COAL BASIN MINE RECLAMATION CASE STUDY [1]

by

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Abstract. The State of Colorado, Division of Minerals and Geology, is in the process of accomplishing reclamation of a previously permitted coal mining operation located in a high mountain basin in the central Rockies of western Colorado. Coal Basin is a large erosional feature located on the east facing slope of the Grand Hogback in Pitkin County, Colorado. High average annual precipitation, steep slopes and erosion prone soils combine to create the highly erosive nature of this area. Previously permitted mining operations substantially added to the sediment load in local stream systems.

Five underground coal mine portal facilities, developed in the 1950's and 1960's along the steep flanks of Huntsman Ridge, are situated at elevation 3,048 meters (10,000 feet) in this rugged sub-alpine environment. Coal processing facilities, including a wash plant, thermal drier and coal refuse piles are located approximately five miles east of the mine entry areas at the confluence of Coal and Dutch Creeks at elevation 2,530 meters (8,300 feet).

Due to the many unique geologic, topographic, environmental and operational challenges of Coal Basin, classic reclamation techniques and concepts were re-evaluated and subsequently modified in order to meet the reclamation goals established for the site. Reclamation operations have focused on addressing the many environmental needs of Coal Basin by primarily minimizing active and potential erosion and resultant sedimentation from mining related facilities. The reclamation challenges are being met by implementing large scale geomorphic restoration operations and through innovative steep-slope revegetation practices. To this end, alternative, yet effective, erosion and sediment control techniques have been adopted, and unique revegetation procedures have been undertaken, as the reclamation process continues. This paper provides an overview of some of the techniques and methods used to stabilize this steep, highly erosive site.

Introduction

Since 1995 the Colorado Division of Minerals and Geology (DMG) has been actively accomplishing reclamation of a previously permitted underground coal mining complex in Pitkin County, Colorado (Figure 1, Coal Basin Mine). The Coal Basin Mine complex is large and diverse, with great variations in elevation, exposure, slope and topography throughout the Basin. Reclamation of the Coal Basin Mine complex has been subdivided into numerous sub-components or tasks. The public and various governmental agencies have been very involved in the reclamation process, which has contributed to the overall reclamation success at Coal Basin.

The original Coal Basin Mine began operations in the 1890's. Coal was mined from near the headwaters of Coal Creek as a part of the coal mining and steel empire of John Osgood. Operations ceased in the early 1900's. Mining resumed at Coal Basin in about 1953, and continued until 1991. Metallurgical quality coal was produced from five separate underground mines located in the western portion of the Basin. The mine entries are located high in the Basin at elevations of about 3,048 meters (10,000 feet).

Following cessation of operations, the mining permit was revoked and the reclamation bond forfeited by the State of Colorado. In early 1992 the company filed for Chapter 11 bankruptcy protection. The Colorado Mined Land Reclamation Board was a secured creditor in the bankruptcy proceedings, and eventually received three million dollars in cash and services to satisfy its claims.

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The cash proceeds are being used to finance most of the on-going reclamation projects at the site.

Environmental Setting

The Coal Basin Mine is located within a topographic feature known as Coal Basin. Coal Basin is a large erosional feature situated on the flank of the Grand Hogback, just north of the West Elk Mountains. Coal Creek and Dutch Creek drain Coal Basin. These streams are confluent near the eastern margin of Coal Basin. Coal Creek is confluent with the Crystal River near Redstone, Colorado, four miles downstream from the mine site. The Crystal is confluent with the Roaring Fork River at Carbondale, Colorado, approximately 29 kilometers (18 miles) downstream of Redstone.

Coal Basin is located in a sub-alpine environment. Plant communities are predominately aspen at lower elevations and Engelmann spruce at the mine entry areas. Average annual precipitation within the Basin is 78.74 centimeters (31 inches).

Coal Basin is characterized by unique geologic conditions. Cretaceous Mancos Shale, a deep marine grey to black silty shale, predominates within the Basin to an elevation of about 2,987 meters (9,800 feet) above mean sea level. The Mancos Shale forms steep erosive slopes throughout the region.

Conformably overlying the Mancos Shale is the upper Cretaceous Mesaverde Formation. The Mesaverde is a thick sequence of interbedded sandstones, shales and minable coal units. The Mesaverde Formation is a steep cliff-forming unit, with sandstone members forming the vertical walls of Huntsman Ridge at the western margin of the Basin.

Due in large part to the relatively high annual average precipitation and the great exposures of the erosive Mancos Shale and Mesaverde Formation, the Basin experiences a very high degree of erosion annually. Because of the high natural erosion rates, Coal and Dutch Creeks transport large volumes of sediment annually. The mining permit application estimates that 13,812 metric tons (15,225 tons) of sediment per year is generated due to naturally occurring processes within Coal Basin.

Reclamation Challenges

The challenges faced in accomplishing reclamation at Coal Basin are related to the large size of the mining operation and the physical characteristics of the Basin.

