Reclaiming Disturbed Land Using Supplemental Irrigation in the Great Basin/Mojave Desert Transition Region After Contaminated Soils Remediation: the Double Tracks Project

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Abstract—Approximately 3.8 hectares (9.3 acres) were reseeded following contaminated soil remediation operations at the Double Tracks site in south-central Nevada during the fall of 1996. Four irrigation/topsoil treatments, including a nonirrigated control, were studied to determine plant response to the different treatments. Seedling emergence and subsequent establishment (one-and-a-half years later) of seeded species were highest in the spring irrigated with topsoil treatment. Initial seedling emergence was significantly lower when no irrigation was used, which suggests the need for supplemental irrigation for seed germination. Seedling and plant densities were highest for winterfat (*Krascheninnikovia lanata*), Indian ricegrass (*Achnatherum hymenoides*), squirreltail (*Elymus elymoides*), Nevada jointfir (*Ephedra nevadensis*), and shadscale (*Atriplex confertifolia*).

On May 15, 1963, the Double Tracks test, which consisted of plutonium and depleted uranium, was exploded on the Nellis Air Force Range (NAFR) to study the dispersal of radionuclides in the environment (Church 1969; Shreve 1965). As a result of the explosion, approximately 0.98-1.6 kilograms (kg) (2.2-3.5 pounds) of plutonium was scattered across the Double Tracks site (Shreve 1964).

During the summer and early fall of 1996, remediation of the Double Tracks site occurred. The remediation process entailed scraping the top 5 to 15 cm (2 to 6 inches) of contaminated topsoil, packaging the soil, and transporting it to a disposal site at the Nevada Test Site. The last phase of the remediation process was to reclaim the land surface disturbed by the remediation process. The reclamation objective was to establish a permanent native vegetative cover on the site to prevent soil erosion and re-establish wildlife habitat. The purpose of this paper is to describe techniques used to accomplish the reclamation objective, explain some of the results to date, and describe a monitoring plan used to evaluate reclamation success.

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Methods

Site Description

The Double Tracks remediation site is located on the NAFR, approximately 22 kilometers (14 miles) east of Goldfield, Nevada, located in the south-central part of the State (fig. 1). The site is on the northwest edge of Stonewall Flat on an alluvial fan extending off the western slope of the Cactus Spring Mountains. Elevation at the site ranges from 1,487 to 1,584 m (4,879 to 5,197 feet) above sea level. Common vascular plant species found on the site include

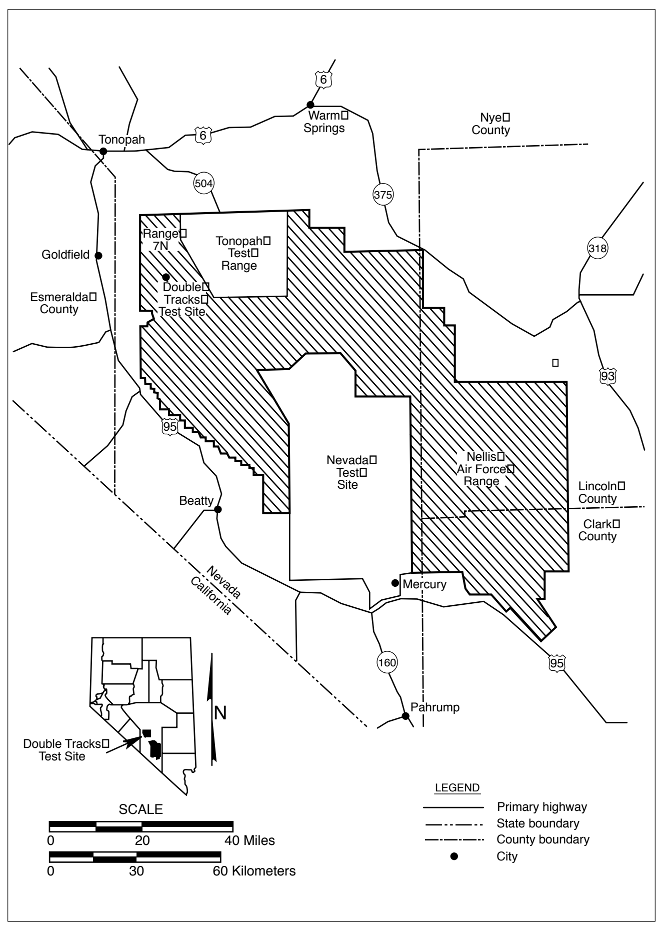

Figure 1—Location of Double Tracks remediation site.

greasewood (*Sarcobatus vermiculatus*), budsage (*Artemisia spinescens*), winterfat (*Krascheninnikovia lanata*), desert pepperweed (*Lepidium fremontii*), and shadscale (*Atriplex confertifolia*). Soils are predominantly gravelly sandy loams and gravelly loams (Leavitt 1978). Average annual precipitation at Goldfield is 118 mm (5.2 inches) (Office of the Nevada State Climatologist, unpublished).

