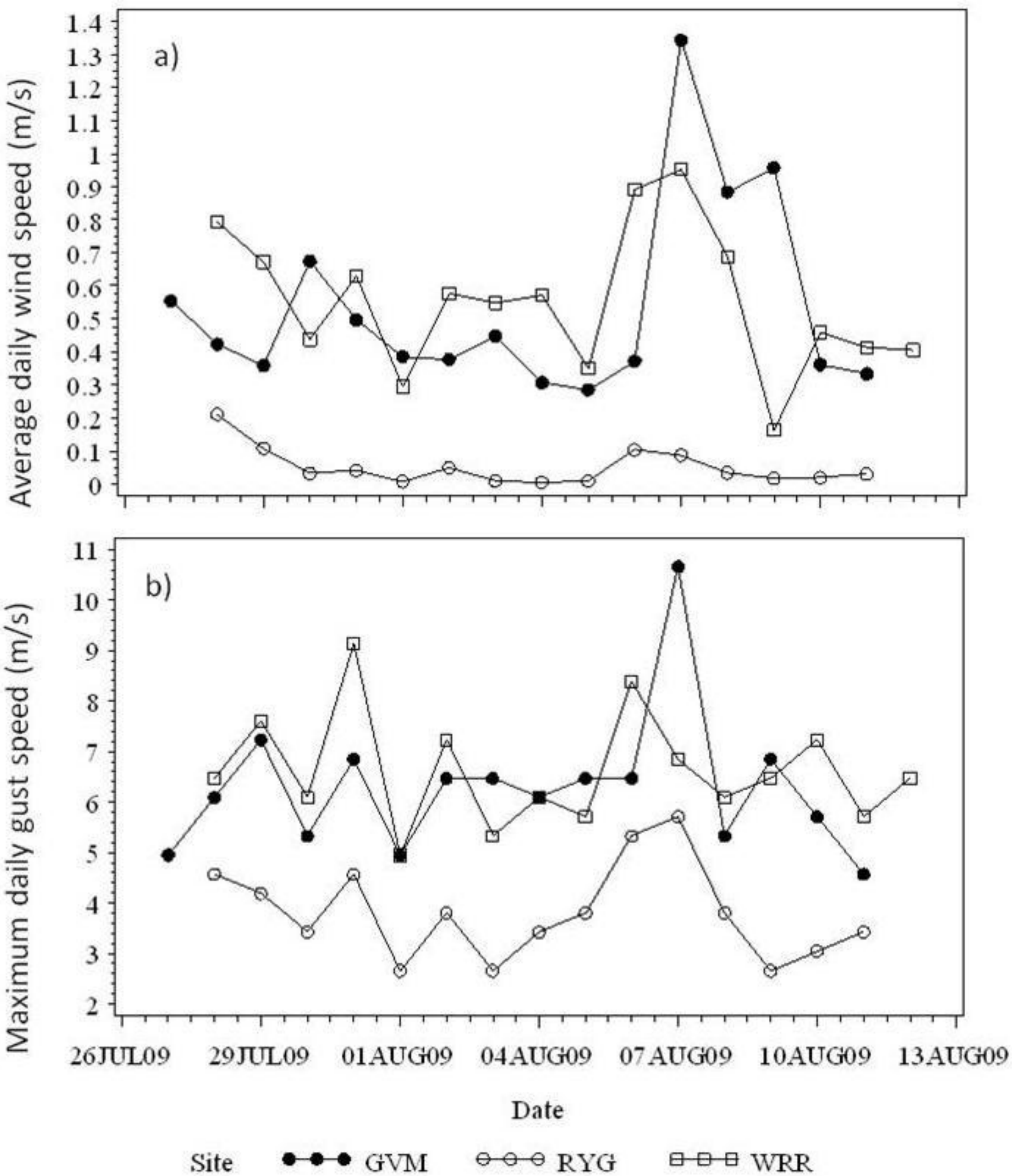

Figure 1. Average daily wind speed (a) and maximum daily gust speed (b) 30 cm from the ground surface at a mesa study site (GVM), a gulch study site (RYG) and a ridge study site (WRR).

Over 94% of seeds were relocated at all three sites on the first relocation attempt, one to two days following release (Figure 2). On the second relocation attempt, 67% of seeds were relocated at GVM, and 87 % of seeds were relocated at RYG and WRR. On the last relocation attempt, recovery had dropped to 60-70% at all three study sites (Figure 2).

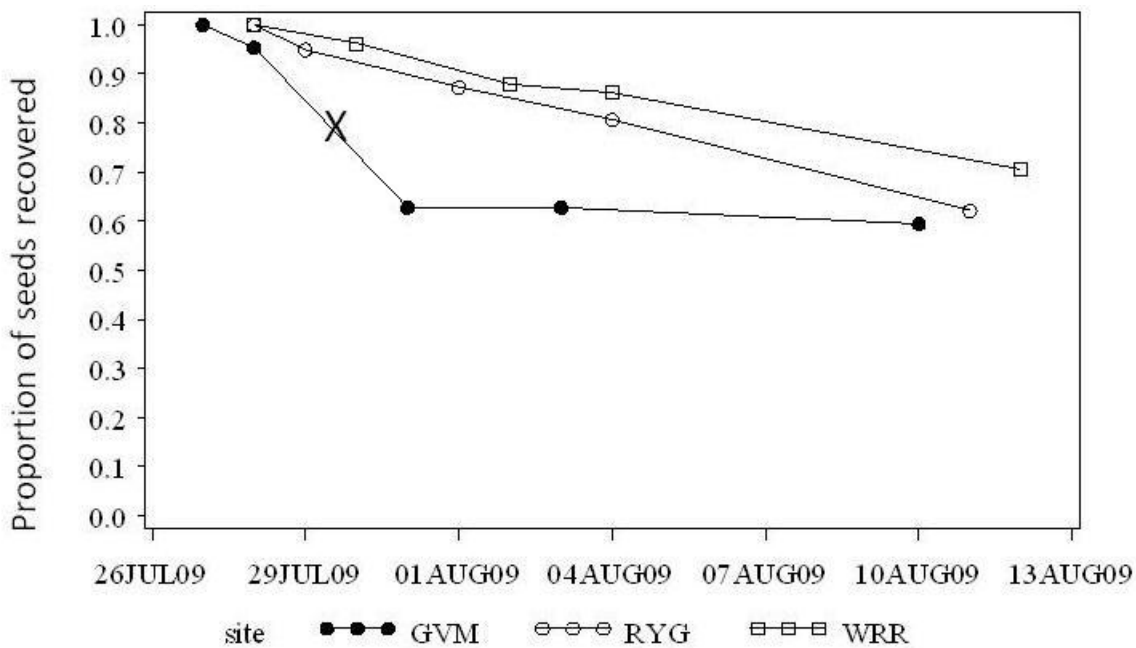

Figure 2. Proportion of released seeds recovered at three study sites. The first time point represents the release date. The X denotes a heavy rain event which occurred at the GVM study site.

At GVM, average measured dispersal distance increased until 3 days following release, when it reached 289 ± 30 cm, and then did not detectably change in the two subsequent measurement intervals (Figure 3a). At RYG, average measured dispersal distance increased until 3 days following release, did not detectably change between the second and third measurement intervals, and then increased between the third and fourth measurement intervals ($p= 0.006$) when it reached a maximum of 267 ± 17 cm (Figure 3b). At WRR, average measured dispersal distance did not detectably change between the first and third measurement intervals, but increased between the third and fourth measurement intervals ($p = 0.0002$), when it reached a maximum of 180 ± 15 cm (Figure 3c).

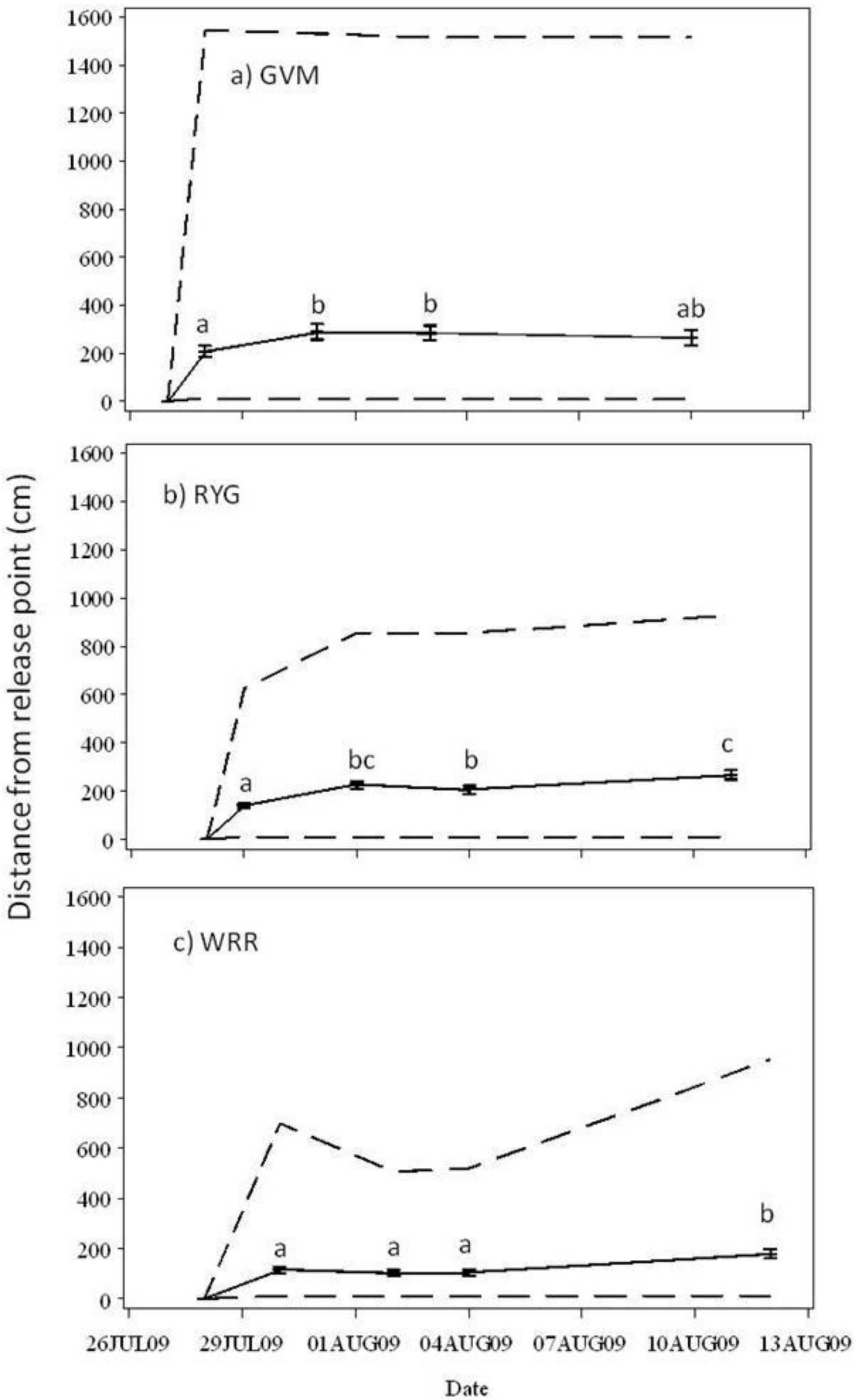

Figure 3. Dispersal of marked cheatgrass seeds at three study sites: a) Grand Valley Mesa, b) Ryan Gulch, and c) Wagon Road Ridge. Solid lines= mean distance from release point, dashed lines= 5% and 95% quantiles, error bars= SE. Time points not sharing letter represent significantly different means at $\alpha = 0.05$.

Maximum recorded distances were: 1863 cm at GVM, 1579 cm at RYG, and 2082 cm at WRR. 95th percentile distances were: 1514 cm at GVM, 927 cm at RYG, and 953 cm at WRR.

DISCUSSION

The average dispersal distance measured in this study was 235 ± 13 cm, while the maximum movement observed in an intact sagebrush stand was only 35 cm (Kelrick 1991). The difference may be due to a lack of impediments to secondary dispersal, as many have reported that shrubs, litter, and other obstructions entrap seeds (Marlette and Anderson 1986, Kelrick 1991, Chambers 2000). At GVM, our field crew noticed a florescent powder impression in the shape of a cheatgrass seed. By tracking the trajectory defined by the release stake and this impression, the crew found three additional such impressions, and then found the seed. At WRR, a significant increase in average dispersal distance was detected between 7 and 15 days after release. In absence of plants or litter, cheatgrass seeds may continue to disperse over several days or weeks.

At GVM, a rain event of 3.2 mm occurred after the measurement date (Figure 2). The proportion of seeds recovered at the next measurement date dropped to 63% from 94%, and no further change in average dispersal distance was detected (Figure 3a). Field crews noted several instances where an awn of a marked seed protruded from the ground surface, and the rest of the seed was buried. Data from the weather station nearest the other two study sites indicates no such heavy rain event. Buried seeds were not found at those sites, and average dispersal distance continued to increase over the following week (Figures 3b and 3c). Rain is likely important for halting dispersal and promoting burial of cheatgrass seeds, as has been shown for several other seeds in an agricultural environment (Benvenuti 2007).

The least windy site in this study, RYG, did not coincide with the site with the lowest average dispersal distance, which was WRR. We did not find any evidence of a dispersal mechanism other than wind in this study; there were no caches of seeds found or tracks indicating that rodents had altered the distribution of the recovered seeds. A difference in recovery rate, and therefore error in measuring dispersal distance, is not a likely explanation for the difference in average measured dispersal distance, as recovery rates at WRR and RYG were nearly identical. A possible explanation for the results of this study is that all sites had wind gusts sufficiently energetic to lift cheatgrass seeds off of the ground, and either soil type or some unmeasured spatial variability in gusts determined average distance traveled. Although the difference in average wind speed between RYG and WRR was ten-fold, the difference in maximum gust speed was only two-fold. It is unknown how sufficiently energetic gusts were distributed across the study areas, but the distribution may have been restricted at WRR, which was bordered by pinyon and juniper trees and a large topsoil pile. Potential windbreaks at RYG had only about a quarter as much vertical relief, which may have allowed the anemometer, placed near the middle of the simulated well pad disturbance, to more accurately reflect wind gusts across the study area. It is also possible that WRR received more rain than RYG or had a soil type more favorable for seeds to adhere to the soil surface (Benvenuti 2007).

The average dispersal distance reported here is likely an underestimate of what should be expected in most field conditions. The fact that an increase in dispersal distance was found at the last measurement interval indicates that the measured distance may have been higher if we had been able to continue the study longer. There were several instances where seeds encountered topsoil piles or vegetation at the edge of the study area which may have hindered further movement, and several instances where a seed traveled far enough that it was difficult to determine the stake from which it had been released, and a measurement to the nearest stake was taken. Seeds were 10% heavier than normal due to the fluorescent coating, and the coating was somewhat sticky, which could have hindered movements. Recovery rates dropped off over the course of the study, and seeds traveling further, especially those traveling outside the simulated well pad area, were probably less likely to be detected. Each of these factors would lead to an underestimate of dispersal distance.

IMPLICATIONS

From the perspective of promoting re-establishment of desirable vegetation in reclamation areas, the average dispersal distance is less important than the distance over which we can expect a number of cheatgrass seeds sufficient to impede the establishment of desirable plants. Cheatgrass is a prolific seed producer. Cheatgrass seed rain in a year of above average precipitation was 13, 942 seeds/m^2 at a site in western Utah (Smith et al. 2008). Our study found that 5% of cheatgrass seeds travel further than 10.6 m over bare soil. Assuming a productive seed year and that the seed of a 25 cm wide strip of cheatgrass blows into the reclamation area, then we would expect 70 cheatgrass seeds/m^2 10.6 meters from the edge of the reclamation area. Given that cheatgrass seeds germinate earlier in the year than most perennials and rob later-germinating seeds of moisture, 70 cheatgrass seeds/m^2 might hinder reclamation. In areas where cheatgrass is prevalent, reclamation may be more successful if dispersal barriers are used in conjunction with measures to control cheatgrass in the seed bank.

We found the method of marking cheatgrass seeds with fluorescent powder to be useful in the study of cheatgrass dispersal dynamics. At the two study sites where heavy rain events did not occur, we were able to recover over 80% of seeds within the first week following release. However, our crew noticed that the fluorescent coating grew less visible in the second week of the study. The usefulness of this method may be restricted to short-term studies of seed dispersal.

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THE ECONOMIC BENEFITS OF COMPLETING RECLAMATION SUCCESSFULLY THE FIRST TIME FOR OIL & GAS SITES

David Chenoweth, David Holland, Gerald Jacob,

Lindsey Kruckenberg, John Rizza and Bryan Whiteley

BIOGRAPHICAL SKETCH

David Chenoweth

Mr. Chenoweth, a Certified Professional Soil Scientist, started his career with ARCO Coal Company as a soil and environmental scientist completing work on surface and underground mines in the western U.S. Mr. Chenoweth founded Western States Reclamation. Inc. in 1983; He has over 31 years of experience in soil science, revegetation planning/construction, land restoration, land use planning, and environmental permitting. He has written revegetation training manuals and conducted stormwater management training seminars. Mr. Chenoweth has provided expert witness reports and testimony on cases involving natural resource damages including fire restoration erosion control evaluation. He has just completed a three year term as President of the American Society for Mining Reclamation.

David Holland

Mr. Holland is currently the Environmental and Regulatory Manager, Rockies Asset Team for Pioneer Natural Resources USA, Inc. in Denver, Colorado. He is responsible for the environmental and regulatory compliance programs involving the company's oil and gas exploration and production in the Rockies. Mr. Holland currently oversees all reclamation and stormwater compliance activities in the Rockies. Prior to joining Pioneer, Mr. Holland was the Natural Resources Program Director for SWCA Environmental Consultants' in Salt Lake City, Utah focusing on environmental permitting and compliance services for the highway construction and oil and gas industries. Mr. Holland received his B.S. and M.S. degrees in Forest Management from Utah State University.

Gerald Jacob

Mr. Jacob, Ph.D. is an Environmental Advisor to the senior management of Pioneer Natural Resources Inc. in Denver, Colorado. Previously he was the Environmental-Regulatory Manager responsible for all aspects of environmental monitoring and compliance for Pioneer's oil and gas operations in the Western U.S. and, prior to it's acquisition by Pioneer, served in a similar capacity with Evergreen Resources Inc. He has extensive experience in coalbed methane as well as conventional oil and gas operations. Dr. Jacob has degrees from the University of Chicago, Utah State University and the University of Colorado-Boulder.

Lindsey Kruckenberg

Ms. Kruckenberg works for EnCana Oil & Gas as a Coordinator within the Surface Management team. The Surface Management team maintains disturbances created by EnCana in the Piceance Basin. The team maintains environmental compliance with regards to Reclamation, Stormwater, SPCC, Weed control, Pit/Net inspection, etc. Lindsey is involved in all phases of planning, implementation, interaction with regulatory agencies, monitoring, and reporting. She graduated from the University of Colorado with a Bachelors degree in Geology and has previous experience with remediation of soil and groundwater along with chemical analysis of soil, water, and air.

John Rizza

John Rizza, is a Certified Arborist and Estimator for Western States Reclamation Inc. He has conducted research in relation to obtaining his Masters degree on reclaiming strip mine spoils in eastern Tennessee. John received his B.S. degree at Colorado State University where he focused on Forestry and Forest Reclamation. He has experience working in a variety of ecosystems throughout the U.S. John's innovative ideas have helped improve reclamation practices and promote healthy establishment of native vegetation on drastically disturbed sites.

Bryan Whiteley

Bryan Whiteley, Landscape Architect, has been recognized for his thoughtful construction, operations and maintenance cost management while delivering outstanding design solutions on many interdisciplinary design teams for major projects including *Leadership in Energy and Environmental Design* certified projects involving site selection, protection and restoration; water efficient landscaping and planting design, non-potable irrigation; stormwater management and construction activity pollution prevention plans. In 2005, Bryan founded LandStewards™ and set new precedence in reclamation, stormwater and VRM within the energy industry. Bryan's topsoil conservation strategies have been adopted by the BLM for oil, gas and geothermal development. In 2009, Bryan accepted a new position with EnCana as their Piceance Basin Surface Management Coordinator managing 900,000 acres of development.

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ABSTRACT

Environmental Managers employed by energy companies are often plagued with the lack of adequate cost data to support appropriate budgets for successful initial reclamation programs. Insufficient budgeting and improper initial reclamation for drill pads and access roads can result in higher overall operating cost and lower net profits over the life of the well. Pioneer Natural Resources and EnCana Oil and Gas Inc. have provided actual cost data for this case study and information from operations in the Piceance Basin and Raton Basin of Colorado. Minimizing reclamation and maintenance costs over the life of the well by properly budgeting and planning initial reclamation activities is essential to ensure cost savings. Reclamation failures can result in a 50% cost increase over initiating proper reclamation techniques from project implementation. The economic impacts associated with the direct costs of additional earthwork for sediment clean up and re-grading, importing topsoil or applying soil amendments when poor soil conditions generate initial revegetation failures, re-seeding, re-installation of erosion control products, and weed control are significant. Operators can expect to spend upwards of $20,000 on sites where initial reclamation programs have failed. Additionally, hidden indirect costs, which are difficult to quantify, include environmental manager and consultant time to coordinate reclamation work that needs to be redone, potential agency fines for storm water management violations, and potential lost opportunity cost due to poor agency and landowner relationships that delay mineral extraction. Developing more effective programs to track these reclamation and stormwater management costs would benefit operators in the long term. Providing reasonable estimates for reclamation activities on sites to be capitalized up front would ensure resource protection.

I. INTRODUCTION

At the onset of the Phase II Storm Water Quality Regulations enforcement by the Environmental Protection Agency (EPA) many energy companies found their storm water management and reclamation programs lacking compliance with the new laws. Numerous energy companies learned the hard way, through hefty fines, what non-compliance with the storm water regulations can mean. Environmental Managers were grappling with budget constraints as well as what the constituents of a reclamation and storm water management program that can comply with state and federal laws. Western States Reclamation has worked for both Pioneer Natural Resources and EnCana Oil and Gas Inc. as a reclamation and storm water management contractor. Western States has witnessed the growth curve that oil & gas companies have gone through in trying to develop storm water management and reclamation programs. In a time of low natural gas prices the cost of storm water management and reclamation programs are being scrutinized by upper management. Environmental Managers with energy companies need to establish budgets that are adequate for successful reclamation and meet the requirements of federal and state regulatory agencies. Inadequate unsuccessful reclamation programs can result in an exponential increase in the comparative cost to retrofit sites which may exceed the costs of implementing a more thorough and successful reclamation program the first time around.

The purpose of this case study is to compare the cost of successfully reclaiming a site at the outset compared to the cost to retrofit an unsuccessfully reclaimed site. Western States Reclamation encouraged environmental managers with both Pioneer and EnCana to compile costs for previous reclamation projects. These costs could then be evaluated to determine the cost of successful reclamation work against the costs associated with retrofitting inadequately reclaimed sites.

While the cost data provided in this case study can be considered subjective it still provides evidence that there are economic benefits to performing reclamation right the first time. This case study also shows the importance of Environmental Managers setting up a system for cost data collection to establish credible reclamation budgets. Poor quality reclamation programs could result in higher lease operating expenses – a critical metric in the oil & gas industry. Western States Reclamation, Pioneer, and EnCana established a list of several key factors that are needed for successful reclamation projects:

- Locate facilities and access roads to minimize slope and stormwater run-on.
- Identify areas for potential topsoil salvage and establish a replacement plan for interim and final reclamation.
- Properly grade pads and install terraces, berms, benches, etc. to reduce sediment loading during interim and final reclamation.
- Apply the proper types and amounts of soil amendments to the soil when topsoil is lacking or poor in quality.
- Perform proper soil tillage to loosen compaction.
- Design proper seed mixtures and application rates.
- Adequately install and maintain BMPs and erosion control devices until the desired vegetation achieves self sustaining cover.
- Complete mechanical and chemical weed control for as long as needed to control noxious weeds.
- Construction supervision & monitoring so that all parties have an understanding of how their work fits in the overall project design.

Poor quality reclamation work results in cost increases to reconstruct and reclaim these sites. Experience demonstrates that most reclamation failures can be traced back to three factors; the lack of available quality seedbed materials (topsoil), the lack of implementing proper storm water BMPs, and the lack of clear upfront project design and follow-up performance supervision. Poor quality soils are typically the most erodible. Poor quality soils typically support less final vegetative cover for long term erosion control and significantly more weed species growth than desirable grasses or forbs. Improperly implementing BMPs can result in undesirable protection for newly seeded or planted vegetation. This ultimately creates poor vegetative health and delays the establishment of a desirable self sustaining cover. Failure to address erosion and sediment issues in the design of any site reclamation and properly supervising their execution can greatly increase the cost of reclamation programs.

i. Commonly Associated Direct Costs

Direct costs for reclamation and stormwater management failures include the following:

- Retrieving sediment from erosion and sediment events, including off-site.
- Replacing sediment or other suitable materials in washout areas.
- Regrading
- Reseeding
- Replacing and possibly adding more BMPs to avoid future washouts.
- Extending the duration for weed management activities.
- Additional maintenance and inspection costs due to restarting the reclamation clock.

ii. Commonly Associated Indirect Costs

There are many indirect costs that energy companies often may not recognize as significant in the cost of reclamation and stormwater management failures which include:

- Increased staff and consultant time to deal with sediment and erosion issues and redoing reclamation work and inspections
- Tarnished Agency and Landowner relationships
- Potential regulatory non-compliance

The costs associated with reclamation may be a relatively small percentage of the capital cost to drill and develop an oil and gas well. However, reclamation can become a significant factor in the operating expenses associated with a well, particularly on older wells where less sophisticated reclamation measures were used. Often, issues in Lease Operating Expense (LOE), a metric commonly used in the oil and gas industry, are followed closely by managers and financial analysts as indicators of profitability. LOE per unit of oil or gas produced is often used as an indicator of an operator's efficiency. Unexpected inputs and resource allocation can lead to some level of impact to profitability.

This case history assesses the varying successes of reclamation and storm water management efforts experienced by Pioneer Natural Resources environmental staff operations in southeast Colorado. Also investigated is the Piceance Basin operation near Rifle, Colorado managed by EnCana environmental staff. These case study examples will demonstrate the financial advantages of reclamation planning in the early stages to ensure long term success. Evidence suggests that improper reclamation, storm water management, and associated budget programs could significantly reduce company profits over time. Properly designing and implementing BMPs, site monitoring, and progressive management will enable managers to successfully reclaim surfaces which will reduce waste and costs.

II. CHALLENGES AND PROPOSED SOLUTIONS FOR INCREASING RECLAMATION SUCCESS ON DRILL PADS AND ACCESS ROADS

i. Initial Planning and Site Surveys

An initial site survey conducted by environmental and engineering personnel should be the first step in the reclamation process to determine optimum routing of access roads and pad location for successful interim and final reclamation. Degree of slopes to be encountered, watershed size, exiting vegetation species inventory, and soil resources present should be evaluated and considered in the planning process. Operators have found that proper site selection is essential to avoid costly site development and reclamation issues.

Many of the challenges related to site selection are due to topographic variation including slope, drainage features, and subsurface material composition. Often, operators must implement a variety of techniques to address site concerns. Whenever practical, benching or terracing should occur on steep slope areas. Every effort should be made to retrieve viable topsoil during road and pad construction. Often, operators and engineers feel they have ample knowledge of what topsoil is by simply looking at soil color. However, proper identification of possible topsoil materials requires collecting and sampling an adequate number of sample sites. The sample data has to be evaluated for suitability as topsoil by rating the material according to standards that have been published by the U.S. Department of Agriculture and State Agencies such as Department of Environmental Quality. Currently, managers are modifying their practices to conduct their activities within the new Colorado Oil and Gas Conservation Commission (COGCC) rules. Background samples are an important part of conducting development activities. Program managers are continually adding sampling parameters for measuring soil vitality. Soil samples are typically rated by parameter as to good, fair, or unsuitable material. Any indication of unsuitable soil ratings may be cause for a soil scientist to reject material as topsoil for salvage. When seedbed quality material does not exist on site for use in reclamation, a variety of soil amendments may be utilized to build a suitable soil from local materials. Amending soil located in close proximity of the work site to create suitable growth media should be compared to the cost of importing topsoil. Management teams are implementing programs which utilize perimeter windrowing for topsoil conservation. The windrow is seeded and hydraulic erosion control mulch is applied almost immediately after its construction. The windrow minimizes the slope length facing the exterior edge of the disturbed area. Ideally this maximizes the topsoil surface area which helps to maintain its viability. This technique reduces the overall quantity of erosion control BMPs utilized for a well site, contains and diverts stormwater within the disturbance, and maintains topsoil adjacent to its previous position. Suitable quality seedbed material is the most critical building block to achieving successful reclamation on the first attempt.

ii. Topsoil Placement and Site Re-grading

The sites encountered in this case study often lack salvageable topsoil material. Operators are faced with thin soils which are often poor in nutrient content and lacking in organic matter. The significant amount of course fragments occurring on these sites also impedes the ability to salvage soils. Operators must account for the creation of adequate topsoil or topsoil substitute materials early in the planning process. Seedbed quality material placement followed by site regrading of disturbed areas should be completed in a manner which limits water run-on and runoff. Geomorphic landforming and earthen hydrological controls are utilized to manage water run-on, runoff, to reduce slope potential for erosion, and contain sediment. Terracing and berming on disturbed areas are a few methods utilized to effectively control water erosion. Channelizing flow from disturbed areas and routing through adequately sized detention ponds are also effective methods of treating water flow to prevent sedimentation and reduce the need for re-grading operations. When these landforms and drainage controls are properly constructed with suitable subsoils to achieve proper grade and sediment containment, they are then ready for topsoil spreading. When utilizing perimeter windrows for topsoil conservation, the topsoil is easily placed on the adjacent subsoils limiting compaction and potential losses.

iii. Seed Mixture Design

Seed mixtures, seeding rates, and seeding methods are all very important elements for successful reclamation practices. Considerations for the actual seed mixture should include species of grasses, forbs, and shrubs that are common to the area. Also, the intended land use after final reclamation is completed should be considered and related to vegetative species selection. For example, if managers choose livestock grazing as the future land use, the vegetative cover mix should focus on a balance of warm season and cool season grasses which are palatable. Wildlife habitat should include native forbs and shrubs for browse and cover. Forb species are important for game birds such as pheasants, turkey, quail or grouse. These native species will attract insects as a food source for young chicks and in turn benefit overall site establishment. Selecting the appropriate seeding rates represents both an art and a science. Educating landowners to the timeline for vegetative establishment and addressing their concerns during the planning process is imperative to creating a cooperative working environment.

Seed mixture designs must take into consideration items such as ease of establishment of individual species, number of seeds per pound per species, and aggressiveness of individual species. Grass species can vary greatly in their number of seeds per pound. For example, Buffalo Grass has 56,000 seed per pound and Sand dropseed has 5,298,000 seeds per pound. A targeted goal for planting seeds per square foot according to most revegetation experts ranges from 75 seeds per square foot up to

140 seeds per square foot. Regulatory agencies often specify required minimum seeds per square foot depending on site conditions and seeding type. Increasing the number of seeds per square foot is based on the risk of loosing seed to water erosion on steep hill sides or wind erosion in high wind prone areas.

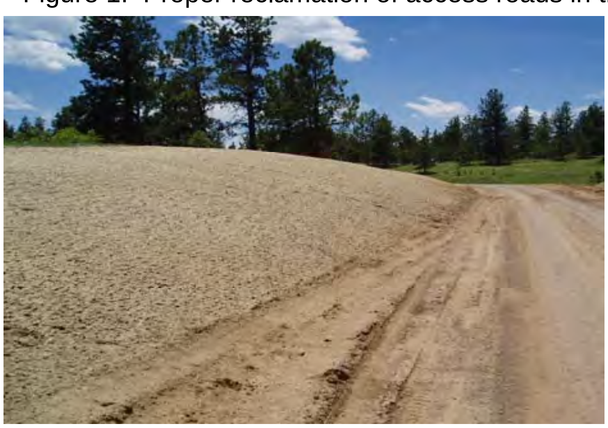
To promote species diversity and sustainability, managers should design seed mixtures containing 4 to 10 different native species. The number of pounds of individual species should be based on a relatively equal number of seeds per square foot while taking into consideration ease of establishment and interspecies competition. Having a number of species in the mixture will promote diversity in the final vegetative cover and will reduce the risk of revegetation failure. The amount of time needed for certain species to establish can play a significant role in site stabilization. Often, native species take 2 to 3 growing seasons to achieve an adequate amount of cover. Managers need to account for this and recognize the increased risk associated with utilizing native species. Any expert in the revegetation industry knows that there are no absolutes in designing a seed mixture.

A seed mixture at a minimum will consist of native grasses and forbs. As previously mentioned at least three grass species should be in any revegetation seed mixture. The operator (such as EnCana), landowner (either private landowner or federal agencies such as the Forest Service or BLM), and Revegetation Specialist typically consult with one another to determine what the seed mixture should contain. These individuals or organization will determine if the seed mixture should contain only grasses or whether shrub and forbs seed should be added to the seed mixture as well. Typically cost of seed is a driving factor on deciding if these species are added to a seed mixture.

iv. Seeding Methods

Common options for seeding methods include drill seeding, hand and machine broadcasting, and hydroseeding. Drill seeding is considered the most reliable method of seeding since there is more control over seed depth placement and seed covering with soil (Figure 1). However, drill seeding is not always possible on drill pads and access roads since steep slopes and rocky terrain prohibit access with equipment. Hand broadcasting or hydroseeding are typically used where drill seeding is not practical. However, these methods are often costly and exhibit limited success. Sources of water for hydroseeding operations can be difficult to obtain and increase the cost of reclamation. Managers need to be aware of the costs and benefits related to each method of seeding to make an informed decision. Regardless of which of these practices are used, it is important that the seed is properly covered with soil by hand raking, slope chaining, or harrowing.

Figure 1: Proper reclamation of access roads in the Raton Basin before (2005) and after (2008)



Drill seeders should be calibrated for use on a small area before all seeding is completed. Most manufacturers of drill seeding equipment can provide general guidelines as to the amount of seed output by seed box for flowable seeds versus trashy seeds. Calibration will help ensure that the proper amount of Pure Live Seed (PLS) is planted. All drill seeding should be completed parallel to slopes or on the slope contour. Drill seeding up and down a slope can result in accelerating erosion after rainfall since the indentations from the drill rows help to concentrate flow and accelerate soil movement down hill. It is recommended to plant most native grass and forbs species to a depth of ¼ inch for optimal germination.

Broadcast seeding is typically done where seeding areas prohibit safe operation of a farm tractor, access is limited, scope of work is small or the soil surface is covered with large rock that cannot be economically removed. Hand seeding may be needed in small, tight access areas where machinery cannot effectively operate. Broadcast seeding is performed using hand seeders or tractor mounted spreaders. Broadcast spreaders typically spread an even swath of seed onto the soil surface. Broadcast seeding by hand or machine alone will not typically provide good results unless the seed is covered with soil. Broadcast seeding with a tractor should be followed by using a flex harrow to cover the seed with soil. Hand broadcast seeding should be followed by hand raking with a hard tine rake. In both cases the seed should not be raked deeper than ½ inch into the ground. And in all cases, the chance for broadcasted seed germination is greatly increased when followed by mulch application.

Often operators utilize hydraulic applications of seed on pads and roadways. The operator will mix the seed, amendments, required tackifiers, and hydromulch in the tanker. The objective of using the hydraulic pressure of the machine is to use enough force to shoot or push the seed into the ground. If the seed is not adequately covered with soil, hand raking of the area or slope harrowing should be employed.

v. Mulch and Erosion Control Fabrics

Surface mulch and erosion control blankets are needed to conserve soil moisture and serve as BMPs to control erosion. Lack of proper erosion control can result in seed being washed away before it germinates. Mulch materials also promote increased moisture infiltration from rain and snow, cool the soil surface, and provide valuable soil organic matter to increase soil structure. Mulch considerations include conventional hay/straw mulch and hydromulch. Innovative products being applied to meet the needs of challenging sites include Bonded Fiber Matrix (BFM), and Flexible Growth Medium (FGM). These products tend to be more expensive and create application difficulties on certain sites. Experienced operators must employ techniques to ensure adequate seed germination and soil stabilization. In many circumstances, erosion control blankets can be an effective way to control sediment movement. On the sites investigated by this case study, operators have determined that these blankets are most useful when used in place of mulches on steep uniform slope areas, drainage areas, and constructed diversion channels. These products come in a number of different fabric ratings to control erosion. Some examples include excelsior blankets, straw blankets, straw coconut blend blankets, coconut blanket, and geotextile blankets for more permanent erosion control. Mulches and blankets need to be complemented with other BMPs to ensure proper erosion control and comply with state and local agency requirements for disturbed construction sites.

Erosion Control Mulch (ECM) is hydraulically-applied, flexible erosion control blanket composed of long strand, thermally refined wood fibers, crimped, interlocking fibers and performance enhancing additives. Operators utilize ECM that requires no curing time and when applied forms an intimate bond with the soil surface to create a continuous, porous, absorbent, and erosion resistant blanket that allows for rapid germination and accelerated plant growth. Many applicators have determined specifications for the ECM application rates and techniques on a site specific basis to ensure soil and vegetation stabilization.

vi. Structural BMPs

Some of the structural BMPs that are available on the market include erosion logs, straw wattles, silt fence (including wire backed fence), erosion bales, and rock socks. Constructed physical devices can include wood logs placed perpendicular to the slope, wood slash piles in drainages to slow water flow, diversions, terraces, rock check dams, and many others. On disturbed sites, these products can create significant maintenance challenges when failures occur. Combining different techniques is an effective way to utilize the benefits of structural devices. Areas with concentrated flows created by landforming can receive erosion control blanket with wattle check dams. Riprap can also be applied to containment outlets to limit impacts caused by concentrated flows. These types of stabilization techniques are very effective methods for reducing soil loss and they are also cost effective due to low initial cost and reduced maintenance requirements.

VII. MAINTENANCE AND MONITORING

The objective of surface management programs is to utilize a wide range of tools and management practices to establish a diverse self sustaining mosaic of vegetation cover that exceeds regulatory agency compliance requirements and provides a new precedent for the visual resource, stormwater management, revegetation, and productive land use. Establishment successes are often achieved by early planning for the long term. Maintenance and monitoring programs developed from project implementation will benefit site establishment and sustainability. Maintenance of seeded areas includes weed control, erosion control, and touch up seeding. Most newly seeded sites require these maintenance operations during the first growing season to help insure successful revegetation. Observing the site in regularly scheduled intervals and evaluating changes will allow proactive management to reduce the need for unexpected repairs and erosion control additions.

i. Weed Control

Managers must address weed control concerns by treatment consisting of mechanical methods such as hand cutting and removal, weed eating, and bush hog mowing. Ideally, operators should mow or cut weeds when twenty percent (20%) canopy cover for any surface area is achieved. Mechanical weed control is typically used the first growing season and often needs to be completed twice per year. If weed species continue to be a problem for the native grasses after a 12 month grow-in period control techniques shift to use of approved herbicide applications

ii. Touch-up Seeding

A consensus among local ecologist has shown that two healthy seedlings per square foot after one growing season are typically adequate for successful reclamation. Thus, any areas not containing at least two seedlings per square foot should be evaluated and reseeded. Most surface management programs are performance based. Revegetation results are directly related to the quality of the site design, earthwork, seeding, mulching and stormwater applications. A lack of attention to detail during earthwork and soil preparation adversely affects the quality of the visual resource, stormwater management, revegetation and ultimately lengthens the maintenance cycle. Each phase of site activities can adversely affect the following phase if implemented poorly.

iii. BMP Repairs, Re-grading, and Additions

Inspections and maintenance are an extremely important part of the stormwater management process. Inspectors ensure controls are constructed or applied in accordance with governing specifications or good engineering practices. The goal is to minimize the potential for inadvertent removal or disturbance of BMPs and to prevent the off site transport of sediment and other pollutants. Maintenance activities will ensure that all control measures are functioning at optimum levels and that all procedures and techniques will be in proper working order during a runoff event or spill condition.

When inspections determine that repairing areas where rill or gully erosion has occurred, immediate action is required. These repairs will increase financial and resource inputs long past well construction completion. When channel erosion is severe enough to warrant re-grading, the vegetative cover will also have to be repaired. Seeding steep slopes and waiting to achieve the desired amount of cover increases the likelihood of additional site repairs. These reworked sites need to be inspected after every rainfall event or every two weeks. In certain situations, re-grading and reseeding have to be completed on a semiannual or annual basis as needed to make sure that the vegetative cover is progressing towards a self sustaining cover and 70% of background cover. These repairs can prove costly and will add to the time for site recovery.

IV. LESSONS LEARNED

i. Cost of Proper Reclamation Programs as Completed by EnCana and Pioneer Natural Resources

Both EnCana and Pioneer have experienced the learning curve of using less adapted reclamation techniques versus their site-specific reclamation practices that are currently on-going. Costs were compiled from EnCana and Pioneer Environmental staff for each major technique related to proper site reclamation activities (Table 1). These operators provided average costs by slope category for drill pads and access roads on a per acre basis for comparison. Steeper slopes accounted for an increase of approximately 25% over gentile grades for both operators.

