RECLAMATION AND BOND RELEASE AT THE CARBON NO. 2 MINE IN NEW MEXICO: A NATIONALLY RECOGNIZED SUCCESS[1]

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Abstract. In early February, 2002, the New Mexico Mining and Minerals Division (MMD) nominated Carbon Coal Company (Carbon) for a National Award from the Office of Surface Mining Reclamation and Enforcement (OSM) for outstanding overall performance in meeting and exceeding the goals of the Surface Mining Control and Reclamation Act of 1977. Specifically, the MMD considered the reclamation completed at the Carbon No. 2 Mine to be exemplary in terms of enhancement of the permit area's hydrologic balance and its capability to support the postmine land use. The mining and reclamation completed by Carbon reduced the risk of flash flooding in the southern part of the City of Gallup from routine to nil. The postmine livestock carrying capacity of the reclamation was more than double the premine capacity. The potential long-term benefit to other western coal mining operations resulting from Carbon's pioneering application of New Mexico's "Hydrologic Window" regulation also merited recognition. Carbon applied for final (Phase III) bond release for Carbon No. 2 Mine in December of 2001. The MMD approved final bond release and terminated jurisdiction over the mine permit area in late March, 2002. OSM recognized Carbon's reclamation efforts with a National Award at the September 2002 awards ceremony in Washington, D.C.

Additional Key Words: recreation, revegetation, success criteria, wildlife habitat

Introduction

Carbon No. 2 Mine was operated by Carbon Coal Company (Carbon), a subsidiary of Arizona Electric Power Cooperative (AEPCO). The 361-acre permit area is located in McKinley County, New Mexico, approximately 4 km (2.5 mi) south of the City of Gallup. Extraction of coal from five seams of the Dilco Member of the Crevasse Canyon Formation began in 1982. The coal was hauled by truck to a wash plant and tipple at Carbon's Mentmore Mine, northwest

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of Gallup. The cleaned coal was then delivered by rail to AEPCO's electrical generating facility in Benson, Arizona.

Mining operations at Carbon No. 2 ended in 1986. Backfilling and grading of portions of the disturbed area commenced in 1985, and final revegetation seeding was completed in 1991. Phase I bond release for the reclamation was approved in 1992, after the completion of backfilling and grading. Phase II bond release was approved in 1999, upon demonstration of successful revegetation establishment and control of soil erosion. Carbon submitted an application for Phase III (final) bond release in December 2001.

The objectives of this paper are to document and quantify reclamation and management efforts that both MMD and OSM consider to be an outstanding example of effective land use restoration and enhancement.

Site Conditions and Reclamation Methods

The elevation at Carbon No. 2 averages about 2057 m (6750 ft). The 60-year average annual precipitation for Gallup is about 241 mm (9.5 in), although annual precipitation as low as 91 mm (3.6 in) was recorded during the years when reclamation was being conducted. Portions of the permit area had been chained and seeded with crested and intermediate wheatgrasses *(Agropyron cristatum* and *A. intermedium)* as a range improvement technique several years before the area was mined; seeds of these species apparently persisted in the stockpiled soil and the wheatgrasses became well established on the reclamation. In response to these difficult conditions, and to improve the quality and performance of the revegetation, the operator used different seed mixtures to establish and interseed the revegetation on six separate occasions (Table 1).

Carbon No. 2 is located in the east arm of a drainage known as Catalpa Canyon. Although the watershed is not large at 828 ha (2046 ac), Catalpa Canyon had a history of flash flooding in response to thunderstorms. The City of Gallup's municipal golf course and a residential subdivision were routinely subject to flooding prior to the mining and reclamation operations, and the active mine pit was flooded on one occasion. Pre-existing stock ponds upstream of the mine were improved for flood control and two impoundments were constructed below the mine pit. Reclaimed drainage channels were armored with limestone.

Table 1. Reclamation seed mixtures and years of seeding on Carbon No. 2 Mine (Carbon 2002) .