The mines were separated by about 8 kilometers (5 miles) from the southern-most to northern-most entry areas. The entries were connected by an approximately 24 kilometer (15 mile) long road system, which joins each of the entry areas to the Wash Plant Area, located near the confluence of Coal and Dutch Creeks. Three refuse piles are located about 1.6 kilometer (1 mile) apart from each other, while the coal preparation plant and office warehouse areas are in a relatively confined area near the confluence of Coal and Dutch Creeks. In total, approximately 134.8 hectares (333 acres) of disturbed area is located within the 4,608 hectare (11,386 acre) permit area.

Inherent challenges of working in Coal Basin include the steepness of the topography, a paucity of available soil, the erosive nature of the area and the relatively short growing and construction season. Erosion of the fill slopes located below the mine entry areas, and erosion resulting from the road drainage system have been identified as the two largest contributors of sediment from mining related facilities to adjacent water resources.

Reclamation Goals

The primary goals of the reclamation process at Coal Basin have been three fold; minimize erosion from mining related facilities, reduce sediment delivery from mining related disturbances to water resources in Coal Basin, and implement the post mining land uses identified in the mining permit and as described by the land owners and the land management agency.

These goals are being implemented via the reclamation process, as the goal of each Project is to attain a greater degree of geomorphic stability through earth moving, runoff conveyance and revegetation techniques which are implemented during each reclamation construction phase.

Reclamation Sequencing

Funding for the reclamation projects has been primarily derived from funds made available to DMG from the proceeds of the bankruptcy liquidation of the former operator. The assets were liquidated over a five year period of time. This resulted in reclamation funding being provided on a somewhat sporadic basis, because projects were bid out only as funds became available. As a result, twenty two large scale reclamation construction projects were accomplished during a six year period.

Because funding was provided over a five-year period, reclamation priorities had to be established. An inventory of the mine facilities and a ranking of the existing or potential environmental hazard of each was established. This review indicated that the greatest environmental needs were at the mine entry areas, at portions of the road system and at one of the coal refuse piles. Given this evaluation, reclamation at Coal Basin began in 1995 at Mines 3 and 4, and at the Sutey Coal Refuse Disposal Area (Figure 1, Coal Basin Mine).

In subsequent years, reclamation proceeded at discreet locations, progressing down hill toward the coal preparation facilities area. A notable exception to this sequencing was the timing of revegetating the mine bench outslopes. Evaluations of how to best accomplish revegetation of the slopes occurred through 1997. The revegetation effort was accomplished in two stages, and is discussed in some detail later in this paper. In the mean time, it was decided to reclaim three haul roads which provided access to two of the mine entry areas in 1996. This decision was primarily made to quickly reduce the sediment contribution from the road drainage.