Table 1 - Estimated Costs of Proper Reclamation Practices on Drill Pads

	EnCana - Piceance Basin		**Pioneer - Raton Basin**	
	(2.1:1 to 3:1)	**(1:1 to 2:1)**	**(2.1:1 to 3:1)**	**(1:1 to 2:1)**
Treatments	Cost per Acre	Cost per Acre	Cost per Acre	Cost per Acre
Lifespan Planning	$950 to $1,150	$950 to $1,150	$1,250 per acre	$1,500 per acre
Topsoil Conservation	$525 - $1,142	$450 - $1,101	$750	$1,000
Topsoil Replacement	$1,100 - $1,060	$950 - $1,020		
Pad Re-grading	$1,224 - $1,632	$1,224 - $1,632		
Landforming	$9,500.00	$9,900.00	All Inclusive, Drill Seeding w/ straw mulch, tackifier, BMPs $14,000	All Inclusive, Hydroseed w/ Flexterra hydromulch, BMPs $17,000
Soil Preparation	All Inclusive, Drill Seeding & Crimped Straw $2,620.00	All Inclusive, Broadcast Seeding & Flexterra Mulch $7,015.00		
Soil Amendments				
Seeding				
Mulching				
BMP's	$900.00	$900.00		
Weed Control	$125.00	$200.00	$125	$200
Total Costs	**$16,944 to $18,129**	**$21,589 to $22,921**	**$16,125**	**$19,700**

ii. Estimated Costs of Low Budget Reclamation Practices on Drill Pads

In past times, operators often reclaimed sites with minimal inputs and disregarded revegetation standards and erosion control BMPs (Table 2). Sites were often reclaimed without adding any type of soil amendments or any type of tilling activities to create quality seedbed materials. Seeding was often conducted using aggressive forage species including perennial rye that were not drought tolerant but could be purchased at a relatively low cost and quickly achieve densely vegetated stands. Operators could spend as little as one to two percent of capital on reclamation activities under the old regime. That is compared to 5-8 percent of capital that is currently spent on reclamation.

Table 2 - Estimated Costs of Low Budget Reclamation Practices on Drill Pads

	EnCana - Piceance Basin		**Pioneer - Raton Basin**	
Treatments	**(2.1:1 to 3:1)** Cost per Acre	**(1:1 to 2:1)** Cost per Acre	**(2.1:1 to 3:1)** Cost per Acre	**(1:1 to 2:1)** Cost per Acre
Initial Planning	$520 to $570	$520 to $570	$1,000	$1,000
Topsoil Stockpiling	$775	$625	none	none
Topsoil Replacement	$1,350	$1,250	none	none
Pad Re-grading	$1469 to $2122	$1469 to $2122	$1,000	$2,000
Subsoil Contour Grading	$11,100	$10,750	none	none
Soil Preparation	none	none	minimal	minimal
Soil Amendments	none	none	none	none
Seeding	$500	$500	$500	$500
Mulching	none	none	none	none
BMP's	minimal non-structural	minimal non-structural	minimal non-structural	minimal non-structural
Weed Control	$250	$400	$250	$400
Total Costs	**$15,964 to $16,667**	**$15,514 to $16,217**	**$2,750**	**$3,900**

iii. Costs Associated with Unsuccessful Reclamation Programs

EnCana and Pioneer Environmental staff compiled costs associated with reclamation work that required redo treatments (Table 3). While redo cost can be very subjective, expert opinion and costs compiled by the three different companies (EnCana, Pioneer, and Western States) added to the credibility of the results. Redo work on these sites often ranges from $20,000 to $40,000 depending on the severity of site degradation and need for re-grading and reseeding. The addition and reworking of BMPs on these sites is another significant area of economic and resource input.

Table 3 - Costs Associated with Reclamation Failures				
	EnCana - Piceance Basin		**Pioneer - Raton Basin**	
Redo Treatments	**(2.1:1 to 3:1) Cost per Acre**	**(1:1 to 2:1) Cost per Acre**	**(2.1:1 to 3:1) Cost per Acre**	**(1:1 to 2:1) Cost per Acre**
Sediment Clean Up	\$500 to \$1000	\$500 to \$5,000	\$500 to \$1,000	\$1,000 to \$5,000
Fill Placement	\$500 to \$1000	\$500 to \$5,000	\$500 to \$1,000	\$1,000 to \$5,000
Re-grading	\$11,100 to \$13,100	\$10,750 to \$13,750	\$5,000 to \$10,000	\$8,000 to \$15,000
Reseeding and Mulching	Drill Seeding & Crimped Straw \$2,620	Broadcast Seeding & Flexterra Hydromulch \$8,017	Drill Seed, Straw Mulch w/Tackifier \$2,000	Hydroseed, Flexterra Hydromulch \$8,000
Fix BMP's and Add More	\$5,000	\$5,000 to \$10,000	\$5,000	\$10,000
1 Year Extended Weed Control	\$350	\$450	\$250	\$400
Total Costs	**\$20,070 to \$23,070**	**\$25,217 to \$42,217**	**\$13,250 to \$19,250**	**\$28,400 to \$43,400**

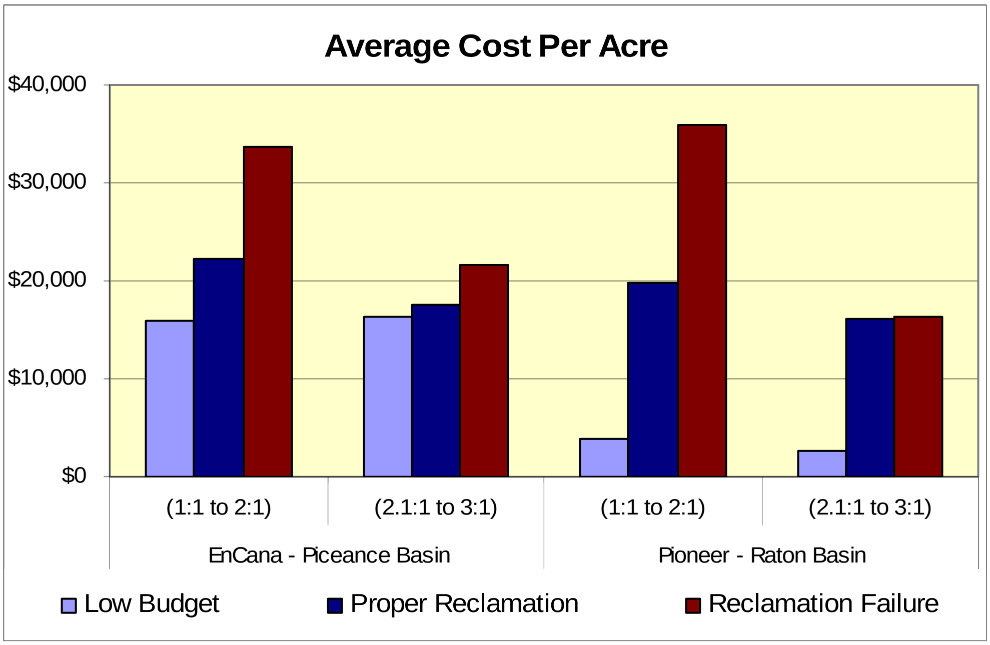
iv. Indirect Cost Estimates Resulting from Unsuccessful Reclamation

EnCana and Pioneer were asked by Western States to provide estimates of indirect cost to handle storm water management issues with state agencies and reclamation issues with individual land owners. The categories were divided into estimates of regulatory fines on a per acre basis, administrative time to deal with land owner and state agency issues, and finally what potential lost opportunity could be for delayed mineral extraction especially during the peak pricing periods of 2007and 2008.

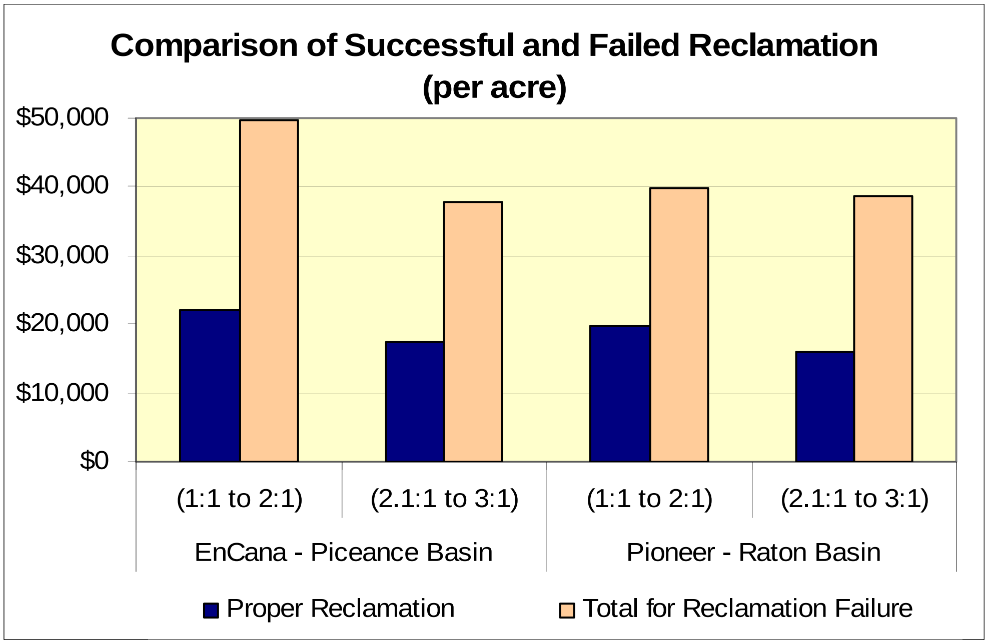
Calculating these costs proved to be very difficult since they were based on memory by EnCana and Pioneer Environmental staff. While the cost estimates are very subjective for indirect cost, they are conservative figures and have merit in being considered for illustrating to upper management the benefits of good reclamation programs. Upon further investigation of several example sites, we found that agency fines could range from \$0.10 to \$15 per acre depending on site conditions and other relevant factors. This is a significant total cost when considering both companies operate across several hundred thousand acres. We also found that a significant amount of time is spent by operators communicating with landowners or regulatory agency representatives about the deficiencies associated with poor reclamation. Administrative costs can range from \$20,000 to \$120,000 per year depending upon the amount and severity of conflicts. If effective initial site analysis and design are not adequately implemented environmental managers inherit additional-unneeded risk and additional cost over the lifetime of the asset. Again, although difficult to quantify, we can estimate the potential lost opportunity costs to be in the area of \$1000 per acre in standard situations. Operators feel that linear disturbances after reclamation activities remains the highest surface management risk and most difficult to change.

v. Cost Comparison of Successful to Unsuccessful Reclamation Work

Operators have found that any lack of attention to one detail adversely affects the others. Each component of the reclamation is interconnected and failure of one element causes failure of the entire reclamation program. Costs are significantly compounded when failures occur due to operators minimizing initial expenses for reclamation (Chart 1). Successful management of the landscape can only be achieved when planning for stormwater, revegetation, weed control, and reclamation over the lifespan of the assets. Poor stormwater design and topsoil conservation adversely affects revegetation which impacts future weed management. Poor reclamation design adversely affects operating and maintenance costs and public perception during the production lifespan of the asset.



When comparing the total cost of initial low budget reclamation and associated reclamation work due to site failure, we find that generally, the cost per acre is significantly higher than implementing adequate reclamation on the first attempt (Chart 2). Pioneer, being relatively youthful with respect to the data available for this case study, demonstrates similar trends as EnCana with respect to higher costs for steeper slope reclamation operations. EnCana has collected data on a much more intensive and larger area, approximately three times the area of Pioneer's operations. These experiences represent the norm for operators as they have adjusted their approach over time based on better tracking of reclamation and stormwater maintenance costs.



vi. The need for Cost Data Through Annual Assessments of Reclamation and Stormwater Management Work

It became quite evident while preparing the case study that the previous years reclamation and storm water efforts needed to be evaluated on an annual basis to determine what practices were working the best and what redo work might be avoided in future efforts. In Pioneer's case cost allocation practices were recently altered to capture reclamation and stormwater efforts separately from traditional earthwork and well site construction costs.

Reclamation work has long been viewed as both an art and a science. There is no cookbook method to making sure that reclamation efforts are successful across a wide variety of sites found in company's area of operations. Site specific adjustments to reclamation and stormwater management programs should be expected since energy development covers a variety of different environmental factors and ecosystems that does not allow for a one practice fits all technique.

vii. Time Saving Areas for better use in Reclamation Project planning and budgeting

All environmental managers agreed that a significant percentage of their time and their staff's time was spent on problem solving old stormwater management and reclamation issues which could have been better spent on new well sites and increased production. Also, time could be utilized to continually determine through site evaluations where reclamation efforts could be improved to reduce the need and cost impact of redo work. While the authors feel that the cost data provided was useful, more accurate data would be beneficial in the future to pin down the cost of successful reclamation. Proper reclamation cost data will help establish better program budgets and select better adapted practices. More reliable economic forecasting will provide better credibility for planning and budgeting reclamation programs.

V. Conclusions

i. Findings

In conclusion, even with subjective cost data supplied in this case study the authors feel that by using conservative figures there is significant proof that there are many economic benefits to proper reclamation work completed the first time around. When either operator had utilized the minimal input reclamation procedures of the past, the opportunity for failure was significantly higher and in turn the cost of redo work ends up costing the company much more money. Reclamation failures can result in a 50% cost increase over initiating proper reclamation techniques from project implementation. This is related to many factors including the lost opportunity of advancing and moving on to more lucrative sites. EnCana's numbers represented a much larger area and demonstrated that in the big picture, the costs of reclamation failure is much higher on steep slopes due in particular to site re-grading and seeding operations.

ii. Future developments

Environmental managers have found that the accounting department should be involved in assessing reclamation program success. At this time most operators are tracking the project costs on an individual pad and associated access road basis. For the future, it is essential to track out-of-house contractor costs for reclamation and stormwater management activities as well as in-house staff time for handling reclamation tasks. Separate project costing codes are needed to track costs for original reclamation efforts against any redo work. As reclamation and storm water management programs are steadily improved, project costing should help illustrate these reductions in direct and indirect costs for problem sites. Most contractors are utilizing a job cost based accounting software system that tracks costs and profitability on an individual job basis. Thus, reclamation contractors may be able to provide assistance to energy companies on how to set up project costing programs. Developments in technology and data collection should allow managers to create custom programs adapted to company accounting software for ease of analysis.

ACHIEVING SUSTAINABLE FORESTS

Western Governors' Association
Policy Resolution 07-13

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BACKGROUND

American forests directly and positively influence the social, economic, and ecological conditions of the country. They sustain and enrich the well-being of individuals and communities. And in the West, they are a huge part of the identity of its citizens and communities. The threats our forests face and the inadequacy of our current response to these threats have caused concern as to whether the nation's forests are, in fact, sustainable. The values at risk are not trivial – clean and abundant water, clean air, stable employment, energy self-sufficiency, wildlife habitat, and access for recreation and spiritual renewal.

The United States has the fourth largest forest estate of any nation, with 8 percent of the world's forests, exceeded only by the Russian Federation, Brazil and Canada. The total forestland in the United States is approximately 749 million acres — about one-third of the Nation's total land area. This is about two thirds of the area estimated to have been forested in 1630. These forests and woodlands vary from sparse scrub woodlands of the arid, interior west to the highly productive forests of the Pacific Coast and the South, and range from pure coniferous forests to multi-species mixtures, including extensive and diverse deciduous forests. In the West these include what can, and should be, magnificent forests of redwood, giant sequoia, Douglas-fir, ponderosa pine, Sitka spruce, lodgepole pine, noble fir and many other species.

There is a compelling national interest in sustainable forests for all of America. The nation's forests provide a tremendous array of goods and services and add to our quality of life.

- A clean and healthy environment for the nation's urban and rural citizens.
- Employment and economic opportunities.
- Quality habitat for America's plants and animals.
- Open space and outdoor recreation.
- America's cultural and traditional heritage.
- Energy self-sufficiency.

Further, there is a set of disturbing trends threatening these forest values across the country. They include:

- Rapid loss to development - less green space and open space for recreation, wildlife, clean air and clean water;

- the sale of industrial forest lands to real estate interests – forest land is being chopped up and sold
- increasing insect and disease outbreaks and large-scale wildfires – loss of life, property and natural resources, enormous firefighting costs, threats to our water supply;
- loss of forest industry – increasing unemployment, damage to the social fabric of forest dependent rural communities, loss of tax dollars for schools, roads and other services;
- Ineffective tax policies and assistance programs - families find it increasingly costly and difficult to keep forestland, and to pass it down to their children.
- A failure of US international policy to ensure that all wood and wood products imported into the United States meets the same high environmental and social standards as wood produced within our own borders.

Considering the above, we have come to a number of conclusions:

- Our nation lacks a clear vision and policies that promote the sustainable management of the nation's public and private forests as an integrated and high priority;
- Many of the problems faced by our forests derive from other much larger social and economic forces;
- Engagement and collaboration with other partners outside of the traditional forestry community is needed; and,
- Efforts to address these concerns across all regions of the country are needed.

Sustainable forest management (SFM) is an internationally accepted and applied concept that balances the environmental, social, and economic values and services that forests provide. In 1987 the Bruntland Report, more formally known as *Our Common Future*, published by the UN World Commission on Environment and Development, broadly advanced the notion that sustainable development must meet the needs of the present generation without compromising those of future generations. Using that work, a set of *Forest Principles* were adopted by consensus on the part of nearly 180 countries in attendance at the1992 Rio Earth Summit. And since that time, numerous international forest policy dialogues have built on these *Principles* to develop and refine the criteria which serve to define forests as sustainable. The United States has been a leader in these dialogues since inception and from this last nearly twenty years of work has matured a concept of sustainable forest resources that is globally endorsed and that represents a solid foundation for the development of a domestic national policy.

Key to this vision of sustainability is that, across large areas, forests must be able to deliver a full and integrated set of economic, environmental and social values. Forests which generate economic value provide the means to fund environmental and social benefits. This is true on both public and private ownerships. At the same time, by protecting a forest's environmental values, sustainable forestry maintains the basic soil, water, and biological elements that underpin economic value. Equally important is the need for forests to deliver a robust set of social values so that citizens ultimately have the emotional commitment to keep and nourish forests appropriately for all benefits.

Our goal is to create a renewed commitment and social contract, both in the west and across the nation, to understand, enhance, and protect the health, productivity, and sustainability of America's forests. A fundamental policy discussion needs to occur on the national stage across all ownerships about the future of forests in the United States.

GOVERNORS' POLICY STATEMENT

Western Governors believe the country needs to look at new, more effective models for government and societal involvement aimed at sustaining America's forests for future generations. To this end, the Governors recommend pursuit of a national policy on sustainable forests.

Western Governors are committed to clarifying and enhancing the roles of federal, state, and local governments in relation to sustainable forests, promoting regional collaboration, joint planning and coordinated action.

The Western Governors hold that:

- The management and conservation of forest resources in the United States should be guided by a mandate to meet the forest related needs of the present generation without compromising the ability of future generations to meet their needs.
- Doing so requires that economic, social and environmental values from forests be provided within a framework where these values are mutually supportive.
- Laws and programs that promote this vision of sustainable forests and the inter-connectedness of environmental, social and economic values are acceptable expressions of federal policy. Government functions that do otherwise are not.

Western Governors believe that pursuit of policies true to the concept of sustainable forests would result in:

- Improved consistency and delivery of forest goods and services.
- Regional landscape level approaches to forest management that assure core areas for economic/community sustainability and biodiversity.
- Revision of relevant forest and tax legislation.
- Interagency cooperation for forest management & related data gathering & reporting.
- A framework and policy context to U.S. engagement in international forest policy.

GOVERNORS' MANAGEMENT DIRECTIVE

WGA will seek Congressional mandate within the 2007 Farm Bill, or another appropriate vehicle, to engage upon a nationwide discussion across all ownerships about the future of forests in the U.S. This discussion should result in development of a national policy on sustainable forests which needs to be based on the interdependency of the ecological, economic and social values we derive from our forests. It should draw upon the 20 year foundation and globally endorsed body of work related to sustainable forests as contained in the Bruntland report and subsequent international forest policy dialogues for sustainable forest management.

WGA will seek funding to assist in the implementation of this resolution. Further, WGA will post this resolution to its web site to be used and referred to as necessary.

WGA will serve as a catalyst and leader to ensure that this important national forest policy review and discussion results in tangible improvements to the nation's forest resource.

BARRICK GOLD CORPORATION'S STANDARDIZED PROTOCOLS FOR: RECLAMATION MONITORING & FINAL RELINQUISHMENT

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ABSTRACT

Reclamation monitoring targets several mine closure elements including: vegetation establishment and development, soil quality, and soil surface stability; all critical to a productive post-mine land-use and final relinquishment. Most current programs have no real systemic link to operational mining processes, no feedback system for improved reclamation performance, and no functional link to a determination of success. Relinquishment addresses processes, regulatory mandates, and milestones that assure stakeholders that reclaimed land will not be problematic to the future "well-being" of the environment.

This protocol describes the soil surface and reclamation evaluation procedures to be used by Barrick held mines for monitoring and analysis of reclamation performance. Unless superseded by site-specific permitting requirements, these procedures support the process leading to effective financial guarantee or assurance release. Two important side-benefits are: 1) the timely detection of latent reclamation issues along with corrective action guidance, and 2) a standardized means of recording information that precludes loss due to staffing changes / turnover. This protocol is based on step-wise procedures developed in the United States and Australia that concentrate on: information control; evaluation of soils; evaluation of soil stability; performance of revegetation; consistent and meaningful reporting; and development of, and compliance with, release criteria to facilitate relinquishment of any regulatory mandated financial assurances and/or liability. Key to the success of these components is the fifth step (reporting) that provides an effective feedback loop conveying pertinent and/or corrective information to site managers or their successors. Once reclaimed surfaces have achieved satisfactory results, final relinquishment can be effected.

INTRODUCTION

This document describes the soil surface and reclamation evaluation procedures to be used by Barrick Gold Corporation (Barrick) held mines for monitoring and analysis of reclamation performance in accordance with Barrick's Environmental Management Systems (EMS). These procedures have been developed in accordance with Barrick's EMS and Corporate Closure Group in Salt Lake City, Utah. In this regard, this document details the step-wise procedures for evaluating final reclamation / revegetation of lands disturbed by mining operations under Barrick direction. This document is based on procedures developed in the United States and Australia that concentrate: first, on information control; second, on an evaluation of soils; third, on an evaluation of soil stability; fourth, on performance of revegetation (given that reclamation is designed to return the land to a productive post-mine land use); fifth, on consistent and meaningful reporting; and finally, development of, and compliance with, release criteria to facilitate relinquishment of any regulatory mandated financial assurances and/or liability. Key to the success of these components is the fifth step providing an effective feedback loop that conveys pertinent and/or corrective information to site managers or their successors.

It is the intent of Barrick to establish a reasonable, effective, and scientifically defensible program to track the progress of soil stabilization and revegetation on areas generally closed to active mine operations. This program will track progress both during the period of vegetation establishment and development (typically 3 to 5 years after planting) and during the period that follows (5 years +) until the financial assurance or liability is released. When implemented, this "program" will provide a scientifically defensible means to determine when units of reclaimed land will meet reclamation success criteria and can be identified as "ready for surety and liability relinquishment" (releasable). These procedures will also identify those areas, or substantive portions of areas, that are not responding sufficiently to be releasable. If potentially problematic areas are not identified early in the reclamation process, the costs to Barrick in terms of both time and financial commitment will become excessive. Properly designed monitoring procedures will also provide a forum for the determination of corrective measures.

1.0 ORGANIZATION OF EXISTING INFORMATION (STEP 1)

The first step in the overall monitoring process is to collect and organize any and all existing information regarding each unit of currently reclaimed land and then complete an "as-built" sheet (Figure 1) for those units and then do likewise for all future units. A reclaimed unit (or management unit) consists of a defined area based on managerial criteria (e.g., areas with common reclamation procedures, initiation times, defined functions such as a waste rock area, or areas with other unique designations or segregation). Often, segregation can be made based on slope, aspect, change of reclamation metric or practice, perceived problem or other informational basis, or simply based on land use management. It is important not to define a managerial unit too broadly. Eventual sampling will provide detailed findings on the unit and if it has not been defined properly, the utility of resulting information will be compromised.

The "as-built" sheet should be designed as a "check sheet" to facilitate recording of the most pertinent data from a unit of reclaimed land that may be necessary to facilitate a determination of problematic conditions, or simply to document the reclamation metrics that occurred. Given such information, the number of "unknowns" is minimized thereby leading to a more rapid determination of the best reclamation metrics for any given site, or sub-site. Also, a complete information base facilitates more rapid isolation of problematic circumstances.

Managerial units should also be represented in two additional summary formats to assist both mine and corporate management with decision-making. The first of these formats is "spatial" i.e. mapping. Pertinent detail such as the location, areal extent of applied metrics, year(s) of reclamation, etc. can be presented in a readily comprehensible format. It is most helpful to provide such mapping in a digital format, especially using software such as ArcView, but paper copies are valuable as well for archived information. The second format is an annually updated overall spreadsheet summary of all reclamation along with pertinent notes and schedules. At the time of bond relinquishment, or when remediation is necessary, such summary information becomes highly valuable.

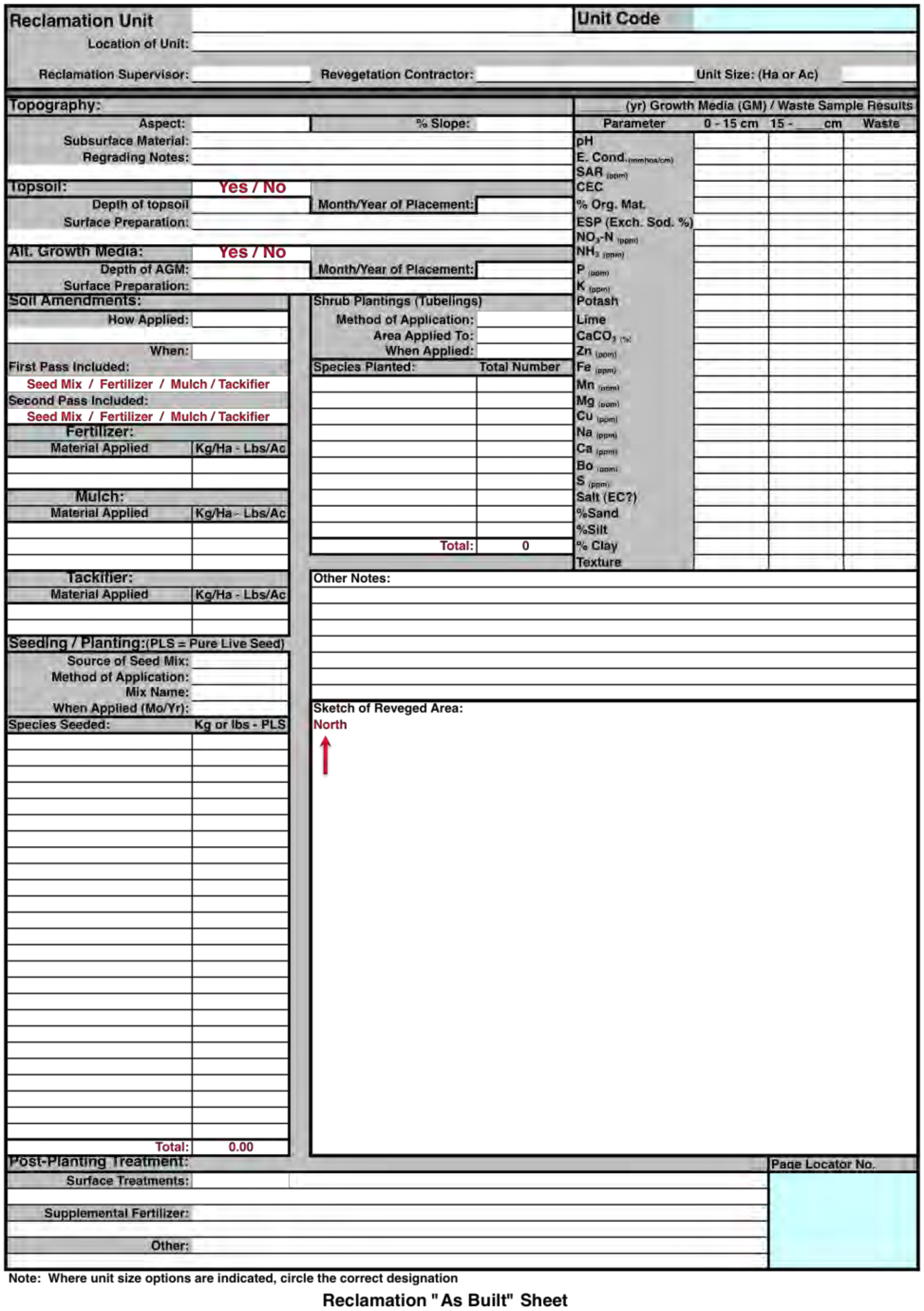

Reclamation Unit
Unit Code
Location of Unit:
Reclamation Supervisor:
Revegetation Contractor:
Unit Size: (Ha or Ac)
Topography:
Aspect:
% Slope:
Subsurface Material:
Regrading Notes:
Topsoil:
Yes / No
Depth of topsoil
Month/Year of Placement:
Surface Preparation:
Alt. Growth Media:
Yes / No
Depth of AGM:
Month/Year of Placement:
Surface Preparation:
Soil Amendments:
How Applied:
When:
First Pass Included:
Seed Mix / Fertilizer / Mulch / Tackifier
Second Pass Included:
Seed Mix / Fertilizer / Mulch / Tackifier
Fertilizer:
Material Applied
Kg/Ha - Lbs/Ac
Mulch:
Material Applied
Kg/Ha - Lbs/Ac
Tackifier:
Material Applied
Kg/Ha - Lbs/Ac
Seeding / Planting:(PLS = Pure Live Seed)
Source of Seed Mix:
Method of Application:
Mix Name:
When Applied (Mo/Yr):
Species Seeded:
Kg or lbs - PLS
Total:
0.00
Shrub Plantings (Tubelings)
Method of Application:
Area Applied To:
When Applied:
Species Planted:
Total Number
Total:
0
(yr) Growth Media (GM) / Waste Sample Results
Parameter
0 - 15 cm
15 - ___cm
Waste
pH
E. Cond. (mmhos/cm)
SAR (ppm)
CEC
% Org. Mat.
ESP (Exch. Sod. %)
NO3-N (ppm)
NH3 (ppm)
P (ppm)
K (ppm)
Potash
Lime
CaCO3 (%)
Zn (ppm)
Fe (ppm)
Mn (ppm)
Mg (ppm)
Cu (ppm)
Na (ppm)
Ca (ppm)
Bo (ppm)
S (ppm)
Salt (EC?)
%Sand
%Silt
% Clay
Texture
Other Notes:
Sketch of Reveged Area:
North
Post-Planting Treatment:
Surface Treatments:
Supplemental Fertilizer:
Other:
Page Locator No.
Note: Where unit size options are indicated, circle the correct designation
Reclamation "As Built" Sheet

Figure 1 – Reclamation As Built Sheet

2.0 SITE-SPECIFIC PROCEDURES FOR EVALUATING GROWTH MEDIA ON RECLAIMED LAND AND SELECTION OF REFERENCE AREAS (STEP 2)

2.1 General

Among other factors, successful reclamation is highly dependent upon the quality of growth media and occasionally the underlying material (spoil, tailings, etc.). If a soil must develop under the conventions of primary succession, desirable vegetation establishment and growth may take many decades if not centuries. To the contrary, if the highest quality locally available growth media is utilized for reclamation, the conventions of secondary succession will be emplaced and desirable vegetation establishment and growth will only take a few years. This factor alone will have the greatest impact on closure costs or savings. Occasionally, adequate quality growth media can be found within overburden materials (e.g., buried alluvium) and use of such materials can directly translate into significant cost savings. Attention to this potential resource during development exploration drilling will pay significant dividends at closure.

It is strongly recommended that in-situ growth media be sampled and evaluated for quality prior to recovery in advance of operations such as occurs for U.S. coal operations. Where such baseline data are not available, then reclamation monitoring must begin with an initial evaluation of the growth media that has been distributed across the surface of a reclaimed unit (unless the borrow source has been sampled or otherwise is known to be adequate or non-problematic). Such an evaluation would be designed to provide data and information necessary to the development of appropriate reclamation metrics, plans, seed mixes, etc. to optimize opportunities for successful reclamation. This one-time evaluation (unless problematic pockets are found) ideally would occur prior to development of reclamation plans, but lacking such activity must occur immediately following lay-down of growth media and prior to seedbed preparation for a given unit of land. In this circumstance, the following procedures would be implemented.

2.2 Establish a Grid for Soil Sampling

Following lay-down and prior to seedbed preparation, the emplaced growth media should be sampled on a systematic basis to determine suitability and/or need for remediation or special reclamation procedures. This process would require establishment of a grid and one sample point or composite sample per grid interval (polygon). The size of the grid polygon to be used would be determined based on the overall size of the managerial unit to be reclaimed. A typical minimum grid would be as follows:

- Units 10 hectares or less -1 sample pt. or composite sample per 5 hectare polygon
- Units from 10 to 60 hectares -1 sample pt. or composite sample per 10 hectare polygon
- Units from 60 to 300 hectares -1 sample pt. or composite sample per 15 hectare polygon
- Units over 300 hectares -1 sample pt. or composite sample per 20 hectare polygon

In addition to this systematic distribution of sample points, any notable areas of aberrant growth media should be identified and sampled separately. Such areas might include low points that accumulate water, demonstrate salt accumulations, exhibit potential acid generating materials, appear to be comprised of poor-growth media, exhibit excessive coarse fragment levels, etc. An illustration of this grid distribution for soil sampling is presented below along with an area of aberrant material.

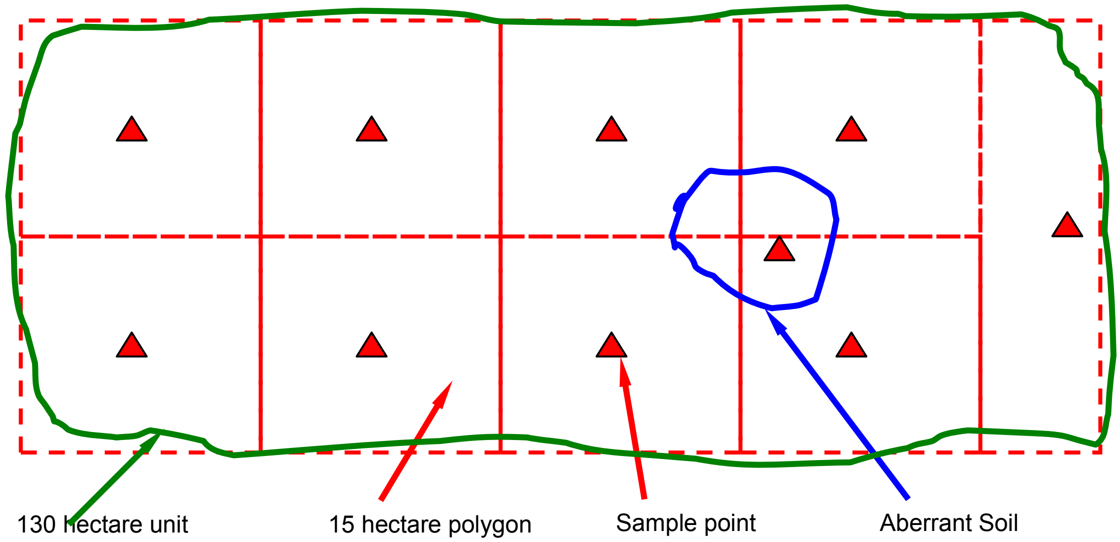


Figure 2 - Example of a Systematic Grid Distribution for Sampling Growth Media

2.3 Collect Growth Media Samples

At each sample point, a total of 2 or 3 soil samples should be collected from each vertical soil profile. These would correspond to the following depths: one sample from the uppermost 15 cm of material (0 – 15 cm depth); a second sample taken across the range of the lower portion of the applied growth media (below 15 cm but above the underlying waste material); and a third sample taken from below the growth media and within the underlying waste material unless the applied growth media is greater than 60 cm in depth. If the total depth of applied growth media is about 20 cm or less, the second sample can be deleted but the waste material sample is still necessary. If the contact between applied growth media and underlying waste material cannot be determined with certainty, then samples should be collected from the 0 - 15 cm interval, the 15 – 30 cm interval and from the 30 – 60 cm interval or the point of auger refusal (rock). Individual samples should be collected across the vertical extent of the interval using a tile spade, auger, or similar instrument and placed within clean heavy-duty polyethylene bags. Each bag should be marked with indelible ink as to the mine name, reclaimed unit, grid polygon number, GPS coordinates, sample depth increment, date, collector, and any other pertinent managerial information. Additional observational data (e.g., soil structure, coarse fragment content from sieving, salt crusting, etc.) should be recorded as well. The total amount of sample material collected from each depth increment should be at least 0.5 liter, or more appropriately one liter.

Prior to sieving, soil structure of the reapplied growth media should be noted for possible use with the RUSLE evaluation in Step 3. Soil structure is defined as the arrangement of soil particles into aggregates that form structural units. Soil structure can be determined by collecting a small excised sample from the uppermost 10 cm of the exposed soil profile. Careful examination of the soil particles as they are gently reviewed in the hand will result in one of the following four classifications:

1) Very fine granular < 1 mm
2) Fine granular, 1-2 mm
3) Medium to coarse granular, 2-5 mm
4) Blocky, platy, or massive, > 5 mm.

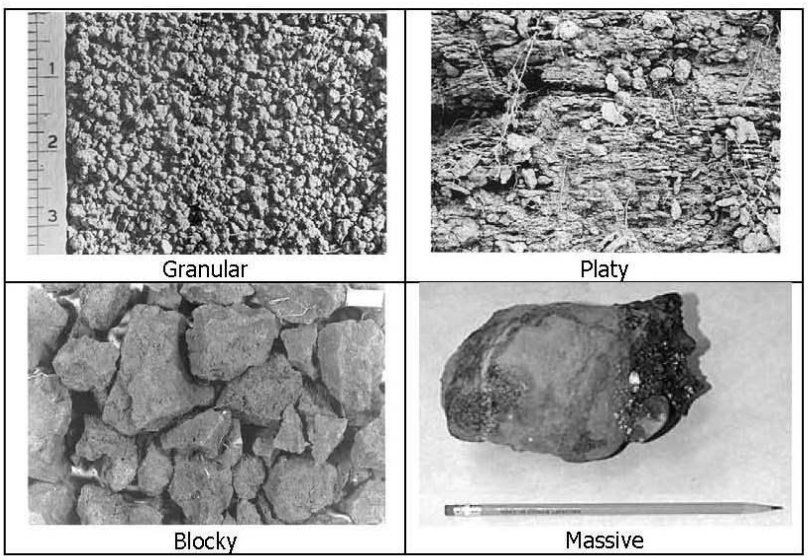
Definitions and photo examples of these terms is as follows:

Granular - This type of structure consists of small, porous aggregates that tend to be somewhat rounded in shape.

Platy - This type of structure consists of aggregates that have longer horizontal faces than vertical faces. The fragments are flat and thin.

Blocky - This type of structure consists of aggregates clinging together in nearly square or angular blocks having sharp edges. Large blocks normally do not allow rapid entry of water into the soil. This condition is mainly found in the subsoil.

Massive - This represents a soil condition where there is no evidence of aggregation. The soil particles tend to stick together in no definite pattern or arrangement.



Following an evaluation of soil structure, samples should be sieved in the field with a screen allowing passage of material less than about 5 mm (~ coarse fragment limitation). Where sieving occurs, the percent of coarse fragment content should be estimated to the nearest 5% or 10% by comparing the two piles of material (sieve passage vs. sieve collected). If ¼ of the initial sample volume is retained in the sieve, then coarse fragment content would be recorded as 25%; ½ of the initial sample volume would be recorded as 50%; and so on. This estimate should then be recorded for future analyses and the coarse fragment fraction can be discarded. If the remaining small gravel fragments are excessively sharp (e.g., chert), then the sample should be double bagged to help prevent loss of fines.

Collected samples should be air-dried before sealing and shipment to a qualified laboratory. Shipment should occur at the soonest practicable time after collection and drying to avoid degradation of samples or false readings. Variables to be evaluated should include: **pH**, **EC** (for saline soils), either **SAR** or **CEC / ESP** (for potentially sodic soils), **texture** (laboratory method), and basic fertility components (**N**, **P**, **K**, and percent **OM** (organic matter)). **Soil permeability** may also be requested to facilitate classification into one of six categories to aid in the RUSLE analysis. These categories are: 1) Rapid, 2) Moderate to Rapid, 3) Moderate, 4) Slow to moderate, 5) Slow, and 6) Very slow. However, this tends to be an expensive test and an alternate determination of this parameter can be estimated with fair accuracy by evaluating soil texture in conjunction with soil structure (see Section 2.4). It can also be estimated by performing a "percolation test" in the field. Additional variables as appropriate can include: **carbonates**, **base saturation**, **water saturation percentage**, and **potentially problematic elements** (e.g., selenium, boron, etc.) where these may be indicated in the region.