Species (Variety)	Approximate Number of Seeds/lb (in thousands)[1]	Mix 1 PLS[2] lbs/ac	Mix D[3] PLS lbs/ac	Mix E PLS lbs/ac	Mix F PLS lbs/ac	Mix G PLS lbs/ac	Mix H PLS lbs/ac
Year Seeded		1980	1985	1986	1987	1990	1991
Agropyron dasystachyum (Critana)	154.0	--	0.66	--	--	--	--
Agropyron riparium	156.0	--	1.86	--	--	--	--
Agropyron smithii (Arriba)	110.0	4.00	5.31	2.43	2.50	3.00	3.00
Atriplex canescens	52.0	0.80	3.83	0.24	1.00	1.25	1.00
Atriplex confertifolia	64.9	--	--	--	1.00	1.25	1.00
Bouteloua curtipendula	191.0	0.60	0.56	--	--	--	1.00
Bouteloua curtipendula (El Reno)	191.0	--	--	0.60	1.50	--	--
Bouteloua curtipendula (Vaughn)	191.0	--	--	--	--	1.50	--
Bouteloua gracilis	825.0	--	--	1.86	1.00	--	1.00
Bouteloua gracilis (Hachita)	825.0	--	--	--	--	1.00	--
Elymus elongatus (Jose)	79.0	--	2.16	--	--	--	--
Festuca arizonica (Redondo)	550.0	--	--	--	--	1.00	--
Festuca idahoensis (Idaho)	450.0	--	--	--	--	--	0.50
Gaillardia aristida[4]	132.0	--	--	--	--	0.02	0.02

Species (Variety)	Approximate Number of Seeds/lb (in thousands)[1]	Mix 1 PLS[2] lbs/ac	Mix D[3] PLS lbs/ac	Mix E PLS lbs/ac	Mix F PLS lbs/ac	Mix G PLS lbs/ac	Mix H PLS lbs/ac
Year Seeded		1980	1985	1986	1987	1990	1991
Hilaria jamesii	Unk	--	0.37	1.46	--	--	--
Hilaria jamesii (Carey)	470.0	--	--	--	--	--	1.00
Hilaria jamesii (Florets)[4]	159.0	--	--	--	--	--	0.30
Hilaria jamesii (Viva)	Unk	--	--	--	2.00	1.00	--
Krascheninnikovia lanata[4]	56.7	0.30	--	0.20	1.00	1.00	1.00
Linum lewisii[4]	293.0	--	--	--	--	0.025	0.025
Machaeranthera tanacetifolia[4]	496.0	--	--	--	--	0.02	0.02
Melilotus alba	260.0	--	0.23	--	--	--	--
Oryzopsis hymenoides	191.0	0.90	1.86	--	--	--	2.50
Oryzopsis hymenoides (Nezpar)	191.0	--	--	1.46	--	--	--
Oryzopsis hymenoides (Paloma)	191.0	--	--	--	2.50	2.50	--
Penstemon palmeri[4]	610.0	--	--	--	--	0.02	0.02
Penstemon strictus[4]	592.0	--	--	--	--	0.025	0.025
Penstemon strictus (Bandera)	592.0	--	--	0.02	0.50	--	--
Petalostemum purpureum[4]	293.0	--	--	--	--	0.01	0.01

Species (Variety)	Approximate Number of Seeds/lb (in thousands)[1]	Mix 1 PLS[2] lbs/ac	Mix D[3] PLS lbs/ac	Mix E PLS lbs/ac	Mix F PLS lbs/ac	Mix G PLS lbs/ac	Mix H PLS lbs/ac
Year Seeded		1980	1985	1986	1987	1990	1991
Poa sandbergii	925.0	--	--	--	0.50	--	--
Ratibida columnaris[4]	1,230.0	--	--	--	--	0.025	0.025
Sphaeralcea coccinea	500.0	--	--	--	0.15	0.005	--
Sphaeralcea grossulariaefolia[4]	500.0	--	--	--	--	--	0.005
Sporobolus airoides[4]	1,758.0	--	0.05	1.46	0.25	0.25	0.30
Sporobolus cryptandrus[4]	5,290.0	--	--	--	0.10	0.10	0.10
Stipa comata	115.0	--	--	--	1.00	1.00	--
Stipa neomexicana	70.0	--	--	--	--	--	1.00
Viguiera multiflora[4]	1,055.0	--	--	--	--	0.015	0.015
Total lbs/ac		6.60	16.89	9.73	15.00	15.02	13.87

[1] Source: Granite Seed Company (1991).
[2] PLS = pure live seed.
[3] All areas seeded with this mixture were burned, disced, and replanted in 1987 due to dominance of *Elymus elongatus*.
[4] Broadcast seeded.