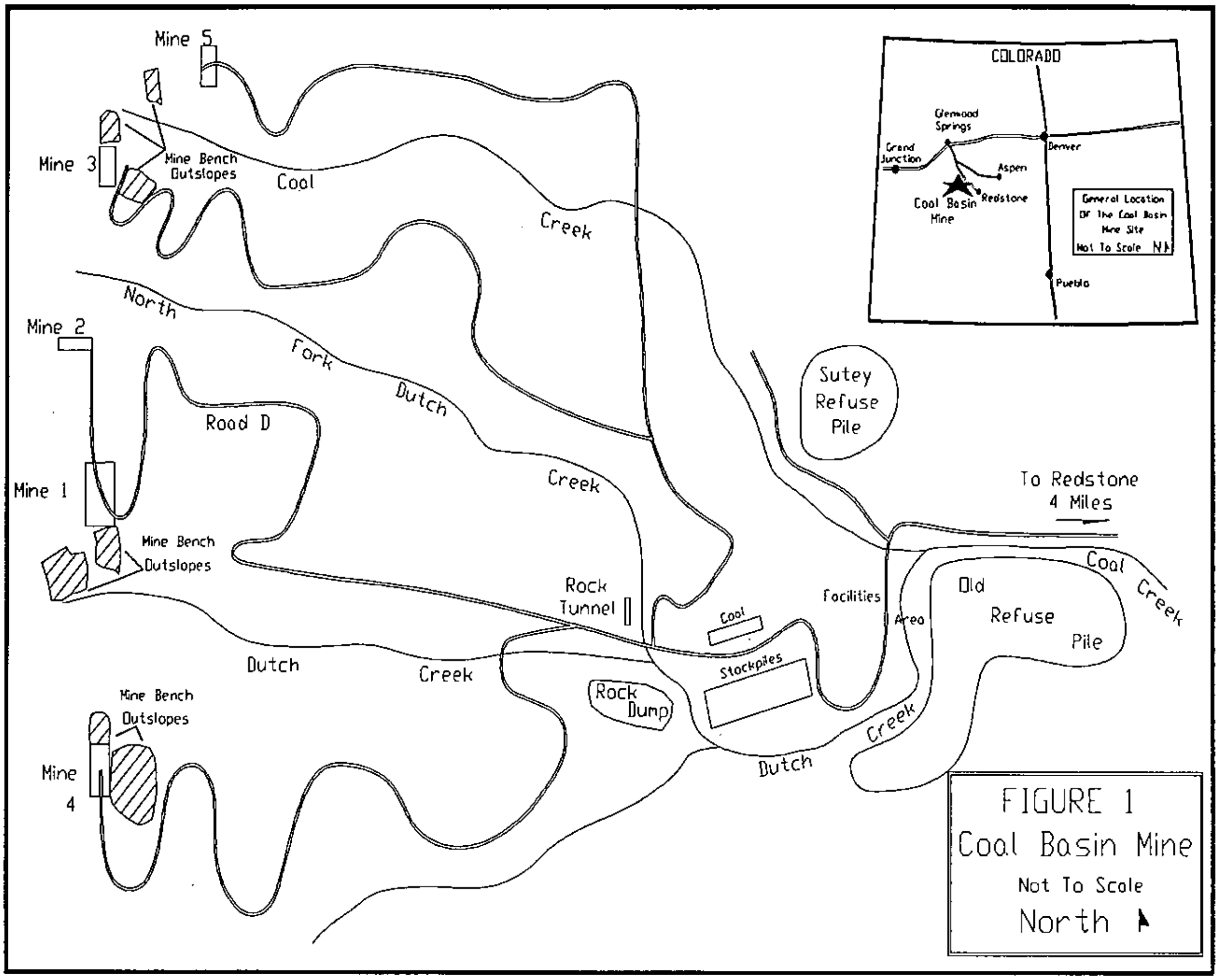

FIGURE 1
Coal Basin Mine
Not To Scale
North

Project Overview: Interesting and Challenging Projects

Whenever possible, reclamation projects were designed to accomplish as many tasks at one construction area as feasible, in order to maximize the environmental benefit from the costs involved in the construction.

An example of accomplishing multiple goals through a single reclamation task is the backfilling of the mine entry areas. In order to accommodate structural demolition during the reclamation process, all metallic materials were removed from the site, while concrete was demolished and placed at the base of the highwall. Coal materials were excavated from the bench areas, placed and compacted over the concrete rubble. Earthen materials were excavated from the crest of the mine bench outslopes, then transported, placed and compacted over the coal. Excavation from the crest of the mine bench outslopes served dual purposes. First, it provided a relatively coal-free growth medium backfill for the final reclamation of the, which eliminated the operational drainage system, which was partially responsible for severe gullying on the outslopes. Excavation in this manner promoted more uniform dispersal of snowmelt and rain water over the outslopes, thus helping to begin the outslope stabilization process.

Road E, F, G Reclamation Project, 1996.

Approximately 24 kilometers (15 miles) of haul roads existed at the Coal Basin Mine. The roads began at the coal preparation facilities area at about 2,530 meters (8,300) feet elevation, and continued on to the various mine entries at 3,048 meters (10,000 feet) elevation. These roads traversed Coal and Dutch Creeks, as well as a number of tributaries and small drainages. During mining operations, the roads were designed to accommodate coal haulage trucks year round, and varied in width from about 13.7 to 18.3 meters (45 to 60 feet). The roads sloped toward the hillside at about two to five percent. A drainage ditch was present at the inside margin of each road. The drainage ditch allowed the road run off to drain to culverts which passed under the road. The drainage emerged from the culverts, and spilled onto the fill slope at the outside margin of the road. The fill slopes are generally composed of highly erosive marine shales, and thus experienced significant erosion as a result of the additional road runoff.

The road reclamation plan contained in the mining permit called for narrowing the roads to about 6.1 meters (20 feet), but contemplated retention of the ditch and culvert drainage system. Because reclamation in this manner would not significantly alleviate erosion caused by the road drainage, DMG formulated a plan to accomplish the goal of minimizing sedimentation from the roads and fill slopes.

Reclamation entailed removing about 36 culverts from 14.5 kilometers (9 miles) of haul roads located on the north side of the Basin. Following culvert removal, the road gradient was reversed by moving dirt from the fill, or outside, of the roadway to the cut, or inside, of the road. This gradient reversal caused the roads to slope to the fill side at a grade of two to five percent. Once the gradient was reversed, low water crossings were constructed at the creek crossings. Water bars, or rolled dips, were constructed at each larger ephemeral drainage, and at numerous other locations as well. All of these structures were designed to move water from the cut side to the fill side of the road as it would before the road system interrupted the drainage pattern. As a final surface flow modification technique, the graded road surface remnants were deeply ripped using a light dozer. Rippers were spaced at 78.7 centimeters (30 inches) and sunk to a depth of about 40.6 to 45.7 centimeters (16 to 18 inches). This caused the road remnant to become severely roughened, promoting revegetation potential and encouraging infiltration while disrupting surface flows, thus decreasing flow concentration. Finally, the reclaimed road surface was revegetated using weed free straw mulch at about one metric ton per hectare (2 tons per acre) and the Coal Basin Seed Mixture (Table 1, Coal Basin Mine Seed Mixture).