If requested, certain laboratories will provide an interpretation of the results with regard to suitability as a growth media. If such an assessment is not available, laboratory results should be reviewed by a soil professional or other professional familiar with parameter ranges necessary for material to service as an adequate growth media. In certain instances, "out-of-bounds" parameters may be compensated by application of amendments (e.g. lime application for low pH soils.). If one or more samples result in overly problematic findings, the target polygon(s) can be sub-sampled using a smaller grid interval to isolate the offending source (assuming the identified problem is sufficiently severe or extensive to warrant the effort). Given these additional data, appropriate remediation can be designed and implemented as necessary with the help of either a soil or reclamation professional. Of particular importance with regard to amendments, nitrogen should **NOT** be used, or should be used only under the careful supervision of a qualified professional, if annual weeds are potentially problematic in the vicinity of the operation. Nitrogen encourages weedy annuals that can be detrimental to the establishment of desirable plants. Species native to the area are typically well adapted to deal with poor soil fertility.

In many circumstances, offending or problematic materials can simply be buried under an adequate depth of more conducive material. In other circumstances, especially where surface drainage considerations will be impacted, problematic materials may have to be excavated and transported elsewhere for burial.

2.4 Determination of Permeability

Soil permeability is defined as the rate at which water moves through the soil, and factors affecting soil permeability include; soil compaction, soil structure, and soil texture. As indicated above, a direct determination of soil permeability can be an expensive parameter to measure in a lab, but can be determined in a more practical manner based on less expensive laboratory data using certain guidelines as presented below for selecting a suitable permeability class for reclaimed soils. For purposes of the RUSLE application (Step 3), permeability must be classified into one of six classes:

1) Rapid
2) Moderate to rapid
3) Moderate
4) Slow to moderate
5) Slow
6) Very slow

Soil compaction is the first factor to consider. Compaction is typically not an issue on reclaimed soils, unless haulage roads were in the area and were not ripped before reclamation activities.

Therefore, soil compaction can generally be ignored unless circumstances arise in which severe compaction has occurred. In these circumstances, permeability would be reduced by at least one classification.

As indicated above, soil structure on reclaimed mine sites is typically granular. However, sometimes a more developed structure can be observed, especially in older reclaimed areas. If an encountered growth medium is characterized as having a platy, blocky, or massive structure, it will shift the permeability class downward (slower) by one classification. This is a guideline and should be re-evaluated at the site scale if conditions dictate.

Finally, soil texture is the variable most affecting soil permeability. Lab results from the soil texture analysis will be used in this regard for a determination of soil permeability class. The texture of soils is an indication of the different particle sizes of clay, silt, and sand that greatly impact the rate at which water moves through the profile. The table below demonstrates the permeability of different soil "separates". However, this table represents each soil separate in its pure form, a condition that effectively does not occur on reclaimed land. Therefore, interpretation of the soil texture analysis is required. For example, if a soil texture analysis indicates that the soil is 70% silt and 30% sand, then the observer would likely classify the soil as moderately slow as opposed to slow. It must be emphasized that these are guidelines for evaluating soil permeability into classes. If aberrant conditions occur, then special considerations should be applied to address those circumstances to facilitate an accurate classification of soil permeability; and/or a professional soil scientist should be consulted[1].

Soil Separate	Particle size Diameter (mm)	Permeability
Clay	Below 0.0002	Very slow
Silt	0.05-0.002	Slow
Very fine sand	0.10-0.05	Moderately slow
Fine sand	0.25-0.10	Moderate
Medium sand	0.5-0.25	Moderately rapid
Coarse sand	>0.5	Rapid

2.5 Selection of Reference Areas

Although it may seem to be out of sequence, the selection of reference areas must necessarily occur early in the reclamation process and certainly before stability and / or vegetation evaluations are implemented. Therefore, this discussion is placed here to emphasize selection of appropriate reference areas at this time in the process.

Reference areas may also be termed "analog" areas or "comparison" areas, but effectively the three terms should be considered synonymous. The selection of reference areas must occur with great care and should be performed by a well-experienced reclamation specialist. Reference areas should be selected from undisturbed (by mining operations) and representative examples of local vegetation communities and physical topography (especially slope) that support the land

[1] This procedure for collecting information on soil permeability is based on general guidelines and should be considered for adaptive development. Improvements to the protocol should be implemented on a regular basis to further refine and develop the accuracy and use of these guidelines.

use that is the target of post-mining reclamation. If the selected reference areas exhibit excessive or dense vegetation in comparison to the norm for the area, then the standard will be artificially elevated. To the contrary, overly sparse or disclimactic vegetation will reduce the standard and the potential for acceptance by oversight agencies will be compromised.

At least one reference area should be selected for each separate reclaimed vegetation community targeting a specific land use. For example, if the post-mining land use (PMLU) is grazingland for livestock on rolling topography, then a reference area should be established on rolling topography that supports palatable native grasslands. If the PMLU is heavily managed livestock grazing (pasture-rotation, etc.), then a reference area should be established on a unit of "managed pastureland". If the post-mining land use includes wildlife habitat or open (undeveloped) rangeland (wildland), then a reference area should be established in an area supporting native grassland / shrub steppe communities (or similar), which tend to be the early seral stages of the eventual desirable community. In this latter case, care must be taken to avoid reference areas that exhibit overly disclimactic or dense stands of shrubs and trees as these life forms often take decades to mature and/or evolve (hence the need for an early seral equivalent).

The selected reference area(s) should be as "ecologically and topographically similar" to the pre-mining area, surrounding area, or area representing the desired PMLU as possible, and be based on five main considerations, as follows:

1. The reference areas should be representative of the desired PMLU or vegetation community supporting the PMLU.

2. The reference areas should exhibit topography, slopes, and aspects that are representative of the majority of reclaimed areas, especially with regard to slopes that may be subject to erosion.

3. The reference areas should exhibit similar physical soil conditions as reclaimed areas and therefore, should be an "approximate ecological equivalent".

4. Excepting managed pasturelands and/or occasional invasive weeds, the reference areas should support native tree/shrub/grass plant communities similar in structure to what can be obtained on reclaimed areas in the short term (e.g. 5 – 8 years).

5. The plant communities selected for comparison should provide an appropriate and logical target for reclamation efforts.

Once reference areas have been selected, adequately sampled, and found to be appropriate by Barrick and/or their reclamation consultants, they should be submitted for approval to oversight agencies as appropriate. A field review of the selected reference areas should be scheduled with the oversight agencies at the earliest opportunity to obtain "formal" approval. However, it is recommended that site reviews of reference areas (as well as reclaimed areas up for bond / liability relinquishment) be scheduled during the late Spring / early Summer to avoid the visual complications of litter and standing dead vegetation.

3.0 SITE-SPECIFIC PROCEDURES FOR EVALUATING SOIL STABILITY (STEP 3)

3.1 General

Following Step 2, soil stability monitoring (consisting of two procedures) will be implemented to 1) show trend and provide insight regarding problematic circumstances and 2) show rates that will provide increased defensibility, especially for relinquishment evaluations. Trend monitoring will be co-located with vegetation monitoring transects and is designed to provide easily collected data that can be used to show erosional stabilization trends, or lack thereof, as well as provide information that will indicate solutions for problematic circumstances.

The second evaluation is designed to document rates of erosion and provide for a means to document erosional stability and therefore, facilitate bond relinquishment and liability release. Depending on site-specific circumstances or local preferences, two options could be selected: 1) Landscape Function Analysis (LFA) as developed in Australia, or 2) the Revised Universal Soil Loss Equation (RUSLE). Use of LFA procedures is somewhat less defensible, and though there are places where its use may be reasonable, it will not be further developed in this document. For additional information, the reader is directed to a summary of LFA (Tongway, 2005).

RUSLE procedures have been developed over the last 6 decades in the U. S., and version 1.06c, designed for construction and mining disturbances, is recommended. This procedure utilizes the most pertinent and applicable site-specific information to perform a reliable and cost-effective evaluation of erosional stability across the most potentially problematic portions of a reclaimed unit. Most of the input parameters are very easy to collect, or in many cases, are collected during other field monitoring procedures and can be used for both applications.

Furthermore, documentation of soil stability using RUSLE need only occur at the time of bond relinquishment unless stability issues are detected during interim periods. If stability issues arise, RUSLE could be implemented annually to provide feedback regarding remedial measures.

3.2 Erosion Monitoring for Trend Analysis

Trend monitoring for erosional stability will be comprised of two observational procedures, one that is co-located with each vegetation sampling transect (from Step 4) and one that is established and monitored independently. The first of these annual monitoring procedures (co-located with each vegetation monitoring transect) will be comprised of a ten-meter transect extended along the contour and beginning at the vegetation transect starting point. Along this transect, all rills and gullies that cross the transect will be enumerated and data about each recorded. Data to be collected for all observed rills and gullies include: width (in cm), depth (in cm), current status ("active", "stabilizing", or "indeterminate"), and if "stabilizing", the evidence so indicating. Such evidence may include: caving sidewalls, deposition within the channel of small fraction sediments, litter accumulation, and/or plant establishment within the cross-section. In addition, the percent slope of the transect will be recorded perpendicular to the contour.

When compared over time and coupled with rock, litter, and vegetation cover data from the vegetation transect, this information will provide a strong indication of trend and factors contributing to erosional progression or stabilization. An analysis of such data will aid determination of corrective measures necessary to stabilize the soil surface or to preclude such problems by correct construction techniques for future facilities. Corrective measures may include: reduced slope angle; increased surficial rock cover (rock mulch); increased vegetation cover; need for mechanical techniques such as contour furrowing, pitting, etc.; or need for improved surface water control measures such as berms, benches, reinforced water courses, etc. Although the need for such measures may fall under the category of "common sense", the threshold at which they become necessary given site-specific circumstances is typically an unknown without such empirical data.

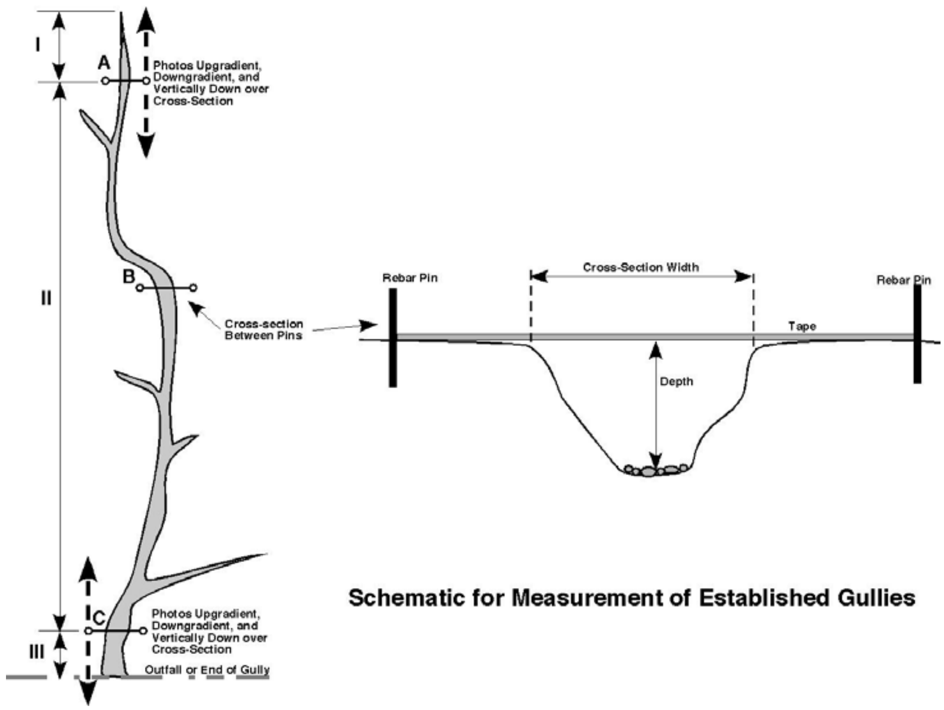
The second erosional observation procedure to be utilized is independent of the vegetation monitoring transects. This procedure should be used in arid environments where episodic precipitation following soil lay-down leads to gully formation before vegetation can become established (e.g. Western Australia). Once formed, regardless of "stabilizing status", these gullies can become the focus of regulatory scrutiny. Without trend information, there is little opportunity to counter "negative opinion" without expensive mitigation.

In this regard and depending on the size and revegetated status of a target reclaimed unit, one to several gullies should be located (following an episodic event), permanently marked, and monitored annually. If a reclaimed unit vegetates quickly and gully formation does not occur, this procedure can be omitted. To the contrary, where revegetation is slower and gullies do form early in the revegetation sequence, the following minimum number of gullies should be identified for monitoring.

- 1 gully per 10 hectares in units up to 40 hectares in size;
- Units 40 to 100 hectares – 5 to 6 gullies should be identified for monitoring;
- Units larger than 100 hectares – 7 to 8 gullies should be identified for monitoring.

Once gullies are located and permanently marked in the field (including GPS coordinates), the slope (percent) should be recorded and three sets of cross-sections (A, B, & C) need to be established as indicated in the schematic below. The endpoints of each cross-section may be permanently marked with a length of rebar driven into the ground sufficiently distant from the edge of the gully to allow for possible changes with time (at least 0.5 meter from either edge should be sufficient for most gullies). A tape stretched across the gully as indicated in the schematic will facilitate a determination of width and depth at each location. Any other pertinent observations such as stabilization and the evidence thereof, should also be recorded at this time. Such evidence may include: caving sidewalls, deposition within the channel of small fraction sediments, litter accumulation, and/or plants establishing within the cross-section.

In addition, at cross-sections A and C, three photos should be exposed, one upgradient, one downgradient, and the third vertically downward over the gully from a height of about 1.5 meters. Finally, three linear distances represented by lengths I, II, and III should be recorded. The linear distance from the start of the gully to cross-section A (I) is the most likely distance to change from year to year. The distance from A to C (II) should not change, and the distance from C to the end of the gully (III) may change if the gully extends downgradient. If the gully is tributary to a collection ditch, mid-slope bench, or some other similar structure, this final distance may remain constant as well.



Schematic for Measurement of Established Gullies

Special care must be taken during the collection of these measurements and photos to not step near the edge of the gully and cause the sides to collapse, especially in the vicinity of the cross-sections. Such action will adversely impact future measurements or conclusions drawn. Assuming such annual monitoring can indicate that early reclamation formed gullies tend to stabilize rather than remain active as vegetation establishes, then the "proof" will be available to counter negative opinion.

3.3 Erosion Monitoring for Relinquishment Using RUSLE Procedures

3.3.1 Application

The RUSLE protocol (Renard et al. 1992) will be used to determine whether the potential for soil erosion is sufficiently low, and for surface stability sufficiently high, to conclude that stability has been achieved. This protocol employs site-specific climatic, edaphic, topographic, and vegetation data to identify erosion potential. For practical use of this procedure, it must be applied after growth media characterization (Step 2) has been completed and in conjunction with vegetation monitoring (Step 4). A version of RUSLE, 1.06c, has been developed specifically for use on mined land reclamation.

RUSLE 1.06c is a powerful program that is capable of predicting soil loss from fields or hillslopes that have been subjected to a full spectrum of land manipulation and reclamation activities. RUSLE 1.06c can accommodate undisturbed soil, spoil, and soil-substitute material (growth medium), percent rock cover, random surface roughness, mulches, vegetation types, and mechanical equipment effects on soil roughness, hillslope shape, and surface manipulation including contour furrows, terraces, and strips of close-growing vegetation and buffers.

Though a reasonably advanced tool, it should be noted that there are limits with respect to the applicability of the model. This model predicts erosion potential as a result of sheet, rill, and inter-rill erosion. Gully erosion is not a part of the predicative capability of RUSLE. Where gullying may occur, the bearing that this type of erosion would have on soil stability must be evaluated independently. RUSLE also does not, in and of itself, predict the fate of generated sediments. RUSLE is a predictive model and must be used as such in the comparative sense against values that exhibit the same level of potential accuracy. This is the intent of the application of this model as a part of the overall reclamation success protocol discussed in this document.

The RUSLE model is based on six parameters utilized to estimate or quantify the factors that affect the potential for soil erosion. The RUSLE model (Renard et al. 1992) is as follows:

$$\boxed{\mathbf{A = R \bullet K \bullet L \bullet S \bullet C \bullet P}}$$

Where:

A = Soil loss in tons / acre / year

R = Rainfall/runoff erosivity factor
K = Soil erodibility factor
LS = Hillslope length and steepness factors (combined as one)
C = Cover-management factor
P = Support practice factor

"**R**" represents the rainfall-runoff erosivity factor. The effects that climate, in terms of amount of incident precipitation, storm intensity, etc. have on erosion are accounted for by this factor. Values for this factor are developed using site-specific climatic data. Data needs for calculating the **"R"** factor in RUSLE 1.06c are as follows:

Office Data Collection:

Site-Specific Climatic Data - Local monthly precipitation (in inches) and temperature (^{o}F) data must be collected from either an on-site weather station or available internet sources for areas with published data that are in close proximity to the site. Larger data sets with a longer period of record will increase the accuracy of the soil loss prediction. Ideally, 30 years of monthly precipitation and temperature data will provide a strong data set. At present, data inputs must be in English units as opposed to metric.

Field Data Collection: - None – other than from site-specific meteorological station(s).

The "**K**", or soil erodibility, factor is related to the integrated effect of rainfall, runoff, and infiltration on soil loss. It is typically considered to be the soil loss rate/unit for a specified soil as measured on a standard plot experimentally. K-factors to be used for this protocol may be taken from a standard nomograph developed for this purpose (NRCS 1993) since the surface growth medium may not directly correspond to any recognized soil series. Subfactors to be considered in developing the appropriate K-factor are texture, percent organic matter, soil structure, and permeability. Data needs for calculating the **"K"** factor in RUSLE 1.06c are:

Office Data Collection:

None, unless an NRCS nomograph is used or a detailed soil survey has been completed for the project area and the soil utilized for reclamation can be correlated to that survey.

Field Data Collection:

Soil Texture (% sand, % silt, and % clay)
Collected with growth media analyses described in Step 2 where all samples in the analysis are averaged to generate one set of values for the RUSLE application.

Soil Organic Matter (%)
Collected with growth media analyses described in Step 2 where all samples in the analysis are averaged to generate one set of values for the RUSLE application.

Soil Structure
Collected as part of the growth media analysis described in Step 2). For the purposes of the RUSLE application soil structure is classified into one of four classes:

1) Very fine granular < 1 mm
2) Fine granular, 1-2 mm
3) Medium to coarse granular, 2-5 mm
4) Blocky, platy, or massive, > 5 mm.

Soil Permeability
Soil permeability is defined as the rate at which water moves through the soil and is strongly correlated with soil texture that is collected as part of the growth media analysis described in Step 2. For purposes of the RUSLE application permeability will be classified into one of six classes as described in Section 2.4.

Percent Rock
The percent of the surface covered by rock (>5mm), collected as part of the vegetation monitoring protocol described in Steps 4 and 6. An average across the entire unit will be used to allow for one value to be entered into the RUSLE application.

Slope length (**L**) and gradient (**S**) will be combined into one factor using charts developed for this purpose. Data have shown that this method offers the best means of integrating the effects of slope length and gradient into the equation. Slope length accounts for the effect topography has on erosion potential. Lengths should be measured in the field to supply the correct data for the L-factor and compound slopes will be defined if existing. Slope steepness (gradient) measured as a percent, is a representative of the slope and will also be determined in the field to supply the most relevant data. However, slope lengths and gradients may also be taken from detailed post-reclamation contour maps if maps accurately represent site conditions. Data needs for calculating the **"LS"** factor in RUSLE 1.06c are as follows:

Office Data Collection: None - unless data are from detailed "as builts" of reclamation features.

Field Data Collection:

Slope length (in feet) and gradient (%) should be measured in the field. The slope should be divided into segments in such a way that each segment can be considered uniform. A measuring tape should be used to determine the length of each segment and a clinometer to measure gradient (%). This process should be executed on an average slope following an extended reconnaissance effort. The selected slope must be representative of the slopes and lengths found on the unit.

Alternately, at least four or five typical slopes could be measured as described above and then averaged. If one particular area exhibits excessive slope gradient or length, it may be isolated and separately analyzed to determine its unique erosional circumstances.

The cover-management factor **(C)** reflects the effect of vegetation and related management practices on erosion rates. This factor will be based largely on site-specific data collected from, or which is relevant to, each area for which reclamation success is being evaluated. The type of vegetation currently existing on site, estimated soil roughness, measured soil surface cover (vegetation, coarse fragments, litter, other non-erodible material), plant canopy height, measured plant canopy cover, and estimated below-ground plant biomass factors will all be used to develop the C-factor using a computer program sub-routine. It has been postulated that this factor is the most influential of all factors for determining potential erosion from a site. Data needs for calculating the **"C"** factor in RUSLE 1.06c are as follows:

Office Data Collection:

Effective root mass in the top 4 inches of the soil profile will be based on correlation to published ratios (cover to biomass) for appropriate life-forms. Ratios of biomass to percent surface cover will be gathered from scientific literature sources and then weighted based on site-specific canopy cover for entry into the RUSLE application. Occasional circumstances may occur where a dominant plant does not fit a typical life-form category, whereby it can be researched separately and treated on an individual basis.

Field Data Collection:

<u>% Canopy Cover</u>
Canopy cover is the cover by vegetation above the soil surface that intercepts raindrops (but does not contact the soil surface). Open spaces, whether within the perimeter of a plant canopy or between adjacent plants, are not considered as canopy. It is for this reason, among others, that ground cover data are collected with the point-intercept technique. These data are collected during Step 4 (vegetation monitoring) and Step 6.

<u>Average Fall Height (in feet)</u>
Defined as the height within the canopy from which intercepted raindrops re-form into water droplets and fall to the ground; this fall distance is known as the "effective fall height." In plant communities that have more than one type of life form composing the canopy, such as on rangeland with a mixture of grasses, shrubs, and trees, a fall height should be determined for each life form. These data should be collected as part of the vegetation monitoring protocol described in Steps 4 and 6. These fall heights will then be

weighted using the canopy cover to establish an average fall height for entry into the RUSLE application.

% Rock Cover
Collected as part of the vegetation monitoring protocol described in Steps 4 and 6. An average across the entire unit will be used to allow for one value to be entered into the RUSLE application.

% Plant Litter Surface Cover
Collected as part of the vegetation monitoring protocol described in Steps 4 and 6. An average across the entire unit will be used to allow for one value to be entered into the RUSLE application.

The "**P**", or support practice factor takes into account the effects of mechanical practices applied to the surface of the growth medium to increase infiltration, reduce runoff, and decrease erosion. Such practices include ripping, pitting, and contour furrowing and result in a parameter value of less than 1.0. A value of 1.0 may be appropriate where no support practices have been employed on a reclaimed area. The effects that basic tillage or fertility practices have on erosion potential are included in the cover management factor of the equation. Data needs for calculating the **"P"** factor in RUSLE 1.06c are as follows:

Office Data Collection:

Gather information on reclamation activities such as contour furrowing and terracing from reclamation records ("as builts").

Field Data Collection:

Make observations regarding procedures that may have been implemented should there be no file data available as to past practices.

3.3.2 Evaluation

Following data collection and parameter development, the RUSLE model will be engaged for each area requiring an evaluation. Implementation of the RUSLE model on reclamation units will occur as an average of the entire unit[2]. A potential soil erosion value "A" in tons/acre/year of growth medium loss will be estimated by the model. This value can then be compared to any one of three options (A, B, or C) for success evaluation:

A) The standard will be met if the soil loss value (A) determined by RUSLE for the reclaimed unit is equal to or less than the "T" value (effectively the soil genesis rate) appropriate to the site <u>and</u> the "trend" analysis detailed in Section 3.2 indicates stable or positive results.

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[2] When applied in this manner this methodology does not account for small or isolated areas of potential reclamation failure. These areas must be identified and addressed separately by onsite personnel, or they can become individual units subject to investigation using the overall procedure.

The "T" value will be assigned independently based on the limiting properties of the subsurface growth medium and/or geologic material present beneath the reclaimed units. Criteria for assigning a "T" value include the physical and chemical characteristics of subsurface layers and the properties of soil moisture and temperature as influenced by climate. This process accounts for the weatherability and suitability as a growth medium of the subsurface materials (i.e. rate of genesis of suitable sub-soils). A soil scientist can be consulted to help calculate or determine the "T" values for the types of reclaimed sites to be evaluated if they are not already available in the literature or public domain.

In lay terms, the "T" value approximates the rate of soil genesis (tons/acre/year). If the potential loss of growth medium as predicted by the model ("A") is less than or equal to the "T" value, the area will be considered stable and the test passed. If the potential loss ("A") is greater than the "T" value, the area will not be considered sufficiently stable and the area will fail the success test. The addition of the need for a "stable" or "positive" trend from the analysis in Section 3.2 addresses the fact that RUSLE does not account for gully erosion.

B) The standard will be met if the soil loss value determined by RUSLE for the reclaimed unit is less than 110%[3] of an established soil loss <u>baseline</u> value determined by RUSLE for the mine area (prior to disturbance) <u>and</u> the "trend" analysis detailed in Section 3.2 indicates stable or positive results.

A baseline value (A_B) will be determined by implementing RUSLE using data from the baseline soil and vegetation surveys (prior to mining disturbance). This method accounts for site-specific conditions including similar vegetation type, growth media, and climate.

In effect, the baseline "A_B" value approximates the rate of soil loss on the ground before mining disturbance. If the potential loss of a reclamation unit as predicted by the model ("A") is less than 110% of the baseline "A_B" value, the area will be considered stable and the test passed. If the potential loss is greater than 110% of the baseline "A_B" value, the area will not be considered sufficiently stable and the area will fail the success test. The addition of the need for a "stable" or "positive" trend from the analysis in Section 3.2 addresses the fact that RUSLE does not account for gully erosion.

C) The standard will be met if the soil loss value determined by RUSLE for the reclaimed unit is less than 110%* of a soil loss value from a reference (analog) area as determined by RUSLE <u>and</u> the "trend" analysis detailed in Section 3.2 indicates stable or positive results.

The reference value (A_{RA}) will be collected from a reference (analog) area in the same year as the reclamation unit sampled for comparison. The selected reference area(s) should be as "ecologically and topographically similar" to the pre-mining area, surrounding area, or area representing the desired post-mining land use (PMLU) as possible, and be based on the five main considerations indicated in Section 2.5.

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[3] Given the vagaries of biotic and edaphic systems, the vast majority of regulatory agencies have allowed a modest level of flexibility when comparing reclamation to native or undisturbed lands. In the more restrictive circumstances, this flexibility has been limited to a 10% variance.

The reference “A_{RA}” value approximates the rate of soil loss on a selected reference area adjacent to the mining disturbance. If the potential soil loss from a reclamation unit as predicted by the model (“A”) is less than 110% of the reference "A_{RA}" value, the area will be considered stable and the test passed. If the potential loss is greater than 110% of the reference "A_{RA}" value, the area will not be considered sufficiently stable and the area will fail the success test. The addition of the need for a “stable” or “positive” trend from the analysis in Section 3.2 addresses the fact that RUSLE does not account for gully erosion.

These suggestions for success evaluation must necessarily remain dynamic as such testing for erosional stability is in its infancy. There are circumstances (e.g., the Outback of Australia) where the land surface has been subjected to the erosive forces of nature for so long a period that they are now extremely stable and the “T”, “A_B”, or “A_{RA}” values may not present a reasonable target for reclamation. In this regard, it may be possible to develop a standard similar to the “inflection point” concept presented for LFA analyses. Once several reclaimed units are sampled, data generated, and analyses made, the efficacy of the currently proposed standards versus the need for an alternate RUSLE success comparison will be further evaluated.

4.0 EVALUATE ESTABLISHING VEGETATION USING VEGETATION MEASUREMENT PROTOCOLS (STEP 4)

4.1 General

By using established, scientifically defensible procedures to track the progress of newly establishing vegetation communities, a determination of either latent problems or a prediction of future “releasability” will be reliably determined. At some point, the reclaimed community will have progressed sufficiently to be “tested” and thereby trigger final bond and/or liability relinquishment on areas no longer potentially necessary for operations.

The initial stage (Stage I) of vegetation monitoring will occur the first growing season following seeding and will consist of two components: 1) a brief qualitative evaluation of the reclaimed surface and manifested physical and biotic attributes, and 2) a brief evaluation of emergent plant density. Following this initial stage of monitoring, units that appear to be advancing will be evaluated and assessed to determine progress toward “releasable” status and/or to determine if latent problems may need attention. In this regard, Stage II vegetation monitoring protocols will be implemented for all reclamation units that have achieved sufficient vegetation growth and development to warrant the effort.

For the vast majority of circumstances Stage II monitoring will target the vegetation variable of “Ground Cover”, and because most vegetation used in reclamation does not or will not achieve heights in excess of approximately 1.5 meters over the short-term, a concentration on vegetation ground cover below 1.5 meters will be the primary emphasis. However, for older reclamation and other exceptions where ground cover due to vegetation exceeds 1.5 meters in height, a secondary procedure will be used to incorporate “overstory” cover.

In typical circumstances, Stage II procedures would be implemented for a period of 1 to 3 years, assuming reclaimed communities are progressing as expected until either Stage III is reached or the area becomes “releaseable”. Stage III is essentially a “holding” period where reclamation has achieved adequate parameters to be relinquished, but the area is not operationally ready to be released from the permit. In these instances, compliance monitoring would be initiated requiring an evaluation once every 3 years to insure the reclaimed area has not regressed or shows evidence of decline. In certain circumstances (such as poor growth media or rainfall), the progress of reclaimed communities may take a longer period of time and Stage II procedures may be scheduled for implementation on a biennial basis (once every two years).

4.2 Physical and Biotic Attributes and Emergent Plant Density Monitoring (Stage I)

4.2.1 Physical and Biotic Attributes

During the first growing season following seeding a reclaimed unit will be subjected to a relatively brief one-time evaluation to document plant establishment as well as other reclamation considerations. This evaluation consists of a qualified observer traversing the subject area and evaluating vegetation establishment and related physical and biotic conditions. Approximately 1 hour of qualitative review time per 20 hectares should be expended. During the traverses, the observer should note, among other items: 1) areas of poor seedling emergence, 2) pervasively weak or stressed seedlings, 3) indicators of soil fertility problems (e.g. certain anthocyanine colorations), 4) noxious weeds or invasive plant infestation, 5) evidence of unintended livestock grazing, 6) excessive erosion and type, 7) evidence of acid formation, 8) evidence of structural instability (stress fractures, piping, etc.), 9) evidence of hyper-saline soils, 10) “pockets” of the aforementioned, and 11) any other similar revegetation / reclamation related problems. Also at this time, any gullies that may have formed during rainfall events should be identified and a portion subjected to the trend evaluation as indicated in Section 3.2.

4.2.2 Emergent Plant Density

In addition to the physical and biotic attributes evaluation, the surveying observer will collect semi-quantitative samples to document the emergent density of seeded species. This procedure will occur as follows. For areas up to 5 hectares in size, a total of 5 samples will be collected. For areas between 5 and 35 hectares in size, a total of 10 samples will be collected. For areas between 35 and 150 hectares in size, a total of 20 samples will be collected. Finally, for areas larger than 150 hectares in size a total of 30 samples will be collected. Each sample will consist of a group of five 0.1-m^2 quadrats distributed in an unbiased manner (a blind toss is adequate). The number of emergent plants rooted within the perimeter of each quadrat will be recorded accordingly into one of five classes: perennial grass, perennial forb, shrub/tree, annual grass, or annual forb. This procedure typically takes about 2 minutes per sample point (5 quadrats) yet yields valuable information on the success of the seeding effort. Efforts that result in fewer than 1 perennial emergent per 0.1-m^2 should be considered to be poor and a possible candidate for remediation. Efforts with 1 – 2 perennial emergents per 0.1-m^2 are considered to be fair, 2 - 3 perennial emergents per 0.1-m^2 are considered good, and 3 - 5 perennial emergents per 0.1-m^2 are considered to be very good. Finally, greater than 5 perennial emergents per 0.1-m^2 are considered to be excellent.

In certain droughty areas (e.g., Mojave desert of the U.S. or Goldfields of Western Australia), quadrat size may need to be increased to 1-m^2 to facilitate emergent plant evaluation. In these areas, efforts with 1 – 2 perennial emergents per 1-m^2 are considered to be fair to good and 3 - 4 perennial emergents per 1-m^2 are considered very good to excellent.

In addition to the qualitative and emergent density surveys, the reclaimed unit should be circumnavigated on foot or with all-terrain vehicle utilizing a sub-meter GPS to field delineate the unit boundary. In this manner, discrepancies between planned and actual area of reclamation will be documented. Such information becomes important during relinquishment activities.

4.2.3 Recommendations

The results of the qualitative, and semi-quantitative emergent density survey will form an initial basis for recommendations for future needs of the reclaimed unit. For most efforts it is anticipated that a recommendation to proceed to Stage II monitoring will be made. Other possible recommendations may include:

1. Allow additional time for seed to emerge and re-evaluate using Stage I Protocols. The amount of additional time may be one or more years.

2. Re-treat all or parts of a unit by resoiling, reseeding, fertilizing, weed control efforts, addressing acid generation or stability concerns, etc. An important concept that must be taken into account is that precipitation is not always favorable for reclamation efforts in any given year or environment. Also, species selected, growth form, depredation by granivores, and mold or fungus may impact emergence. Therefore, a second or third growing season is often necessary to achieve the desired seedling emergence. If however, after three growing seasons emergence is still unsatisfactory, reseeding may be necessary to replenish the seed bank. If mitigation occurs, re-monitor the following growing season using Stage I Protocols.

Advancement to Stage II monitoring would be based on the estimated amount of expressed vegetation in the target reclamation unit(s). When the amount of vegetation cover visually exceeds an estimated 10 percent of the value expressed by the appropriate reference area, then Stage II activities should commence. For example, assume the reference area exhibits a value of 50% ground cover by live vegetation. Then Stage II activities would commence when absolute ground cover by live vegetation on the reclaimed unit is approximately 5% (50% x 10% = 5%).

4.3 Quantitative Vegetation Monitoring (Stage II)

4.3.1 Ground Cover

During Stage II vegetation monitoring, evaluation will consist of a reasonably rapid quantitative evaluation of ground cover (for most circumstances) to document the level of progress. This effort will entail a qualified observer systematically establishing "ground cover" sampling transects across the reclaimed unit (using a visually-based grid as opposed to a more formal measured grid) at the following sampling intensity:

- Units 5 hectares or less — 5 Transects
- Units between 5 and 35 hectares — 10 Transects
- Units between 35 and 150 hectares — 20 Transects
- Units larger than 150 hectares — 30 Transects

These transects will be systematically distributed as opposed to being randomly distributed. In this application a systematic distribution of samples is superior because it ensures sample representation from across the entire reclaimed unit (population). Also, this procedure better accounts for heterogeneous expressions of multiple seedings or reclamation conditions by "forcing" a patterned distribution of samples which minimizes sample bias resulting from vegetated pockets being either entirely missed or overemphasized. This "forced" distribution also facilitates a second overall look at the entire reclaimed unit for the qualitative parameters discussed for Stage I (physical attributes) monitoring.

Ground cover transects will typically consist of 10-meter long 100-intercept "line-point transects" ("point-intercept transects"). There may be some instances (elevated variability) where longer transects would be appropriate, and these circumstances can be addressed on a site-specific basis. The actual sampling methods are described in detail in Step 6. As routinely documented in the heavily regulated US coal industry, this methodology, using modern laser instrumentation, facilitates the collection of the most unbiased, repeatable, precise, and cost-effective* ground cover data possible. As indicated in Section 3.2, a co-located erosion observation transect will occur with each vegetation transect.

4.3.2 Recommendations

Depending on the results of data analyses from the quantitative surveys and interpretation of observations, appropriate management recommendations will be generated for the target unit. For most efforts on a reasonable path to growth and development, it is anticipated that a recommendation to continue with Stage II or proceed to Stage III or Bond Relinquishment (Step 6) will be forthcoming. Other possible recommendations include:

1. Allow additional time for the establishing community to mature and then re-evaluate using Stage II Protocols.

2. Re-treat all or parts of a unit by reseeding, fertilizing, weed control efforts, addressing acid generation or stability concerns, etc. and continue monitoring using Stage II protocols as necessary.

Advancement to Stage III monitoring or Bond Relinquishment (Step 6) would be based on the estimated amount of expressed vegetation in the target reclamation unit(s) in comparison to the success criterion based on the appropriate reference area. When the amount of vegetation cover approaches (and is expected to exceed the following year) or presently exceeds the appropriate success criterion, then either Stage III or Bond Relinquishment activities may commence. Typically, a minimum period of three growing seasons is necessary before final relinquishment sampling could or should occur.

4.4 Compliance Monitoring for Units Not Operationally Ready for Release (Stage III)

* In typical reclamation, transects completed with laser instrumentation can be implemented by an experienced observer at a rate of 6 or 7 transects per man-hour of effort with a range of 4 to 9 depending on the diversity of vegetation and size of the reclaimed unit. Addition of the co-located erosion observation transect will slow this rate of speed by 50% +/-.

Following passage of Stage II, many units of reclaimed land will not be operationally ready to be released by mine management (i.e., there may be potential need to reopen any given facility). As indicated above, if an area is not managerially or operationally ready for relinquishment, monitoring using Stage II protocols should continue to occur to validate the status of the unit and insure that no additional work or remediation is necessary. In this regard, compliance monitoring once every 3rd year should be completed until as such time as mine management indicates a particular facility is managerially or operationally ready to be released.

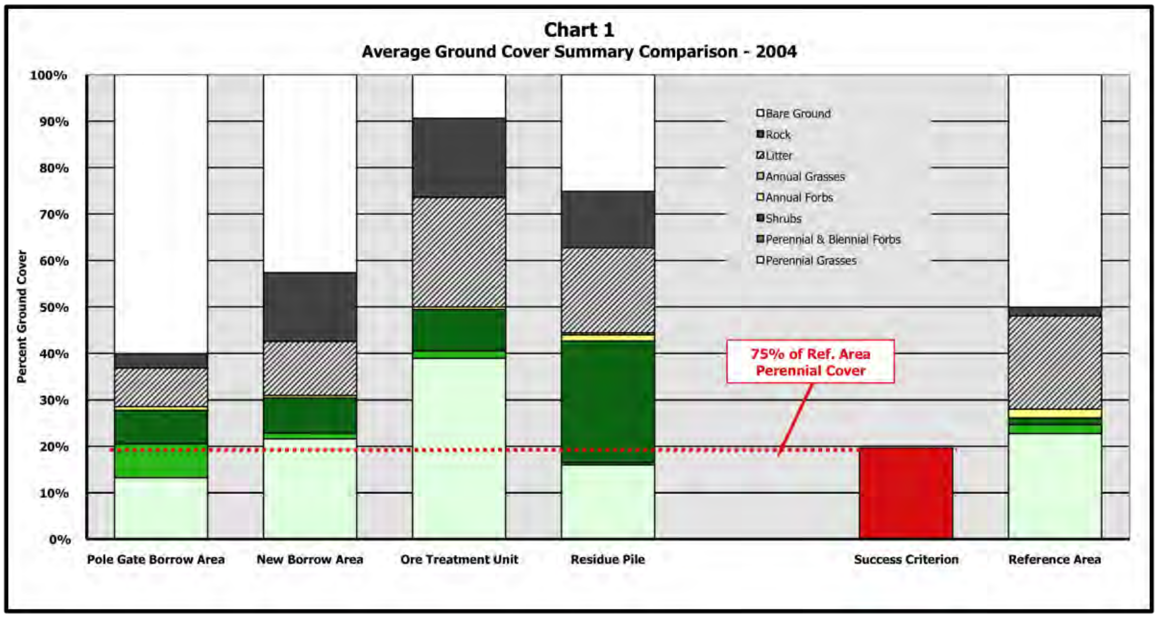
5.0 PREPARE MONITORING REPORT (STEP 5)

Monitoring reports should consist of three levels of communication: 1) immediate, 2) short-term, and 3) standard longer-term documentation. Immediate reporting should be used for observations of conditions (or lack thereof) that need immediate attention from environmental or reclamation department staff. Such reporting would be verbal and may consist of a site review with appropriate staff either immediately (same day) or at the end of the field evaluation period (within a few days). If conditions requiring immediate attention are not observed, then immediate verbal feedback of "nil" circumstances should still occur at the end of the field evaluation period.

Short-term reporting should be used for observations of conditions that need attention during the current field season, but do not warrant "immediate" attention. For example, poor take by seeded species over a portion of a reclamation unit that would benefit from reseeding during the current field season. Such matters could be addressed by a brief, field report of only a few pages length utilizing sketches rather than computer generated mapping for spatial information. Short-term reports should be delivered to the appropriate department staff within a matter of weeks (less than four would be best). Furthermore, short-term "field" reports should also include documentation of any "immediate reporting" that occurred during fieldwork.

The third level of reporting involves the standard longer-term documentation of field activities and findings that will be prepared during the non-field season. This report will present the results of monitoring data analyses and any management recommendations in a user-friendly format. Reporting will provide a detailed description and exhibition of the methodology utilized in a manner similar to that presented within a refereed journal article that would allow an independent 3rd party to repeat the work. Results will be presented and described, by segregate unit (treatments and/or reclamation units) in text, tabular, and as possible graphic form to aid interpretation by reviewers. For example, comparisons with reference / analog area data (shown as a "threshold value") will facilitate immediate comprehension of a reclaimed unit's status. An example of this type of graphic follows below as Chart 1.