After backfilling the pit, suitable spoil material (primarily sandstone-derived) was spread to a depth of about 1.2 m (4 ft) over all regraded areas, and 15 cm (6 in) of topsoil was applied. The final pit area reclamation was seeded and mulched with native hay at a rate of 2250 kg/ha (2 tons/ac) in June 1991. Trees and shrubs were transplanted adjacent to small sandstone bluffs and rock piles. These habitat features harvest moisture, provide shade and windbreaks, and together with the rip-rapped channels provide protection and burrowing sites for small mammals and reptiles. Four permanent impoundments, ranging in volume from 2219 to 11590 m^3 (1.8 to 9.4 ac-ft), provide flood control and seasonal water sources that meet New Mexico livestock and wildlife water quality standards (Fig. 1).

The landowner requested that the shop building be left for storage of supplemental feed and equipment to facilitate the grazing postmine land use. The mine access road was also requested

Figure 1. Carbon No. 2 reclamation in September 2001.

and approved as a permanent feature to facilitate residential development on adjacent land. Several new homes have been built along the access road and overlooking the reclamation, and in addition to the grazing and wildlife habitat postmine land uses approved for the mine, the reclamation was designed to provide a common area for hiking, wildlife viewing, and horseback riding for the neighboring residents. Approximately 12 km (7.5 mi) of trails were built to provide access to the entire reclaimed area. Wooden bridges provide all-weather stream channel crossings.

Hydrologic Window Demonstration

The requirement to pass all disturbed area runoff through impoundments may be waived if an operator demonstrates that alternate sediment control practices result in runoff water quality from regraded areas that is as good or better than the waters entering the permit area, and that erosion is adequately controlled (19.8.2009.E New Mexico Administrative Code [NMAC]). Sampling surface water in the arid and semi-arid western states can be difficult due to ephemeral flows and highly mobile stream beds. Single stage sediment samplers are inadequate for monitoring surface flow under these conditions. To demonstrate that alternate sediment control was approvable, Carbon developed a new sampler for monitoring shallow ephemeral flows in small watersheds (Fig. 2 and 3). Four reclamation watersheds and two undisturbed watersheds with similar drainage area, gradient, and vegetative cover were selected for monitoring. Since the sampler could capture suspended sediment as well as bedload, grain size separation (fractionation) was performed in the lab. Suspended sediment concentrations were based on the USGS definition of 0.062 mm as the upper limit. Sedcad+ was also used to model runoff and sediment loads in each watershed. Based on monitoring data and the corroborating watershed modeling, which showed that reclaimed runoff sediment concentrations were well below sediment concentrations on undisturbed lands, the MMD waived treatment for reclaimed area runoff in April of 1990. Two months later, Carbon No. 2 was released from NPDES monitoring requirements by the EPA. The sampler designed by Carbon has been successfully used on three other coal mines in the San Juan Basin of New Mexico. In 2000, New Mexico's hydrologic window regulation was cited by the EPA as an example in support of NPDES permit changes promulgated at 40 CFR 434 (fr11ap00-35):

Under New Mexico's "ASC Windows Program" (19 NMAC 8.2 Subpart 20, Section 2009), SMCRA requirements to pass all disturbed area runoff through sedimentation ponds can be waived if the operator demonstrates that erosion is sufficiently controlled and that the quality of area runoff is as good as, or better than, that of water entering the permit area. The operator's plan for alternative sediment control must demonstrate that there will be no increase in the sediment load to receiving streams. Several mine operations in New Mexico have applied for and received reclamation liability bond releases for lands where sediment control BMP plans were implemented. These sites demonstrated that there was no additional annual contribution of

suspended solids to the hydrologic regime of the area and that runoff from regraded areas had characteristics similar to runoff from undisturbed areas.