TABLE 1. COAL BASIN SEED MIXTURE

SPECIES	SCIENTIFIC NAME	VARIETY	LBS/ Acre PLS
Kentucky Bluegrass	Poa pratensis	Banff	0.25
Slender Wheatgrass	Agropyron trachycaulum	San luis	3.00
Mountain Brome	Bromus marginatus	Bromar	3.00
Tufted Hairgrass	Deschampsia caespitosa	Peru creek	0.20
Sheep Fescue	Festuca ovina	Covar	1.50
Timothy	Phleum pratense	Climax	0.25
Orchardgrass	Dactylis glomerata	Dawn	0.76
Alpine Bluegrass	Poa alpina	VNS	0.25
White Clover	Trifolium repens	Ladino	0.76
Cicer Milkvetch	Astragalus cicer	Monarch	0.76
Lewis Blue Flax	Linum lewisii	Appar	0.76
Yarrow	Achillea millifolium	VNS	0.10
Snowberry	Symphoricarpos sp.	VNS	0.38
Woods Rose	Rosa woodsii	VNS	0.38
Rocky Mountain Penstemon	Penstemon strictus	Bandera	0.38

The techniques employed were successful in meeting the goals of minimizing sediment contributions from the road system. Erosion of the reclaimed road surfaces and of the adjoining fill slopes was virtually non-existent three years following completion of reclamation.

When accomplishing reclamation of the remaining roads in 2000, it was considered advantageous to increase the reversed gradient to 8 % to 10% toward the fill slope. This increased slope promotes the desired drainage characteristics, and helps to stabilize the cut slope. The increased cost of placing additional fill was weighed against the predicted benefit, and found to be cost effective. Another technique which was modified during the 2000 construction season was the road surface ripping. The 1996 ripping occurred parallel to the road. In 2000 additional runoff control was achieved by ripping sub-parallel to the road surface, with the dozer angled toward the downhill and into the cut slope at 30^0 to 45^0.

Dutch Creek Diversion Project, 1998.

During mining operations, Dutch Creek, immediately above its confluence with Coal Creek, was diverted into a concrete lined channel. This 3.7 to 4.3 meter (12 to 14 feet) wide by 1.2-meter (4 feet) tall structure was over 183 meters (600 feet) long, and was bounded on the east by coal refuse and on the west by the mine facilities yard. Near the end of the mine life, the structure suffered from holes punctured in its base, as a result of the boulders, which pass down Dutch Creek during flash floods and spring runoff. Further, the end wall foundation appeared to be near failure.

DMG spent a considerable amount of reclamation funds to maintain the integrity of the flume during heavy runoff, and to accomplish repairs to the base of the flume. Although planned by the mining company to be a permanent structure, it became increasingly apparent that the flume would be a perpetual maintenance problem, and would certainly fail at some point in the future.

In order to address this problem, DMG applied for a grant from the Office of Surface Mining (OSM). The grant was approved and funds were awarded for the purpose of constructing a replacement channel for the flume.

OSM personnel, assisted by DMG staff, conducted extensive field work during the summer of 1995. These investigations, which focused upon the geomorphologic characteristics of Dutch Creek above its point of diversion into the flume, led to the development of a stream channel design by an OSM hydrologist. The design accommodated the dynamic nature of Dutch Creek, including its propensity to transport large volumes of coarse sediment on a yearly basis. The new channel is not an engineered structure, but is designed to be a geomorphically active system which mimics the natural characteristics of Dutch Creek. The approximately 381 meter (1,250 feet) long stream segment is a channel within a channel. The outer channel consists of four large meanders, while the incised inner channel has about twenty five meanders. The incised inner channel has sufficient capacity to accommodate normal annual flows, while the outer channel acts as an overflow channel to accommodate larger flows. The design allows for migration of the inner channel meanders over time.

The channel was constructed during low water conditions in the fall of 1998. The foot print of the channel was established using real time global positioning system (GPS) instruments to locate and stake the top of the channel sides on-the-ground, including cut and fill depths and the outer channel meander locations. Once the heavy equipment had roughed out the outer channel, the inner channel was similarly surveyed and staked. Construction of the inner channel was accomplished by over-excavating using a track hoe. Rip rap, salvaged from the old Dutch Creek channel, was then placed within the inner and outer channels to design specifications. The creek was diverted away from the flume and into the new channel, in November, 1998.

As expected, step pools formed during the spring 1999 runoff. The inner channel accommodated the runoff volume, but cutting at the junction of the diversion and the natural Dutch Creek channel caused some aggradation to occur within the inner channel between the first and second outer channel meanders. This deposition created a braided stream pattern within the inner channel for about a one hundred feet length of the stream.

Morphology of the reconstructed channel will be monitored over time. Permanent cross section monitoring points have been established along one bank of the channel. These cross sections are surveyed on an annual basis to document channel modifications.

Old Refuse Pile / Abandoned Mined Land Fee Funded Projects; 1998, 1999.