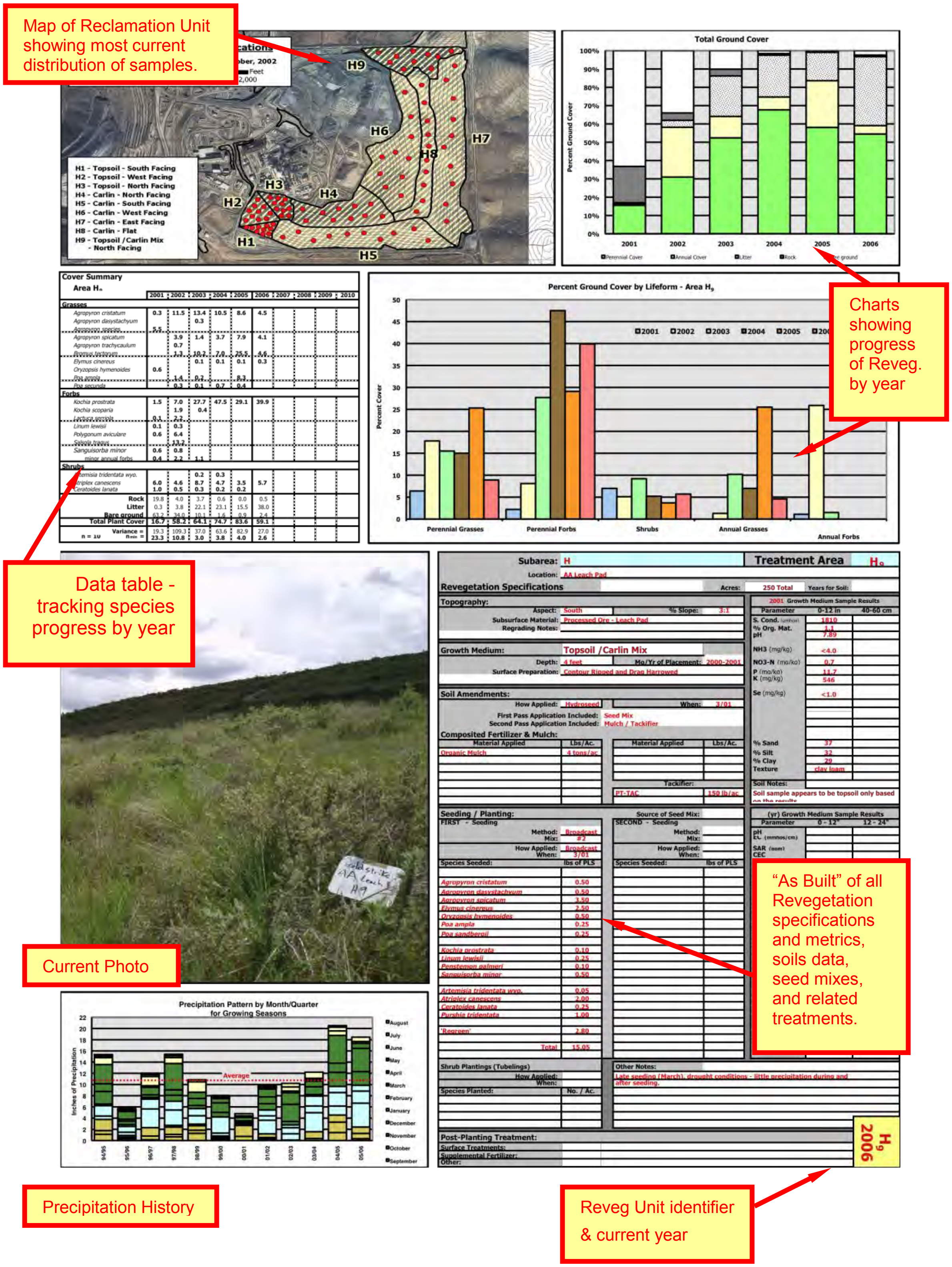
Each full report should present three levels of information: 1) an executive summary, 2) a detailed presentation of findings (including summarized data) that targets the technical reviewer such as the mine's reclamation staff or regulatory oversight personnel, and 3) an appendix that presents all raw data (tabulated and organized) and 1st order summaries to facilitate an independent corroboration of findings.



An executive summary with summary graphics (such as presented immediately above) should be developed to provide higher level management a quick synopsis of the most pertinent findings, especially with regard to reclamation units that have achieved sufficient status as to be "releasable" from the permit. All technical analyses, 2nd and 3rd order summary information, interpretation of findings, recommendations, etc. should be presented in the main body of the document along with supporting mapping and analyses. Included within this section of the report, or appended as appropriate, should be a detailed summary and compilation of all pertinent current and past data with regard to each unit of reclaimed land under investigation during that year. These compilations ("Compendiums") are very useful to technical managers as they present a current "snapshot" of the status of reclaimed lands as well as all pertinent historic, background, and spatial data in a one page format (see Exhibit 2). Finally, all supporting, but non-essential raw data for the technical component of the report should be tabulated and organized and presented in an appendix to the document.

In this manner, all managerial needs and requirements of agency permitting / documentation should be satisfied. In addition to recommendations relating to financial assurance relinquishment, additional recommendations resulting from the monitoring program may include: recommendations to modify reclamation procedures and/or seed mixtures for future reclamation areas, recommendation for weed control and recommendations regarding future grazing management. A summary section should be developed as a portion of the monitoring report that includes an overall summary table and map exhibiting the reclamation status of all reclaimed areas.

Exhibit 2 - Compendium – Summary of All Pertinent Data re: Each Segregate Reclamation Unit – 11x17 Format


Map of Reclamation Unit showing most current distribution of samples.
Charts showing progress of Reveg. by year
Data table - tracking species progress by year
Current Photo
“As Built” of all Revegetation specifications and metrics, soils data, seed mixes, and related treatments.
Precipitation History
Reveg Unit identifier & current year
H9 2006

6.0 DEVELOPMENT OF SITE-SPECIFIC STANDARDS FOR DETERMINATION OF SUCCESSFUL RECLAMATION AND SUBSEQUENT FINANCIAL GUARANTEE OR ASSURANCE RELINQUISHMENT FOR MINED OR "MINE-RELATED" AREAS (STEP 6)

6.1 General

This section details sampling and analysis procedures and the final reclamation success criteria (standards) for evaluation of reclamation of mine-related disturbances. These criteria and protocols are developed in accordance with Barrick's Environmental Policies and will typically meet or exceed regulatory requirements in the U.S. and elsewhere in the world. <u>This section does not include a separate analysis for Erosional Stability (see Step 3 – Section 3.3.2). However, a demonstration of Erosional Stability as detailed in Step 3 should occur for final relinquishment to document success with regard to this variable.</u>

In addition to identified "standards" a set of "goals" may/will be identified to assist in the evaluation and interpretation of targeted reclamation efforts. However, it is important to understand the difference between goals and standards, especially within the context of their use in this document and the reclamation permit. A "standard" is a legally binding level of reclamation performance that must be attained to trigger release of financial sureties and future liability. A "goal" is a desirable result (level of reclamation) that serves to act as guidance for reclamation activities, but has no legal bearing on the release of financial sureties or liability if attainment is not achieved. In other words, goals help to guide reclamation in the desired direction, but standards offer the minimally acceptable level that must be achieved to have a legal consequence.

Consistent with the requirements of Reclamation Permitting, final reclamation success will be evaluated through three broad concepts:

- Documentation that erosional stability has been achieved as detailed in Step 3.
- Comparison to an adequate analog or reference area(s) representative of the pre-existing vegetation community(s) and/or desirable baseline / ecological conditions which will act as surrogate for the post-mining land use;
- Evaluation of plant species present in, and/or resulting from, the proposed (and planted) seed mixes.

Total vegetative cover and composition are important factors in determining the success of reclamation efforts. However, of equal importance to reclamation success is the achievement of soil stabilization. Without soil stability, reclamation efforts may regress along the successional continuum and thereby preclude the achievement of long-term land use goals. In this regard, prior to, or concurrent with a vegetation evaluation, a determination of soil stability should be documented through procedures detailed under Step 3 of this document.

The long-term goal of reclamation efforts is to establish self-sustaining biotic systems with appropriate ecological resistance and resilience. This does not necessarily mean that the reclaimed area will exactly replicate the surrounding vegetation communities, but that it will successfully support the designated post-mining land uses. In general, it would be an undesirable condition that the reclaimed area match exactly the surrounding vegetation communities, since community diversity adds significantly to overall habitat diversity for an area. As appropriate, seed mixtures designated by the reclamation plan are largely composed of species native to the region. Also as appropriate, seed mixes contain a complement of grasses, forbs, shrubs and trees to provide establishment of a diverse plant community within reclaimed areas.

6.2 Proposed Reclamation Targets

6.2.1 Reclamation "Goals"

The Reclamation Plan establishes the goal of reclamation as follows:

- Perennial vegetative cover as close as possible to 100 percent of selected comparison (analog or reference) areas; or

- Perennial vegetative cover that is on a reasonable successional path to achieve as close as possible 100 percent of selected comparison (analog or reference) areas.

In certain circumstances, woody plant density may need to replace the variable of cover, and in other circumstances the limitation to perennial vegetation may not be appropriate. However, the stated goals will suffice for most operations.

Although the goal of the reclamation program is to achieve "as close to 100% of the perennial plant cover as possible, success must be based on reasonably achievable standards that reflect the minimum levels necessary for return of the permit area to a self-sustaining ecosystem. Therefore, reclamation success will be assessed against a performance "standard" for vegetative ground cover. Reclamation efforts will be considered successful when standards have been met following at least three growing seasons since planting efforts.

6.2.2 Vegetative Ground Cover Standard (Success Criterion)

Vegetative ground cover should be utilized for the vast majority of reclamation circumstances and must meet the following criterion:

> The total vegetative ground cover (exclusive of annual species and litter) in the reclaimed unit equals or exceeds a value set between 60% and 90%, of the total vegetative ground cover (exclusive of annual species and litter) of the analog or reference area. The exact percentage must be based on site-specific circumstances or negotiated values with regulatory agencies. Absent such negotiated values, the initial standard shall be set at 75% until site-specific evaluations dictate otherwise. (Precedent for 75% has been set in the U.S.)

In those environments where annuals form a significant component of the floral composition and cover, the 75% standard shall apply to all live (during the current growing season) vegetation (excluding noxious weeds).

6.3 Reclamation Evaluation Procedures

Monitoring and eventual evaluation will typically involve sampling of ground cover within each reclaimed unit under consideration for financial guarantee or assurance relinquishment (and at least 3 years of age) and the appropriate analog or reference area. Species diversity information will be calculated from the ground cover data and presented for informational purposes to document goal-related composition that will then indicate ecological resilience and progress toward the desired land use. Sampling for ground cover will be accomplished utilizing the point-intercept procedure along transects of 100 intercepts each, preferably using modern instrumentation (e.g. lasers or optics).

6.3.1 Sampling

The first step of the vegetation sampling procedure is to obtain ground cover data from each reclaimed (managerial) unit to be evaluated. Ground cover samples also will be obtained from the analog or reference area(s). Sampling will occur approximately during the peak standing biomass period of the year (early- to mid-summer) and sampling locations will be determined utilizing a systematic (bias-free) method with a random start[4]. This systematic procedure also provides proportionate representation from across each reclaimed unit for additional characteristics such as aspect, slope, etc.

6.3.1.1 Sample Site Location.

The systematic procedure for sample location in both a reclaimed unit and the analog or reference area will occur in the following stepwise manner. First, a fixed point of reference will be selected for the area to facilitate location of the systematic grid in the field. Second, a systematic grid of appropriate dimensions will be selected to provide a reasonable number of coordinate intersections (e.g., 15 or 20) that could be used for the initial set of sample sites. Third, a scaled representation of the grid will be overlain on field maps of the target unit extending along north/south and east/west lines or other appropriate direction. Fourth, the initial placement of this grid will be implemented by selection of two random numbers (an X and Y distance) to be used for locating the first coordinate from the fixed point of reference, thereby making the effort unbiased. Fifth, where an excess number of potential sample points (grid intersections) is indicated by overlain maps, the excess will be randomly chosen for elimination unless it is later determined that additional samples are necessary to meet sample adequacy. If additional samples are needed, the eliminated potential sample sites will be added back in reverse order until enough samples have been collected. Sixth, utilizing compass and pace techniques or a handheld GPS, the sample points will be located in the field.

6.3.1.2 Ground Cover Determination.

[4] Systematic sampling (with random initiation) is superior to other sample distribution procedures because it forces representation from across the reclaimed unit. It accounts better for heterogeneous expressions of multiple seedings or reclamation conditions by "forcing" a patterned distribution of samples. This method thus minimizes the risk that significant pockets will be either entirely missed or overemphasized. However, in research applications statistical analysis methods may be limited.

Ground cover at each sampling site will be determined utilizing the point-intercept methodology as illustrated In Exhibit 1. This methodology will be applied as follows: First, a transect 10 meters in length will be extended from the starting point of each sample site toward the direction of the next site to be sampled. Then, at each one-meter interval along the transect, a “laser point bar”, “optical point bar” or 10-point frame will be situated vertically above the ground surface, and a set of 10 readings recorded as to hits on vegetation (by species), litter, rock (>5mm), or bare soil. Hits will be determined at each meter interval as follows:

1. When a laser point bar is used, a battery of 10 specialized lasers situated along the bar at 10-centimeter intervals will be activated and the variable intercepted by each of the narrow (0.02”) focused beams will be recorded (see Exhibit 1);

2. If an optical point bar is used, intercepts will be recorded based on the item intercepted by fine crosshairs situated within each of 10 optical scopes located at 10-centimeter intervals;

3. If a 10-point frame is used (historical instrumentation), sharpened needles will be used to determine intercepts at 10-centimeter intervals. Care will be taken to NOT record “side touches” on the pins as this will result in a significant overestimation error.

The following sampling rules should apply during data collection. Intercepts will be recorded by species for the first (typically tallest below 1.5 meters) current annual (alive during the current growing season) plant part intercepted without regard to underlying intercepts or attachment to a living base. Otherwise, the intercept will be classified as cryptogam, litter, rock or bare soil. Rock intercepts are based on a particle size of 5 mm or larger to facilitate RUSLE evaluations, otherwise it would be classified as bare soil. To distinguish between current year senescent plant material and litter (including standing dead), the following rule should apply: 1) if the material is gray or faded tan it should be considered litter; and 2) if the material is bright yellow or beige it should be considered current annual (alive) and recorded by species. On occasion, experience with non-conforming taxa may override this rule.

When using laser or optic instruments during windy field conditions, the observer should consistently utilize one of the following techniques for determining a hit: 1) record the first item focused upon that is intercepted by the narrow laser beam or cross-hair; 2) wait a few moments and record the item intercepted for the longest time, or 3) block the wind and record the intercept. When using a pin frame, the observer must wait for the wind to subside.

With regard to gaps in the overstory, the point-intercept procedure naturally corrects for overestimations created by 2-dimensional areal (quadrat) or 1-dimensional linear (line-intercept) techniques. In this regard, the 0-dimensional point is extended along a line-of-sight until it “intercepts” something that is then recorded. Frequently points simply pass through overstory gaps until a lower plant part, litter, rock or bare soil is encountered.

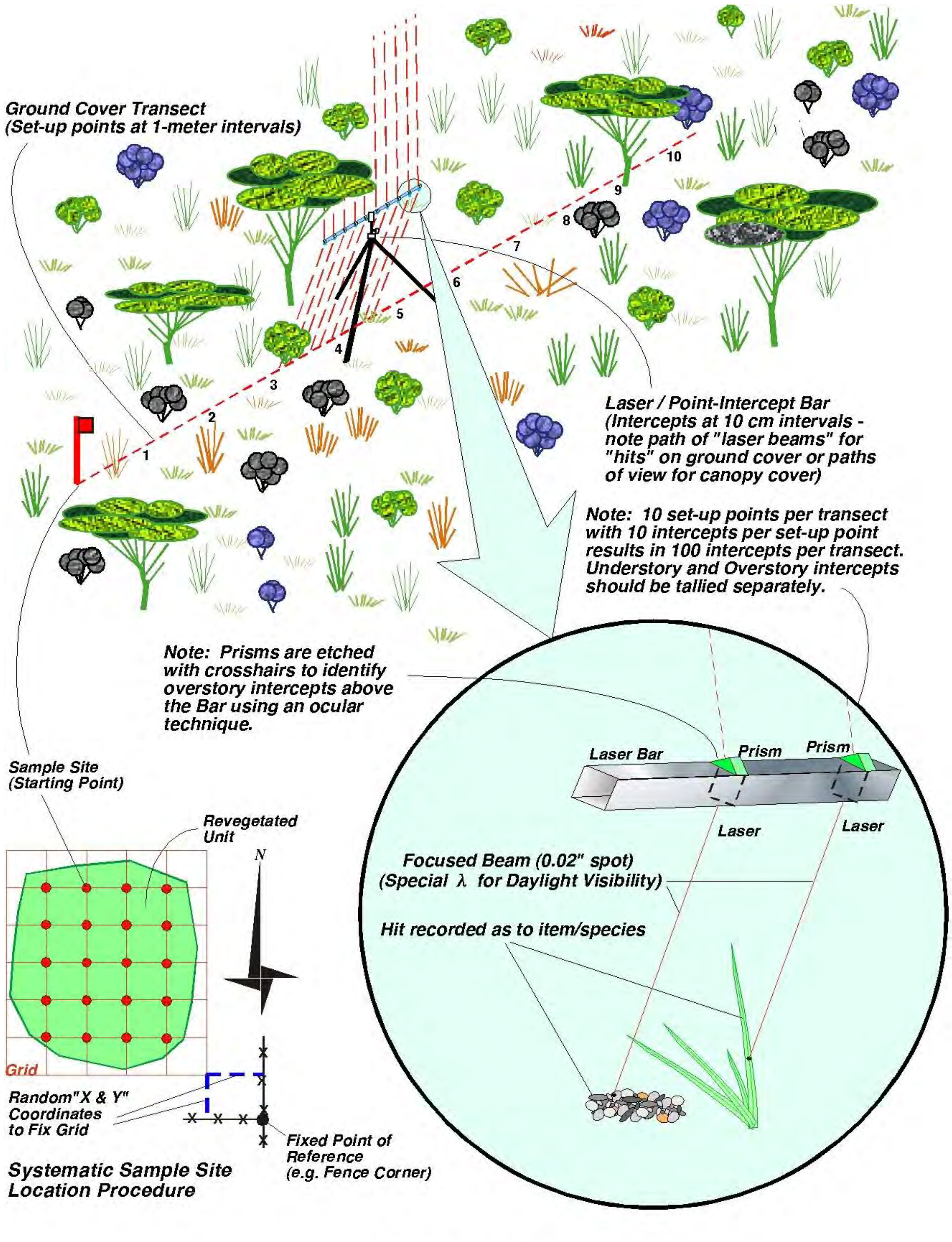


Exhibit 1

Sampling Procedure at a Systematic Sample Site Location

Regardless of instrument, a total of 100 intercepts per transect will be recorded resulting in 1 percent cover per intercept. This methodology and instrumentation (excepting the 10-point frame) facilitates the collection of the most unbiased, repeatable, precise, and cost-effective ground cover data possible.

Overstory Cover. In certain circumstances (e.g., various Acacia species in Australia), young reclamation can exceed 1.5 meters in height. In these instances, overstory cover should be recorded separately from the understory cover (below 1.5 meters). Point-intercepts can be collected above the ground cover equipment with the aid of prisms etched with cross-hairs (see Exhibit 1). In this regard, intercepts will be recorded by species, with all other intercepts being non-applicable (sky). The sampling rules indicated above should again be used as appropriate. To facilitate ground cover calculations, any understory hit that occurs concurrently with an overstory hit will be recorded as a 2nd intercept and will not be included in the total that must add up to 100%.

RUSLE-Specific Measures – Fall Height. When a RUSLE evaluation is to occur, the following metric will be included with the ground cover procedures to facilitate proper input variables. Following completion of each ground cover transect, an estimate of average fall height (closest 1/2 foot) will be recorded. Average fall height is defined as the height within the canopy from which intercepted raindrops re-form into water droplets and fall to the ground; this fall distance is known as the "effective fall height." In plant communities that have more than one type of vegetation composing the canopy (e.g., both a shrub and tree stratum), a fall height should be determined for each life form. It is typically unnecessary to estimate an average fall height for grasses and forbs, as they are relatively close to the surface and rain droplets tend to follow the stems to the ground rather than reforming and falling. At the completion of each vegetation transect a visual estimate of the average fall height for shrubs encountered should be recorded as well as a separate estimate for any trees. Where necessary, a height measurement tool (rule, staff, etc.) may be utilized to obtain the estimate. The upper limit for the measurement should be the average height of the mid-point for the volume of canopy. For example, if the canopy where spherical in nature, the height would be estimated from the ground to the central radius point. If the canopy were pear shaped, the height would be determined from a point somewhat lower. These fall heights will then be weighted based on canopy cover of each life form to establish an average fall height for the transect, and the fall heights for the total number of transects for a given unit will be averaged for entry into the RUSLE application.

6.3.1.3 Sampling Adequacy.

Data collection will continue within each discrete sampling unit (reclaimed unit or analog / reference area) for ground cover until a statistically adequate sample has been obtained. Adequacy of sampling will be achieved when, for each discrete unit, the number of samples actually collected (n) provides a level of precision within 10% of the true mean with 90% confidence (n_{min}), i.e., when $n_{min} \leq n$, and n_{min} is calculated as follows:

$$\boxed{\mathbf{n_{min} = (t^2 s^2) / (0.1\bar{x})^2}}$$

where: **n** = the number of actual samples collected with a minimum of 10 in each unit;

t = the one-tailed value from the t distribution for 90% confidence with n-1 degrees of freedom;

s^2 = the variance of the estimate as calculated from the initial samples;

$\bar{x}$ = the mean of the estimate as calculated from the initial samples.

For environments that are arid and native vegetation is somewhat sparse (e.g., areas with less than 380 mm (15 inches) of annual precipitation), sampling adequacy may be relaxed by sampling to within 20% of the true mean with 90% confidence. In this regard, the 0.1 in the denominator of the $\mathbf{n_{min}}$ equation above will be changed to 0.2.

For environments that are very arid and native vegetation is quite sparse (e.g., areas with less than 250 mm (10 inches) of annual precipitation), sampling adequacy may be further relaxed by sampling to within 20% of the true mean with 80% confidence. In this regard, the 0.1 in the denominator of the $\mathbf{n_{min}}$ equation above will be changed to 0.2, and the t value from the t distribution will be selected from the 80% confidence column with n-1 degrees of freedom (one-tailed distribution).

As indicated above for most circumstances, this formula provides an estimate of the sample mean to within 10% of the true population mean (μ) with 90% confidence. Calculations of the mean and variance will be based on "total vegetation ground cover" exclusive of litter, but including annuals. Furthermore, a minimum sample size of ten (10) samples (20 for units larger than 50 hectares) will be collected from each discrete reclaimed unit or the analog / reference area. If the initial ten (or 20) samples do not provide an adequate estimate of the mean (e.g., the inequality above is false), additional samples will be collected until the inequality is satisfied. However, in no case will more than 40 ground cover transects be collected in any given sampling unit.

6.4 Ground Cover Comparison Standard

After adequate sampling, the comparison process will be initiated by calculating the mean ground cover value for non-annual plants (non-annual ground cover, or "NAGC") for each reclaimed unit and analog / reference area. The test for reclamation success for ground cover will occur as follows.

Determine whether the mean NAGC of the reclaimed unit(s) ($\bar{x}_{(rv)}$) equals or exceeds 75 percent of the mean NAGC for the analog /reference area ($\bar{x}_{(co)}$). In other words, if the inequality $\bar{x}_{(rv)} \geq 0.75\ (\bar{x}_{(co)})$ is true, then the ground cover test has been passed.

In areas with less than 250 mm (10 inches) of precipitation, annual ground cover shall not be excluded from the above comparison unless they are locally identified as noxious or invasive weeds.

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CASE STUDY: PEANUT MINE RECLAMATION PROJECT; GUNNISON COUNTY, COLORADO

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ABSTRACT

The Peanut Mine is located near the Town of Crested Butte in the central Colorado Rockies. The Peanut is an historic coal mine that was active in the late 1800's and early 1900's. Thousands of yards of anthracite coal waste materials, some of which displayed a propensity to spontaneously combust, were left at the site following abandonment.

Following abandonment of the coal mine, a silver mill was constructed at the site. The silver mill, which processed ore transported to the site from throughout Gunnison County, operated sporadically through the mid 1970's. Acid generating silver mill tailings were stored in impoundments situated within and immediately adjacent to the Peanut Mine site.

The Colorado Division of Reclamation, Mining and Safety; Inactive Mines Reclamation Program and Peanut Mine Inc, a non-profit corporation committed to preserving open space for public use, formed a partnership dedicated to reclaiming this mixed waste site. This unique partnership not only overcame significant environmental issues, but was able to design and construct this abandoned mine restoration project using innovative reclamation and revegetation techniques, while providing for federal, state and local involvement at all stages of project design and construction. The Inactive Mines Reclamation Program was presented with the Excellence in Abandoned Mine Land Reclamation National Award by the U.S. Office of Surface Mining in 2008 for its reclamation efforts at the Peanut.

INTRODUCTION

The Peanut Mine Reclamation Project represents a number of unique circumstances that melded together to create an interesting restoration problem. The complexity of the problem required innovative partnerships and technical reclamation techniques in order to accomplish environmental restoration of this property.

The Peanut Mine is located approximately one mile north of Crested Butte in Gunnison County, Colorado (Figure 1). The site is located at approximately 9,000 feet above sea level, and annually receives about fifty six inches of moisture, primarily as snow and intense summer thunder showers. The vegetative communities adjacent to the Peanut Mine are composed mainly of mountain big sagebrush shrub grasslands with interspersed trees.

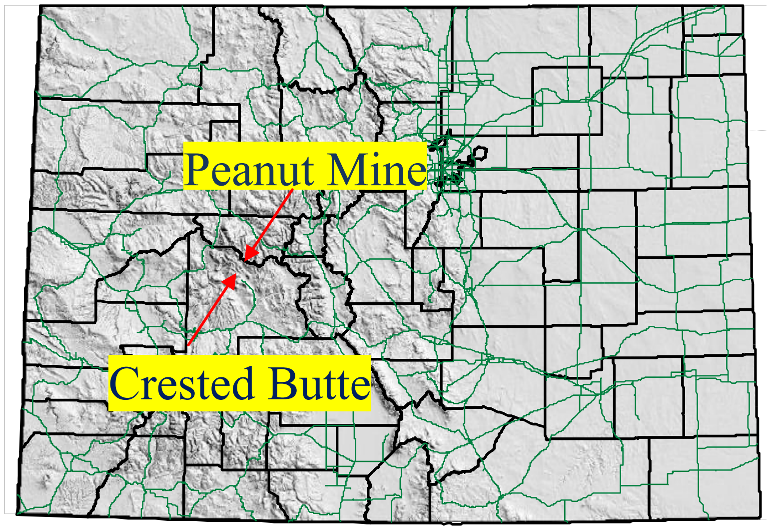

Figure 1. Locations of Crested Butte and the Peanut Mine, Gunnison County Colorado.

This paper discusses reclamation of the sixteen-acre Peanut Mine, an atypical reclamation project. In order to put the reclamation task into an appropriate context, a history of the site is provided, and a discussion of the partnerships formed between the Colorado Division of Reclamation, Mining and Safety, and local public interest groups, the town school and state and federal agencies is included. Reclamation techniques used in the process are discussed as are project outcomes.

PEANUT MINE SITE HISTORY

The Peanut was a moderately significant coal mine, active in the late 1800's and early 1900's. A hard anthracitic coal was extracted from two, four feet thick seams that were mined at the Peanut. Large quantities of refuse were left at the site as a result of the relatively inefficient coal mining and preparation techniques employed at the time. The refuse piles contained large quantities of slightly metamorphosed shales and sandstones intermixed with remnant anthracite. Production at the Peanut ceased as mining operations in the Crested Butte area began to focus on more easily extractable seams of bituminous coal located closer to town.

The higher elevation mountains of northern Gunnison County supported a myriad of relatively small hard rock mines in the late 1800's and into the 1900's. These mines extracted silver, tin, lead, gold, and other semi-precious metals. A Crested Butte area mill site was needed to process hard-rock ore extracted from nearby mining districts. The Peanut mine site was selected for a custom milling operation that accepted ore from throughout the area. It is presumed that this site was selected as it was located close to a railroad, power was available, and water was easily obtained.

The milling facility was constructed on the west side of the Peanut Mine site. Ore was brought to the site, stockpiled and processed at the west side mill. Mill waste materials were deposited at the east side of the Peanut Mine. This mill waste was accumulated in both constructed tailings ponds and in naturally occurring topographic depressions.

Milling operations reportedly occurred on a sporadic basis through the early 1970's. Milling operations had completely ceased by the mid 1970's, and the property fell into disrepair, primarily being used as a convenient, albeit illicit, junkyard and paint ball facility through the late 1990's.

During the 1990's a trail system was being established through the upper Gunnison valley for use by hikers and mountain bike riders. A significant portion of the trail system includes the Lower Loop Trail, which begins at Crested Butte, bisects the Peanut Mine property and extends further north (Figure 2). As a result, hundreds of walking or bicycling visitors pass through the Peanut Mine property daily during the summer months. Historically, these visitors have complained about the yellow stained dirt and the sulfuric smell associated with it.

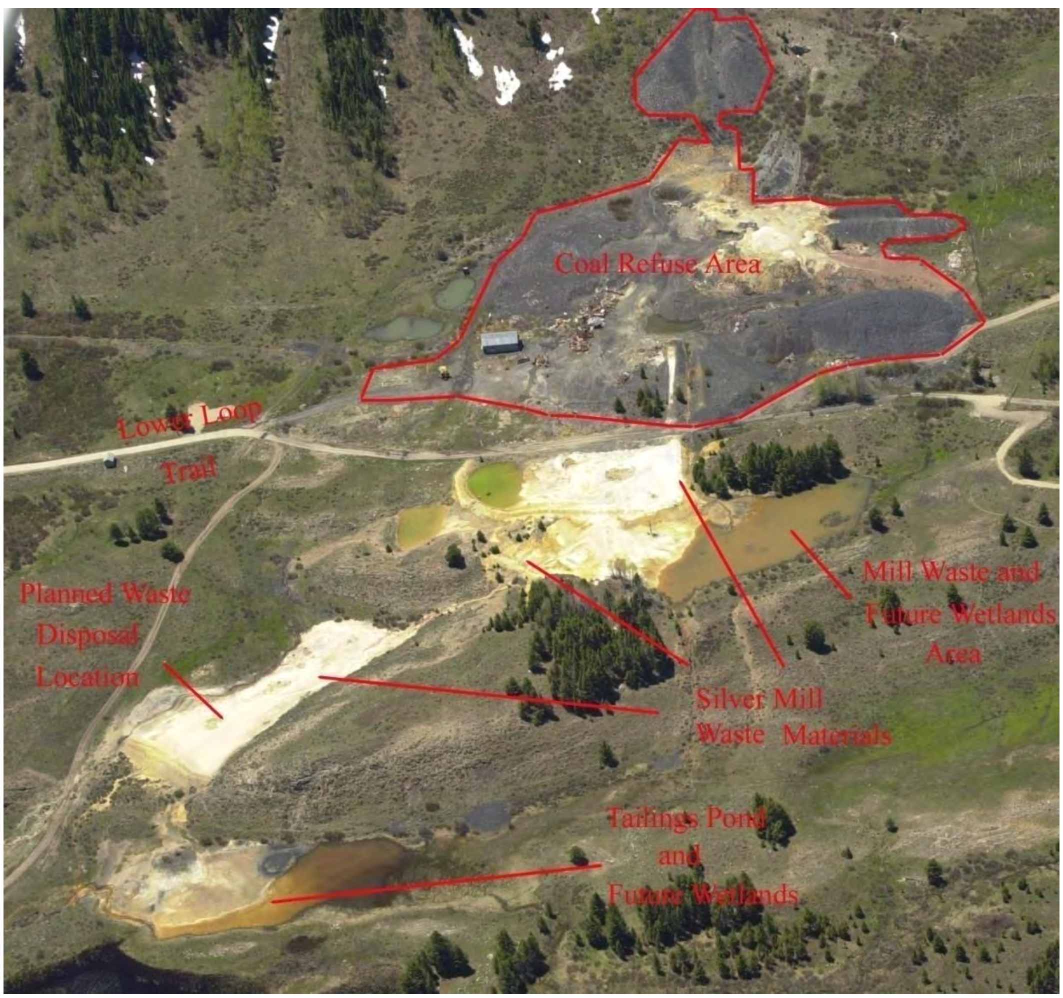

Figure 2. Aerial View of Sixteen Acre Peanut Mine Site, With Locations of Coal Refuse Materials and Silver Mill Wastes.

The property languished as an eyesore and an environmental problem along the Lower Loop Trail due to the acid production and metals mobilization that occurred as a result of the weathering of the silver mill wastes. The coal waste material on the west side of the Lower Loop Trail compounded site problems. Additionally the lack of any vegetative cover at the site lead to erosion of the mine and mill wastes, and resultant sediment deposition in nearby Peanut Lake.

During the summer of 2000, one of the coal refuse piles spontaneously combusted, reportedly not for the first time. The land owner, an energy company, was notified of the occurrence, and responded to the site. The Colorado Division of Reclamation, Mining and Safety (the Division) consulted to the Crested Butte Fire Protection District, providing guidance on how best to advise the energy company to extinguish the burning refuse pile.

The fire was eventually excavated and extinguished by the land owner. The propensity of the Peanut coal mine refuse to spontaneously combust elevated the mine to a Priority 1 site by the Division, as the potential for another combustion event to occur was thought to be high.

Following the fire, the Crested Butte Land Trust (Land Trust), a local non-profit organization dedicated to preserving open space in the Crested Butte area for public use, began to negotiate with the land owner to purchase the Peanut Mine property. Simultaneously, the Division began to develop plans geared toward ameliorating the spontaneous combustion potential of the coal refuse. Shortly after it acquired the property, the Land Trust and the Division agreed that reclamation of the entire site was an appropriate course of action to pursue in order to relieve the coal ignition issues and to eliminate the acid production and metals mobilization problems that develop at the site. To that end, the Division and the Land Trust began a five-year process to characterize the site, develop community partnerships, establish funding mechanisms, design a reclamation plan, and complete reclamation construction.

State and Local Cooperation

Within a year of the coal refuse fire the Land Trust acquired the property. The Division had previously communicated to the Land Trust its desire to ameliorate the coal combustion issues at the site. Both parties were well aware that reclamation of the entire area was more desirable than reclamation of only the coal related issues. However reclamation of the mixed waste Peanut Mine site exceeded the mission of the Division, as only the coal mine portion of the site was eligible for reclamation funding under the Colorado Inactive Mines Reclamation Program. The easterly portion of the property, which was not eligible for reclamation funding through the Division, was heavily impacted by the deposition of silver mill tailings and thus needed to be an integral part of the overall site reclamation plan. Therefore innovative processes needed to be developed in order that the entire site benefits from the reclamation efforts.

Discussions between The Division and the Land Trust evolved until a conceptual plan addressing reclamation of all mine wastes as complimentary components of a larger site restoration project were agreed upon. The Division would design, and manage site reclamation and finance all of the coal related reclamation tasks, while the Land Trust would finance reclamation of the non-coal portions of the reclamation plan using a variety of non-traditional sources.

The Crested Butte Land Trust holds many properties for public open space in Gunnison County. Typically, the properties that the Land Trust purchases are ranches, grazing lands, and other agricultural or undisturbed areas. Adding an abandoned mixed waste mine site to its inventory of properties was a novel concept for the organization. In order to protect its many land holdings from liabilities it could incur at the Peanut Mine, the Land Trust created a subsidiary corporation, Peanut Mine Inc (PMI), to act as sole owner of the Peanut Mine property. In order to further insulate other properties held by the Land Trust from potential Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) liabilities at the Peanut, PMI applied for and received a Voluntary Clean Up Permit (VCUP) issued by the Colorado Department of Public Health and the Environment (CDPHE). This permit protects PMI from CERCLA liabilities, and allowed the organization to apply for both State and Federal grants to help fund their portion of the Peanut Mine reclamation. A primary component of the VCUP was the reclamation plan ultimately developed by the Division. The VCUP also contained vegetation establishment and erosion control performance standards as conditions of permit termination.

Peanut Mine Inc. applied for grants from the Environmental Protection Agency and the Colorado Department of Public Health and the Environment in order to finance the majority of its reclamation funding obligation. An EPA Brownfields grant in the amount of $200,000 and a CDPHE grant in the amount of $70,000 were awarded to PMI. These funds, in addition to a $50,000 grant from the Gates Foundation, were used to offset the PMI silver mill waste reclamation financial obligations.

The Division and PMI agreed that for economic and construction management purposes, hiring a single contractor to accomplish reclamation of the Peanut would be most efficient. However, both parties had to carefully account for the expenditure of their respective funds during the reclamation construction process. To that end, it was necessary to create a mechanism through which a contractor could be paid for accomplishing specific tasks, and yet account for the source of the funds used to pay for completion of individual components of specific reclamation tasks.

PMI and the Division crafted a Cooperative Agreement and associated cost-by-task based spreadsheet that provided for distribution of funds from the various grants and sources to the contractor as certain reclamation tasks or portions of tasks were completed. Pay centers were established and a project expense / cost center spreadsheet was developed so that billing of individual line items could be accurately and efficiently assigned to the corresponding responsible entity. To accommodate this arrangement, the Division established a reclamation account into which all of the reclamation funds from both parties were deposited.

COMMUNITY PARTNERSHIPS AND SITE EVALUATION

The first steps in planning reclamation of the Peanut Mine site was to gain an understanding of the environmental impacts of the mixed coal and hard rock waste materials, define the characteristics of these materials, map existing site conditions and determine the volume of the various waste materials by type.

Rather than completing reclamation planning in a vacuum, the Division decided that it would involve the community in the entire reclamation process. To this end, the Division funded a

Reclamation Studies class at the Crested Butte Community School. This high school class emphasized characterization of highly disturbed areas, and planning for rehabilitation of such a site. The class used the Peanut Mine as an outdoor classroom, obtaining samples of the various mine wastes for geochemical analysis, performing water quality sampling, and establishing vegetation test plots to help design site-specific soil and revegetation suggestions, among other reclamation related activities.

The Division also enlisted the help of the community when developing the reclamation seed mixture. Division ecologists developed a conceptual seed mix for the site. Area residents knowledgeable about local vegetative communities were asked to review the seed mixture and offer suggestions regarding alternative species, seeding rates and other pertinent aspects of the plan. As a result of this collaborative effort, the mixture was refined so that local conditions were best accommodated (Table 1). Further, local volunteers gathered seed from a number of area specific species to supplement the commercial seed mixture.

In addition to this work, the Division recruited the Office of Surface Mining, Western Coordinating Center (OSM), to construct a pre-reclamation topographic map of the site using LIDAR technology. The OSM flew the site and provided the LIDAR generated data to the Division. This information, field verified by the Division, was used as the basis for topographic maps that were manipulated to design post-reclamation topography and to ascertain material cut and fill volumes for bidding purposes.

The Division also conducted geochemical evaluations, geotechnical investigations, water quality analysis, ground water and surface water evaluations, wetlands delineation and other pertinent investigations to fully characterize the site. This information provided the basis for development of a reclamation plan that addressed the entirety of the site so that a holistic approach to site remediation could be developed.

In order to accommodate various regulatory requirements, two reclamation construction related permits were necessary before construction could begin. Peanut Mine Inc, as owner of the property, was the applicant for each permit. Because the Division was designing and supervising reclamation construction, it acted as the on-site coordinator for each permit.

The U. S. Army Corps of Engineers was consulted early in the reclamation planning process, in order to ascertain whether any Clean Water Act issues would be presented during site reclamation. Because the watercourse that conveys the adit drainage would be reconstructed during reclamation, a Section 404 permit was issued. The permit was later modified to accommodate dredging and reconstructing a wetlands area contaminated by mill waste products.

The Colorado Department of Public Health and the Environment was contacted to determine the necessity of obtaining a stormwater discharge permit to accommodate construction and post reclamation sedimentation issues. At the advice of CDPHE, a stormwater management plan was developed and a stormwater discharge permit was issued to PMI. The stormwater management plan was developed in such a manner so that reclamation requirements imposed on the contractor

Table 1. Peanut Mine Seed Mixture

GRASS MIXTURE

Species	**Common Name**	**Variety**	**PLS #/ac**
Pascopyrum smithii	western wheatgrass	Rosanna	1
Pseudoroegneria spicata ssp. Inerme	beardless bluebunch		3
Elymus trachycaulus ssp. Trachycaulus	slender wheatgrass	San Luis	3
Elyus glaucus	blue wildrye		3
Poa canbyi	Canby bluegrass		0.5
Stipa comata	Needle and Thread		3
Bromus marginatus	Mountain brome	Bromar	4
Festuca arizonica	Arizona fescue		1
Festuca idahoensis	Idaho fescue		1
Tritocale ssp	“Quickguard”		12

FORB MIXTURE

Species	**Common Name**	**PLS #/ac**
Balsamorhiza sagitatta	arrowleaf balsamroot	3
Penstemon strictus	Rocky Mtn penstemon	0.5
Erigeron speciosus	Aspen daisy	0.25
Geranium viscosissimum	wild geranium	1
Lupinus alpestris	mountain lupine	2

SHRUB MIXTURE

Species	**Common Name**	**PLS #/ac**
Artemisia cana	silver sagebrush	0.5
Artemisia tridentata vaseyana	mountain big sagebrush	0.25
Chyrysothamnus viscidiflorus	low rabbitbrush	0.5
Ribes cereum	wax currant	1
Rosa woodsii	Wood's rose	7

as part of the construction specifications dovetailed with the requirements of the plan. Therefore, if construction proceeded as required in the reclamation contract, the site would remain in compliance with the stormwater permit.