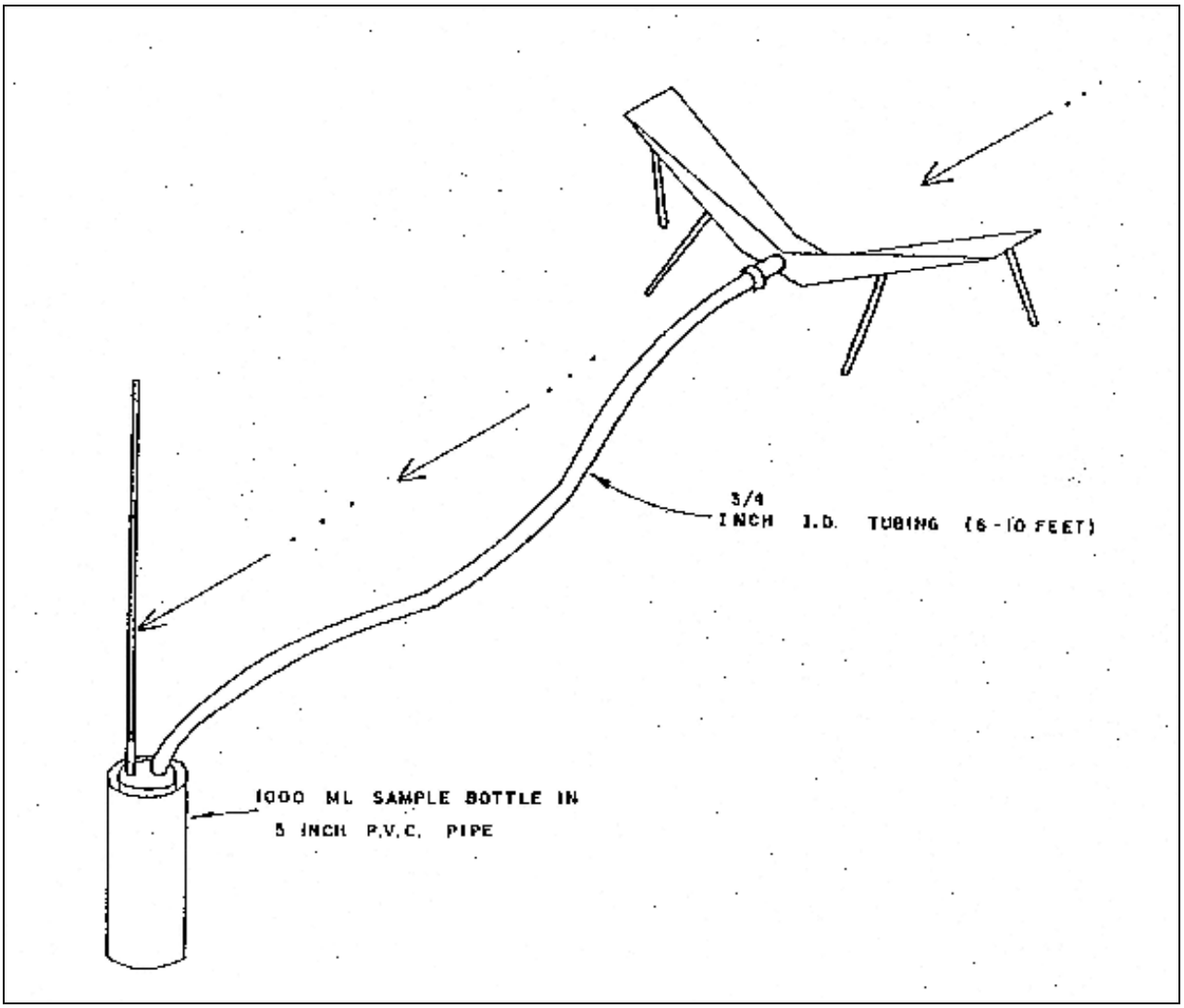

Figure 2. Typical hydrologic window monitoring site (Porterfield 1989).