The Old Refuse Pile is a large facility which accommodated reject from the wash plant for at least twenty years. The older, eastern portions of the pile were constructed prior to enactment of the Surface Mining Control and Reclamation Act of 1977. Therefore, this area was eligible for reclamation funds provided to DMG by Abandoned Mined Land Fees. Two Projects have been undertaken at the Old Refuse Pile in order to reduce the risk of large failures, and to ameliorate the steep slopes which characterized this area. The Huntsman Project was completed during the 1998 construction season, while the Bear Creek Project was completed during the 1999 construction season. These Projects reduced the 1 H : 1 V slopes of the Old Refuse Pile to 2 H : 1 V or flatter.

Huntsman Project. The Huntsman Project is an example of Abandoned Mined Land funds being used to accomplish pre-law reclamation while enhancing overall site rehabilitation.

In order to achieve the desired 2 H : 1 V slope configuration at the approximately 2.4 hectare (six-acre) Huntsman Project area, approximately 42,050 cubic meters (55,000 cubic yards) of coal refuse had to be cut from the refuse pile. However, due to the proximity of Coal Creek at the toe of the pile, there was no room to store the majority of the excavated material near the cut area.

During completion of structural demolition at the wash plant area earlier in 1998, about 38,227 cubic meters (50,000 cubic yards) of demolished concrete had been pushed into a flat – topped pile about 0.61 hectares (1.5 acres) in size. The refuse excavated during the Huntsman Project was transported about 402 meters (1/4 mile) from the cut area, and was placed over the top of the rubbelized concrete, and compacted in place. Placement of the material in this area created an approximately two acre, slightly crowned hill at the base of a vertical cut slope. This landform compliments the post mining land use in this area, while accommodating the completion of the Huntsman Project.

Due to the length of the Huntsman cut slope, it was apparent that a slope break was desirable. The reclamation contract specified the construction of an approximately 3 meter (10 feet) wide, slightly inclined bench located mid-slope to address the slope break concern. However, observations at other reclaimed facilities in Coal Basin indicated that snow accumulation and differential melting at bench slope breaks generally leads to their failure, resulting in large gully development, a process particularly prevalent on north facing slopes, as is the case at the Old Refuse Pile. A different method of creating the desired slope breaks needed to be implemented in order to disperse snowmelt runoff and minimize slope erosion. As a result, the concept of creating dozer dips to act as slope breaks was formulated.

Hundreds of dozer dips were constructed by placing a light dozer at the toe of the reclaimed fill slope following topsoil placement. The dozer backed up the slope about 3 to 4.6 meters (10 to 15 feet), dropped its blade and pushed forward (downhill) until a mound of topsoil 15.24 to 20.3 centimeters (6 to 8 inches) tall accumulated at the blade. The dozer would then lift its blade and back up and repeat the process until it reached the crest of the slope, where it would move to the side and proceed to the base of the slope to start the process all over again. This occurred until the entire slope was covered by these dips. Following construction of the dozer dips in the topsoil, the area was seeded using the Coal Basin Seed Mixture (Table 1) and mulched with certified weed free straw mulch at a rate of about one metric ton per hectare (2 tons per acre).

Observations made the spring following construction indicated that, for the most part, the dips functioned as intended. In some areas where the vertical spacing was too great, the dips had a tendency to drain at the edges, periodically forming small rills at these locations. Overall, the height and horizontal spacing of the dips appeared to be adequate to prevent gully formation.

Bear Creek Project. Like the Huntsman Project, the Bear Creek Project was designed to ameliorate pre-law oversteepened slopes of the Old Refuse Pile. This was accomplished by cutting approximately 68,810 cubic meters (90,000 cubic yards) of material from the upper segment of the facility, and compacting it at the toe until the target overall slope gradient was achieved. Following completion of cut and fill operations, the cut portion of the slope was ripped using a light dozer working horizontally across the slope. 20.3 to 25.4 centimeters (8 to 10 inches) of topsoil were applied to the slope after ripping operations were completed.

After completion of topsoil application, weed free straw mulch was applied at a rate of one metric ton per hectare (2 tons per acre). A light trackhoe was then used to create thousands of small hummocks on the 2.3 hectare (6 acre) reclaimed area. The hummocks are approximately 76.2 centimeters (30 inches) wide, 30.48 to 35.56 centimeters (12 to 14 inches) across and 25.4 to 40.64 centimeters (10 to 16 inches) deep. The hummocks were constructed in a random pattern, but never more than 76.2 centimeters (30 inches) apart from one another in any direction. These hummocks severely disrupt the runoff pattern from the face of the pile, thereby minimizing erosion on the reclaimed surface. Construction of the hummocks also incorporates the straw mulch into the soil surface, which helps to hold soil particles in place during snow melt runoff and following rain storms. The extreme roughness of the area should also enhance revegetation potential. Following hummock construction, the area was fertilized and seeded.