RECLAMATION PLANNING

The reclamation product that the Division and PMI envisioned for the Peanut Mine was a geomorphically stable landform that included isolation of silver mill wastes and reduction of coal spontaneous combustion potential, while accommodating eventual use of the area as public open space for non-motorized recreation. A multifaceted approach to reclamation of the site was adopted in order to meet the post reclamation site goals:

- Consolidate all waste materials into a disposal facility for the purpose of isolating the silver mill wastes from the environment and to reduce acid generation potential;
- Dilute and compact the coal wastes in the disposal facility in order to reduce spontaneous combustion potential;
- Create geomorphically stable landforms at the disposal area and at the former locations of the coal and silver waste materials;
- Accommodate overland flow of snowmelt and stormwater runoff through creative placement of channels;
- Encourage wetlands development at specific portions of the site;
- Create a plant growth medium capable of sustaining vegetative growth;
- Establish species capable of replicating the characteristics of adjacent vegetative communities.

In order to comprehensively address the environmental issues at the site, a reclamation plan was developed that accommodated the geochemistry of the various materials and the topography of the site.

Pre-Reclamation Analysis

Geochemical testing of the waste materials when mixed indicated that the coal refuse would buffer the acid generation potential of the mill wastes. Analysis of the testing results indicated that mixing the materials at a ratio of two parts silver mill waste to one part coal refuse would sufficiently buffer the mill waste materials. Analysis of the material volume balances indicated that using this mixture ratio would allow for a minimum five feet thick compacted coal refuse cover to be applied over the mixed waste materials. This compacted coal refuse cover would act as a cap to minimize water infiltration to the mixed wastes while providing a rooting medium for vegetation.

Geotechnical testing of the mixed materials demonstrated that combining the wastes at the specified ratio, and compacting them on a one foot vertical interval would provide sufficient structural strength for a free standing disposal area approaching thirty five feet in height at a 2H:1V or steeper outslope angle.

Evaluation of various physical and topographic characteristics of the site revealed that a canyon used as a mill waste disposal area would provide adequate capacity for the disposal of the mixed waste materials. This location allowed the fill to be buttressed on three sides by the canyon walls, minimized the potential for overland flow to encroach on the disposal area, and provided an opportunity to design a geomorphically functional fill surface.

Because the Peanut was severely disturbed by past mining and milling operations, virtually no topsoil or topsoil substitute was available for reclamation purposes. Initial reclamation concepts envisioned adding organic material to remnant coal refuse and revegetating that material. However, local housing and commercial construction activity accelerated between 2002 and 2004. A large quantity of fill dirt was generated in the upper Gunnison valley due to excavation of building sites. The Peanut Mine site was offered as a place to dispose of this relatively clean fill dirt, and eventually approximately 15,000 cubic yards of fill was stockpiled at the site. Additionally, the Town of Crested Butte provided approximately 500 cubic yards of EPA approved bio-solids to the site.

Conceptual Reclamation Plan

The reclamation concept evolved as analysis of the various physical characteristics of the site was completed. The final reclamation design contemplated construction of a mine- and mill-waste repository in the horse-shoe shaped canyon located at the southern portion of the Peanut property. Construction of a waste disposal repository in this location would entail removal of silver mill tailings from the canyon floor, shaping and compacting the exposed base of the canyon. An acid-neutralizing underdrain system would be built to form the basement of the disposal facility. Mill tailings and coal refuse were to be placed at a specified mixture and compacted to 90% dry density at 15% optimal moisture content. A five to six feet thick cover of coal refuse, compacted to the same specifications, would be placed over the top of the mixed materials.

The reclamation concept for the site included components of the following concepts:

- Coal refuse was to be excavated until natural ground was encountered;
- Two feet of native ground surface below the mill tailings was to be excavated;
- Construct channels to accommodate mine adit drainage, snowmelt and stormwater runoff;
- Use plant materials to aid in channel stabilization and runoff velocity control;
- Establish or re-establish wetlands areas;
- Imported fill distributed at a nominal twelve-inch depth across the site;
- Organic material (certified weed free straw mulch, dry cow manure and bio-solids) to be incorporated into fill material prior to revegetation;
- Shrub islands to be established in small but distinct areas across the site;
- Grass and forb seed to be hand distributed outside the shrub islands;
- Seedling trees planted in clusters around the site following completion of all other reclamation operations.

Once completed in draft form, public meetings were held in Crested Butte so that the public had an opportunity to review the plan, make comments or recommendations and to ask questions. The meetings also served as a vehicle to educate the public as to what they could expect to occur at the site during construction, and for the years following completion of the project.

CONSTRUCTION

Reclamation construction was planned to begin during the summer of 2003. A slower than usual contracting process, and a long delay in processing the EPA Brownfields grant resulted in construction being delayed until 2004.

During site characterization work, three previously unknown underground petroleum storage tanks were discovered. Exploratory excavation around the periphery of the tanks suggested that some amount of leakage had occurred. The Colorado Geologic Survey (CGS), the State authority in mitigation of underground storage tank contamination, was contacted by the Division to assess the site and develop a remediation plan. Under CGS supervision, the underground storage tanks, along with associated stained soils were excavated and removed from the site in the late summer of 2003.

During the winter of 2003 / 2004, the Division, PMI and the reclamation contractor agreed to begin construction in early July 2004. In mid-June 2004 the contractor notified the Division that it was financially unable to conduct the work, was on the verge of filing for bankruptcy protection and would not begin the project. The second lowest bidder was contacted in an effort to salvage the summer construction season, but that contractor declined to honor the prices bid the previous year. As a result, reclamation construction did not begin as planned in 2003. However, this delay provided the Division with an opportunity to further refine the reclamation plan, and allowed the Land Trust the chance to secure additional funds to help fund their portion of the work. The project was again put out to bid in the fall of 2004 in anticipation of 2005 construction.

Equipment arrived on the site in July, 2005. Site preparation included construction of a safety fence on both sides of the Lower Loop Trail for the length of the project area, placement of silt fence below the waste disposal area, stripping of soil and vegetation from the canyon side slopes at the disposal area, removal of tailings from the footprint of the planned disposal area, and application of magnesium chloride on the Lower Loop between Crested Butte and the project area for dust control purposes.

In order to prepare the disposal area to receive the mixed wastes, a french drain was constructed along the westerly margin of the disposal area perpendicular to the ground water flow path in order to intercept near surface ground water and allow that captured water to drain to a surface channel built at the southern margin of the area. The drain was constructed so that it gradually decreased in depth as the ground surface elevation fell, with the base of the drain being relatively horizontal. Therefore, at its outlet, the elevation of the base of the drain coincided with the ground surface elevation, allowing for a free draining system.

When removal of the tailings from the footprint of the disposal area was completed, shaping and compaction of the canyon base was accomplished. The area beneath the tails had supported a drainage channel prior to tailings deposition. This former drainage channel now formed a groin-like inflection sloping from north to south through the area. This old drainage footprint was used to create the primary segment of an underdrain system meant to capture and convey any water which would percolate through the waste materials once placed in the repository. Five lateral interceptor drains were built to extend westerly from the central drain to capture drainage from the western periphery of the disposal area, and deliver this drainage to the central drain, which daylighted at the southern toe of the disposal facility.

The drainage system trenches were excavated into the graded and compacted base of the disposal area to one foot below ground surface. Geotextile was placed within the cuts, and crushed limestone was placed within the geotextile so that the excavations were filled to about one foot above ground surface elevation. The geotextile was wrapped over the top of the limestone, so that the rock was completely enclosed by the geotextile.

Following underdrain construction, the base of the disposal area was ready for placement of limestone base material. Permeable geotextile fabric was placed over the base of the compacted disposal area, with a six inch lift of crushed limestone placed over it. This limestone layer acts as a final acid buffer should pockets of undiluted mill wastes within the disposal area come into contact with percolating water, thus encouraging acidic drainage. A permeable geotextile was then placed over the limestone lift.

Coal and silver waste materials were then transported to the disposal area as the limestone placement was completed. Coal Refuse and mill waste materials were trucked to the disposal area and were mechanically mixed on the pad using a dozer at a ratio of two parts mill waste to one part coal refuse. The mixed material was pushed out over the pad in one-foot thick lifts.

Compaction and moisture testing of the mixed waste material occurred on a predetermined schedule. Twenty tests were conducted per foot of elevation gain for each of the first five lifts. Ten tests per lift were completed at about five feet elevation intervals between lifts five and twenty two.

In some areas, excavation of the mill waste from the former tailings disposal areas resulted in creation of large enclosed depressions, varying from six to eight feet in depth. These depressions were not conducive to the post reclamation land use. In order to create a more functional landform, coal refuse was placed and compacted into these depressions to create a more desirable topography and drainage pattern.

The silver mill waste material became increasingly saturated as excavation of the material deepened. Saturation became so severe that the material oozed water immediately when cut with a track excavator. While this was not an unexpected condition, it caused some disposal area stability concerns, due to the plasticity of the material, its apparent lack of strength and the elevated moisture content. In order to accommodate this situation, coal refuse was added in sufficient volumes to the wet mill waste in order to stiffen the mixture so that it would not cause structural problems within the fill. Approximately three to four parts of coal were added to every part of saturated mill waste to create a material sufficiently dry to compact appropriately. Additionally, this material was preferentially placed so that it was located no closer than approximately eighty feet from the face of the disposal area so as to minimize the potential of near surface slope failure.

Periodically, the contractor was directed to selectively take certain coal materials to use in the mixing process. It was preferred that specific materials, such as coal clinker, be buried deeper within the disposal area, as they are a poor growth medium, while fine grained coal refuse material appeared to be better suited to support vegetation, and thus were more desirable for placement in the upper reaches of the disposal area.

Following completion of the fifteen foot lift, all of the mill wastes had been mixed and placed in the disposal area. The Division then re-surveyed the disposal area and the remaining coal refuse materials to be placed in the fill. The survey revealed that the disposal area contained excess design volume; that is, the volume of remaining coal refuse materials was insufficient to meet the design elevations of the disposal area.

One important consideration in the disposal area design parameters was to construct the back slopes of the disposal area to an elevation equivalent to that of the adjacent canyon margins. This was an important consideration in order that the volume of run-on water from off-site areas was minimized, and so that a functional landform in the context of adjacent areas was created during the reclamation process. In order to accomplish this, given the apparent material shortage, the outslope angle of the disposal area was relaxed from 3H:1V to 6H:1V beginning at the sixteen foot lift. Changing the outslope angle allowed the surface elevation of the fill to rise more rapidly toward the canyon walls so that when completed, the surface of the fill would match the elevation of the adjacent canyon rims.

Excavation and disposal of all coal refuse and mill wastes was completed by mid-October, 2005. Approximately 87,000 cubic yards of mine waste material had been excavated and placed in the disposal area by that time.

Approximately 15,000 cubic yards of clean fill that had been imported to the site was evenly distributed over final cut and fill land surfaces of the project area. This volume of material allowed an average placement of one foot of dirt over most of the project area. Because most of the imported fill was essentially devoid of organic materials, and lacked any soil-like characteristics, organic materials were incorporated into the fill dirt after it was distributed across the site.

Project specifications required that two tons of certified weed free straw per acre be distributed over the sixteen acre project area. Other organics were added to the imported fill, including dry cow manure at three tons per acre, Biosol Mix (7-2-3) at 1,200 pounds per acre, and approximately 500 cubic yards of bio-solids.

The straw mulch was hand distributed over the site, while the manure, BioSol and bio-solids were mixed using the track excavator, placed in a manure spreader, and distributed. A dozer was used to rip the organic materials into the imported fill at the flatter portions of the area until all the materials were completely incorporated. Final ripping occurred parallel to contour, so as to encourage disruption of surface water drainage in order to slow overland flow velocities and reduce erosion potential.

The organic materials were incorporated into the imported fill distributed over steeper slopes using a track excavator. To do this, the operator pushed the teeth of the bucket into the dirt to a depth of about eight to twelve inches, and then curled the bucket toward the machine to create an upslope depression and down slope mound in the dirt surface. This process occurred so that an eighteen to twenty four inch separation between gouges was created parallel to contour. The gouges were constructed in an offset pattern, so that a gouge was constructed immediately above and below any open space between two horizontal gouges. This created an extremely disrupted landscape, which severely inhibits overland water flow patterns.

Concurrently with surface roughening, channels were built to convey water across the site. A site drainage concept to support a diversity of land uses and eco-types was devised. The drainage plan allowed for water to move through the site at the slowest possible velocities while providing water to existing wetlands or to areas that were targeted for wetlands development. Whenever possible, topographic relief was constructed that allowed for dispersed overland flow of snowmelt without promoting concentrated flow patterns. This also allowed for accumulation of water in some areas in order to promote a diversity of vegetation throughout the site.

Following surface roughening and incorporation of organic material, shrub island areas were established. In order to create the shrub islands, approximately three shrub areas per acre were designated. Only shrub seed was planted in these approximately thirty feet diameter areas.

Following shrub seed distribution, grass and forb seed was planted outside of the shrub island margins. In addition to the reclamation grasses, sterile quick growing wheat – rye cross was also planted as a cover crop.

When all of the seed had been distributed, two tons per acre of certified weed free straw mulch was applied to the ground surface. Hand crimping was required in the contract, but rather than using hand-crimping tools the contractor fitted ski boots with sharpened metal plates constructed to drive the mulch into the ground. The crew walked the area with the crimping boots, which served to firmly secure the mulch to the ripped ground surface.

Approximately 1,200 willows were planted at the site. Five hundred of the willows were containerized, while the remainder of the willows were obtained from cuttings collected on site. Willows were preferentially planted along the margins of the constructed channels and at appropriately moist areas throughout the site. Plantings along the channel sides serve to anchor the channel slopes, and when planted within the channel, serve to reduce flow velocities.

The contractor was required to provide 5,600 seedling trees to the site. Approximately 1,866 trees each of Quaking aspen (*Populus tremuloides*), Blue Spruce (*Picea pungens*) and Engelmann Spruce (*Picea engelmannii*) were delivered to the site in mid-October, 2005.

In order to keep the public informed of reclamation progress, weekly reclamation tours were conducted. During construction, a public site tour was conducted each Tuesday evening by Division or PMI staff. Weekly progress reports were made and questions regarding the reclamation process or work progress were answered. This simple but effective tool went a long way toward promoting project benefits, and in educating the public regarding environmental restoration concepts.

The Division, in conjunction with Peanut Mine Inc and the Crested Butte Land Trust, hosted a public tree-planting day at the site following completion of all other revegetation activities. Trees were planted in designated areas that were located so that they complimented the shrub islands and took advantage of site micro-topography. Seventy five volunteers helped plant approximately 4,500 trees on October 22, 2005.

RECLAMATION SUCCESS

Reclamation at the Peanut Mine succeeded in accomplishing the two primary technical goals of the project; isolating acid producing silver mill wastes from the environment to prevent acidic drainage, and eliminating the potential for coal waste products to spontaneously combust.

A number of subsidiary goals were also achieved during and as a result of the project. A previously unused, blighted area was reclaimed into a useable public open space. Sediment transport from the site was eliminated. An aesthetically pleasing and geomorphically stable landform was created. Enabling the reclamation class at the Community School provided an opportunity for students to become involved in natural sciences in a practical way, and to utilize their knowledge to help solve a local problem. The general public was actively involved with the project, providing the opportunity for them to not only become aware of reclamation processes, but to assume an ownership in the project.

Vegetatively, reclamation was very successful. Pre-reclamation vegetative ground cover was estimated to vary from zero to five percent, which was essentially composed of annual weeds with interspersed perennial grasses and some willows in wetter areas. Prior to reclamation beginning, reference areas were established at nearby undisturbed areas with similar aspect, relief and environmental conditions. Following completion of reclamation work, revegetation sample plots were established at the disposal area in order to measure long term reclamation success.

Mean live, non-noxious herbaceous and woody vegetation in the reclaimed area was estimated at 47.2% (Table 2) in 2009, while mean cover of live, non-noxious herbaceous vegetation in the reference area was estimated to be 46.6%. Mean total ground cover was estimated at 78.9% (Table 2), while mean total ground cover in the reference area was estimated to be 86.7%.

Ten non-noxious perennial grass species met or exceeded 20 percent frequency. The most prevalent grasses based on frequency of occurrence were mountain brome, Idaho fescue, western wheatgrass, slender wheatgrass, blue wildrye, Kentucky bluegrass, Thurber's fescue, subalpine needlegrass, beardless bluebunch wheatgrass, and common timothy.

Table 2. 2009 Peanut Mine Reclaimed Area Ground Cover Summary

Species/Category	% Cover	Relative Cover (Composition)
Perennial Grasses and Grass-likes		
Slender wheatgrass (*Agropyron trachycaulum*)	4.4	9.2
Kentucky bluegrass (*Poa pratensis*)	3.3	7.0
Mountain brome (*Bromus marginatus*)	3.2	6.8
Blue wildrye (*Elymus glaucus*)	3.3	6.9
Thurber's fescue (*Festuca thurberi*)	2.8	5.8
Subalpine needlegrass (*Stipa Columbiana*)	1.6	3.4
Idaho fescue (*Festuca idahoensis*)	1.5	3.2
Western wheatgrass (*Agropyron smithii*)	1.2	2.5
Beardless bluebunch (*Pseudoregeneria spicata inerme*)	0.5	1.0
Miscellaneous other species	*1.4*	*2.9*
Subtotal	**23.0**	**48.6**
Non-noxious Perennial Forbs		
Rocky Mountain penstemon (*Penstemon strictus*)	13.6	28.8
Red clover (*Trifolium pratense*)	5.8	12.3
Mountain lupine (*Lupinus alpestris*)	1.1	2.3
Sticky geranium (*Geranium viscosissimum)*	0.5	1.1
Dandelion (*Taraxacum officinale*)	0.5	1.0
Arrowleaf balsamroot (*Balsamorhiza sagitatta*)	0.3	0.6
Miscellaneous other species	*1.1*	*2.3*
Subtotal	**22.3**	**47.2**
Non-noxious Annual and Biennial forbs	**0.5**	**1.0**
Woody Plants		
Big sagebrush (*Artemisia tridentata*)	0.3	0.6
Miscellaneous other species	*0.6*	*1.3*
Subtotal	**0.9**	**1.9**
Noxious Weeds		
Yellow toadflax (*Linaria vulgaris*)	.05	0.1
Non-Vegetation Ground Cover		
Litter	16.7	
Rock	15.0	
Subtotal	**31.7**	
TOTAL NON-NOXIOUS VEGETATION COVER	**47.2**	
TOTAL NON-NOXIOUS GROUND COVER	**78.9**	

Ten non-noxious perennial forbs met or exceeded 20% frequency. In order of occurrence, these species were Rocky Mountain penstemon, sticky geranium, red clover, dandelion, mountain lupine, arrowleaf balsamroot, a native aster species, an herbaceous native cinquefoil, aspen daisy, and curly dock.

Big sagebrush frequency was 50%, while two other shrubs (silver sagebrush, wax currant, and Douglass rabbitbrush) met or exceeded 10% frequency, along with three planted tree species (blue spruce, Engelmann spruce, and quaking aspen).

Table 3 illustrates some selected shrub island (patch) plant numbers and composition. Within-patch total shrub count ranged from 51 to 402, averaging 145 shrubs per patch. Within-patch mountain big sagebrush count ranged from 8 to 278, averaging 66 big sagebrush plants per patch.

Erosion at the reclaimed area has essentially been eliminated as a result of the reclamation process. Visual evaluations of the site are conducted on an annual basis. No evidence of rilling or gullying has been observed at the site.

CONCLUSIONS

The Peanut Mine reclamation project provides many examples of how a dedicated collaborative process coupled with a variety of reclamation strategies can lead to highly successful results.

The technical difficulties presented by the mixed waste site were solved using sound scientific principles and careful planning. The materials that, at first blush, appeared to present great technical difficulties, were eventually found to work in tandem to mitigate site issues. The landforms created at the cut and disposal areas appear to be extremely stable in terms of functionality and by supporting a variety of micro ecosystems for long-term vegetative success.

In the case of the Peanut project, the Division had committed to a reclamation planning and implementation process that provided for the involvement of not only the landowner, but the entire community. The Division felt that community involvement in the entire process was extremely important in order to ensure a successful reclamation outcome at the Peanut due to the proximity of the site to town, because the Lower Loop trail, which bisects the Project Area, is an important and highly used hiking and biking path, and because community interest in the local environment is strong. The agency desired to facilitate a community based solution to the environmental issues presented by the Peanut, rather than compel a solution.

Table 3. Sample of 2009 Peanut Mine Shrub Patch Woody Plant Count

Patch #3 (39' diameter)

Big Sagebrush (*Artemisia tridentata*)	103
Silver sagebrush (*A. Cana*)	54
Douglas rabbitbrush (*Chrysothamnus viscidiflorus*)	29
Wax currant (*Ribes cereum*)	92
Wood's rose (*Rosa woodsi)*	9
Subtotal	287

Patch #7 (22' diameter)

Big Sagebrush (*Artemisia tridentata*)	28
Silver sagebrush (*A. Cana*)	11
Douglas rabbitbrush (*Chrysothamnus viscidiflorus*)	2
Wax currant (*Ribes cereum*)	36
Wood's rose (*Rosa woodsi)*	13
Subtotal	90

Patch #10 (25' diameter)

Big Sagebrush (*Artemisia tridentata*)	80
Silver sagebrush (*A. Cana*)	62
Douglas rabbitbrush (*Chrysothamnus viscidiflorus*)	6
Wax currant (*Ribes cereum*)	5
Wood's rose (*Rosa woodsi)*	2
Subtotal	155

Shrub Patch Summary

Average # Shrubs per Patch	145
Average # Big sagebrush per Patch	66
Average # Trees per Patch	1

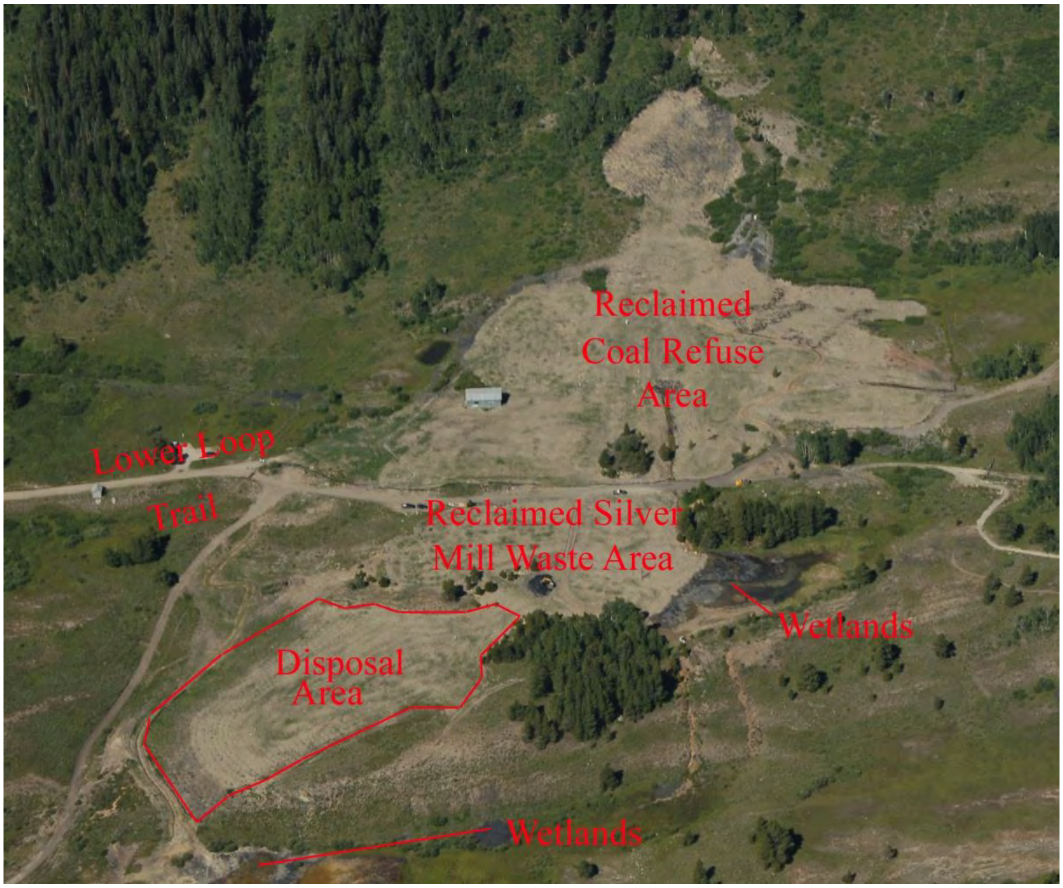

Figure 3. Aerial View of Peanut Mine, Early Summer Following Completion of Reclamation Construction.

By acting as a clearinghouse for problem analysis and resolution, the Division helped create a dialogue between the community, the landowner, and various state and federal agencies. This communication enabled a trusting relationship that, in the long term, allowed for great latitude in reclamation creativity.

Attainment of this goal was possible because the agency was willing to invest time and resources in the community. Funding the Community School to initiate the Reclamation Studies class, holding public meetings and site tours, assisting the Fire Department when the coal spontaneously combusted, enlisting public involvement at various stages of the reclamation planning process, hosting the volunteer tree planting and providing a willingness to discuss the various aspects of the project were extremely valuable activities that allowed the community to fully participate in the various aspects of accomplishing this project just outside of the town.

By fostering an atmosphere of collaborative planning and implementation, numerous hurdles were overcome and many issues resolved, all of which served to improve the final reclamation product at the site.

The Peanut Mine Reclamation Project was awarded the Excellence in Abandoned Mined Land Reclamation National Award by the U. S. Office of Surface Mining at the 2008 National Association of Abandoned Mine Land Programs annual conference.

ACKNOWLEDGEMENTS

Daniel Mathews, Environmental Protection Specialist with the Colorado Division of Reclamation, Mining and Safety was responsible for developing the seed mixtures used at the Peanut Mine. Dan also coordinated all vegetation studies and inventories, and reduced and collated all of the vegetation data.

Jim Starr and John Hess, former members of the Crested Butte Land Trust, were instrumental in all phases of the project. Without their help and foresight, this project would not have been possible.

OVERBURDEN REVEGETATION WITH LOW SEEDING RATES AND MINIMAL SOIL AMENDMENTS AT TIJERAS LIMESTONE QUARRY, NM

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ABSTRACT

Four soil amendment treatments, three broadcast seeding rates, and transplanting of woody species were evaluated to determine the best strategy to enhance reclamation efforts on redbed overburden materials used in lieu of salvaged topsoil for soil growth medium reconstruction at GCC Rio Grande, Inc's Tijeras Cement Plant and Limestone Quarry located in Tijeras, New Mexico. In 2008, after five years of monitoring, the different treatment combinations have all been successful at promoting increased vegetation cover, desirable species establishment, shrub densities, and species diversity. Additionally, soil parameters tested in 2008 were all within suitable limits and showed little difference between treatments or over time. Results of soil and vegetation data after five years suggest several conclusions: (1) Applying an organic amendment, such as the horse manure and stable waste used, was not cost effective; (2) The native hay mulch used on some plots was beneficial in reducing erosion, but the costs associated with this application and the introduction of undesirable plant species outweighed the benefit in this case; (3) All of the low broadcast seeding rates were effective at establishing cover and diversity with the 10 and 20 PLS/sf treatments providing the best overall vegetation results; and (4) While the transplants increased woody diversity and density, the added cost in materials and labor did not pay off in terms of overall cover, diversity, or production.

INTRODUCTION

GCC Rio Grande, Inc's ("GCC") Permit No. BE001RE required the development and implementation of a reclamation test plot study at its Tijeras Cement Plant and Limestone Quarry located in Tijeras, New Mexico. The study was approved by the New Mexico Mining and Minerals Division ("MMD") on November 20, 2002. Construction of the test plots began in May 2003 and planting was completed in November 2003. The goal of the study is to identify and evaluate specific methods and practices having the potential to enhance reclamation efforts on redbed materials used in lieu of salvaged topsoil for soil growth medium reconstruction at the quarry. Specifically, the test plots investigate two primary variables (soil amendments and seeding density) that can be controlled during the reclamation process. These variables have the potential to significantly affect vegetation stand characteristics within the reclaimed area.

Past studies have shown that soil amendments such as mulch, compost, and sewage sludge have the potential to increase organic carbon, total nitrogen, and moisture availability, and decrease erosion potential, when applied to mine spoil materials (Chambers et al. 1994, Cogger 2005, Moreno-Peñaranda et al. 2004). Zvomuya et al. (2007) compared compost and hay mulch incorporated into soils on reclaimed natural gas well sites. They found both carbon and nitrogen to be more stable when derived from compost, but no difference was found in final organic carbon between treatments. Nitrogen content increased with increasing hay application, but was unaffected by compost application rate. Moreno-Peñaranda et al. (2004) showed that sewage sludge increased biomass and cover after 5 years over non-amended soils; however, species richness was lower and fewer legumes were present. Organic amendments are often thought to increase weedy species abundance, but this can be managed if care is taken in selecting the material sources.

Seed mix species selection and application rate can also play a significant role in the character of the final reclaimed community. Species selected need to be appropriate to the site and climate, but considering their competition roles is also important (Jefferson 2004). Competition for water, nutrients, and other resources will affect the structure and diversity of the community. Reclamation efforts often utilize high seeding rates (100 – 300 PLS/sq. ft.) to ensure adequate cover quickly. While this increases costs slightly, if several individuals die, the overall effect on cover is minimal. However, the community will often be dominated by the more competitive species in the mix with minimal diversity and little room for natural colonization of other species. This can potentially lessen the threat of weedy invaders, but again, decreases diversity. In this study, we evaluate several low rates for broadcast seeding (5 – 20 PLS / sq. ft.) with the hypothesis that adequate cover can still be achieved with decreased competition leading to greater diversity (both from the seed mix and outside colonizers) and heartier individuals.

This paper documents the trends in cover, transplant survival, species composition, diversity, growth, and plant health observed after five growing seasons with four soil amendments and three low rate seeding treatments. Changes in soil characteristics between pre-construction and post-construction are also evaluated.

METHODS

Site Description

The GCC Limestone Quarry is located east of Albuquerque and south of I-40 in Tijeras, New Mexico. It is New Mexico's only cement manufacturer and has been in operation since the early 1950’s. Two potential sites were evaluated for this test plot study at the Tijeras Quarry and several factors contributed to the final decision on which site to use. The watershed area above the selected area was relatively small and it could be readily diverted and controlled. The north aspect of the site was similar to the majority of the lands currently disturbed or scheduled to be disturbed at the quarry and the slopes are characteristic of those expected in the postmining topography at the quarry. The elevation covers a fairly central range within the permitted quarry and no further quarry disturbance is scheduled for this area. Finally, access to the base of the proposed test plot site already exists and is maintained by the quarry in support of its ongoing operations. The environmental characteristics and location of the test plots served to ensure that the results of the study were universally applicable to the quarry to the extent possible. Although the test plot area does not contain all elevations, slopes, and aspects potentially occurring on the site, the reclamation treatments evaluated by the study are expected to perform satisfactorily within the full range of quarry conditions.

The test plot site is located between 6,390 and 6,525 feet elevation with a generally north aspect. Slopes on the test plots range between 5% and 30%. Gradient terraces provide drainage control and minimize the potential for impacts on the vegetation test plots associated with surface water runon from adjacent slopes. The site was backfilled and graded to approximate post-mining contours prior to placement of soil reconstruction materials. Redbed materials, located between two limestone members in active quarry areas, were excavated and hauled to the test plot site for use as a plant growth medium. Redbed materials were graded to final contour with a minimum of two feet of depth.

Test Plot Design

Four soil amendments, three broadcast seed rates, and a transplanted treatment were applied in a randomized strip plot design (Figure 2) with three replicates for a sample size of 48. Soil amendment treatments included: composted horse manure wastes applied at two rates of 20 and 30 tons of dry organic matter per acre, native hay mulch applied at a rate of two tons per acre, and an untreated control. All plots were seeded at rates of 5, 10, or 20 pure live seeds (PLS) per square foot. The test plots were seeded with a variety of native grass, forb, and shrub species as well as two desirable introduced species (Table 1). These different life forms germinate and mature on different timescales, with their populations responding differently to ecologic and climatic variation. In addition to seeding, 12 plots that received 20 PLS also received a total of 60 transplants of 12 woody species planted in a matrix for easier monitoring. Transplanted species included: *Juniperus monosperma* (oneseed juniper); *Cercocarpus montanus* (mountain mahogany); *Rhus trilobata* (skunkbush sumac); *Krascheninnikovia lanata* (winterfat); *Pinus ponderosa* (ponderosa pine); *P. edulis* (pinyon pine); *Rosa woodsii* (Woods' rose); *Ericameria nauseos*a (rubber rabbitbrush); *Quercus gambelii* (Gambel oak); *Chrysothamnus viscidiflorus* (yellow rabbitbrush); *Purshia mexicana* (Mexican cliffrose); and *P. tridentata* (antelope bitterbrush)

To insure the validity of the strip plot design (Miliken & Johnson 1984), treatments were randomly assigned to the rows (soil amendments/treatments) and columns (broadcast seeding densities) within each study plot replication (Figure 2). Because the treatment combinations were randomly assigned to rows and columns to facilitate soil amendment applications, rather than each individual test plot as in a completely randomized design, special care was taken to properly test for main effects and interactions among treatment factors.

Test Plot Construction

Test plot construction was completed in April 2003. The site was backfilled and graded and redbed topdressing soil was placed at a uniform depth of two-feet over the study area. Two drainage terraces were constructed using additional redbed material rather. The organic amendment used for 20 and 30 tons/acre treatments was manure. The manure was analyzed for organic matter, ash, and moisture content as well as bulk density to determine actual tons of manure required to achieve the desired rates of dry organic matter per acre.

Plot-specific fertilizer applications were developed after organic amendment applications to ensure that availability of plant macronutrients was approximately equivalent on a per unit volume of soil basis across all reconstructed soils. Incorporation of organic and fertilizer amendments and surface roughening (i.e., contour furrowing) was performed on all test plots to a depth of six inches immediately after fertilizer application. All plots were broadcast seeded in January 2004 with a mixture of grass, forb, and shrub species (Table 1). These different life forms germinate and mature on different timescales, with their populations responding differently to ecologic and climatic variation. After seeding, native hay mulch was hand applied at a rate of 2-tons per acre to each of the 12 mulch treatment plots and guar gum tackifier was applied.

Vegetation Monitoring

Vegetation test plots were monitored following applicable MMD monitoring guidelines and standards to the extent this was appropriate and possible. Monitoring in 2004 included abiotic and biotic observations of seedling germination, seedling establishment, and transplant survival and growth. In 2005, 2006,and 2008 we monitored vegetation and total ground cover, shrub density, and transplant survival and growth.

Table 1: Vegetation Test Plots - Permanent Seed Mixture

Species	Common Name	Desired %
Grasses		
Pascopyrum smithii (Agropyron)	Western wheatgrass: arriba	5
Pseudoroegneria spicata (Agropyron)	bluebunch wheatgrass: Secar	5
Andropogon hallii	sand bluestem	5
Bouteloua curtipendula	sideoats grama: Butte	5
Bouteloua gracilis	blue grama: S Native	5
Pleuraphis jamesii (Hilaria)	James's galleta	5
Achnatherum hymenoides (Oryzopsis)	Indian ricegrass	5
Sporobolus cryptandrus	sand dropseed	5
Stipa neomexicana	New Mexican feathergrass	5
Grass Total (%, PLS/Acre, PLS Pounds/Acre, PLS/Foot^2)		*45.0*
Forbs		
Achillea millifolium	western yarrow	3.5
Astragalus cicer	Cicer milkvetch: lutana CT	3.5
Gaillardia aristata	Indian blanket flower	3.5
Linum lewisii	Lewis (Blue) flax	3.5
Lupinus argenteus	silver mountain lupine	3.5
Onobrychis viciifolia	sainfoin: eski	3.5
Penstemon angustifolia	narrow-leaf penstemon	3.5
Ratibida columnifera	coneflower	3.5
Sphaeralcea coccinea	scarlet globemallow	3
Forb Total (%, PLS/Acre, PLS Pounds/Acre, PLS/Foot^2)		*31.0*
Shrubs		
Atriplex canescens	four-wing saltbush	3
Krascheninnikovia lanata	winterfat	3
Cercocarpus montanus	mountain mahogany	3
Ericameria nauseosa	rubber rabbitbrush	3
Chrysothamnus viscidiflorus	yellow rabbitbrush: Douglas	3
Purshia mexicana (Cowania)	New Mexico cliffrose	3
Purshia tridentate	antelope bitterbrush	3
Rosa woodsii	Wood's rose	3
Shrub Total (%, PLS/Acre, PLS Pounds/Acre, PLS/ Foot^2)		*24*
Seed Mixture Total (%, PLS/Acre, PLS Pounds/Acre, PLS/ Foot^2)		*100.0*

Vegetation Cover

Each test plot was subdivided into five monitoring transect panels. A five-foot buffer zone was provided around the perimeter of each test plot to minimize edge effect from adjacent treatments. The five transect panels were oriented lengthwise across the hill. The panels are approximately 13 feet wide and 40 feet long. Sample start point locations were randomly located within each of the five sample panels using a fixed one-foot interval grid on an x and y axis.

Line-transect point-intercept methods were used to collect ground cover data from the vegetation communities in all five panels of each test plot. Cover measurements were taken from point-intercepts at ten centimeter intervals along a ten-meter transect using a laser bar point frame, for a total of 100 intercepts per transect. When the line-transect intersected a panel boundary, it was redirected into the panel at a 90˚ angle. Each point-intercept represents 1/5 of 1% toward total cover measurements. Cover measurements recorded "first-hit" point-intercepts by live foliar vegetation species, litter, rock or bare ground. Litter included all dead organic material. Rock fragments were recorded when equal to or greater than two millimeters in size. First-hit data were tabulated to evaluate total ground cover and vegetation cover. Total ground and vegetation cover measurements are expressed in percentages for each test plot.

Woody Plant Density

We evaluated woody plant density using ten-meter square belt transects (1 m width X 10 m length) established at a one-meter distance from the right side of the line transect used for cover sampling. When necessary, adjustments to the belt transect location over the line-transect were made to avoid overlapping measurements. We recorded each woody plant rooted within the belt transect by species. Woody plants with multiple stems from a specific crown were recorded as one individual.

Transplant Survival

We recorded baseline height and basal diameter measurements of woody transplants in April 2004, and all subsequent growth values were based on these measurements. Shrub height was measured from root crown to apex of the main stem, or longest branch in the case of multi-stemmed shrubs. Crown area was measured on each shrub species with two perpendicular measurements collected on north/south and east/west ordinates.

Herbaceous Production

Herbaceous biomass productivity was monitored in five locations within each plot. Rectangular or circular quadrats of 0.5-m^2 were placed around the sample point and all current year herbaceous production rooted within the quadrat was clipped and separated by habit (grasses or forbs). All production samples were oven dried prior to weighing to determine dry biomass.

Soil Monitoring

Soil data were collected prior to reclamation activities in April 2003, after soil amendment placement in June 2003 and again in September 2008 at the end of the test plot period. Soil chemistry, organic matter accumulation, and fertility were monitored and compared between the various sampling events. The initial sampling and analysis was performed to establish baseline soil chemical and physical properties for reclamation suitability, fertility status and to enable soil pedogenic comparisons over time. Another set of samples were collected and analyzed after organic amendment application to verify, that nutrient availability was uniform across the test plots. Soil sampling was again conducted in 2008 five years after reclamation to determine changes in soil chemistry and fertility over time and evaluate any differences in soils across amendment treatments.

The same sampling procedures were used for each of the three sampling events. Five samples were collected in each plot in an "X" pattern approximately 20 feet apart.
Each continuous core was split into six-inch depth increments (0-6, 6-12, and 12-18 inches) and was collated and mixed by depth increment. The post-amendment sampling only included the top 6 inches to account for the changes caused by organic and fertilizer amendments incorporated into the surface six inches.

Pre-reclamation soil samples were sent to Soils Analytical Services, Inc. in College Station, TX and post-reclamation soil samples were sent to Midwest Laboratories in Omaha, NE for analysis. All pre-reclamation samples were analyzed for pH and electrical conductivity (Saturated Paste Extract); calcium, magnesium and sodium (Saturated Paste Extract) to determine Sodium Absorption Ratio (Calculated); texture and texture class; sand fraction analysis; calcium carbonate %; nitrate nitrogen; saturation %, % coarse fragments, erosion factor K, acid-base potential, boron, total selenium, and water soluble selenium. Plant available phosphorous, plant available potassium, and total organic carbon were also analyzed to further define redbed fertility and organic content. The 2008 soil samples did not include as many analyses. Several parameters that did not pose any concerns in pre-reclamation testing and are relatively stable over time were removed from post-reclamation testing.Post-reclamation testing instead focused on pH, electrical conductivity, calculated sodium absorption ratio, nitrate nitrogen, bicarbonate phosphorous, potassium, and organic matter.