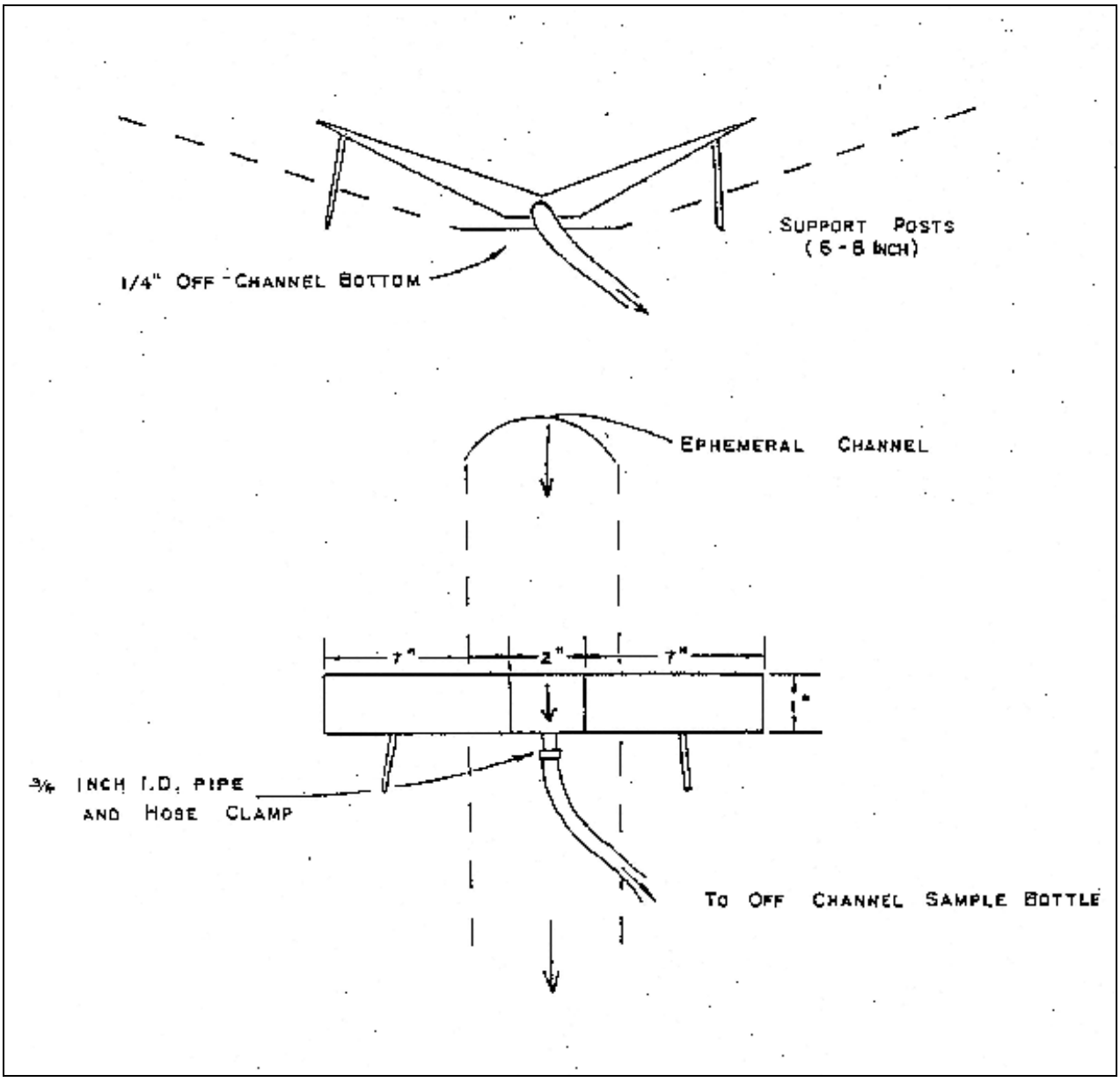

Figure 3. Window sampler (Porterfield 1989).

Grazing Management and Demonstration

Winter grazing was the traditional premine land use for the Carbon No. 2 permit area. Baseline data in the mine permit indicated an average premine carrying capacity of 0.44 animal unit months (AUM) per hectare (0.18 AUM/ac). Grazing of the revegetation as a husbandry practice was begun in January 1996. With the exception of 2001, when drought resulted in insufficient forage production, reclamation grazing was conducted each winter through 2002

during the months of January-March (Table 2). The 1999 and 2000 episodes provided the grazing demonstration required during two of the last four years of liability by New Mexico regulations. A forage utilization rate of 50% was targeted each year except 2002, when 40% utilization was prescribed in response to the previous year's drought.

Table 2. Grazing history, Carbon No. 2 reclamation.