Approximately 1,200 shrubs were planted at the toe of the reclaimed slope. The eastern half of the toe was planted with containerized shrubs, while the western half was planted using locally obtained willow cuttings. As these shrubs mature, it is anticipated that a natural sediment barrier will be created. To complete the reclamation process, eight hundred trees were planted in clusters throughout the cut and fill area.

Outslope Revegetation Projects; 1996, 1999.

As previously discussed, development of the mine entries resulted in the creation of long, steep fill slopes, commonly referred to as mine bench outslopes. Typically, the outslopes are over 168 meters (550 feet) in length, and vary in size from 0.9 to 3.2 hectares (2.1 to 7.8 acres). The outslopes are predominately composed of dark, generally fine-grained sandstone and shale materials, with soil being essentially non-existent. Overall slope angles vary from between 72% and 80%. The slopes are generally devoid of vegetation and are subject to significant erosion, as evidenced by well developed gullies, which are common on each outslope. Observations indicate that the mine bench outslopes are significant areas of sediment generation.

Because of the sediment contribution attributed to these areas, it was determined that outslope stabilization was a necessary component of site reclamation. The constraints of elevation, access and steepness of the mine bench outslopes, as well as the sheer volume of material contained on the slopes required that they be stabilized in place. Therefore, one or more methods of revegetating the mine bench outslopes had to be developed.

Demonstrations were conducted at Mine 1 in 1996 for the purpose of creating shelves on the outslopes which would serve the dual purpose of breaking the surficial crusting which is common on the slopes, and of providing a resting place for seed, moisture and fertilizer.

In order to accomplish these goals, a 1.22 meter (4 feet) diameter drum roller was fitted with steel plates welded with a 30.48 centimeter (12 inch) spacing (horizontal and vertical) between plates. The plates, made of 1.27 centimeter (½ inch) steel, are 30.48 centimeters (12 inches) in length and 15.24 centimeters (6 inches) in height, and are welded to the drum perpendicular to the curvature of the roller in an alternating pattern. The roller is designed with a tongue so that it can be pulled up and down the outslopes by a cable attached to a heavy dozer.

The roller performed differently than an imprinter in an important way. While an imprinter creates a depression by compressing the ground surface into a depression in which seed, fertilizer and moisture can accumulate, the modified roller gouges a shelf into the slope. This distinction is important in that the full weight of the approximately four ton roller is applied to two or three thin steel plates at any one time. This pressure forces the plates into the outslope material, and digs material out of the slope as the roller moves up or down the outslope. The modified roller, because of the limited width of the plates, was observed to wedge between rocks, continuing to create the desired surface modifications even in these adverse conditions.

In the fall of 1996, the roller was applied to an approximately 22.9 meters (75 feet) wide by 38.1 meters (125 feet) long area of the Mine 1 outslope. Following this scarification process, seed was hand broadcast at a rate of about 6.8 to 9.1 kilograms (15 to 20 pounds) pure live seed per acre. Commercial fertilizer (18-24-0) was applied at a rate of 74 kilograms per hectare (300 pounds per acre) and mulch was applied to the slopes at a rate of about one metric ton per hectare (2 tons per acre). Slope scarification and seeding in this manner were also accomplished at this time on a steep east facing fill slope located below Road D immediately north of Mine 1.

The use of mulch as a cover was intended to shade the seed from the sun on these dark colored slopes. The dark colored, generally south and southeast facing slopes get very hot at the Project Area elevation. Therefore, the use of the mulch as a shade mechanism was thought to be beneficial to the germination potential of the seed.

Initial observations of the slope in 1997 were encouraging. Visually, vegetative cover at the Mine 1 outslope was estimated to be about fifteen percent to twenty percent. In 1998, transects were evaluated for cover and species composition. The results of this analysis are presented in Table 2, Vegetative Cover Establishment.

Table 2. Vegetative Cover Estimates
(1999 Cover Estimate)

	Mine 1 Outslope	Road D Outslope [1]
Vegetative Cover (%)	25	20 – 25
Predominate Species	Agropyron trachycaulum, Bromus inermis, Festuca ovina, Poa pratensis, Achillea millifolium, Penstemon strictus, Linum lewisii, Astragalus cicer	Bromus inermis, Agropyron trachycaulum, Phleum pratense, Festuca ovina, Achillea millifolium, Penstemon strictus, Linum lewisii, Astragalus cicer

[1] Seeded September, 1996

During the early stages of developing a revegetation procedure for the mine bench outslopes, it was observed that a native grass species, purple reedgrass (*Calamagrostis purpurascens*), was growing on the outslopes and on adjacent, undisturbed steep slopes.

Seed from the plant was harvested in the early fall of 1996. The seed was cleaned by hand, and broadcast both separately onto the scarified outslopes, and in conjunction with the commercial seed mixture used during the revegetation efforts at Mine 1. No germination was detected until the summer of 1998, when *Calamagrostis purpurascens* seedlings were observed to be establishing on the site. In the area where *Calamagrostis purpurascens* had been seeded without the commercial species, visual estimations indicate a cover of up to fifteen percent had been established.