Statistical Analysis

The test plot full-factorial design had an adequate sample size (48) to test for differences in seeding rates, organic amendment procedures, and their interactions. Statistical analyses were performed using SPSS 15.0 statistical software (SPSS, Inc. 2006). Unless otherwise noted, statistical significance was determined at $p < 0.05$.

We used two-way analysis of variance (ANOVA) to test for seeding rate and organic amendment main effects and interactions on total ground cover, total vegetated cover, total species diversity, cover and diversity by growth form, herbaceous production, and woody density (Milliken and Johnson 1984). Soil data from post-reclamation soil analyses were also compared to the pre-amendment and post-amendment results for each of the three soil depths using ANOVA tests.

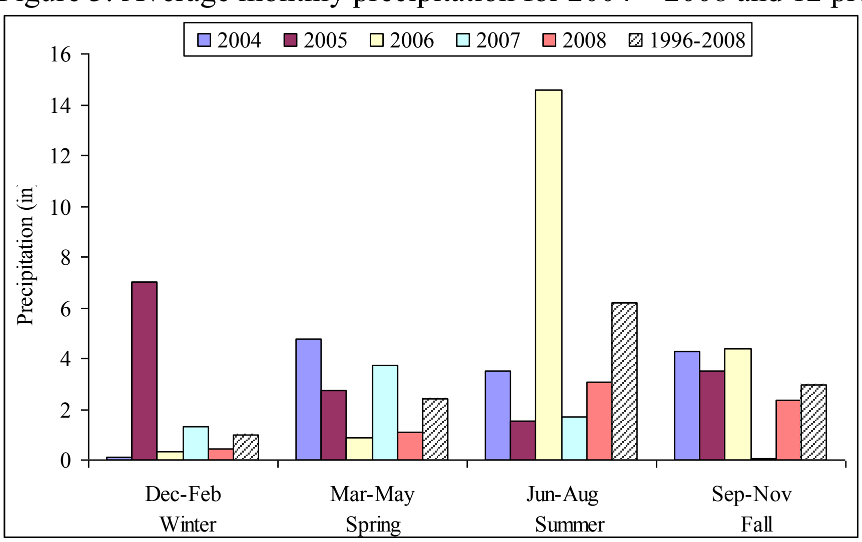
Woody densities were converted to stems / sq. ft. prior to analyses. The Tukey Honestly Significant Difference (HSD) correction was used to control maximum family-wise error rate (MFER) at ≤ 0.01.

Due to the small sample size (n=3), ANOVA tests were not appropriate for measuring transplant success in the 20 PLS + Transplants test plots. Rather, a binomial dataset with the number of trials (woody plants transplanted) and number of successes (woody plants alive) was tabulated to infer the percentage of transplants that were alive. We used the ellipsoid volume, calculated from horizontal and vertical axis width measurements, to determine trends in survival and growth.

Climate

The Quarry is located in a transitional zone between mountain shrub and semi-arid coniferous forest ecosystems, and is surrounded by steep foothills and rocky outcrops. Historic annual precipitation for the Tijeras region averages 16.4 inches (1971 – 2000, Western Regional Climate Center 2007) with the majority falling in July through October. The weather station at the Quarry has recorded precipitation since 1996. Over these 12 years the average annual precipitation has been 12.58 in., with the lowest precipitation in the last two years (6.78 in. in 2007 and 7.02 in. in 2008). The highest rainfall (19.89 in.) occurred in 2006, but with an unusual distribution of below average rainfall January through April and above average rainfall June – October (Figure 3). With the exception of 2006, every year since the test plots were established has had below average growing season precipitation and 2006 and 2008 had below average winter precipitation. The most extreme case being the fall and winter of 2007/2008 when only 0.44 inches of precipitation were recorded from a single event from November through

Figure 3: Average monthly precipitation for 2004 – 2008 and 12 preceding years



VEGETATION RESULTS

Vegetation Cover

Vegetation cover is used to evaluate the overall soil productivity, and the ability of the reclamation treatments to foster a diverse, stable, persistent community. We also performed analyses of desirable (native species and planted introduced species) versus undesirable species to gauge which treatments are establishing a diverse and desirable community.

Mean vegetative cover ranged from 33.5% to 53.7% (Table 1) with an average of 44.5% across all plots. There was a significant main effect for seeding density (p=0.004) in which mean vegetative cover was significantly higher with 5 and 10 PLS than 20 PLS + Transplants (

Figure **4**). However, when looking specifically at desirable cover (p=0.033), it was higher at 10 and 20 PLS than at 5 PLS (

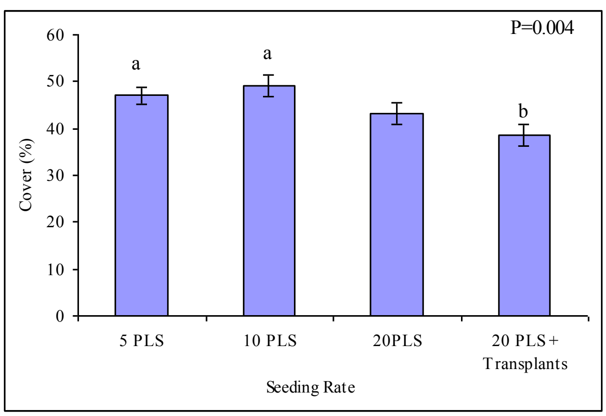
Figure **4**). The percent of vegetative cover that was native increased from 23% in 2005 to 37% in 2006 to 81% in 2008.

Table 1: Total vegetative cover (%) by treatment

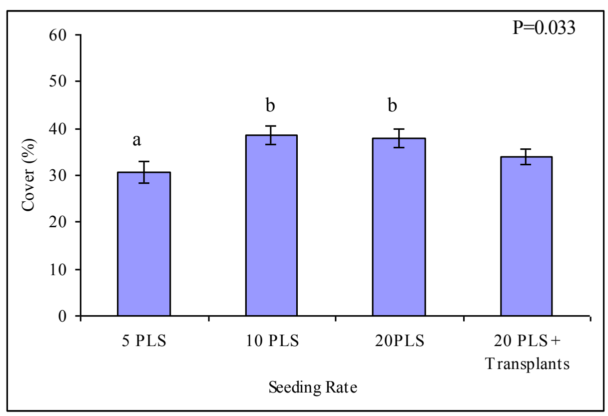
	Soil Amendments						
Seeding Density	*Untreated Control*	*2 tons Native Hay*	*20 tons OA*	*30 tons OA*	2008 Mean	2006 Mean	2005 Mean
5 PLS	45.0	48.9	44.3	50.3	47.1	55.9	32.18
10 PLS	46.6	49.6	46.8	53.7	49.2	61.8	32.28
20 PLS	44.8	41.9	45.2	41.2	43.3	58.0	29.98
20 PLS + Transplants	33.5	49.5	34.8	36.8	38.7	51.0	24.62
2008 Mean	42.5	47.5	42.8	45.5			
2006 Mean	52.1	66.0	54.3	54.2			
2005 Mean	30.12	28.62	30.40	29.93			

Figure 4: Mean (+ 1 SE) (A) total & (B) desirable vegetation cover by seeding density

A.



B.



There was a significant interaction effect for vegetative cover between year and soil amendment (p=0.033). In 2005 vegetative cover did not differ between soil amendments, in 2006 it was greater in plots treated with 2 tons native hay and again in 2008 it did not differ between treatments. Vegetative cover also varied significantly by year with 2008 cover greater than 2005 and less than 2006. There was also a significant interaction effect for desirable vegetation cover between year and seeding density. In 2005 desirable vegetative cover did not differ between treatments, in 2006 it was greater in plots seeded with 20 PLS + Transplants than all others, and in 2008 it was greater in plots seeded with 10 and 20 PLS than those seeded with 5 PLS ($p=0.012$).

Mean grass cover was significantly higher in plots treated with 2 tons native hay (30.6%) than with any other amendment ($p \leq 0.0001$). However, there were no significant main effects on desirable grass cover. There were also no main effects on desirable forb cover, but mean total forb cover for 5 PLS (16.5%), was significantly higher than 20 PLS (5.3%) or 20 PLS + Transplants (4.0%) ($p<0.001$). These effects shown for total graminoid and forb cover, but not desirable cover led to the evaluation of dominant individual species.

Native grasses made up an average of 92% of total grass cover in 2008. Five native perennial grasses (*Achnatherum hymenoides* or Indian ricegrass, *Bouteloua curtipendula* or sideoats grama, *Bromus ciliatus* or fringed brome, *Pascopyrum smithii* or Western wheatgrass, and *Pseudoroegneria spicata* or bluebunch wheatgrass) and one introduced perennial grass (*Poa pratensis* or Kentucky bluegrass) each contributed over 1% of average absolute cover across treatments (Table 2). The average relative cover contributed by these five dominant species increased from only 10.9% in 2006 to 41.3% in 2008 this was a statistically significant increase for all species ($p \leq 0.0001$).

Table 2: Dominant species (>1% average absolute cover) cover and frequency

		2008			2006		
Species	Common name	Average Absolute Cover (%)	Average Relative Cover (%)	Frequency (%)	Average Absolute Cover (%)	Average Relative Cover (%)	Frequency (%)
Graminoid: Perennial Undesirable							
Festuca arvernensis	field fescue	0.2	0.5	19	2.2	3.9	44
Poa pratensis	Kentucky bluegrass	1.4	3.2	40	0.1	0.1	8
Graminoid: Perennial Desirable							
Achnatherum hymenoides	Indian ricegrass	4.8	10.8	96	2	3.5	90
Bouteloua curtipendula	sideoats grama	1.8	4.1	88	1	1.8	90
Bromus ciliatus	fringed brome	1.5	3.3	40	0	0	0
Pascopyrum smithii	western wheatgrass	8.1	18.3	100	2.6	4.6	92
Pseudoroegneria spicata	bluebunch wheatgrass	2.2	4.9	92	0.6	1	50
Forbs: Annual Undesirable							
Kochia scoparia	kochia	3.1	6.9	75	6.9	12.2	90
Salsola paulsenii	Russian thistle	3.5	8	88	5.6	9.8	100
Forbs: Biennial Undesirable							
Melilotus officinalis	sweetclover	0.3	0.6	27	14.9	26.4	94
Forbs: Perennial Desirable							
Astragalus cicer	cicer milkvetch	0.1	0.3	25	3.4	6.1	96
Onobrychis viciifolia	sainfoin	0.3	0.7	54	1.3	2.3	85
Shrubs: Desirable							
Atriplex canescens	four-wing saltbush	6.7	15.1	98	5.3	9.3	100
Chrysothamnus viscidiflorus	yellow rabbitbrush	1.5	3.4	58	2.7	4.7	98
Ericameria nauseosa	rubber rabbitbrush	3.1	7	81	0.4	0.7	60

Relative cover of forbs across all treatments averaged 20.30% in 2008, decreasing from 66.29% in 2006. Desirable species made up more of the forb cover with 38% of forb cover being desirable in 2008 compared to only 12% in 2006. The only two desirable species that contributed more than 1% of the absolute cover in 2006 were *Astragalus cicer* (Cicer milkvetch) and *Onobrychis viciifolia* (sainfoin). These species contributed a combined total of 8.4% of the relative cover in 2006, but in 2008 they both decreased significantly ($p<0.0001$) to only a combined relative cover of 1% (Table 2).

In 2006 the introduced, undesirable forbs *Melilotus officinalis* (sweet clover), *Kochia scoparia* (kochia) and *Salsola paulsenii* (Russian thistle) dominated cover with a combined average relative cover of 48.4% (Table 2). All three species decreased significantly ($p\leq0.0001$) in 2008 to a combined average relative cover of 15.4%. This was most striking for the sweet clover which went from being the most dominant species at the site in 2006 (26.4% relative cover) to only 0.6% relative cover in 2008.

Kochia and Russian thistle were each analyzed for main effects of seeding and organic amendment in 2008, as well as changes over time. Sweet clover was not prevalent enough in 2008 to analyze. As in 2006, Russian thistle was significantly lower with 30 tons organic amendment than untreated plots or those treated with 2 tons native hay ($p=0.005$), and kochia cover was significantly greater in plots with 30 tons organic amendment ($p=0.006$). In 2008, unlike 2006, there were also significant differences between seeding densities where both kochia and Russian thistle had greater cover with lower seeding densities ($p\leq0.0001$). There was also a significant interaction between year and seeding density for Russian thistle ($p\leq0.0001$). While Russian thistle cover was the same in all seeding densities in 2006, it increased in the 5 PLS plots, held steady in the 10 PLS plots and decreased in the 20 PLS plots in 2008.

Unlike forb and graminoid cover, there was a significant main effect on mean woody cover in 2008 ($p=0.011$). Plots treated with 2 tons native hay mulch (9.1%) had significantly lower woody cover than plots treated with 20 (15.1%) or 30 (15.7%) tons organic amendment. While significant at the 95% confidence level, there was a potential effect for seeding density as well ($p=0.058$). Mean woody cover tended to be greater with 10 PLS than with 5 PLS or 20 PLS + Transplants. Woody cover also increased significantly from 4.2% in 2005 to 9.8% in 2006 and 12.9% in 2008 ($p\leq0.0001$).

Relative cover of woody species across all treatments averaged 28.96% in 2008 and all woody species observed on the site were native. Three native shrubs (*Atriplex canescens* or four-wing saltbush *Chrysothamnus viscidiflorus* or yellow rabbitbrush, and *Ericameria nauseosa* or rubber rabbitbrush) each contributed more than 1% to absolute cover (Table 2).

Species Diversity

Total diversity ranged from 14.3 species in plots seeded at 20 PLS + Transplants with 30 tons organic amendment to 20.3 species in plots treated with 2 tons native hay and seeded with 20 PLS + Transplants (Table 3). There were no significant main effects for seeding density or soil amendment.

Table 3: Total Diversity by treatment

	Soil Amendments						
Seeding Density	*Untreated Control*	*2 tons Native Hay*	*20 tons OA*	*30 tons OA*	2008 Mean	2006 Mean	2005 Mean
5 PLS	18.0	17.3	18.3	19.3	18.3	19.3	11.5
10 PLS	19.0	15.7	17.3	16.7	17.2	21.2	9.9
20 PLS	16.7	18.3	17.3	15.3	16.9	23.2	12.6
20 PLS + Transplants	17.7	20.3	16.3	14.3	17.2	22.9	11.9
2008 Mean	17.8	17.9	17.3	16.4			
2006 Mean	20.0	22.9	21.8	21.9			
2005 Mean	9.8	10.7	12.8	12.7			

Both total diversity and desirable diversity changed significantly with time ($p \leq 0.0001$). Total and desirable species diversity was greater in 2006 than in 2005 or 2008 and greater in 2008 than 2005. However, while the percentage of total species that were desirable held steady from 2005 to 2006, it increased in 2008. The trends observed for total and desirable diversity were also observed to total and desirable graminoid, forb, and woody diversity when evaluated separately.

Woody Species Density

Woody species density ranged from 0.77 stems/m^2 in plots seeded at 5 PLS with 2 tons native hay to 2.09 stems/m^2 in plots treated with no soil amendment and seeded with 20 PLS + Transplants. There was a significant main effect for seeding density ($p \leq 0.0001$) in which woody density mean with 20 PLS (1.67 stems/m^2) and 20 PLS + Transplants (1.74 stems/m^2) was significantly higher than with 5 PLS (0.83 stems/m^2), 20 PLS + Transplants was greater than with 10 PLS (1.30 stems/m^2), and 10 PLS was greater than with 5 PLS.

The most common woody species observed in shrub transects were four-wing saltbush, which comprised 37.6% of all observations and was present in all 48 plots. *Krascheninnikovia lanata* (winterfat) was also present in every plot and comprised 19.3% of observations. Rubber rabbitbrush was present in 45 of the 48 plots (93.8%) and comprised 27.2% of all observations and yellow rabbitbrush made up 10.8% of observations, being present in 75% (36) of plots. None of the other 19 woody species observed along the transects comprised more than 1% of the total observations and only four (*Purshia tridentata* or antelope bitterbrush, *Gutierrezia sarothrae* or broom snakeweed, *Sphaeralcea fendleri* or Fendler's globemallow, and *Artemesia ludoviciana* or white sagebrush) were present in more than 10% (5) of the plots.

Herbaceous Production

Mean total production ranged from 67.0 g/m^2 in plots treated with 20 tons organic amendment and seeded with 20 PLS + Transplants to 147.2 g/m^2 in unamended plots seeded at 5 PLS. There were no statistically significant differences between seeding densities or soil amendments for total or graminoid production. There was significant difference ($p=0.003$) between seeding densities for forb production with greater biomass in plots seeded at 5 PLS than those seeded at

20 PLS or 20 PLS + Transplants. Because 2008 was the first year biomass productivity was monitored, no comparisons can be made over time.

Transplant Growth & Survival

Transplant growth and survival data presented here represent the total change since April 2004. Overall these data suggest that untreated test plots yield the greatest transplant growth (4,188 in^3) and survival (48.8%), while 20 tons organic amendment plots yield the least change in volume (1,688 in^3) and 30 tons organic amendment plots yield the lowest survival rate (21.3%, Table 4). Across all organic amendment treatments *Cercocarpus montanus* (CEMO, mountain mahogany) exhibited the greatest survival (75.0%), but with the lowest average volume (876 in^3) among shrub species (Table 4). Mountain mahogany also exhibited the greatest amount of grazing with 45.0% of affected individuals, this likely led to its negative height growth (-2.64 in). *Rhus trilobata* (RHTR, threeleaf sumac) exhibited grazing on 45% of individuals, but on average was still taller than in 2006 by 6.92in. Rubber rabbitbrush (ERNA10) exhibited the greatest volumetric growth (7,178.27 in^3) and had a high survival rate (66.7%, Table 4). The two pine species, *Pinus edulis* (PIED, pinyon pine) and *Pinus ponderosa* (PIPO, ponderosa pine), and the antelope bitterbrush (PUTR) experienced the greatest mortality overall with only 10.0%, 11.7%, and 11.7% survival, respectively (Table 4).

Table 4: Woody Transplant Survival, Growth and Size (April 2004 – Sept 2006)

	Untreated		2 Tons Native Hay		20 Tons Organic Amendment		30 Tons Organic Amendment		Average (2008)			
Species	Growth (in^3)	Survival (%)	Growth (in^3)	Survival (%)	Growth (in^3)	Survival (%)	Growth (in^3)	Survival (%)	Height (in)	Volume (in^3)	Survival (%)	Grazed (%)
CEMO2	216	100	104	60	293	100	-252	40	16.6	876	75	45
CHVI8	6,055	66.7	5,990	66.7	5,411	66.7	2,283	53.3	21	4,730	63	23.3
ERNA10	10,551	80	8,326	53.3	5,407	80	3,596	53.3	23	7,210	67	10
JUMO		66.7		66.7		66.7		33.3	14.7		58.3	3.3
KRLA2	3,505	86.7	2,879	73.3	1,821	53.3	2,936	33.3	18	2,898	62	21.7
PIED		13.3		13.3		6.7		6.7	8.8		10	0
PIPO		33.3		6.7		6.7		0	10.2		11.7	1.7
PUME	2,258	60	403	20	1,344	53.3	994	13.3	17.7	1,730	36.7	28.3
PUTR2	1360	26.7		0	364	13.3	248	6.7	9.7	992	11.7	6.7
QUGA		66.7		13.3		33.3		26.7	5.8		35	6.7
RHTR	2,737	86.7	557	60	2,002	66.7	1,362	40	16	2,062	63	45
ROWO	5,688	93.3	1,533	33.3	1,296	40	3,023	33.3	16	3,863	50	23.3
Average	4,188	48.8	3,093	29.6	1,688	36.7	2,053	21.3	16.5	3,309	41	16

Seeded Species Establishment

When determining whether or not a reclamation effort is successful, it is important to consider the performance of the species seeded as well as the vegetative cover, diversity, biomass production, and transplant survival. For each seeded species, each plant life form, and the seed mixture, an establishment rating was calculated by dividing the average absolute cover by the percent contribution to the seed mix.

The establishment rating for this seed mixture after five years was 31%, which was an increase over the 22% rating calculated in 2006 (VEGETATION discussion

Based on five growing seasons at the Tijeras test plots, these data strongly suggest that reclamation on redbed alternate topsoil materials can be very successful. While this is not a long-term data set, it is possible to discern some differences between the various seeding and organic amendment treatments that were employed. These data show that different treatments and combinations of treatments had differing effects on the various measures of success. However, after five years we can begin to determine the relative successfulness of the various treatments. One of the driving factors in changes over time in the test plots was the great variation in precipitation over the past 5 years. Since the reclamation was completed in 2003, every summer has had well below average (25% - 56%) precipitation, except for 2006 when it was more than twice (235%) the average. However, spring and fall precipitation have been at or above the average in all but 2 years.

Vegetation Cover

In 2008, organic amendment treatments had apparently little effect on vegetative cover. Total and desirable vegetative cover, total and desirable forb cover, and desirable grass cover all showed no significant difference between soil treatments. However, woody cover was greater

Table **1**). The establishment rating for seeded grasses increased from 14% to 40%, for forbs it decreased from 21% to 4% and for shrubs it increased from 38% to 51%. Of the 26 species used, only five currently have establishment ratings over 50% (*Achnatherum hymenoides* or Indian ricegrass, *Atriplex canescens*, *Chrysothamnus viscidiflorus, Ericameria nauseosus,* and *Pascopyrum smithii* or Western wheatgrass). Cicer milkvetch was very common in 2006, but almost disappeared in 2008. Fifteen more species established at a rate of less than 50% and 6 were not present in the cover observations (VEGETATION discussion

Based on five growing seasons at the Tijeras test plots, these data strongly suggest that reclamation on redbed alternate topsoil materials can be very successful. While this is not a long-term data set, it is possible to discern some differences between the various seeding and organic amendment treatments that were employed. These data show that different treatments and combinations of treatments had differing effects on the various measures of success. However, after five years we can begin to determine the relative successfulness of the various treatments. One of the driving factors in changes over time in the test plots was the great variation in precipitation over the past 5 years. Since the reclamation was completed in 2003, every summer has had well below average (25% - 56%) precipitation, except for 2006 when it was more than twice (235%) the average. However, spring and fall precipitation have been at or above the average in all but 2 years.

Vegetation Cover

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Table **1**). One species (*Gaillardia aristata* or Indian blanket flower) which was present in 2006, was not observed in 2008. Only four of the seeded species were not observed at all on or near the test plots (*Sporobolus cryptandrus* or sand dropseed, *Stipa neomexicana* or New Mexican feathergrass, *Linum lewisii* or blue flax, and *Lupinus argenteus* or silver lupine). All five of the top performing species are quite drought tolerant and are commonly used in arid lands seed mixtures. The first two growing seasons when seeds were germinating and establishing received below average precipitation, as did the last two growing seasons, which may have hampered the establishment of less tolerant species.

A diverse community can benefit from all present species, even those present in only trace amounts. While the overall establishment rating for this seed mix was low, the fact that 23 of the 26 species were found at the site over the last three years suggests that the species chosen were generally appropriate for the site. Some species rarely observed in point-intercept data, may yet be important place holders in the vegetation community when climatic conditions are unusual or herbivore pressure is high.

VEGETATION DISCUSSION

Based on five growing seasons at the Tijeras test plots, these data strongly suggest that reclamation on redbed alternate topsoil materials can be very successful. While this is not a long-term data set, it is possible to discern some differences between the various seeding and organic amendment treatments that were employed. These data show that different treatments and combinations of treatments had differing effects on the various measures of success. However, after five years we can begin to determine the relative successfulness of the various treatments. One of the driving factors in changes over time in the test plots was the great variation in precipitation over the past 5 years. Since the reclamation was completed in 2003, every summer has had well below average (25% - 56%) precipitation, except for 2006 when it was more than twice (235%) the average. However, spring and fall precipitation have been at or above the average in all but 2 years.

Vegetation Cover

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Table 1: Seeded species average performance & establishment ratings

Species	**Common Name**	**Absolute Cover (%)**	**Relative Cover (%)**	**Seed Mix Contrib. (%PLS)**	**2008 Estab. Rating**	**2006 Estab. Rating**
Grasses						
Achnatherum hymenoides	Indian ricegrass	4.8	10.8	5	96%	39%
Andropogon hallii	sand bluestem	0.1	0.2	5	2%	2%
Bouteloua curtipendula	sideoats grama	1.8	4.1	5	36%	20%
Bouteloua gracilis	blue grama	0.4	0.9	5	8%	2%
Pascopyrum smithii	Western wheatgrass	8.1	18.3	5	163%	53%
Pleuraphis jamesii	James's galleta	0.4	1	5	9%	3%
Pseudoroegneria spicata	bluebunch wheatgrass	2.2	4.9	5	43%	11%
Sporobolus cryptandrus	sand dropseed	0	0	5	0%	0%
Stipa neomexicana	New Mexican feathergrass	0	0	5	0%	0%
Grass Total		17.9	40.1	45	40%	14%
Forbs						
Achillea millifolium	western yarrow	0.1	0.3	3.5	3%	11%
Astragalus cicer	cicer milkvetch	0.1	0.3	3.5	4%	98%
Gaillardia aristata	Indian blanket flower	0	0	3.5	0%	4%
Linum lewisii	Lewis (Blue) flax	0	0	3.5	0%	0%
Lupinus argenteus	silver mountain lupine	0	0	3.5	0%	0%
Onobrychis viciifolia	sainfoin	0.3	0.7	3.5	9%	38%
Penstemon angustifolia	narrow-leaf penstemon	0.7	1.7	3.5	21%	12%
Ratibida columnifera	coneflower	0	0.1	3.5	1%	25%
Sphaeralcea coccinea	scarlet globemallow	0	0	3	0%	0%
Forb Total		1.4	3.1	31	4%	21%
Shrubs						
Atriplex canescens	four-wing saltbush	6.7	15.1	3	224%	175%
Cercocarpus montanus	mountain mahogany	0	0	3	0%	0%
Chrysothamnus viscidiflorus	yellow rabbitbrush	1.5	3.4	3	51%	89%
Ericameria nauseosus	rubber rabbitbrush	3.1	7	3	104%	13%
Kraschenninikovia lanata	winterfat	0.8	1.7	3	26%	24%
Purshia mexicana	New Mexico cliffrose	0	0	3	0%	0%
Purshia tridentata	antelope bitterbrush	0	0.1	3	1%	5%
Rosa woodsii	Wood's rose	0	0.1	3	1%	1%
Shrub Total		12.2	27.4	24	51%	38%
Seed Mixture Total		31.5	70.6	100	31%	22%

with 20 or 30 tons organic amendment and grass cover was greater in plots treated with 2 tons native hay than other treatments. The observed difference in grass cover, but not desirable grass cover, was likely attributable to the large component of *Festuca arvernensis* (field fescue) that came in with the native hay mulch. While the mulch was noxious weed free, the field fescue is an undesirable species that was inadvertently introduced. The annual field fescue was a large contributor to the grass cover in these plots, but every year its cover has decreased significantly such that by 2008 it only contributed 0.2% of the absolute cover overall. While it is still a component of the community after five years it is expected to continue the downward trend exhibited over the past four years.

In 2006, forb and total vegetative cover followed the trend exhibited by grass cover. The above average precipitation in 2006 led to an increase in weedy forb species cover in plots treated with 2 tons native hay. This was driven by sweetclover primarily with contributions from kochia, and Russian thistle. The below average precipitation in 2007 and 2008 decreased the weedy forbs and favored the grass species. Plots treated with 2 tons native hay mulch had 43% grasses, 44% forbs and 13% woody species in 2005. In 2006, these plots had 24% grasses, 66% forbs, and 8% woody species and in 2008 they had 66% grasses, 16% forbs, and 18% woody species.

Weedy forb cover overall decreased significantly from 2006 to0 2008. The trend was especially pronounced for sweetclover which contributed an average of 14.9% of the absolute cover in all plots in 2006 and only 0.3% in 2008. In 2006, late summer precipitation was well above average, while spring precipitation was below average. Anecdotal evidence suggests that sweetclover flourishes in New Mexico when the late summer and winter precipitation is above average. In 2008 precipitation was well below average in every season. Sweetclover is able to take advantage of rainfall whenever it occurs, with later rainfall leading to greater density in 2006 and earlier rainfall leading to greater size in 2005. However, in 2008 the drought conditions all but removed the sweetclover from the community.

As was true in 2005 and 2006, total vegetative cover and forb cover were greater in plots seeded at lower densities. The trends for desirable vegetative cover were not the same as for total vegetative cover. While total vegetative cover was greatest in plots seeded with 5 and 10 PLS and lowest with 20 PLS + Transplants, desirable vegetative cover was greatest with 10 and 20 PLS and lowest with 5 PLS. This was a similar trend to 2006, but less pronounced. This difference is due to a greater weed cover in 5 PLS plots than in 20 PLS plots. At lower seeding rates mortality has a much greater effect on overall cover and diversity than at higher seeding rates. The lowest seeding rates have the most room for weed species to establish, but also the least competition which can lead to heartier individuals of those species that do survive.

Woody plant cover followed a similar trend to desirable species cover with greater cover in plots seeded at 10 PLS than both those seeded at 20 PLS and 5 PLS. Woody species tend to grow more slowly than forbs and grasses and because of this are less effective competitors in initial stages of community development. In 2004 all life forms had greater cover in plots with higher seeding densities and in 2006 woody cover was still higher plots seeded with 20 PLS. After five years the woody species have begun to catch up with the faster growing forb and grass species and can effectively compete for resources. With more time the woody species seem to be developing the same trend as forb and grass species.

There was also an interaction between seeding density and year such that this trend for greater cover at lower seeding densities was even more pronounced in 2008. Because test plot vegetation is well established after five growing seasons, vegetative cover is primarily a result of plants ability to efficiently gain and use resources. In those plots seeded at higher rates, and especially those with transplants as well as seeding, competition was greater in the first few years of establishment and those individuals who survived were likely stunted compared individuals subjected to less competition during establishment. Additionally, the plants with less competition were likely able to establish a stronger root system which allowed them to better withstand the drought conditions of 2007 and 2008.

The percent of grass, forb, and total vegetation cover that was desirable (relative desirable cover) continued to increase in every combination of treatments between 2005, 2006, and 2008. This increase was most pronounced in the forb cover. As mentioned previously, average relative cover of desirable species more than doubled from 2006 (36.1%) to 2008 (79.2%). Average relative desirable forb cover also more than doubled from 11.1% in 2006 to 22.9% in 2008. This was almost entirely due to decreases in weedy cover. Sweetclover, kochia, and Russian thistle contributed a combined absolute cover of 27.4% in 2006, but only 6.9% in 2008. The average relative desirable grass cover also increased from 72.2% to 89.8%, primarily due to a dramatic decrease in field fescue cover in the 2 tons native hay plots.

Species Diversity

Both total and desirable diversity increased from 2005 to 2006 and decreased from 2006 to 2008. However, the relative percentage of desirable species actually increased from 2006 to 2008. This trend suggests that the species composition is stabilizing and the weedy species are becoming less prevalent. This trend would be expected in a successfully developing revegetated community after five years.

Of the 11 dominant species (species with greater than 1% absolute cover) three were introduced. This is an improvement over 2006 when six of 11 dominant species were introduced. All six of the undesirable dominant species from 2006 decreased in 2008 and only two were still dominant. Only 24 of 94 species (25.5%) observed along cover transects were undesirable in 2008. Additionally, the average relative cover of desirable species increased from 36.1% in 2006 to 79.2% in 2008.

Herbaceous Production

Total herbaceous production varied widely within and among treatments, so no statistical differences were found between treatments. However the greatest mean production was in unamended plots seeded with 5 PLS. This was likely driven by the forb production which was significantly greater in plots seeded with 5 PLS than those with 20 PLS or 20 PLS + Transplants. Interestingly, grass species showed the opposite trend towards greater production in 20 PLS plots and the lowest mean grass production was found in 5 PLS plots. Production samples were sorted by growth form (grasses vs. forbs), but they were not sorted by species or plant species desirability. Thus, the greater forb production in 5 PLS plots could be due to significantly greater kochia and Russian thistle cover in these plots than those seeded with 20 PLS. Competition between these weedy species and grasses could explain the opposite trend in grass production.

Woody Density

Woody density in 2008 was significantly greater with higher seeding densities. These plots had lower vegetation cover overall and specifically lower forb cover. This allowed the slower growing woody species to more effectively compete for resources. Woody species density increased from 2005 to 2006, but was not significantly higher in 2008. The same four species have dominated the woody density since 2005: four-wing saltbush, yellow rabbitbrush, winterfat, and rubber rabbitbrush. Also over the past 5 years the number of species observed in woody density transects increased as shown by the significant increase in woody species richness. The number of species observed in woody density transects was 5 in 2005, 7 in 2006 and 19 in 2008.

Transplant Survival

Transplants on test plots that were not treated with a organic amendment experienced the greatest volumetric growth and maintained the highest survival rates. Those plots with 20 and 30 tons organic amendment exhibited the lowest growth and survival, respectively. This trend had held true for all five years. However, the survival of transplants in plots with 30 tons organic amendment appears to decrease faster than other treatments over time, while the survival in unamended plots decreases slowly and had begun to level out.

In previous years it was hypothesized that the transplant mortality was due to competition with invasive forb species (sweetclover, kochia, and Russian thistle) that dominated plots treated with organic amendments. In 2008, all three of these species were much less prevalent than in previous years. Sweetclover was almost absent from the site, and while kochia cover was significantly greater in plots treated with organic amendments, Russian thistle cover was significantly lower in these plots having a combined effect of no difference between treatments. This decrease in weed cover observed in 2008 does not necessarily negate the previous hypothesis. In previous years, and especially in the first two years after transplanting, competition with these weedy species could have stressed transplanted individuals. This combined with grazing and water and nutrient stresses over the past five years could have had a combined weakening effect on these transplants.

Of the 12 species transplanted, 5 shrubs (mountain mahogany, yellow rabbirbrush, rubber rabbitbrush, winterfat, and skunkbush sumac, and 1 tree (one-seed juniper) had over 50% survival after five growing seasons. One shrub (Woods' rose) had exactly 50% survival and 3 trees (pinyon pine, ponderosa pine, and Gambel oak) and 2 shrubs (Mexican cliffrose, and antelope bitterbrush) had poorer (less than 40%) survival. The oak, cliffrose, and bitterbrush are all very palatable for both grazing and browsing by deer and rabbits, which may have led to their lower survival levels; however, the winterfat is generally as palatable and it had a very high survival rate.

Vegetation Summary

After five years, all combinations of seeding and amendment treatments have effectively established plant communities on alternate topsoil materials. Vegetative cover and diversity decreased from 2006 likely due to record precipitation in 2006 and drought conditions in 2007 and 2008. However, cover and diversity are both still high and the relative contribution of desirable species increased from 2006 to 2008. These trends demonstrate that the reclamation in all treatments has, and will continue to, develop and persist under a variety of climatic conditions. Determining which of these treatments is the best at establishing and maintaining desirable plant communities depends on the criteria used to define reclamation success.

The differences between 2006 and 2008 would be expected due to the vegetation communities maturing from three to five years after planting. However, the climatic differences experienced from 2006 to 2008 should also be considered. Record rainfall in 2006 contributed to increases in cover and diversity across the board. These increases also included weedy species. In 2008, cover and diversity were lower, but the 2008 vegetation was on average more desirable.

Of the four seeding densities used, 5 PLS or 10 PLS yielded the greatest vegetation cover, ground cover, forb cover, forb diversity, and forb production while 20 PLS and 20 PLS + Transplants yielded the greatest woody plant density, woody diversity, and grass production. Desirable vegetative cover was greater with 10 & 20 PLS than with 5 PLS. In analyzing the organic amendments it appears that 2 tons native hay yielded the greatest grass cover and diversity. Woody cover was greater in plots treated with 20 or 30 tons organic amendment, with woody density being greater in plots with no soil amendment. Woody transplant survival was also greatest in plots with no soil amendment.

Ideally statistical analyses would have shown interaction effects between seeding densities and organic amendments allowing identification of those combinations that were the most effective. They did not do this. In lieu of significant differences, trends can still be determined by identifying those combinations of treatments that yielded the highest mean for any given success parameter. Those combinations that yielded the greatest mean for the most parameters in 2006 and 2008 were 20 PLS with no organic amendment, and 20 PLS + Transplants with 2 tons native hay mulch. When just the 2008 data are considered these two combinations are dominant. This is a noticeable change from 2006, when the combinations with the most success parameters were 20 PLS with 30 tons organic amendment and 5 PLS with 2 tons native hay. If we look only at those parameters that pertain to desirable species development the difference between 2006 and 2008 is less pronounced. For desirable species, plots with 20 PLS and 30 tons organic amendment and 20 PLS with no soil amendment appear to yield the greatest mean for the most parameters.

These results illustrate the importance of identifying and prioritizing reclamation goals prior to evaluating the effectiveness of treatments; the most effective treatment for one desired outcome, may not be the most effective for another desired outcome. If the goal is ground cover to minimize soil loss, then a low seed rate with 2 tons native hay mulch is the preferred treatment. However, if desirable species cover is more important, then 20 or 10 PLS with no soil amendment or a 30 ton organic amendment would be the preferred treatment. Finally, woody density and total diversity appear best achieved with 20 PLS and no soil amendment, and herbaceous production is best with 5 PLS and no soil amendment.

After five growing seasons all treatments have yielded diverse, effective, and permanent vegetation cover that has experienced dramatic growth and development. All of the practices used on the test plots are adequately supporting development of vegetation communities that are stable and are developing plant species diversity capable of supporting the post-mining land use of wildlife habitat.

SOIL RESULTS

Soil Chemistry

pH

Soil pH in 2008 ranged from 7.7 in the top 6” to 7.9 from 12-18” in depth. There was no significant difference in pH by soil amendment at any depth (p=0.237). Before construction, pH in the soil ranged from 8.0 in the top 6” to 8.1 in the deeper samples. The pH dropped slightly in the top 6” of the soil (from an average of 8.0 to 7.7) with the addition of the organic amendments and inorganic fertilizers. While these amendments were only incorporated into the top 6”, all three depths showed decreased pH from 2003 to 2008 ($p \leq 0.0001$).

Electrical Conductivity

Electrical conductivity (EC) ranged from 0.5 mmhos/cm to 1.0 mmhos/cm in 2008 depending on depth and soil amendment. Plots treated with 30 tons organic amendment (0-6”=1.0 and 6-18”=0.7) had significantly greater EC than those treated with 2 tons hay (0-6”=0.6 and 6-8”=0.5; p=0.018). While EC increased slightly with the addition of organic amendments and inorganic fertilizer, it has decreased to again after five years. None of the plots had a soil EC of concern to plant growth at any time at any depth.

Sodium Absorption Ratio

Sodium absorption ratio (SAR) is calculated from sodium, magnesium, and calcium concentrations. The average SAR in 2008 ranged from 0.6 in the top 6” in plots without organic amendments to 1.4 at the 12-18” depth in plots with 30 tons organic amendment. In the 6-12” and 12-18” depths, SAR was significantly greater in plots treated with 30 tons organic amendment than those treated with 2 tons hay or control plots (p=0.001 at 6-12” and $p \leq 0.0001$ at 12-18”). Plots treated with 20 tons organic amendment were also greater than the control plots, but no different from the 2 ton hay plots. The same trend was observed in the top 6”, but not statistically significant (p=0.056). All plots had equal SAR values pre-amendment, but those that received organic amendment increased after amendment application. Over time SAR decreased in the top 6” in all plots, increased at greater depths in plots that received organic amendments, and remained the same at greater depths in plots without organic amendment.

Cation Exchange Capacity

The cation exchange capacity (CEC) in 2008 ranged from 22.8 meq/100g to 26.0 meq/100g. There was no significant difference between soil amendment treatments in 2008 (p=0.158). in 2003, CEC ranged from 35.0 meq/100g to 37.1 meq/100g. CEC decreased significantly from 2003 to 2008 at all depths ($p<0.0001$) and no interaction effects were observed between soil amendment and year (p=0.527 at 0-6”, p=0.561 at 6-12”, and p=0.674 at 12-18”).

Soil Fertility

Organic Matter

Organic matter in 2008 ranged from 1.2% in the top 6” to 0.9% from 6” to 18” in depth (Table 1). There was a significant difference in organic matter by soil amendment at all three depths ($p \leq 0.0001$). In the top 12”, organic matter was greater in the plots treated with 30 tons organic amendment than all other plots and was greater in 20 ton organic amendment plots than the control plots and 2 ton hay plots. Between 12 and 18” control plots and 2 tons hay plots varied from 20 and 30 ton organic amendment plots, but the 20 and 30 ton organic amendment plots did not differ from each other.

Table 1: Organic Matter (%) by soil amendment over time

	Soil Amendments						
Soil Amendment	*Pre-Amendment*			*Post-Amendment*	*5 year Post-Reclamation*		
	0-6"	*6-12"*	*12-18"*	*0-6"*	*0-6"*	*6-12"*	*12-18"*
Untreated Control	0.3	0.3	0.3	0.2	0.7	0.7	0.6
2 tons Native Hay	0.3	0.3	0.2	0.2	0.7	0.6	0.6
20 tons OA	0.3	0.2	0.3	1.9	1.5	1.1	1.0
30 tons OA	0.3	0.3	0.2	3.0	1.8	1.4	1.2
Mean	0.3	0.2	0.3	1.3	1.2	0.9	0.9

Organic matter in the soil increased significantly from 2003 to 2008 at all depths (Table 1). However there was a significant interaction effect between year and organic amendment at all depths as well. Organic matter in the pre-amendment soils was relatively uniform across all plots, but after 5 years the organic matter increased in all plots at all depths ($p \leq 0.0001$, Figure 1). Not surprisingly this increase was most pronounced in the plots treated with 20 and 30 tons organic amendment.