Figure 2 shows the layout of the remediation site and eight sections that were reclaimed. Only 1.1 ha (2.7 acres) were remediated (A and B). Little or no topsoil from the remaining 2.7 ha (6.6 acres) was removed (C - H). These sections were disturbed in support of the remediation operation but were not remediated because they were characterized as having radioactivity levels lower than the specified interim corrective action level or less than or equal to natural background levels. The eight sections (fig. 2) were categorized into the following four areas: (1) the remediated area where topsoil was removed (A and B), (2) the staging area where some topsoil was removed and later replaced (C), (3) the support facility area where little or no topsoil was removed (D), and (4) the remaining area where little or no topsoil was removed (E, F, G, and H). A total of 3.8 ha (9.3 acres) were reclaimed at the Double Tracks remediation site.

Site Preparation

During the fall of 1996, all of the areas to be reclaimed were ripped to a depth commensurate with the degree of compaction. Areas with large dirt clods were disked to smooth the seedbed. Additionally, portions of the site were recontoured to predisturbance conditions with emphasis on re-establishing natural drainages.

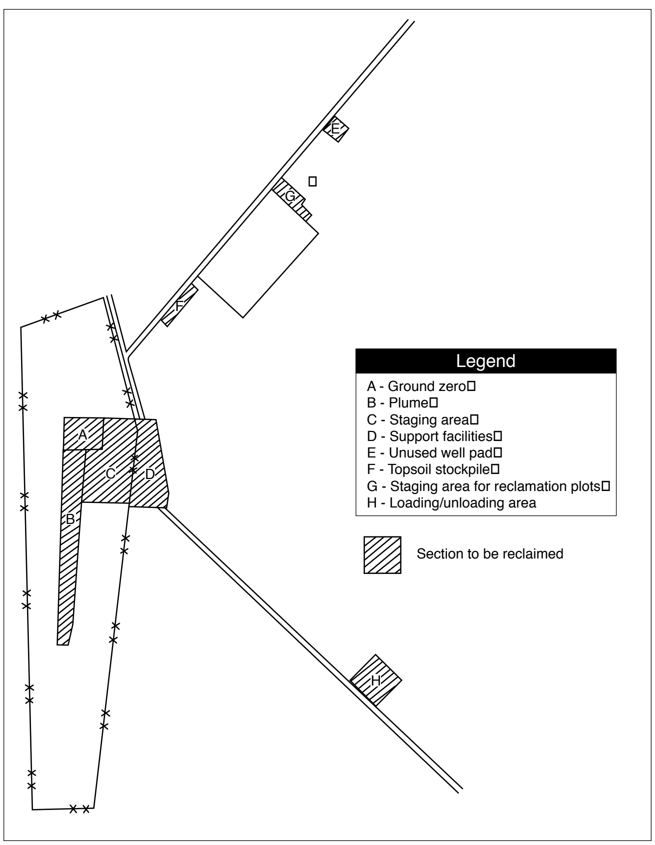

Figure 2—Location of areas reclaimed at the Double Tracks cleanup site.

Seeding/Polyacrylamide Gel Application

Native species were used in the seed mix in proportions similar to what naturally occurs on the site. To determine species composition, a reference area was located adjacent to the remediation site, and plant density and cover data were collected from 15, 50 m (164 ft) transects in July 1995 (Anderson and Hall 1997). A seed mix was then developed based on the density and cover data from the reference area (table 1). Galleta (*Pleuraphis jamesii*), spiny hopsage (*Grayia spinosa*), and fourwing saltbush (*Atriplex canescens*) were not found in the reference area, but were included in the seed mix because they do occur in the general vicinity of the remediation site.