In an effort to promulgate a seed source for this material, DMG entered into a contract with the Upper Colorado Environmental Plant Center (UCEPC), located near Meeker, Colorado. UCEPC agreed to accept some of the *Calamagrostis purpurascens* seed, clean it, conduct germiuation tests and attempt to cultivate it on a limited scale. Germination tests had a positive result, with a 48% to 50% of the tested seed germinating. Cultivation, however, proved to be difficult, with field plantings bearing few seedlings. Greenhouse germination was more successful. UCEPC delivered to the DMG over one thousand greenhouse grown seedlings suitable for transplanting in the summer of 1999.

Due to the success observed as a result of the demonstrations conducted at Mine 1 and at Road D, DMG decided to undertake revegetation of the remaining mine bench outslopes replicating the hill slope scarification and shelf construction accomplished in 1996. However, it was recognized that, for the most part, the slopes which needed to be treated and seeded were much more remote, and provided much greater access challenges than the relatively accessible upper reaches of the Mine 1 outslope. Therefore, an invitation for bid was issued which did not specify the mechanisms of shelf construction to be employed. Rather, the invitation specified minimum dimensions of shelves, shelf spacing and the minimum number of shelves per acre to be established.

The shelves constructed were 25.4 centimeters (10 inches) in width and 20.32 centimeters (8 inches) deep, with a spacing of 91.4 centimeters (3 feet) horizontally (perpendicular to the fall of the slope) and 91.4 centimeters (3 feet) vertically (parallel to the fall of the slope). Construction in this manner would result in creation of 1,435 shelves per hectare (3,588 shelves per acre), representing 638 square meters of flat surface per hectare (1,596 square feet of flat surface per acre) on the steep mine bench outslopes.

In early September 1999 the Project contractor began work as crews were brought onto the site. Using Macleod Fire Rake / Hoes, the shelves were dug into the slopes. The Macleod Fire Rake / Hoe is a rake-like tool that is composed of a steel plate fastened perpendicularly to the base of a four and a half-foot wood handle. One side of the steel plate is a sharpened flat blade, measuring about 25.4 centimeters (10 inches) across. The opposite end is a four pronged rake, also measuring about 25.4 centimeters (10 inches) across the outside of the rake. Crew members worked 3.04 to 4.6 meters (10 to 15 feet) distant from each other, spread horizontally across the slope. The crew worked from the top to the bottom of each slope. Observation of the construction process indicates that about twenty five percent more shelves than was specified were actually created, yielding approximately 1,779 shelves per hectare (4,448 shelves per acre), representing up to 783 cubic meters of flat areas per hectare (1,958 square feet of flat area per acre) of mine bench outslope.

While the hand crew was creating the shelves, a second crew was collecting and cleaning *Calamagrostis purpurascens* seed. In addition, seed from a locally occurring aster (tentatively identified as *Aster glaucodes*) was collected and cleaned.

Seeding was accomplished as the crew worked down the slopes. The commercially obtained seed was distributed with a hand held seeding machine, while the seed from the two native species was distributed on the slope by hand broadcast methods. Biosol 7-2-3, a slow release fertilizer, was applied by helicopter at a rate of 326 kilograms per hectare (1,800 pounds per acre). Certified weed free straw mulch was applied at a rate of 363 kilograms per hectare (2,000 pounds per acre). At four of the five outslopes, the mulch was also applied by helicopter. Approximately 9.7 hectares (24 acres) of steep mine bench outslopes were scarified, seeded fertilized and mulched during performance of this Project.

Approximately two hundred (200) *Calamagrostis purpurascens* seedlings provided by UCEPC were planted across each of the five mine bench outslopes at mid-slope. The mid-slope area was chosen for planting, as it is anticipated that seed produced from the plants will have an equal chance of being distributed either up- or down-slope by winds.

A variety of containerized shrubs were planted at the base of each slope. Approximately 540 shrubs were planted at each area. The purpose of this planting was to begin the establishment of vegetative sediment barriers.

Measurement of the project success will be accomplished not only in terms of vegetative cover, but also in terms of erosion control and sediment retention. In order to help assess sediment retention, staff gauges were placed in sediment traps constructed at the toe of some of the outslopes in order to measure sediment accumulation over time.

In an effort to indirectly measure the relative success of the revegetation effort as it relates to erosion and sediment delivery from the outslopes to the adjacent water resources, gully monitoring points were established within representative gullies on each of the treated slopes. Parameters such as gully width, depth, steepness, soil characteristics and relative percent vegetative cover within each gully contributing area were recorded, and will be monitored in the future.

In conjunction with the slope revegetation project, a stream monitoring network has been established on Coal and Dutch Creeks. Parameters monitored include suspended solids, settleable solids and discharge. This network is designed to isolate the mine bench outslope contributions from naturally occurring sediment so that an analysis of the relative success of the mine bench outslope revegetation effort can be made as vegetation matures.