Year	Head of Cattle	Days of Use	Stocking Rate-AUM/ha (AUM/ac)
1996	21	90	0.49 (0.20)
1997	20	90	0.47 (0.19)
1998	40	90	0.96 (0.39)
1999	45	85	1.01 (0.41)
2000	45	85	1.01 (0.41)
2001	None	None	N/A
2002	30	76	0.62 (0.25)

The grazing of revegetation at rates of 1.01 AUM/ha (0.41 AUM/ac) in 1999 and 2000 met the regulatory requirement to demonstrate that the reclaimed land had the capability to support the postmine land use at rates approximately equal to that of similar non-mined lands for at least two of the last four years of liability.

Final Bond Release Demonstrations

During September of 2000 and 2001, a Phase III bond release study was conducted by TRC Mariah Associates Inc. to determine if the reclaimed lands met the revegetation success standards approved in the mine permit:

- 19% live perennial/biennial cover;
- a sliding scale production standard, with a maximum of 480 kg/ha (427 lb/ac) of current year's growth of perennial and biennial forage in years when the mine received 305 mm (12 in) or more precipitation during the preceding July-March period. The standard was adjusted for precipitation less than 305 mm using the slope of the regression model proposed by Blaisdel (1958); i.e., a 25-mm (1-in) decrease in July-March precipitation results in a 43-kg/ha (38.2-lb/ac) decrease in that year's production standard. The July-March precipitation period was supported by Joyce (1981), who suggested that fall,

winter, and early spring precipitation was the best predictor of peak standing crop for Intermountain Region rangelands;

- species diversity as demonstrated by the presence of one cool season perennial grass with 3-70% relative cover and an additional cool season grass with at least 1% relative cover, two warm season perennial grasses with 3-70% relative cover each, and at least 1% relative cover of perennial forbs; and
- shrub density of at least 370.5 shrubs or subshrubs per hectare (150 shrubs/ac).

Sampling points were established using a 30-m grid overlain on an aerial photomosaic of the permit area and randomly chosen x-y coordinates. Eighty sample points were located in the field by pacing from recognizable landmarks. A production plot was placed at each sample point and a random compass direction was used to determine cover and shrub density transect direction. Percent coverage of vegetation, bare ground, rock, and litter was determined along 50-m point intercept transects at 60 of the 80 sample points. Cover was read at 0.5-m intervals for a total of 100 primary hits on each transect. Secondary hits (i.e., intercepts in the subcanopy) were also recorded. Primary hits were used to evaluate absolute cover. Both primary and secondary hits were used to calculate relative cover, which was used to determine whether the reclaimed area met the species diversity standard. At points where an annual plant was recorded as a primary hit followed by a perennial or biennial plant as a secondary hit, the perennial or biennial was treated as the primary hit in the calculation of absolute perennial/biennial cover. Litter, rock, or bare ground were recorded only at points where no current year's vegetative cover was present. Cover sampling during both years of the study was conducted by one biologist to ensure consistency. New Mexico regulations require only a single demonstration that the diversity standards have been met by the end of the liability period. Since the standards were met in 2000, an evaluation of diversity was not made in 2001.

Peak standing crop was determined by harvesting all qualifying perennial/biennial species within 80 1x1-m production plots. Exclosures were not used because no grazing occurred during the growing season. Clipped biomass was oven-dried at 60°C to a constant weight and weighed to the nearest 0.1 g. During the drying and weighing process, at least 10% of the samples were randomly selected and reweighed to ensure that weights were being properly recorded and that the balance maintained precision.

Shrub density was measured by counting shrubs and subshrubs rooted within a 50-m x 2-m belt transect at each of the 80 sample points used for production. All shrubs counted were at least 2 years old, alive and healthy, and had at least one-third of their length in live crown, per regulation. The shrub density estimate met the technical standard in 2000. New Mexico regulations require that a single demonstration of adequate shrub stocking be made at the end of the liability period, so shrub density measurements were not repeated in 2001.

For the year 2000, biennial/perennial species cover and production averaged 45.5% and 567 kg/ha (505 lb/ac). The nonparametric sign test was used to verify that reclamation cover exceeded 90% of the cover technical standard of 19% with 90% statistical confidence. The one sample t-test was used to verify that reclamation production (normalized by a Box-Cox transformation) exceeded the Year 2000 production technical standard of 355 kg/ha (316 lb/ac) with 90% statistical confidence. The sign test was also used to verify that reclamation shrub stocking, at 3185 stems/ha (1289.5 stems/ac), exceeded 90% of the approved technical standard (150 stems/ac) with 90% statistical confidence.