The remediation site was broadcast seeded in November 1996, at a rate of 23.5 pure live seed (PLS) kg/ha (21.0 lb/ac), using a tractor-drawn seed drill with its disk openers raised above the ground. An average of 444 seeds PLS/m^2 (41 seeds PLS/ft^2) were seeded across the site. Several lengths of chain were attached to the back of the seeder and dragged along the ground to lightly cover the seed. The seed drill had three seed bins: a fluffy seed bin, a hard seed bin, and a small seed bin. The fluffy seed bin contained seed of the following species: winterfat, white burrobush (*Hymenoclea salsola*), rubber rabbitbrush (*Ericameria nauseosa*), spiny hopsage, California buckwheat (*Eriogonum fasciculatum*), and galleta. The hard seed bin contained seed from the remaining nine species (table 1). The small seed bin contained polyacrylamide gel crystals. These were applied at a rate of 22.4 kg/ha (20.0 lb/acres). Gel crystals were used to increase the moisture-holding capacity of the soil and enhance germination.

Mulching/Crimping

After seeding was complete, the site was mulched with wheat straw at a rate of 4,500 kg/ha (4,000 lb/ac). Mulch protects the soil surface from wind and water erosion, and also provides a more favorable microenvironment for seedling establishment. After the straw was blown on the site, a tractor-drawn crimper was used to crimp the straw into the soil. Crimping holds the straw in place, thus reducing erosion, and also incorporates a portion of the straw into the soil, which over time can improve the amount of organic matter in the soil.

Irrigation

An irrigation system was designed by Harward Irrigation Systems of Spanish Fork, Utah, and set up on-site in December 1996. Water was stored in two 37,854 liter (10,000 gallon) storage tanks and pumped through a delivery system using a Berkeley water pump (Model B1-1/2ZQM-12) attached to a Wisconsin 14 horsepower portable gasoline engine (Model S-14D). The delivery system had nine valves that controlled flow into nine separate "zones,"

Table 1—Seedmix for the Double Tracks remediation site.

Life form	Species	Common name	Seed mix	PLS kg/ha	PLS seeds/m^2
			percent		
Shrub	*Atriplex canescens*	Fourwing saltbush	4.3	1.0	12
Shrub	*Atriplex confertifolia*	Shadscale	19.0	4.5	64
Shrub	*Ephedra nevadensis*	Nevada jointfir	11.9	2.8	12
Shrub	*Ephedra viridis*	Green ephedra	9.5	2.2	12
Shrub	*Ericameria nauseosus*	Rubber rabbitbrush	1.9	0.5	40
Shrub	*Eriogonum fasciculatum*	California buckwheat	0.5	0.1	11
Shrub	*Grayia spinosa*	Spiny hopsage	1.4	0.3	12
Shrub	*Hymenoclea salsola*	White burrobush	7.1	1.7	41
Shrub	*Krascheninnikovia lanata*	Winterfat	16.7	3.9	49
Shrub	*Lycium andersonii*	Anderson's wolfberry	8.1	1.9	12
Shrub	*Sarcobatus vermiculatus*	Greasewood	2.4	0.6	26
Grass	*Achnatherum hymenoides*	Indian ricegrass	9.5	2.2	70
Grass	*Elymus elymoides*	Squirreltail	1.9	0.5	19
Grass	*Pleuraphis jamesii*	Galleta	4.8	1.1	39
Forb	*Sphaeralcea ambigua*	Desert globemallow	1.0	0.2	25
Total			100.0	23.5	444

with approximately 25 portable sprinkler stands per "zone." The sprinkler stands, spaced at regular intervals, were placed in the remediated, staging, and support facility areas. The remediated and staging areas were irrigated during the late fall of 1996 and the spring of 1997. The support facility area only received irrigation during the spring of 1997, and the remaining area received no irrigation.

The amount of irrigation to be applied was based on precipitation events favoring good seedling emergence and plant growth. Those events occurred in fall/winter/spring of 1991-1992, 1992-1993, and 1994-1995. Precipitation records were obtained from the Goldfield, Nevada, weather reporting station. The average monthly precipitation for the above years was chosen as a standard. The difference between the average monthly precipitation and that received in 1996-1997 was the amount of supplemental irrigation applied for a given time period.

Irrigation water was obtained from the Roller Coaster Well on the Tonopah Test Range approximately 22.4 kilometers (14.0 miles) east of the Double Tracks remediation site. Water from the Roller Coaster Well was analyzed and found to be suitable for irrigation (Ludwig and others 1976).

Treatments

Four different irrigation/topsoil treatment combinations were studied: (1) fall/spring irrigation with topsoil removed (fall/spring-no topsoil), (2) fall/spring irrigation with some topsoil removed and later replaced (fall/spring-topsoil), (3) spring irrigation with little or no topsoil removed (spring-topsoil), and (4) no irrigation with little or no topsoil removed (nonirrigated-topsoil).