Soil organic matter was evaluated with several of the vegetation parameters to determine whether correlations were present between organic matter and vegetation success. Organic matter did not correlate with vegetation cover ($r^2=0.004$), desirable vegetation cover ($r^2=0.028$), total diversity ($r^2=0.018$), desirable diversity ($r^2=0.008$), woody density ($r^2=0.001$), or herbaceous production ($r^2=0.038$). Only grass and woody cover were significantly different between soil amendment treatments; however, even these measures did not correlate with organic matter ($r^2=0.094$ and $r^2=0.144$, respectively).

Nitrate Nitrogen

Nitrate nitrogen (NO_3-N) ranged from 7.7 lbs/acre in surface soils to 3.3 lbs/acre at 12-18” in depth (P, like NO3-N, spiked after the organic amendment and fertilizer were applied from 3.4 ppm to 52.1 ppm (Table 3). This spike was most pronounced in the plots that received the inorganic fertilizer (control and 2 tons hay). Interestingly, the post-reclamation data show that while P decreased in all plots, the plots that received inorganic fertilizer had lower P than those that received organic amendment.

P was also evaluated with several of the vegetation parameters to determine whether correlations were present between P and vegetation success. P did not correlate with vegetation cover (r2<0.001), desirable vegetation cover (r2=0.038), total diversity (r2=0.001), desirable diversity (r2<0.001), woody density (r2<0.001), or herbaceous production (r2=0.023). Only grass and woody cover were significantly different between soil amendment treatments; however, even these measures did not correlate with P (r2=0.021 and r2=0.069, respectively).

Table **2**). NO_3-N did not differ significantly between soil amendment treatments at 0-6” or 6-12” (p=0.843 and p=0.911, respectively). However, in the 12-18” sample, NO_3-N was greater in control plots than those treated with 2 tons native hay (p=0.002).

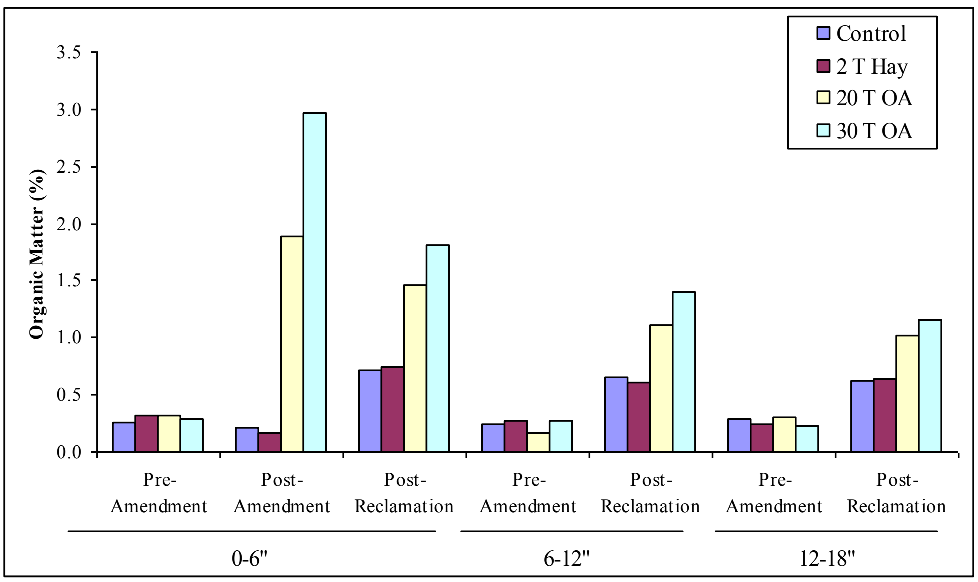

Figure 1: Organic matter interaction effect of soil amendment & year by depth

Plant Available Phosphorous

Plant available phosphorus (P, measured as bicarbonate phosphorus) ranged from 10.7 ppm in surface soils to 7.4 ppm at 12-18” in depth (Table 3). P differed significantly with soil amendment at all three depths (p≤0.0001,). In the top 6”, phosphorus was greater in the plots treated with 30 tons organic amendment than all other plots and was greater in 20 ton organic amendment plots than the control plots and 2 ton hay plots. This trend was the same at the 12-18” depth. However, in the 6-12” depth the there was no significant difference between the 20 ton organic amendment treatment and the control plots and 2 tons hay plots.

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Table 2: Nitrate Nitrogen (lbs/acre) by soil amendment over time

	Soil Amendments						
Soil Amendment	*Pre-Amendment*			*Post-Amendment*	*5 year Post-Reclamation*		
	0-6"	*6-12"*	*12-18"*	*0-6"*	*0-6"*	*6-12"*	*12-18"*
Untreated Control	6.8	6.3	6.3	8.7	7.8	3.4	4.0
2 tons Native Hay	8.2	7.5	8.0	9.0	6.3	4.0	2.5
20 tons OA	7.2	6.6	6.9	104.1	6.9	3.8	3.6
30 tons OA	8.0	7.5	7.1	180.2	8.4	3.4	3.2
Mean	7.5	7.0	7.1	75.5	7.4	3.6	3.3

Table 3: Bicarbonate phosphorous (ppm) by soil amendment over time

	Soil Amendments						
Soil Amendment	*Pre-Amendment*			*Post-Amendment*	*5 year Post-Reclamation*		
	0-6"	*6-12"*	*12-18"*	*0-6"*	*0-6"*	*6-12"*	*12-18"*
Untreated Control	3.3	3.3	4.3	81.3	5.8	5.9	4.8
2 tons Native Hay	3.7	3.9	3.8	61.8	6.2	6.0	5.0
20 tons OA	3.9	1.6	1.5	24.6	11.3	8.3	7.8
30 tons OA	2.8	1.6	1.8	40.6	19.5	13.1	12.2
Mean	3.4	2.6	2.9	52.1	10.7	8.3	7.4

Plant Available Potassium

Potassium (K) in 2008 ranged from 337.8 ppm in the top 6” to 257 ppm from 6 to 18” in depth (Table 4). There was a significant difference in K by soil amendment at all three depths ($p \leq 0.0001$). In the top 12”, organic matter was greater in the plots treated with 30 tons organic amendment than all other plots and was greater in 20 ton organic amendment plots than the control plots and 2 ton hay plots. Between 12 and 18” control plots had significantly less K than all other treatments, but there were no differences between the 2 tons hay plots and the 20 and 30 ton organic amendment plots.

Table 4: Potassium (ppm) by soil amendment over time

	Soil Amendments						
Soil Amendment	*Pre-Amendment*			*Post-Amendment*	*5 year Post-Reclamation*		
	0-6"	*6-12"*	*12-18"*	*0-6"*	*0-6"*	*6-12"*	*12-18"*
Untreated Control	193.5	205.0	208.5	199.3	247.7	215.8	244.3
2 tons Native Hay	186.8	188.1	189.0	205.1	234.8	194.0	202.0
20 tons OA	181.3	193.3	200.5	407.6	376.2	265.5	261.2
30 tons OA	182.0	193.3	198.8	707.3	492.3	354.8	318.8
Mean	185.9	194.9	199.2	379.8	337.8	257.5	256.6

SOIL DISCUSSION

The soil data presented here support the vegetation data in suggesting that reclamation on redbed alternate soil reconstruction materials can be very successful. These data represent a snapshot of soil conditions before reclamation activities, immediately after soil amendment, and five growing seasons after reclamation. Soil data can be used in conjunction with the vegetation data to discern which soil amendment treatments were associated with the most successful reclamation.

Soil Chemistry

While there were some interesting interaction effects observed for soil chemistry, the results were not particularly biologically significant. All pH, EC, and SAR values were within normal ranges and the differences between soil amendments were not large enough to significantly affect vegetation establishment and growth. The pH trends of the developing test plots soils suggest that over time as root development, respiration and production of organic acids continues, pH levels will continue to acidify resulting in a more suitable system for nutrient cycling and microbial activity.

The change in CEC observed over time was the same across all treatments and depths, and thus can likely be attributed to different soil labs rather than any actual change in the soils. Whatever the reason, this change is not biologically significant. However, because CEC is generally pH dependent, we can expect the CEC to also decrease proportionately.

Soil Fertility

Organic matter has increased from 0.3% to 0.7% to 1.5% during the 5 year study. This accumulation of organic matter strongly suggests that the redbed soils are in the process of pedogenesis with developing organic accumulations that will result in improved nutrient cycling, reduction in pH and improved soil structure.

The redbed soil cover was low in readily available nitrate nitrogen prior to amendments and continues to be low even on the organic amended plots. The nitrate nitrogen results suggest that while surface soil levels are stable, mining of nitrate nitrogen in the 6-12" and 12-18" depths is still occurring. The existing levels of organic matter suggest that minimum levels of organic matter may have been attained to sustain nitrogen cycling (Woods & Schuman 1986). Additionally, the nitrogen fixing legumes and shrubs that were seeded and established on the test plots will help to ameliorate some of the predicted nitrogen deficiencies that may occur in the future. Sweetclover, one of the weedy annual species that has declined in the vegetation cover in the last year has been estimated to fix between 100 and 200 kg/ha/year of nitrogen (Stevenson 1982); however, the nitrogen contribution from this species is expected to be significantly diminished as native species establish and sweetclover continues to decline.

Phosphorous availability and uptake efficiency is directly related to the presence of nitrate and ammonium nitrogen. The phosphorous results on the test plots illustrate expected deficient P levels prior to amendments. On fine textured mine soils with less than 7 ppm of phosphorous, inputs of 200 pounds per acre of P_2O_5 are necessary to support long-term productivity with no additional inputs. These results support this amendment rate with phosphorous levels on the untreated and hay amended plots showing improved levels, but still slightly deficient after 5 years. Organic amended plots exhibit suitable levels of P after 5 years and suggest that this rate of organic amendment may result in longer term supplies of plant-available P and possibly enhanced vegetation establishment over time. However, no statistical effects on vegetation were observed due to P levels and this may be due to part to all of the test plot soils exhibiting slightly deficient to acceptable levels of phosphorous.

Most western mine spoils contain adequate amounts of K for revegetation and natural weathering releases a sufficient amount of potassium ions for plant growth. Soil test results suggest that all plots exhibit suitable levels of potassium during the study period with no significant effect on vegetation success.

Soil & Vegetation

If the soil conditions had a significant impact on vegetation success, then a correlation would be expected between soil results and vegetation parameters. Organic matter and P were the primary soil characteristics which showed differences between soil amendment treatments. Thus, it was hypothesized that these variables may be more correlated with vegetation success than others. However, regressions of organic matter and P with all vegetation parameters showed no correlation. Given these results, it seems likely that differences in soil conditions resulting from differing soil amendment treatments had little to no effect on reclamation success. The soil conditions on all plots were suitable for reclamation success. This result confirms that the effort to apply inorganic fertilizer to the control and 2 ton hay plot at a rate sufficient to equal the organic fertilizer in P and K was successful. Further, the boost in N and organic matter provided by the organic amendment was not so great as to have an effect on vegetation success in these plots.

Soil Summary

After five years all soil amendment treatments have resulted in suitable soil conditions for vegetation growth. There were very minor differences in soil chemistry between soil amendment treatments. There were also only minor differences pre-reclamation and post-reclamation (2003 to 2008). None of the soil chemistry results were biologically significant.

While there were some interesting differences in soil fertility between soil amendment treatments, these differences did not correlate to differences in vegetation success. No correlations were found between any of the reported soil characteristics and total vegetation cover. Additionally, no correlations were found between organic matter and P and desirable vegetation cover, total and desirable diversity, woody density and herbaceous production. This suggests that reclamation success was not affected by differences in soil conditions brought about by soil amendment treatments.

CONCLUSIONS & RECOMMENDATIONS

A number of general conclusions can be made from the vegetation and soil data collected five years after reclamation on the vegetation test plots. Soils differed very little between soil amendment treatments and all soil parameters were within suitable limits after five years. While the differential soil amendments applied to the test plots initially spiked soil organic matter and nutrients in some plots, after five years they have begun to even out across the treatments. This result simply suggests that the test plot design was successful in removing differential soil characteristics as a potentially confounding factor in evaluating reclamation success.

Soil testing results support the vegetation data in suggesting that applying an organic amendment, such as the horse manure and stable waste used on the 20 ton and 30 ton organic amendment plots, is not cost effective. Organic amendments are generally in scarce supply and relatively expensive to purchase, import, spread, and incorporate. While the test plots treated with organic matter did have a greater woody cover than the 2 tons hay plots, they were not statistically different from the untreated control plots for any of the vegetation parameters measured. Thus, the added expense of organic amendment does not appear to provide the expected added benefit in revegetation success.

The plots treated with 2 tons native hay mulch exhibited greater grass cover and diversity, but this was likely due to grass seed imported with the hay mulch. Further the native hay mulch also contained a substantial component of non-native annual grass seed. While the mulch could provide a benefit in reducing erosion, the costs associated with this application outweighed that benefit, especially considering the amount of undesirable plant species that were introduced with the mulch. The redbed material used on the test plots is very erosive and considerable erosion problems were identified on the control and mulch plots after the very high rainfall events in

August 2003. This precipitation event occurred after fertilizer, and organic matter amendment placement and incorporation, but before seeding and mulching. Rainfall events in August 2006 also resulted in considerable erosion. While no significant differences were shown between soil amendment treatments and erosion severity in 2006, the highest rate of soil movement was shown in the mulched plots. These plots were dominated by weedy annual grasses and forbs in 2006 which did not have the root systems required to prevent erosion after the hay mulch had weathered and decomposed. If this rainfall had occurred earlier before the vegetation had established the plots treated with mulch or organic amendment may have been better protected than the control plots.

Successful erosion control measures taken in 2007 on the test plots removed erosion as a concern from the 2008 data presented here. However, erosion concerns have the potential to play a role in future reclamation activities at the Quarry. While the 2 ton native hay mulch application did not provide the expected benefit and introduced adverse unwanted variables, these results to do not support the complete removal of mulching from the Quarry's reclamation design. Given the highly erosive nature of the redbed soil reconstruction materials, future investigation using a wood mulch, seed-free straw mulch, or hydromulch could discern the benefit of mulch for erosion control without introducing the confounding factor of weed introduction.

All of the low broadcast seeding rates were effective at establishing cover and diversity. While the results differed depending on which vegetation parameter was used to evaluate "success", the 10 and 20 PLS/sf treatments provided the best overall vegetation results. The transplants added to the 20 PLS + Transplants plots provided a boost in woody diversity and density. However, the added cost in materials and labor did not pay off in terms of overall cover, diversity, or production. None-the-less, transplanting highly desirable plant species that are difficult to establish from seed may be warranted on a limited basis in concentrated areas.

The lessons learned from the data collected over five years on the vegetation test plots can be applied to future reclamation at the Tijeras Quarry. Based on these results the recommended treatments for future reclamation are a 20 PLS/sf seeding rate with no organic amendment. Depending on the site, some mulch treatment for erosion control may also be warranted. Limited transplanting of specific plant species may be justified in selected areas.

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STEAMBOAT SKI RESORT'S BASE AREA

REGRADE AND REVEGETATION PROJECT

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ABSTRACT

The lower part of the Steamboat Ski Resort's mountain where the beginner area is located had a design problem. The draws and double fall lines that Mother Nature provided had a tendency to bunch people together. As a result the terrain was not conducive for teaching both skiing and snowboarding and they chose to regrade and reshape the contours of the Base Area.

The project involved reshaping the lower 25 acres of the mountain terrain from the top of the Christy chair down to the base of the Gondola lift. No soil was removed nor was there any added.

In their efforts to comply with Phase Two of the Clean Water Act the Ski Corp employed over 25 employees full time for nearly three months to install berms, swales, check dams and Erosion Control BMP's to meet the obligations of their Stormwater Permit from the CDPHE.

A Bonded Fiber Matrix was then applied over native seed and soil amendments in the fall of 2008 to Revegetate the area. The end result was the successful germination and growth on the site that allowed the area to close its permit with the state in fall 2009, easily meeting the 70% requirement for Revegetation.

INTRODUCTION

By the time the Steamboat Ski Resort officially broke ground in 1958 It's skiing history was already over 45 years old. That is partially because Carl Howelsen left Norway to immigrate to the United States in 1905. He had no idea he was about to become the grandfather of skiing in the Yampa Valley that the little town of Steamboat Springs rested in. Howelsen, a great Norwegian ski champion, moved to Chicago and joined Barnum & Bailey’s circus and became “The Flying Norseman”. Eventually, he tired of the circus, longed for the outdoors and mountains and headed west to Denver in 1909 (Leif Hovelsen, 1983).

In 1911 he and a friend skied 44 miles from Rollins Pass into Hot Sulphur Springs, where they found a Winter Carnival in progress. After building a jumping ramp he sailed seventy nine feet in the air and wowed the townspeople who immediately plan a jumping tournament for the following February (Middle Park Times, 1984).

By 1941 Steamboat Springs holds its 31st annual Winter Sports Carnival and raises $110,000.00 in war subscriptions during the Fourth War Loan Drive of Routt County (Sureva Towler, 1987).

On July 6, 1958 James Temple broke ground for the new Storm Mountain Ski Area in Steamboat Springs. Between 1958 and 1961 he secured options to buy 827 acres of meadow land at the base of the mountain. "Champagne powder" is the descriptive phrase used to promote the area. He gives credit to a Kremmling rancher, Joe McElroy, who said the fluffy dry snow was "lighter than champagne bubbles". (Sureva Towler, 1987).

Today the mountain consists of a total of 2965 skiable acres ranging in altitude from 6900 ft to 10,568 feet above sea level. They have 164 runs; 14% beginner, 42% Intermediate and 44% Expert.

THE PROBLEM

The very bottom of the mountain serves two purposes; first it is the primary area where beginning skiing and snowboarding lessons are taught. Secondly it is the only way off of the mountain on skis. The problem with this terrain was its pitch. It was relatively flat at the top and almost a twenty two percent grade at the bottom. Mother Nature had originally separated this area into two trails with different elevations and a transition in between that created a double fall line. It did not go straight down the mountain towards the bottom but fell away to the right. While advanced skiers can navigate these lines is difficult for beginners. It also presented a challenge for the machines that groom the slopes on a nightly basis.

THE GOAL

The intent of the regrade was to separate this area into three distinct trails, each with a consistent pitch; The steepest section (lined in Red) would hold annual events such as the Cardboard Classic (A race of sleds constructed out of cardboard) and the Cowboy Downhill which hosts rodeo contestants from the Stock Show in Denver every January). This trail was to be approximately a nineteen percent grade and is to the far right.

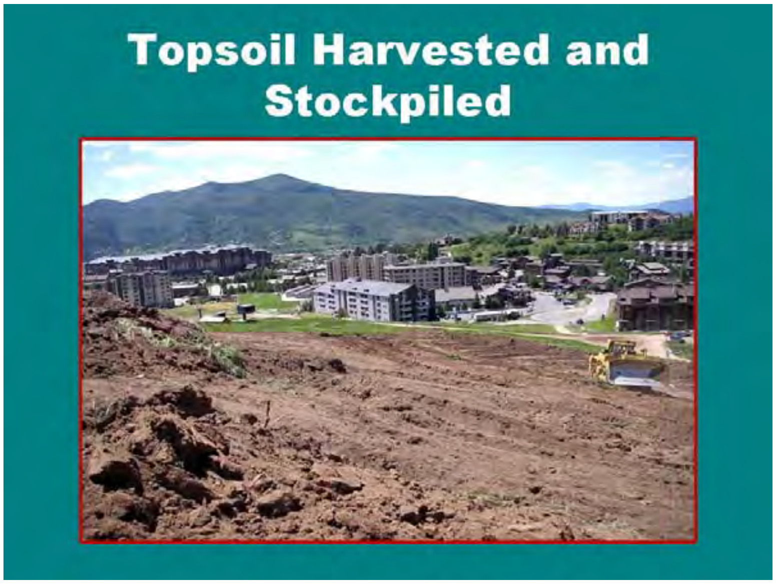
In the center a trail (lined in Yellow) was designed with a medium pitch to allow skiers to transition from the top of the mountain at the end of the day to the base area. This area was to be between a fourteen and sixteen percent grade.

At the far left (lined in Green) was to be the teaching area with the mildest pitch at between a nine to twelve percent grade.

THE PROJECT

GROUNDBREAKING AND COMPLICATIONS

Formal planning began in 2005 and dirt started moving in July of 2007. First of all the **25** lift towers that belonged to the 3 lifts that serviced the area had to be removed. The dirt work was subcontracted to Precision Excavating of Steamboat Springs. Six inches of topsoil was harvested from the entire site and stockpiled. Almost immediately it became apparent that the main power feed that supplied the mountain ran directly up the middle of this slope. It was decided to bulldoze dirt from the old beginner's terrain into the middle to create an area for installing new lines and to cover the old ones until the new lines could be placed.



New lift towers were placed by helicopter while the lines were installed. It took until October to finish the power now placed along the south of the project. At this point they needed to remove the old lines and grade the center trail and teaching area. This took approximately two weeks and all rough grading was completed. Fortunately, it was a mild fall and snow came late, allowing additional time to install temporary drainage swales and BMPS to secure the area for the winter.

SECURING THE AREA

Straw erosion control blankets were installed over the site to mitigate erosion for the winter. A crew of six workers spent two weeks installing the blankets to secure the area (approx 500 man hours).

SPRING 2008

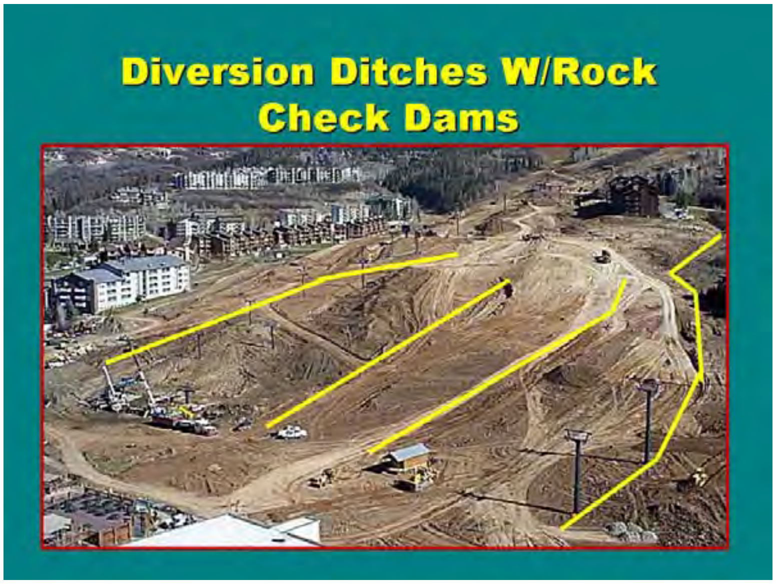
Controlling spring runoff on a site twenty five acres in size that receives four hundred and fifty to five hundred inches of snow a season can represent a huge challenge. It can take over twenty inches of light snow to equal an inch of moisture but only five or six inches of wet heavy snow to equal the same. Splitting the difference and an area such as Steamboat receives about 30 inches of moisture each winter, not including the man-made snow on top of that. During the spring runoff, the melted water runs between the top of the ground and the bottom of the snow. It can erode the soil at an alarming rate with the weight of the snow that remains on top.

A crew of eight workers and a mini excavator were assigned full time to muck out behind check dams and sediment traps seven days a week for three to four weeks during what is referred to as “mud season”. This represents approximately 1800 man hours. The crew also reinforced check dams once they dried out to insure their stability. Water from the three main diversion ditches was funneled toward a series of three oversize dewatering bags 15 feet by 40 feet to decant as much sediment as possible.

FINAL GRADING

After things started drying out the heavy equipment was brought in and the final grading began. Since the beginner’s area had been moved the “Magic Carpets” had to be moved from one side to the other. Magic carpets are small conveyor belts that move slowly to transport beginners standing upright to the top of the area instead of lifts.

The topsoil was reinstalled averaging approximately six inches deep over the entire project. Approximately one half of a million cubic feet of topsoil were removed and reinstalled.



STORMWATER MANAGEMENT

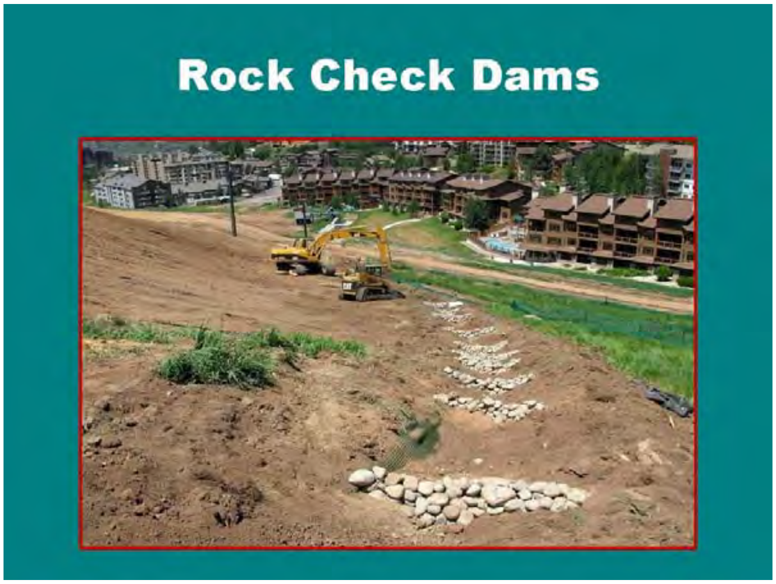
A permanent set of trenches and ditches had to be constructed to channel moisture down the mountain and installed to create permanent drainage. Even after the Revegetation is finalized the sheer volume of water runoff necessitated a series of drainage channels to prevent the combination of snowmelt and subground water from scouring or compromising the integrity of the soil.

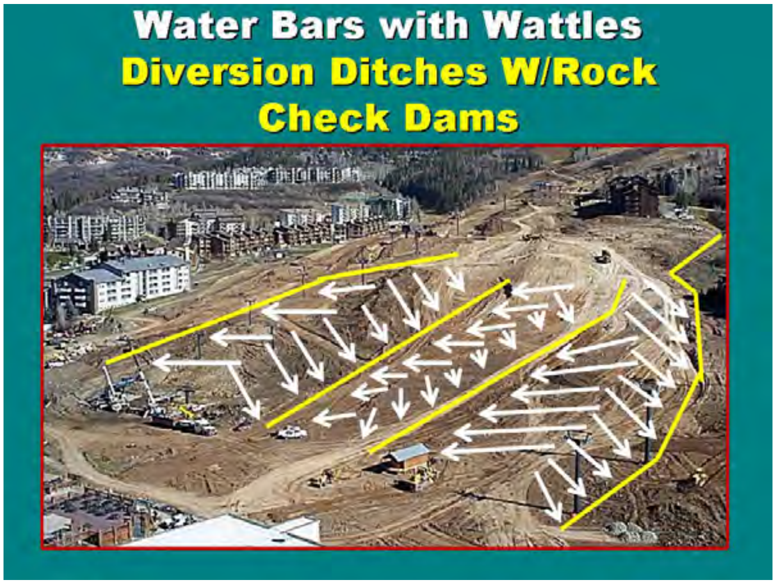
The four main vertical diversion ditches were designed to transport water from the smaller grid of horizontal trenches and withstand greater hydraulic pressures. Permanent Rock check dams were placed to slow the velocity and contain sediment at prescribed intervals. Their distance apart was determined by the slope with the bottom of the upstream dam at the same height as the top of the downstream dam.

They were reinforced with Landlock 300, a synthetic Turf Reinforcement Mat designed to prevent scouring or riling of the ditch. This TRM is designed to protect vegetative growth in velocities above 10 feet per second.

The horizontal water bar trenches were set in a grid that ran across the hill at approximately a ten degree slope to break the square footage of the mountain into small, manageable areas. Biodegradable straw wattles were placed in each trench using the same criteria as the rock check dams to contain the sediment in any given area. They fed into the larger diversion ditches to transport the water down the mountain.

A crew of twenty to twenty five employees worked full time for ten weeks to install the wattles and rock check dams. This took approximately 10,000 man hours to complete. Almost all of the rock used for the check dams was deposited on the hill in batches and hand placed.





THE SEED MIX;

Steamboat Lower elevation custom mix provided by Pawnee Buttes Seed Co, Greeley Colorado;
(This mix has been used at Steamboat for a lot of years and works well in this climate.)

Actual application rate was 50 lbs/acre (Double the recommended rate)

-Smooth Brome (Manchar-Bromus inermis)
-Streambank Wheatgrass-(Elymus lanceolatus)
-Pubescent Wheatgrass-(Elytrigia intermedia)
-Crested Wheatgrass-(Agroptron cristatum)
-White Clover—(Trifolium repens)
-Alsike Clover-(Trifolium hybridum)
-Small Burnet Clover—(Trifolium longipes).

SOIL PREP

The topsoil was then harrowed to soften it up and make sure it was consistent in depth. Seed and fertilizer were then worked into the mix and harrowed once more.

THE FERTILZER

Biosol 7-2-3 Organic fertilizer provided by Bowman Construction Supply Inc. of Denver Colorado. (This mix has also been used at Steamboat prior and works well in this climate.) Because it is organic no hazards were present to wildlife or day hikers.

Actual application rate was 800 lbs/acre due to microbial activity present in the high quality topsoil.

HYDRO MULCHING

A Bonded Fiber Matrix was decided upon in lieu of regular hydro mulch due to the complications of the degree of slope and the amount of snow that would be on it continuously for the 5 to 6 months of winter that was approaching. The cross linkers in the BFM would in essence help it serve as a liquid applied blanket with much better intimate contact than a RECB and at a lower dollar amount. The product chosen was Soil Guard manufactured by Mat Inc.

It was applied at a rate of 2,000 lbs/acre as an average. On steeper slopes the rate was approximately 2500 lbs and on the flatter areas the rate was 1800 lbs.

Hydro mulching was completed in the fall of 2008 well in advance of the upcoming ski season and the project was buttoned up for the year.

RECYCLING STRAW BLANKETS FROM 2007-2008 SEASON

Some of the blankets originally laid down the first fall of 2007 were able to be salvaged when removed in spring 2008 and some were recycled around the lift terminals in areas with slope greater than 1>1.

SPRING 2009

Spring 2009 arrived with all BMP's intact and the diversion ditches and horizontal trenches operating smoothly. Germination was just beginning. Once the snow melted growth occurred very quickly.

The next series of photos will illustrate before and after photos taken between September 2008 and July 2009, approximately 10 months apart. This is the top of the Christy 3 lift looking down towards the Base.

The these were taken just downhill looking back up towards the top of the Christy 3 terminal. Areas that had been dirt the November before experienced vegetation growing between 3 to 8 inches in the first month. By the end of the second month the vegetation was about knee high.

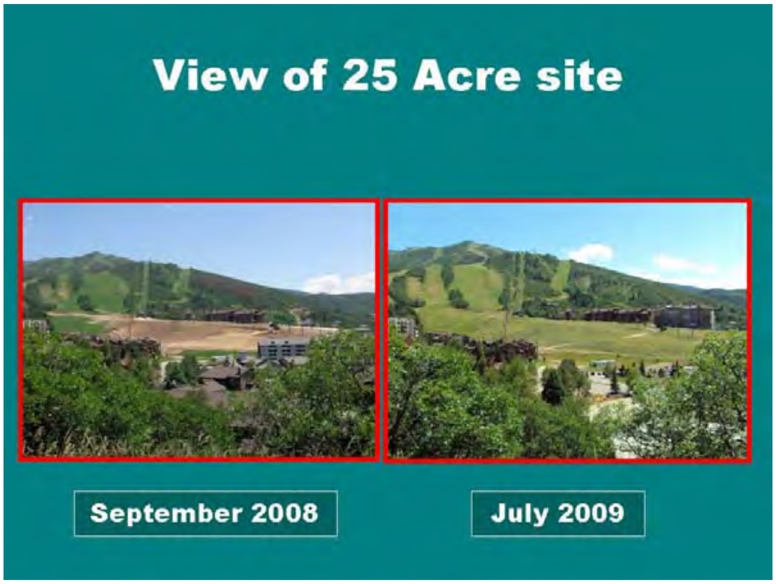
These were taken at the same location as the last slide, only a quarter turn to the left looking downhill. Notice how consistent and dense the growth is on the steeper areas of the slope. Vegetation had grown in at a rate of nearly 75 percent those first two months and by July of 2009 to between 90% and 95%.

This is the lower Christy 3 area., directly about the new beginner's area.

The new beginners area had the advantage of downstream moisture to help with its growth.

During the balance of the summer snowmaking guns were used occasionally to water the area and by August Slope Maintenance Supervisors determined the growth at nearly 100%.

This set of photos perhaps best illustrates the amount of growth that occurred during this growing season.



The CDPHE permit originated in May 2007 and was closed out November 0f 2009.

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SALVAGING A SEEDED NATIVE GRASS STAND AND SAVING THE CLIENT MONEY

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ABSTRACT

Five sedimentation ponds, situated in and around housing development and golf course. The ponds are approximately 1.1 acre each in size. Ponds were seeded, straw mulched and blanketed fall of 2007. Ponds were inspected early 2009, for construction compliance. It was determined that the native grass cover was inadequate for stability even though the slopes showed no signs of erosion. The grass cover was at best 1 plant per sy, and at worst, 1 plant per 5 sy. Recommendation was to remove the blanket, furnish and spread 6" of topsoil, reseed and blanket the sites. This method was estimated to cost $120,136.00, about $0.51 per sft.

DTEC suggested an alternate treatment. Spread seed and soil amendment over the existing blanket. Use the existing plants and fill in with additional plants from seed. The soil in the ponds was sampled and tested, also the topsoil to be imported. While the potential imported topsoil was good, the soil in the ponds was not that much different. The decision was made to overseed and amend the project.

The straw in the bionet blanket had deteriorated, but the bionet was still intact. Initially a walk-behind slit seeder was used to apply seed; however, the slit seeder tore the bionet. Therefore, the seed and amendment was applied over the netting with a hydroseeder. A standard native seed mix was used at double rate, 1800 lbs of Biosol per acre, 900 lbs of humate per acre and 10 lbs of micorrhyzae per acre was sprayed over the blanketed areas, and the non-blanket area was drill seeded and straw mulched. This treatment also included some grading, weed control, and some straw bionet blanket installation. This treatment cost approx. $41,140.00, about $0.15 per square feet.

INTRODUCTION

The immediate problem was discovered during an inspection for compliance with proper sedimentation pond construction. The owners were directed to reconfigure their ponds to include emergency spillways, access/maintenance roads, and armored spillways. The native grass cover, which was installed after pond construction, was deemed insufficient for permanent stabilization. The original seeding, blanketing, and mulching was done the fall of 2007. The specifications were to use a native grass mix, straw mulch at 2 tons per acre, mechanically crimped, and erosion blanket on all sloped areas. While the pond slopes remained stable with the biodegradable blanket preventing any erosion at all, the grass cover at best was 1 plant per square yard, at worst 1 plant per 5 square yards. It was recommended that the soil retention blanket be removed, six inches of topsoil be imported and spread, and seeding and blanketing be reinstalled. These five ponds were approximately 1.1 acre in size, which meant that 4260 cubic yards of soil would have to be brought in and spread. The five acres would then be reseeded and blanketed for a total cost of approximately $120,136.00 or $0.51 per square foot.

Down To Earth Compliance suggested an alternate proposal. Our method would utilize soil amendment and seed spread over the remaining blanket. Enhance the existing grass plants, while filling in additional plants from seed.

INFORMATION GATHERING

Soil tests were done on each pond. The soils to be imported were tested also. The topsoil test, as expected, turned out well. The soil in the ponds was not that much different in quality.
Cost of blanket removal, topsoil spreading, and reseed and reblanket.

Removal and disposal of 5.5 acres of blanket would be about $0.45 per square yard, or $11,979.00. Purchase and delivery of 4260 cubic yards of soil at $8.00 per yard, totals $36,480.00. The spreading with loader and operator would be $10,000.00. Seeding and blanketing the areas at $1.95 per square yard would be $51,909.00. Weed control and amendments for the imported topsoil (it was no better than existing soils) adds another $0.087 per square foot for a grand total of $120,136.00

The owner decided to amend and overseed the existing blanket over native soils.

THE PROJECT BEGINS

Soil testing determined the type and amount of soil amendment. The recommended amount of Biosol, an organic amendment, was 1800 lbs per acre. Humic acid, Humate, also used at 900 lbs per acre. Additionally 10 lbs of mycorrhizae was spread over the areas.

Originally it was thought the soil amendments could be spread dry over the ponds and the seed applied with a walk-behind slit seeder. Since the structural integrity of the blanket was important to retain for soil stability, it became clear that the slit seeder was not going to work. It was too destructive. The coulters on the machine were tearing and ripping up large portions of the blanket. The blanket had deteriorated to the point that the jute strings and some cross woven string was what was left. It was sufficient to hold the soil, but could not withstand the slit seeder. A standard native seed mix was used and the rate was doubled for broadcast purposes. The seed and amendment was spread over the pond areas with a hydroseeder. The existing grass plants and remaining blanket was not keeping the seed and amendment from reaching the soil. The newly constructed access roads and spillways were drill seeded and either straw mulched or blanketed, depending on the steepness of the slope.

The amendments, as described above, were used to spur additional growth of the grasses already in place. The amendment also helps to create a sustainable growth medium for all plant material. The newly germinating seed use the existing grass plants for a nurse crop, while the old blanket keeps the soils in place while the grasses fill in. The newly seeded plants benefit from the mycorrhizae symbiosis to sustain themselves in the dry climate.

The amendments were applied for $2721.00 per acre. The broadcast seed was $0.028 per square foot. The total area seeded was measured to be 6.17 acres. Drill seeding, straw mulching, and miscellaneous blanket on the new construction, cost $3500.00 per acre. The soils testing, approximately70 hours of grading (both hand and machine), removal and repair of some blanket and installation of .79 acres of new blanket, and mobilizations make up the $3500.00 per acre. The total cost for the whole 6.17 acres was $41, 140.00. Approximately $0.15.3 per square foot.

Other benefits include a much shorter time necessary for permit closure, in other words, not starting from scratch, thereby resulting in quicker bond release and fewer storm water inspections. These are hidden costs that the client did not have to spend.

EAGLE RIVER RESTORATION PROJECT
"Edwards Reach"

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Project Overview

The Eagle River Watershed Council is turning dreams of restoring damaged aquatic resources into reality by leading the charge to improve the habitat and function of the Eagle River, where it runs through the heart of the Edwards community.

The "Edwards Reach" begins approximately one half mile downstream of the Edwards Spur Road Bridge and extends downstream to the Hillcrest Drive Bridge, located near the Edwards Wastewater Treatment Plant.

The multi-phase Eagle River Restoration Project will, at completion, restore the 1.6 mile Edwards Reach and over 80 acres of riparian corridor, including aquatic and terrestrial habitats. Moreover, restoration of this reach will reconnect 50 continuous miles of high-quality riparian and aquatic habitat, fragmented by past degradation.

The valley abruptly widens and flattens as the river enters the Edwards Reach, making it unique in this corridor. Adjacent floodplain widths expand to more than 2,000 ft in the upper reach, as compared to typical widths of 100 to 300 ft upstream and downstream of Edwards. The overall gradient of the reach is very flat at 0.25 percent. Local slopes hit a maximum of 0.4 percent and long backwatered sections, exceeding 0.5 mile in length, are present throughout the reach.

In fact, the river's slow pace in this reach and its general resemblance to more of a broad lake than a river caused early settlers in the valley to nickname this area "Frenchman's Lakes". Of further note, this area is a rare location in the valley where large expanses of adjacent floodplain have avoided development and remain free of permanent structures.

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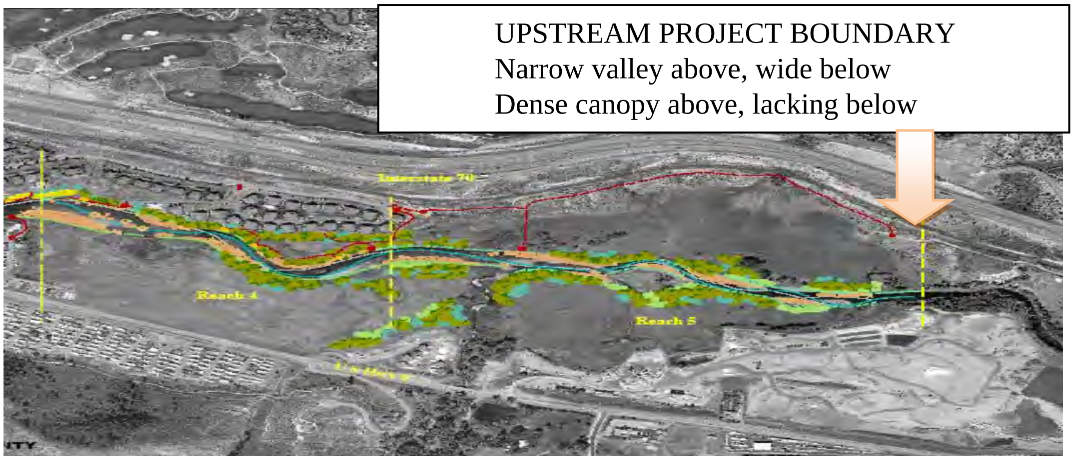


Aerial shows the abrupt widening of the valley as the river enters the Edwards Reach from the right side of the photo. The dense riparian canopy located upstream, but lacking through the reach, can also be seen.