In 2001, cover and production of perennial species averaged 57.4% and 802 kg/ha (714 lb/ac). The sign test was again used to verify that reclamation cover exceeded 90% of the cover technical standard (19%) with 90% statistical confidence. The sign test was also used to verify that reclamation production exceeded 90% of the Year 2001 production technical standard of 335 kg/ha (298 lb/ac) with 90% statistical confidence.

The approved species diversity standards were exceeded. One hundred vascular plant species were documented on the 308 acres of reclamation. This included seven warm-season perennial grasses, 18 cool-season perennial grasses, 14 shrubs and subshrubs, and 21 native perennial forbs. Galleta *(Hilaria jamesii)*, blue grama *(Bouteloua gracilis)*, and sideoats grama *(B. curtipendula)* were the dominant warm-season forage species with 22.0, 5.3, and 3.6% relative cover, respectively; each met the 3-70% relative cover standard. Native and introduced wheatgrasses were the dominant cool-season forage species; thickspike wheatgrass *(Agropyron dasystachyum)*, crested wheatgrass *(A. cristatum)*, and intermediate wheatgrass *(A. intermedium)* contributed 14.9, 11.4, and 4.1% relative cover, respectively, and met the 3-70% relative cover standard. Western wheatgrass *(A. smithii)* and tall wheatgrass *(Elymus elongatus)*, along with Indian ricegrass *(Oryzopsis hymenoides)* and Arizona fescue *(Festuca arizonica)*, provided 1-3% relative cover. Four-wing saltbush *(Atriplex canescens)*, winterfat *(Krascheninnikova lanata)*,

and rubber rabbitbrush *(Chrysothamnus nauseosus)* were the dominant shrub species. Palmer's penstemon *(Penstemon palmeri)*, Rocky Mountain penstemon *(P. strictus)*, and hairy goldenaster *(Heterotheca villosa)* were the most common perennial forbs.

Vegetative diversity, the permanent impoundments, and the rock features have provided reasonably good wildlife habitat. At least 26 wildlife taxa have been recorded on the reclamation during the bond liability period: 10 mammals, 14 birds, and two reptiles. Ducks, sparrows, and rodents were not always identified to species, so these numbers are conservative.

Summary and Conclusions

Final bond release and termination of jurisdiction for Carbon No. 2 was approved by MMD in March 2002. In February 2002, MMD had nominated Carbon for an OSM National Award for mine reclamation that has achieved bond release. The City of Gallup submitted a letter of support in recognition and appreciation of the flood control provided by Carbon's mining and reclamation operations. Based upon the nomination package and a site inspection, OSM selected Carbon for a National Reclamation Award, which was presented at a September 2002 ceremony in Washington, D.C.

We believe that interseeding different seed mixtures over several years provided exposure to varied establishment conditions for a large number of species, and was important in creating vegetative species richness. In addition, the relatively short term stockpiling of soil at this operation probably allowed the seeds of many forb species to survive burial (e.g., Iverson 1981). The application of dormant season grazing as soon as the revegetation was adequately established may also have contributed to perennial species richness (Fig. 4). Winter grazing helped to control annual introduced grasses. Standing litter was knocked down and trampled, and produced seeds were dispersed and pressed into the soil. Dormant season grazing may have application as a reclamation management tool in other regions.

The successful demonstration of erosion and sediment control that Carbon provided has the potential to contribute to improved protection of the hydrologic balance, improved ability to obtain bond release, and significant cost savings for coal mining operations throughout the arid and semi-arid west.

Figure 4. Winter 2002 revegetation grazing.

The landowners of Carbon No. 2 have been very positively benefited by the operation. Livestock carrying capacity has more than doubled. The reclaimed landscape is stable. Property values of the adjacent subdivided lands have surely been improved by the availability of a safe and accessible common area for recreation and relaxation.

The City of Gallup and its residents have also been very positively benefited by the flood control provided by Carbon No. 2 reclamation. It is difficult to put a monetary value on the improved safety, the elimination of property damage, and the freedom from worry that these people experience when they see a summer thunderstorm approaching Gallup.

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