Seed bags

Small samples of seed from the fluffy and hard seed mixes were put into small nylon mesh seed bags and placed in the fall/spring-topsoil, spring-topsoil, and nonirrigated-topsoil treatments to determine the timing of germination of the different species in the seed mix and the effects of different irrigation regimes on seed germination. Seed bags were then collected periodically from each treatment through the winter and spring of 1997. Germinated seeds were counted by species and then discarded.

Data Collection and Analysis

A weather station was set up onsite to measure and automatically record several climatic variables. Precipitation (mm) was collected using a tipping bucket rain gauge. Electrical resistance (ohms) and maximum and minimum soil temperature (degrees Celsius) were measured with thermistor soil cells. Maximum and minimum air temperature (degrees Celsius) were measured with a thermistor probe. All data were recorded using an electronic datalogger. Thermistor soil cells were placed at 2 cm (1 inch), 15 cm (16 inch), and 30 cm (12 inch) depths in two undisturbed places not receiving irrigation, in two places on the staging area receiving fall/spring irrigation, and in one place near ground zero in the remediated area that received fall/spring irrigation to measure electrical resistance. Resistance data were converted to percent soil moisture by volume using a fourth-order polynomial regression equation obtained by calibrating soil samples from the site using a method adapted from Kelley (1944).

Densities of seeded and nonseeded plants by species were counted in five randomly placed 4 m^2 (43 ft^2) quadrats along 15, 50 m (164 ft) transects in each of the four treatment combinations during June 1997, and again during June 1998. Densities were converted to a per-meter-square basis. Additionally, data on wildlife use of the site were documented by noting any animals seen onsite or any passive animal indicators (e.g., animal scat, ant hills). All plant density data were square-root transformed before being analyzed to normalize the data, but means presented are actual means. Standard analysis-of-variance procedures (Wilkinson and others 1992) were used to analyze the data, and Tukey's mean separation procedure was used to determine significant differences ($\alpha = 0.05$) among treatment means.

Results

Precipitation and Irrigation

Total precipitation was recorded at the Double Tracks site. However, due to a malfunction in the precipitation gauge, precipitation data from the Goldfield, Nevada, reporting station was used. Table 2 shows the amount of natural precipitation received and irrigation applied. The total amount of precipitation received added to irrigation applied exceeded the goal by about 8 mm (0.3 inch). Natural precipitation from September through December was almost equivalent to the goal. However, only 6.6 mm (0.3 inch) of precipitation was received after seeding. Therefore, irrigation was applied so that the seed would benefit from the additional moisture. A total of 158.0 mm (6.2 inches) of natural precipitation was received from October 1, 1996, to September 30, 1997, compared to the long-term average of 118 mm (5.2 inches). From October 1, 1997, to June 30, 1998, 297.2 mm (11.7 inches) of precipitation was received. This is more than double the total annual long-term average, so this was an exceptionally wet winter and spring.

Percent soil moisture by volume did not differ significantly between irrigated and nonirrigated plots for the period March 1 to June 30, 1997. This period was chosen for analysis because this is the period during which most of the germination took place. Percent soil moisture by volume averaged 6.0 and 2.1 in the irrigated and nonirrigated areas, respectively, at the 2.5 cm (1 inch) depth. Although not statistically significant, the higher soil moisture in the irrigated areas may help explain why seedling emergence was higher in irrigated areas than in areas receiving no irrigation.

Seed Bags

Seed bags were retrieved on March 4, March 17, April 15, and May 5, 1997. The first retrieval occurred before the March irrigation began. Therefore, germination to this point was a result of natural precipitation and the fall irrigation. Winterfat, greasewood, squirreltail, fourwing saltbush, Nevada jointfir, Indian ricegrass, and rubber rabbitbrush had germinated by the first retrieval date. By the second retrieval date, shadscale had germinated also, but only in the fall/spring irrigation regime. Winterfat and greasewood germinated in all three irrigation regimes by the second retrieval date. No additional species had germinated by the third and fourth retrieval dates. Germination of green ephedra (*Ephedra viridis*), California buckwheat, spiny hopsage, white burrobush, Anderson's wolfberry (*Lycium andersonii*), galleta, and desert globemallow (*Sphaeralcea ambigua*) was not detected. Peak germination across all species was at the March 17 retrieval date.

Seedling Emergence

A total of 6.7 seeded seedlings/m^2 and 6.9 total perennial seedlings/m^2 (including seeded and nonseeded perennials) had emerged across all treatments by June 1997. Based on a seeding rate of 444 pure live seeds/m^2, 1.5 percent of the seeds emerged. The emergence percentage of individual species varied. All 15 seeded species emerged. Additionally, five nonseeded native perennial species emerged; namely, budsage, Fremont's milkvetch (*Astragalus lentiginosus* var. *fremontii*), desert pepperweed, low woollygrass (*Erioneuron pulchellum*), and desert prince's plume (*Stanleya pinnata*).