The Eagle River at Edwards is located more than 30 miles from its headwaters and drains an approximately 600 square mile basin. The flow regime is characterized by the frequency-discharge table below:

DISCHARGE (cfs)		
	Upstream of Lake Creek	**Downstream of Lake Creek**
Low Flow (approx. 85% exceedance)	105	120
Mean Annual Flow	1990	2060
Bankfull Flow (1.5-year)	2430	2730
10-year	3980	4530
100-year	5430	6170

Funding

To make this project a reality, the Watershed Council has procured and continues to manage funds from a myriad of funders and project partners. A $1.4 million award from the Eagle Mine Natural Resource Damage Recovery (NRD) Fund in January of 2007, part of this fund's second disbursement, was the primary funding source for the Phase 1 project. The Eagle Mine NRD Fund contracted projects that restored the natural resources damaged or lost as a result of the operations of the Eagle Mine within the Eagle River basin. The second distribution from the fund in 2007 totaled $2.4 million.

The Watershed Council's partner and fiscal agent, the Eagle River Water and Sanitation District (District), augmented the NRD funding with almost $500,000 towards the Phase 1 project. The project was able to incorporate District needs for an improved mixing zone below the Edwards treatment plant outfall into its restoration plans. This creative leveraging of resources greatly expanded the positive impacts achieved by the restoration project.

Additional funders and project partners, some with multi-phase involvement, include Eagle County, the Colorado Water Conservation District (CWCB), EPA through a Section 319 grant, the Western Eagle County Metropolitan Recreation District (WECMRD), and the Edwards Metropolitan District.

Pre-Existing Conditions

In 2005, the Colorado State University, Engineering Research Center completed a study of the Eagle River, commissioned by the Watershed Council and entitled the Eagle River Inventory and Assessment (CSU, 2005). The report assessed 110 miles of the main stem and lower tributaries of the Eagle River from a basinwide ecological perspective and developed recommendations to guide future river conservation work and help ensure financial resources are spent in areas of ecological priority for the valley.

The report found the Edwards Reach to be one of the most severely degraded reaches in the valley and recommended it as one of three highest priority restoration projects in the watershed due to its potential to reconnect high quality habitats and restore the health and function of the system on a disproportionately large scale. The intent of the prioritization was to focus investment in strategic smaller projects poised to provide benefits over vastly larger areas both directly and indirectly, so that the resulting sum would be greater than its pieces. In this way, restoration efforts effect a synergy and yield a higher level of benefits at the system level.

The pre-existing conditions in the Edwards Reach included overly wide and shallow channel segments, high instream temperatures and low dissolved oxygen levels during critical summer months, areas of fine sediment deposition, and a complete lack of a mature riparian corridor. Both overhead canopy and a mid-level shrub component were missing through the reach. The Edwards Reach was not experiencing system-wide instability, however areas of local bank instability were present throughout the reach.

The degraded conditions resulted from past agricultural land use practices coupled with increasing development linked with non-point source pollution supply, with the most significant impacts associated with fine sedimentation, livestock grazing, and denuded riparian vegetation. Railroad and highway impacts contributed to the decline.

In this lowest gradient reach of the Eagle River, where the valley abruptly widens and flattens, the channel had an extremely high width to depth ratio and an insufficient capacity to transport fine sediment at lower flows. Fine sediment accumulations, which result from insufficient capacity, are identified as significant habitat for the tubifex worm *(Tubifex tubifex)*, an organism associated with the occurrence of whirling disease *(Myxobolus cerebralis)* in trout. Further, the fine sediment accumulations were choking the channel bed substrate, reducing insect populations and hiding cover and food supply for trout. Localized sections of bank erosion contributed to the sedimentation problems by increasing the fine sediment supply.

The high instream temperatures and low dissolved oxygen levels incurred during low flow periods were detrimental to aquatic habitat. The overly high width to depth ratios further contributed to poor aquatic habitat and exacerbated the negative effects caused by the lack of mature overhead canopy and instream cover and the resulting inability to perform shading and cooling functions.

The popularity of the Edwards corridor added challenges due to heavy recreational use. Access to the river from adjacent residences was uncontrolled, consisting of an excessive number of social trails. Access for boaters was also unformalized, causing greater impacts than would be sustained in a controlled setting. The restoration project was therefore tasked with providing well-managed educational and recreational opportunities to equally benefit the community and the natural habitats of the river corridor.

Project Goals

The goal of the Edwards Eagle River Restoration Project was to improve the habitat and function of the Eagle River through the Edwards Reach. Specific objectives identified to achieve the goal included:

- Surface Water Quality
- Sediment Control
- Stream Health and Function
- Aquatic Habitat
- Riparian and Wildlife Habitat
- Land Use Management

Reducing instream temperatures and raising dissolved oxygen levels during the critical summer months were targeted to achieve the ***surface water quality*** objective.

The focus for the ***sediment control*** objective was reduction of the fine sediment supply to the reach and increased capacity through the reach to transport fine sediment during lower flow conditions.

Correction of the overly wide and shallow channel conditions, restoration of appropriate low flow channel geometry and low flow sinuosity, and increased flow diversity were primary targets to restore ***stream health and function***.

Aquatic habitat enhancements were achieved through provision of instream and overhead cover, reduction in potential tubifex worm habitat, and reconnection of high quality fisheries located upstream and downstream. Instream and overhead cover provide the critical functions of shading, cooling, and protective cover. The incorporation of wood materials into treatments adds functions of detritus supply and invertebrate food source and substrate.

The ***riparian and wildlife habitat*** objective was targeted through restoration of the overhead riparian canopy to reconnect the healthy and functional riparian corridors located upstream and downstream of the Edwards reach. Additional focus was placed on increasing the shrub layer and the diversity of native species.

Land use management tools included cattle exclusion fencing, educational signage, controlled recreational access, and strategic plantings.

Project Approach

The Walsh Ecological Solutions and Natural Systems Group is motivated by the pursuit of sustainable landscape planning and design solutions, and by a concern for the interaction between people, wildlife, and our shared ecology. We assert that avoidance or minimization of environmental impacts and use of sustainable solutions is not only the right thing to do, but ultimately yields economic benefits and improves overall projects. Based on decades of experience with Walsh engineers working in concert with Walsh ecologists, biologists, botanists, and landscape architects, an inherent philosophy to river restoration has evolved:

"How would Mother Nature Do It"

This philosophy drives the project approach applied to the Edwards Eagle River Restoration Project with four guiding principles:

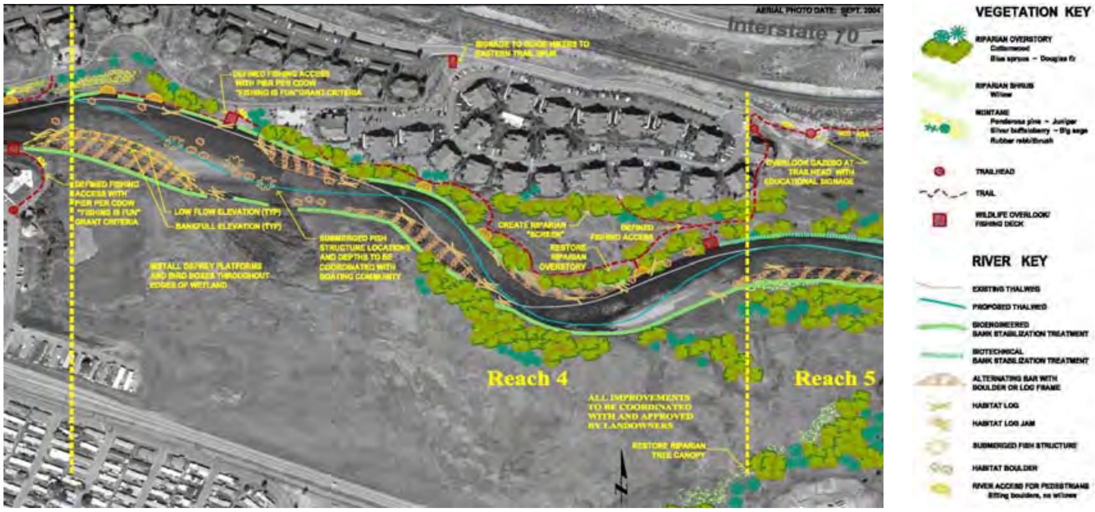
1. Think at the watershed level;
2. Maximize natural form and function;
3. Stay habitat focused; and
4. Do more good than harm

"To protect your rivers, protect your mountains"
–Emperor Yu of China (1600 B.C.)

Under this natural and sustainable design approach, a primary goal is to ensure restoration of habitats and ecosystem structure to an appropriate condition within the current context of the landscape. Respect for the ecosystem and cultural dynamics is imperative so that the project and habitat functions can succeed on a positive track toward maturity in the future. Incorporation of natural processes, patterns, and indigenous materials helps achieve this goal.

Restoration Treatments

With the goal of improving habitat and function, Walsh integrated surface water quality, sediment control, stream health and function, aquatic, riparian and wildlife habitat, and land use management into the design, which includes hydraulic analysis using HEC-RAS software in its scientific basis of design. Educational and recreational considerations round out the design parameters.



Cobble/Gravel Bars

The cornerstone treatments for river restoration in the Edwards Reach are natural point bars, located in an alternating fashion, from right bank to left bank, to mimic naturally occurring depositional bars that form on the inside bend of riffle-pool systems. Some point bar locations enabled a reconnection of remnant depositional areas, while others necessitated bar creation. Additional channel bar features were specified in two locations at small side channels to reduce split flow conditions, as well as to shape and stabilize the confluence areas. All cobble/gravel bars were engineered to meet dual goals of long-term stability and use of natural substrate, primarily cobbles and gravels, as appropriate to the system, rather than large boulders.

Before After

Cobble/gravel point bar in lower reach

A boulder/cobble plug was specially designed to reduce split flow conditions at a midpoint along one side channel, where low flows were able to access the side channel rather than remaining in the main stem. The plug structure afforded the best opportunity to safely locate woody debris out in the main channel, so habitat logs were built into the plug as it was constructed, providing the substantial key-in required to hold the logs in-place farther out in the channel.

The bars and plug function to increase flow depths and velocities during periods of low flow by concentrating water and reducing split flow conditions. The result of the work is reduced fine sediment deposition, lower instream temperatures, and increased dissolved oxygen levels in the summer. The bars additionally improve water quality for downstream waters by enhancing effluent mixing with the receiving waters at the outfall of the Edwards Wastewater Treatment Plant.

The cobble/gravel bars and plug achieve a majority of the project objectives, including surface water quality, sediment control, and improvement of stream health and function and aquatic habitat.

Bank Stabilization

Bank stabilization treatments at the Edwards Eagle River Restoration Project include bioengineered and biotechnical treatments. The distinction between the categories is that vegetation is the primary stabilization component in bioengineered treatments, and only natural materials are used. Biotechnical methods incorporate vegetation into the treatment, thereby maintaining the benefits and natural look and function of "softer" treatments, however biotechnical treatments rely on non-natural materials, such as permanent geotextile fabrics, in addition to the vegetation for stabilization.

Stabilization of the banks works to protect the investment in ameliorating overly wide, shallow conditions by ending the cycling of bank erosion and slumping. Stabilization also improves downstream water quality by reducing a significant source of fine sediment and nutrient loading. Willow and pole cuttings are the predominant bioengineered treatments utilized in less severely eroded areas. Placement of a boulder/cobble toe, using only small boulders – again, to match the natural substrate, was accomplished prior to cutting installation in sections where the naturally occurring toe was lost or degraded. Additional treatment types include willow wattles and log toes, brush mattressing, brush revetments, and soil reinforcement lifts.

Photos illustrate, from left to right, typical degraded condition, target bank condition, and newly constructed condition.

Biotechnical treatments are employed in areas with higher scour potential and where known impacts, such as cattle grazing, will continue. Primary treatments are deflector structures, created with rock and log, which redirect flows off of the banks, alleviating scour and eliminating the need for purely resistive measures, like riprap. Geocellular confinement systems, topsoil-loaded and vegetated, provide upper bank protection for more critical areas.

Bank treatments include detailed features designed to restore the natural variability and high function of unimpacted streambanks. Steep banks are laid back to milder slopes, leaving minor irregularities in grade and working with existing features, such as mature trees and large boulders. The banks receive interim protection from photodegradable erosion control fabric, until revegetation efforts can become established. The fabric is overlain with cobbles and logs in natural groupings to achieve 30 to 40 percent coverage. The cobbles and logs help anchor the temporary fabric and the logs contribute to the woody debris content, improving shading, cooling, and protective cover functions and supplying an invertebrate food source and substrate.

Bank stabilization achieves project objectives of sediment control and stream health and function improvement, while also enabling native revegetation efforts that meet the riparian and wildlife objective, including riparian canopy reconnection.

Aquatic Habitat Features

Instream features to enhance aquatic habitat utilized rock and log materials and included habitat boulders, habitat logs, and log spurs. Using techniques to integrate the boulders and logs, including natural clustering, appropriate materials, and bank key-in, these features have blended into the corridor and are not obvious or obtrusive. Natural groupings typically utilized odd numbers for a more natural and aesthetically pleasing look. Purposeful selection of diversely sized materials further improved the final product.

The boulder and log habitat features create protective instream cover that shades and cools their local areas and afford protective niches and hiding cover for young of the year. The shading and cooling functions are especially important during the critical summer months to reduce high instream temperatures. These features additionally function to increase flow diversity by creating local fast water and turbulent zones to increase dissolved oxygen levels.

The use of logs in addition to boulders is important for restoring a woody debris component to the system, replenishing invertebrate substrate and food source. Use of woody debris was not limited to the specific habitat features. Opportunities to incorporate wood materials into the cobble/gravel bars were maximized during construction to boost detritus supply to the system and increase invertebrate food source and substrate potential.

The aquatic habitat features achieve the project objectives to restore stream health and function and enhance aquatic habitat in the Edwards Reach, including the reconnection of high quality fisheries located above and below the reach.

Native Planting Plan

The planting approach for the Edwards Eagle River Restoration Project took into consideration natural structure, function, plant associations, and density.

The native planting plan was based on biological benchmarks identified in undisturbed areas along the river corridor and site assessments conducted jointly by engineers, fisheries biologists, and landscape architects. Landscape analysis integrated vegetation with river and earthwork treatments measures to remedy deficiencies in existing conditions.

Vegetation restoration includes plantings to increase currently lacking lower and mid-level canopy cover along the channel. Large trees and shrubs were installed to shade the river, and shrub plantings were located to stabilize banks and provide understory diversity and structure.

Ten different plant associations were developed, appropriate to the existing and potential conditions were specified, each with numerous compatible species found to be locally occurring in similar combinations. Plant associations included:

- ***Tall Willow Group***
  (3 willow species, plus thinleaf alder)
- ***Continuous Willow Bank Treatment***
  (3 willow species)
- ***Narrowleaf Cottonwood Group***
  (6 tree and shrub species)
- ***Shrub Bank Treatment***
  (6 shrub species)
- ***Mixed Shrub Group***
  (10 shrub species)

The native planting plan achieves the riparian and wildlife objective, as well as restoring overhead cover to support the aquatic habitat objective. The native plantings increase species diversity, replace the missing shrub component, and with establishment over time will successfully reconnect the riparian canopy that has been fragmented.

Land Management

The Watershed Council is directing a recreational improvement project in conjunction with the restoration project to provide better controls on recreational access and help educate river corridor users. Major components of this project are the Boat Launch Improvement Project, currently underway at the river access fronting the Edwards Wastewater Treatment Plant, and educational signage.

Strategic plantings, including thorny vegetation as a natural barrier, are employed in the project along with more traditional barricades to access. Strategic plantings were similarly incorporated into the planting plan to provide subtle control of fishing access. For example, local breaks in dense vegetation coverage were located intermittently along the corridor, and specifically in concert with designated fishing access points.

The long-term expectation is that cattle grazing activities in the Edwards Reach will cease in the future. Interim cattle exclusion fencing is in use to protect the river's edge in the mean time.

The recreational improvement project, educational signage, grazing controls, and use of strategic plantings achieve the land use management objective. The grazing controls and long-term plan for elimination of impacts contribute to the sediment control goal by controlling and then removing a major cause of bank instability and source of fine sediment supply.

Phase 1 Project and Performance

Phase 1 of the Edwards Eagle River Restoration Project was initiated in 2008 and included 40 acres and 0.9 river miles, or approximately 55 percent of the total length. Phase 1 construction costs totaled $1.7 million, with approximately $1.4 million for river and earthwork and $300,000 for native plantings and seeding regimens.

Views of the completed Phase 1 project.

Implementation of instream improvements was initiated in September of 2008, with completion of all structures except bar 1-15 in December of 2008. Bar 1-15 was delayed due to ice-over in the river and was installed the following Fall of 2009, with completion in November of 2009. Phase 1 instream channel improvements included 11 cobble/gravel bar installations, 8 of which were point bar features, with channel bar enhancements accounting for the remaining 3 bars.

Additional instream treatments included boulder/cobble toe treatments and bank enhancements for stability and improved vegetative conditions. Three boulder/cobble toe treatments were installed, one of which included bank enhancement work. In concert with the bar, toe, and bank treatments, aquatic health and function were improved through the strategic placement of habitat boulders, habitat logs, and log spurs throughout the reaches.

Restoration treatments for the Phase 1 project did not include alterations to channel invert elevations (i.e., no changes to the longitudinal profile). Contractor equipment did not access the channel outside of contained work areas, which were configured along limits of cobble bar treatments and tightly defined by water dams.

Phase 1 vegetation restoration included plantings over a 5-acre area to increase currently lacking lower and mid-level canopy cover along the channel. Large trees and shrubs were installed to shade the river, and shrub plantings were located to stabilize banks and provide understory diversity and structure. Vegetation installation occurred between July and November of 2009 and consisted of approximately 9,300 nursery-grown containerized shrubs and 3,050 containerized trees. Willow cutting installation is scheduled in 2010.

The Phase 1 project has been in-place for over a year and has endured the 2009 peak flow season. The bars and plug are intact and properly functioning to concentrate low flows. A minor repair on one cobble toe bank treatment was completed in the fall of 2009. Plantings are awaiting completion of their first full growing season. Some beaver predation was experienced during plant installation. The Watershed Council installed wire caging around larger cottonwoods and relocated a particularly ambitious beaver. Sand paint as an alternative measure to beaver protection will be considered in future phases and/or as Phase 1 plants get larger over time. An intensive maintenance program has been implemented for the plantings and initial monitoring in compliance with the Section 404 permit has been completed.

Edwards Construction Control Program

In keeping with the project approach to avoid harm, the Edwards Eagle River Restoration Project sought to tread lightly on the river corridor during construction and in so doing broke new ground in construction control.

Protecting the river during construction.

The Phase 1 project implemented a comprehensive and aggressive construction control program that exceeded current requirements and standard methods and helped earn approvals from the State, the County, the Division of Wildlife, and the Army Corps of Engineers. The program included state of the art construction sediment control measures and provided an unusually high level of protection for downstream water quality and fisheries.

The Edwards program included two non-structural best management practices (BMPs) for water quality protection: access control and spawning monitoring. Access routes were kept to a minimum and carefully aligned, primarily in less sensitive upland areas. The contractor was not allowed to track equipment up and down the channel for access. Where required outside of upland areas, acceptable access was identified along the tops of banks and conducted without impact to the riverbanks.

The project was conducted under close coordination with local fly fishing experts, who routinely walked the river, gauging the performance of the construction controls and monitoring for local spawning activity. The fly fishermen gave the project high marks at the end of construction.

Further efforts to reduce potential impacts included conversion of equipment hydraulics to bio-oil. The contractor voluntarily replaced the hydraulic oil in all machinery that would enter the channel bed with bio-oil, a product that has been shown to be less detrimental to aquatic species. More standard controls on spill response and containment were also required.


Aqua Dam installation is labor intensive.

The highlight of the Edwards program was the two structural BMPs for construction sediment controls: water dams and floating silt curtains. Water dams were used to enclose work areas so that sediments stirred up by construction equipment were not released downstream. Water dams were selected because they stir up less sediment and cause less impact to the streambed during installation and operation than their counterparts.

Floating silt curtains were used as supplemental and backup control through two applications. A stationary curtain was installed across the channel below the downstream limits of the project. Mobile curtains moved with construction crews as they began work in new areas. The mobile curtains were installed downstream of the water dams that enclosed work areas, typically with a bank connection and on one side or the other of the channel (i.e., not extending across the channel). The intent of the mobile curtains was to provide backup to the water dams, but also to handle any sediments mobilized during removal of the dams upon completion of a work area.

Aqua Dams functioning to contain sediments stirred up by construction

With new technology relatively untested for this application and in this area, levels of performance to expect were unknown. The contractor used Layfield products for both the water dams and the floating silt curtains. Aqua Dam is Layfield's proprietary name for their water dam product. The Aqua Dams performed extremely well, fully containing sediments mobilized by construction equipment. The Aqua Dams exceeded expectations and afforded a high level of protection for the Eagle River.

The excellent performance of the Aqua Dams meant that the floating silt curtains were largely unutilized throughout construction, however performance when it was needed was poor and the floating silt curtains fell below expectations. On two specific occasions, Aqua Dam removal activities mobilized small amounts of fine sediment, which routed to the mobile curtains located just downstream. The curtains allowed the sediments to progress downstream with no detectable containment or filtering. It is unknown whether the failure mechanism was movement of sediments underneath the curtains and/or fine sediments passing right through the curtains' filter material.

As a last resort, an attempt was made to configure the mobile curtains on alternate banks below the Aqua Dam-enclosed work areas to create a longer flow path and thereby drop out some sediment via reduced velocities. Again, this approach was not fully tested due to the strong performance of the Aqua Dams, however the conclusion for this project was that performance of the curtains in any configuration was not worth the effort required to install and maintain them. It is possible that the very fine gradation of Edwards sediments was a factor in performance here and that the floating silt curtains may perform well in different stream systems.

Stationary floating silt curtain installed at the downstream end of the project.

The stationary curtain at the downstream end of the project, although adequately sized per manufacturer specifications, strained under even the low flow conditions in the Edwards Reach. While the stationary curtain did provide some measure of settling for entrained sediments due to creation of a local backwater, and its anchoring did hold for the duration of construction, this BMP did not function as intended. A plausible conclusion is that cross-channel curtains are not feasible in large river environments. This application may be useful in smaller streams.

The cost of the construction sediment controls for the Phase 1 project was relatively high. At $140,000, including purchase and delivery, the water dams accounted for 8 percent of the construction budget. The cost will be significantly reduced for future phases of the project because the contractor will be able to re-use the water dams. In spite of their price tag, the excellent performance of the water dams and the self-imposed high standards of the Watershed Council made the water dams a worthwhile expense for this project. The cost of the floating silt curtains was notably lower than the water dams at $40,000 or 2 percent of the construction budget. Although less expensive than the dams, this price tag is still significant and the performance of the curtains does not warrant investment in this control for future phases of the Eagle River restoration.

Overall, the comprehensive and aggressive construction control program at Edwards was very successful in protecting water quality and downstream fisheries. At the end of the Phase 1 project, the Division of Wildlife noted that the project received the highest compliment in that no complaints were received during construction.

Equally important to the Watershed Council, the high level of protection provided by control program allowed the Council to stay consistent with their role and responsibilities as advocates for rivers in the Eagle River watershed.

Future

Phase 2 of the Edwards Eagle River Restoration Project is scheduled to begin in the fall of 2010, with funding primarily provided through an EPA 319 award. Eagle County and CWCB are repeat project partners, with other grant funds pending. The intent of the Phase 2 project is to complete the upper reach and extend downstream, as funding allows, toward the evaporate sinkhole located below the confluence with Lake Creek. Channel depths exceed 10 feet in the vicinity of the online sinkhole. The condition of the less substantive bedrock formations in this reach leaves the potential for continued bed dissolution and necessitates detailed geologic investigations into the extent and physical properties of the evaporate prior to final design and implementation of restoration treatments.

Additional work slated for 2010 includes collaboration with a student volunteer group to improve soils and install upland herbaceous vegetation, and to harvest and plant willow and cottonwood stakes for a pond enhancement pilot project.

Reference

Colorado State University (CSU), August 2005. Eagle River Inventory and Assessment, Executive Summary, prepared for the Eagle River Watershed Council.

PROTECTING THE PARACHUTE PENSTEMON DURING CLOSURE OF THE ANVIL POINTS OIL SHALE FACILITY

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ABSTRACT

Parachute penstemon (*Penstemon debilis*) is a candidate for listing as threatened or endangered by the U.S. Fish and Wildlife Service and is recognized as a Sensitive Species by the Bureau of Land Management Colorado State Director. This species' habitat is limited to the steep, white shale talus on the Mahogany Zone of the Parachute Creek Member of the Green River Formation. Of four known locations, the largest occurrence on federal lands is within the Anvil Points Facility near Rifle, Colorado. This facility to research and develop methods of oil shale mining and processing has been inactive since 1983. Beginning in 2008, a removal, clean up, and closure plan has been implemented to remediate and store waste shale and close the mine adits. Several steps were taken to protect this Parachute penstemon population since it is located near mine adits slated for closing. All penstemon plants on the historic mine bench were inventoried, flagged and mapped using GPS. Plants growing on access routes to adits were protected in place with synthetic mats. Plants growing directly in front of adits were transplanted to safe locations up to 30 meters distant. Protection with synthetic mats was very highly effective: over-winter survivorship was 89% which compares favorably to the 92.5% survival observed in non-disturbed plants. Survivorship of transplants varied from 67% to 83%, depending upon the season during which transplanting was performed. Protective measures such as these may be appropriate to minimize and mitigate unavoidable impacts to sensitive species subject to similar development activities.

INTRODUCTION

To minimize impacts to Parachute penstemon during the closure of mines at the Anvil Points Facility, a mitigation plan was developed and implemented (URS 2009). In this report we describe and evaluate preliminary results of several techniques used to prevent loss of existing plants, thereby preserving genetic diversity. Further information about the site and methods has been described elsewhere (URS 2009)

Anvil Points History and Background

The Anvil Points Facility, near Rifle, Colorado, was constructed to pioneer oil shale mining and processing research and development by government and private industry (Mehls 1982). Over 400,000 yd^3 of oil shale was mined and processed at the facility from 1947 to 1982. Following a decline in private sector interest, the facility was decommissioned and demolished by 1986. The Anvil Points Facility has been characterized and studied as a Superfund Removal Action. A facility cleanup and closure plan was developed and implementation began in July 2008.

Figure 1. Parachute penstemon (*Penstemon debilis*), in flower, on the Anvil Points Facility mine bench.

Parachute penstemon

Parachute penstemon (*Penstemon debilis*; Scrophulariaceae; Figure 1) is a candidate for protection under the Endangered Species Act (NatureServe 2008). There are four known locations of this species and the Anvil Points population is the largest occurrence on federal lands (Rondeau et al. 1996, Spackman et al. 1997). Parachute penstemon is substrate specific and is found only on the steep white shale talus of the Green River Formation.

METHODS

Mapping locations: Field surveys were performed to inventory and map all accessible individuals located within 35 acres of habitat that includes the Anvil Points mine bench (URS 2009; see also Figure 4). Individuals were marked with uniquely labeled pin flags, located using sub-foot, handheld GPS units, and mapped onto a geo-referenced aerial photograph.

Estimating natural overwinter mortality: The locations of 80 inventoried Parachute penstemon were revisited in Sept. 2009 to estimate natural rates of mortality (Figure 4). Only locations with undisturbed pin flags were included in this survey. The presence or absence of an associated plant was used to indicate survival or mortality.

Figure 2. Positioning Dura-Base® synthetic mats to create a driving surface and protect 33 penstemon.

Protecting with mats: Two areas of occupied Parachute penstemon habitat were within access routes to required cleanup sites [Adit 1 (n=23) and the Transformer Alcove (n=33; Fig. 4]. No earth removal was planned, but plants would be impacted by heavy machinery. Penstemon within these areas were photographed, re-marked with numbered metal tags, and then protected by covering them with interlocking panels of Dura-Base® composite matting (Figure 3). Panels were set in place in November to December 2008 and removed following completion of construction activities in mid-December 2008.

Transplanting at-risk plants: A total of 21 Parachute penstemon were located directly in front of cleanup and closure sites [Mobil Adit (n=14) and Adit 3 (n=7); Figure 4]. These areas were too steep or unstable to protect with mats, so the affected individuals were removed and transplanted into suitable habitat within 30 m of their original locations (Figure 3). Two transplanting efforts were undertaken: 1) moving 12 individuals in November 2008 and, 2) moving 9 individuals in Jun. 2009.

Statistical Analysis: An evaluation of the increase in risk of mortality associated with the protection measures was assessed using odds ratios. An odds ratio is calculated by dividing the mortality rate of a treatment group (i.e., mats or transplants) by the mortality rate of a control group (Ramsey and Schafer 2002). The odds ratio can be interpreted as the increase in the odds of an individual dying due to the treatment when compared to an individual in the control group. A comparison to a **Z**-distribution is used to assess the probability that the calculated ratio could have come about by chance.

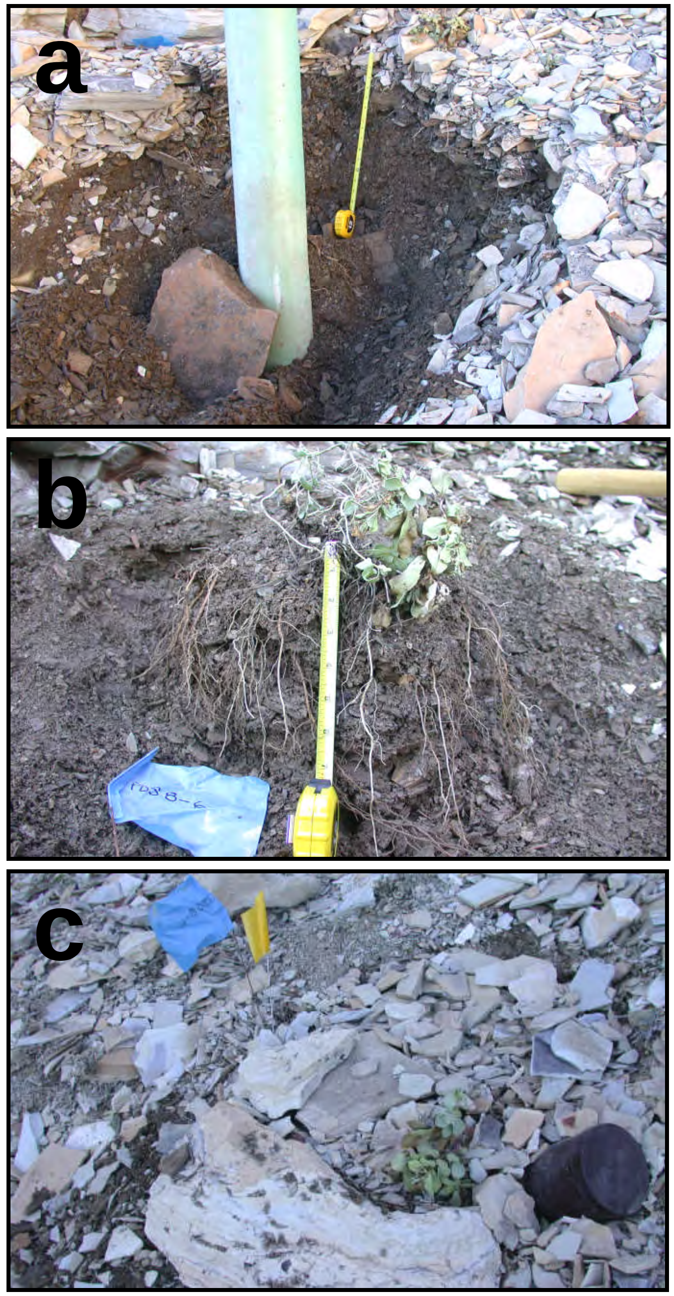

Figure 3. (a) Illustration of the extent of excavation required to remove some Parachute penstemon, and the use of a half-pipe to support a plant and root ball during excavation. (b) Some plants had an extensive root ball. (c) Newly transplanted individual along with its Dri-Water® access tube in lower right.

RESULTS AND DISCUSSION

Over 600 Parachute penstemon were inventoried and mapped within the vicinity of the Anvil Points mine bench (Figure 4). Of these, 84 were at risk of direct impact from mine cleanup and closure activities. An assessment of the protection efforts for 77 of these plants is presented below. An additional 7 plants were protected in other manners, but are not included as part of this study.

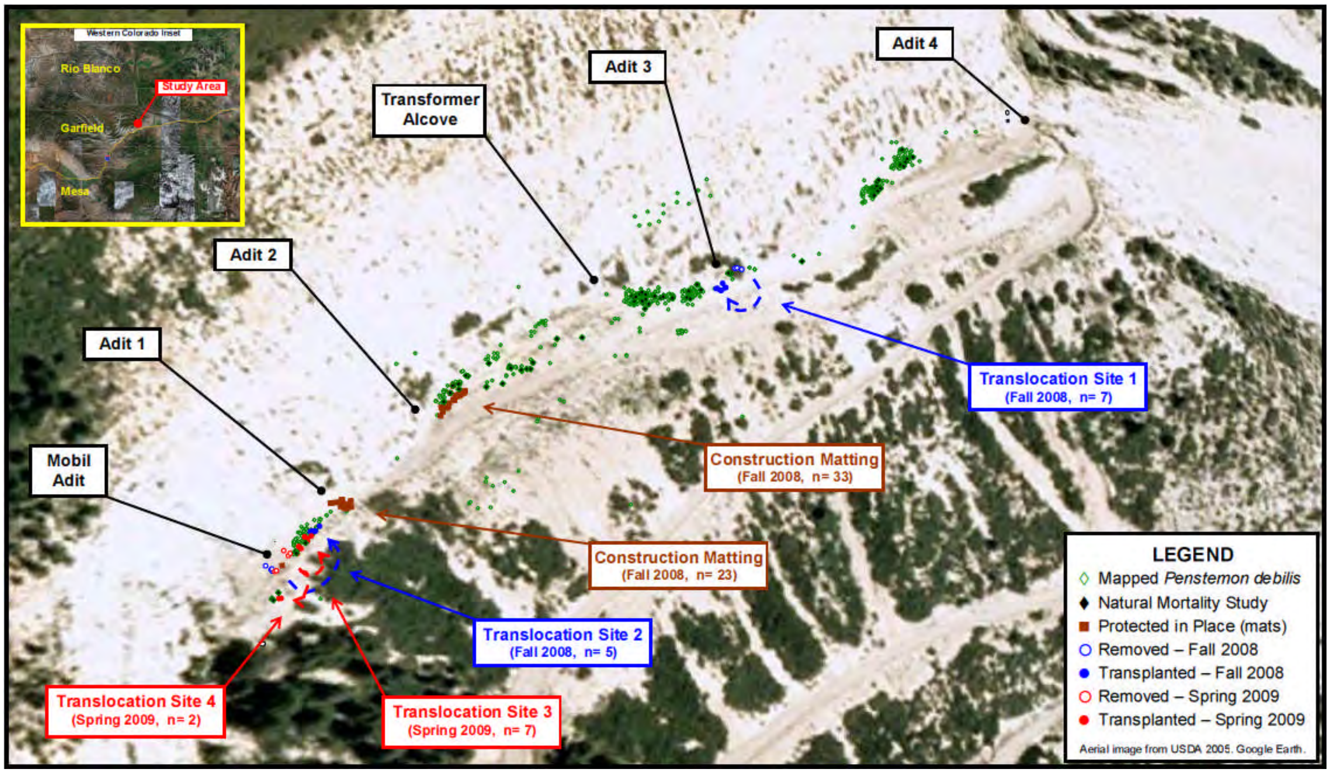

Figure 4. Locations of Parachute penstemon and other features on the Anvil Points Facility mine bench.

Natural mortality (control): Of the 80 plant locations sampled, 6 plants could not be re-identified and are presumed dead (Table 1, Figures 4 & 5). This observed mortality rate (7.5%) is assumed to be the natural rate of overwinter mortality, at least for the duration of this study, and is the baseline from which the efficacy of our protection techniques is being compared.

Protected with mats: The mortality rate (10.7%) of plants protected by synthetic construction mats was not significantly different from controls (Table 1, Figures 4 & 5). These mats effectively minimized

Table 1. Survival rates and mortality odds ratios of Parachute penstemon subject to different methods of protection from mine closure activities.

Treatment	n	Dead	Survival Rate	Odds Ratio	*Z*	*P*
Control (natural mortality)	80	6	92.5%	n/a	n/a	n/a
Protected with mats	56	6	89.3%	**1.48**	0.638	0.26
Transplants	21	5	76.2%	**3.85**	1.714	0.044
Transplants – Fall 2008	12	2	83.3%	**2.47**	0.822	0.21
Transplants – Spring 2009	9	3	66.7%	**6.17**	1.560	0.059

the impacts associated with the movement of heavy machinery. Since the mats were only in place during the winter, after plants had senesced, and were remove after approximately two weeks, any potentially negative effects from being covered were minimized.

Transplants: Compared to controls, a transplanted Parachute penstemon was 3.85 times more likely to suffer mortality (Table 1, Figures 4 & 5). Transplanting is a very invasive technique and could be expected to have negative impacts. Several steps were taken to reduce these impacts, including 1) re-planting each plant immediately after it was excavated, 2) watering plants with 1 liter of water immediately after re-planting and monthly during the first growing season after transplanting, and 3) positioning a tube of Dri-Water® near the roots of each transplant. Dri-Water® is a gel-like product that provides a slow release of water over a period of 30 to 90 days.

Effect of season of transplanting: The mortality rate (16.7%) of Fall 2008 transplants was not significantly different from controls. In contrast, Spring 2009 transplants were 6.17 times more likely to suffer mortality (Table 1, Figures 4 & 5). At the time of the fall transplanting (November 2008) Parachute penstemon appeared to be rapidly senescing which may have contributed to the higher transplant success. Additionally, the soils were quite wet and even the daytime temperatures were cool. In contrast, at the time of the spring transplanting (June 2009) Parachute penstemon was actively growing. However, many of the shoots of the transplants had not yet broken the ground surface. Excavating the plants without causing damage to the shoots was more difficult with the spring transplant.

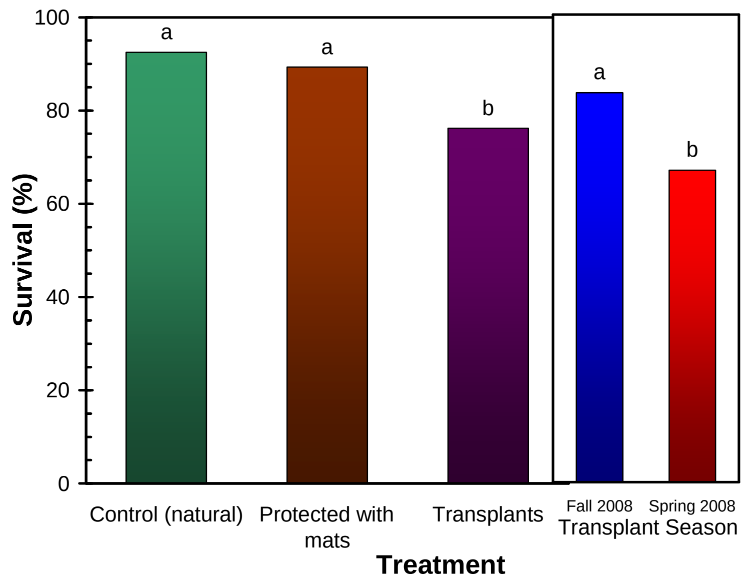

Figure 5. Survival rates of Parachute penstemon subject to several protection methods during mine cleanup and closure. Responses identified with the same letter are not significantly different ($\alpha \leq 0.10$) Colors correspond to treatments indicated in Figure 4.

CONCLUSIONS

Avoiding direct impacts that carry the risk of mortality resulted in the highest rate of survival among sampled Parachute penstemon (Table 1, Figure 5).

When complete avoidance was not practical or feasible, the use of composite construction mats was very highly effective in minimizing negative impacts to this rare plant. Mortality rates among plants protected by mats were not significantly different from the expected rate of over winter mortality (Figure 5).

When complete avoidance was not possible, and the use of mats was not practical or feasible, transplanting could be an effective tool for minimizing impacts to this rare plant.

However, the efficacy of transplanting as a mitigation method was highly dependent upon the season during which transplanting was undertaken. Transplanting during the fall, as plants were senescing, was highly effective in minimizing negative impacts. Transplanting during the spring, when many shoots had not yet emerged above the surface, was much less effective in minimizing negative impacts.

These are preliminary results. Evaluating the success of this mitigation plan is part of an ongoing monitoring program of impacted individuals and areas. Monitoring is scheduled to continue through 2012.

These techniques may be useful for other situations in which development activities are expected to have negative impacts on vegetation.

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