Public Participation and Support

Reclamation has primarily been funded through the bankruptcy proceedings. However, these funds were earmarked only for projects contemplated by the permit reclamation plan. Site observations indicated that, in order to effectively accomplish site remediation, other tasks would need to be accommodated. Therefore, DMG was very active in pursuing other avenues of funding. Additional funding has been mainly developed through grants received from various State and Federal agencies. The communities near the site have been very supportive of the pursuit of additional funding in order to enhance the overall reclamation of Coal Basin.

An integral factor in being able to obtain grants and to build consensus within the community and between interested agencies has been the creation of productive inter-governmental relationships. DMG has been very successful in establishing effective working relationships with OSM, the White River National Forest, the Army Corps of Engineers, Pitkin County, Colorado Division of Wildlife and the Colorado Department of Public Health and Environment. The importance of involving the appropriate agencies at every level of reclamation planning and implementation cannot be overstated. By maintaining productive relationships with the various agencies, coordination of Projects and implementation of reclamation plans proceeded with a minimum of delay.

One of the unique aspects of accomplishing reclamation of the Coal Basin Mine has been the general level of interest that the process has inspired in government agencies and local citizens. One significantly successful aspect of the reclamation processes has been the active involvement of many interested parties. Partnerships in the community which developed between DMG, area citizens, local groups and organizations, served to foster community involvement and enhanced environmental awareness.

Public participation in and support of the reclamation process has perhaps been one of the more critical elements of successfully implementing reclamation at Coal Basin. DMG recognized the importance of gaining the trust of the community in order to achieve successful site reclamation. It was thought that the best way to gain public confidence in the reclamation process was by inviting the public to actively participate in the process.

In order to promote public participation, DMG participated in many community meetings to discuss reclamation plans, and hosted numerous tours of the site to show and explain the reclamation process. Open and frank discussions about reclamation progress, plans and practices have been held. Volunteer tree planting activities have been hosted in the past, and volunteer shrub planting opportunities were provided this season. Citizens have even helped with surveying and pre-construction project layout. The media, as well as County Commissioners, State Representatives and other Local, State and Federal officials have toured the site.

A number of area schools have been very involved at Coal Basin in the past three years. School groups from Pitkin and Garfield Counties have participated in tree planting efforts in the past. Schools have also been using the area as an outdoor lab of sorts, in order to help teach the concepts of geomorphologic restoration, revegetation and other reclamation processes.

Conclusion

Effective and efficient reclamation is being accomplished at the Coal Basin Mine by the Division of Minerals and Geology. This success is largely attributed to the prioritization of reclamation needs, accomplishing multiple reclamation objectives through creative construction planning, the selective use of grant monies to target areas not subject to reclamation funding by the forfeited bond, and the involvement of local citizens in the process.

The use of technology, particularly real time global positioning system, has greatly enhanced the ability of DMG to produce accurate pre- and post-reclamation topographic maps and cross sections, which provide contractors a greater degree of confidence in their ability to efficiently bid a Project. This leads to economic completion of Projects by encouraging well thought out bids, and a minimum of field modifications. The development of close working relationships with contractors has lead to the implementation of innovative reclamation solutions.

The implementation of techniques modified to meet the challenges of the area has helped to enhance the reclamation product. Severe surface disruption enhances revegetation potential, while alleviating erosion problems. Creation of benches on the steep mine bench outslopes, wither by hand or by mechanical means, provides an economic approach to the steep slope revegetation. Finally, the use of geomorphically active design parameters when approaching stream channel reconstruction problems lends itself to the creation of a naturally functioning system, which, ultimately, is the goal of reclamation.

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Coal Basin Reclamation Facts And Figures

Projects Completed (As Of December 1, 2000)

(3) Refuse Piles Reclaimed	(20.6 hectares; 51 acres)
(5) Mine entry areas and five fan entry areas reclaimed	(12.5 hectares; 31 acres)
(6) Haul Roads reclaimed	(34.4 hectares; 86 acres)
(3) Industrial areas reclaimed	(8.9 hectares; 22 acres)
(3) coal stockpiles reclaimed	(3.6 hectares; 9 acres)
(6) Mine bench outslopes re-seeded	(11.7 hectares; 29 acres)
Stream Channel reconstructed	(381 meters; 1,250 feet)
Noxious Weed Control	(8.1 hectares; 20 acres)

Grants Received

Two OSM Civil Penalty Grants	(5.7 hectares; 14 acres)
Non-Point Source Grant	(9.7 hectares; 24 acres)
Noxious Weed Control Grant	(8.9 hectares; 22 acres)
Two Abandoned Mined Land Fee Funded Projects	(6.5 hectares; 16 acres)

Public Involvement

Aspen Public Schools	Tree Planting
Colorado Rocky Mountain School	Tree Planting, Environmental Awareness Field Site
Yampah Mountain High School	Reclamation and Energy Awareness Program Field Site, Shrub Panting
Carbondale High School	River Watch Program
Redstone Caucus	Tree Planting
Redstone Community Association	Tree Planting
Crystal Valley Environmental Protection Association	River Watch Program, Tree Planting
Roaring Fork Conservancy	River Watch Program