Significant differences were detected among treatments for total seeded species as well as all perennials (both seeded and nonseeded) combined (fig. 3). Seedling densities were highest in the spring-topsoil treatment and lowest in the nonirrigated-topsoil treatment. No significant differences were evident between the fall/spring irrigated with topsoil and the fall/spring irrigated with no topsoil treatments.

Significant differences were also detected among treatments for several species. Differences are depicted for the five most abundant species in figure 4. These data reveal that individual species responded differently to the various treatments. For instance, shadscale and squirreltail emerged best in the fall/spring-topsoil treatment, while winterfat and Indian ricegrass emerged best in the spring-topsoil treatment. A trend for densities to be lowest in the nonirrigated-topsoil treatment is evident. Winterfat is the only exception to this trend (fig. 4).

Table 2—Natural precipitation received and irrigation applied at the Double Tracks remediation site.

Month of irrigation	Goal (assuming 90% efficiency)	Natural precipitation (1996/1997)	Supplemental irrigation (1996/1997)	Total water (1996/1997)	Natural precipitation (1997/1998)
			mm		
December	51	48[a]	37	85	65[a]
March	79	34[b]	23	57	82[b]
April	45	0[c]	42	42	41[c]
May	15	1[d]	13	14	21[d]
Total	190	83	115	198	209

[a]Amount received from September through December.
[b]Amount received during January and February.
[c]Amount received during March.
[d]Amount received during April.

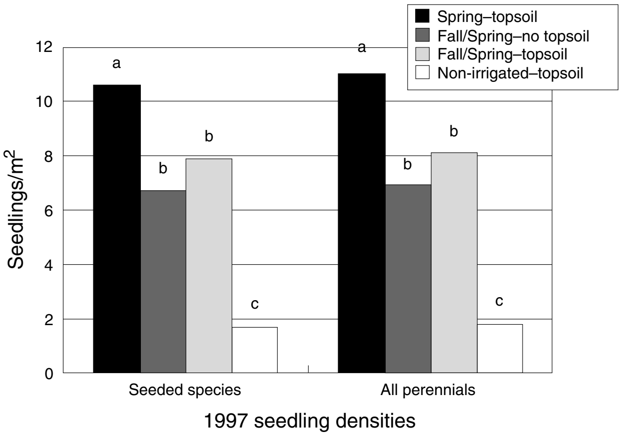

Figure 3—Total seeded and total perennial seedling response to four treatments, June 1997.

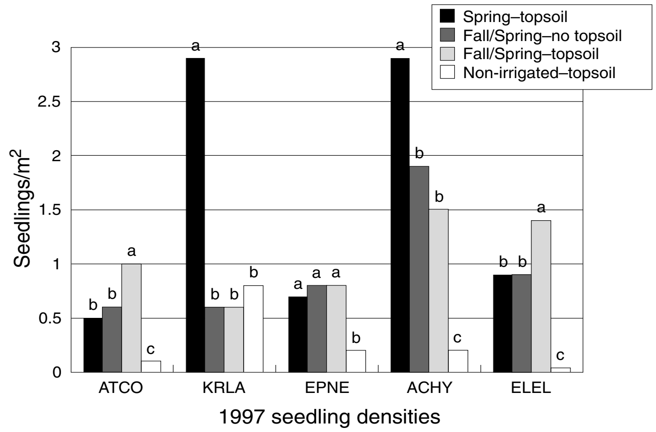

Figure 4—Seedling response of five species to four treatments, June 1997.

Plant Establishment

By June 1998, a total of 6.4 seeded plants/m^2 and 6.7 total perennial plants/m^2 were found across all treatments. Therefore, 1.4 percent of the seeded seeds had emerged and/or established. The establishment percentage of individual species varied. Again, all 15 seeded species had either emerged or established. In addition, five native nonseeded perennial species were found. These included budsage, Fremont's milkvetch, desert pepperweed, desert prince's plume, and low rabbitbrush (Chrysothamnus viscidiflorus). Total plant density in the reference area was 2.1 plants/m^2 in July 1995, as compared to 6.7 plants/m^2 in the reclaimed area in June 1998.

Significant differences were detected among treatments for total seeded species as well as all perennials combined (fig. 5). Seedling densities were highest in the spring-topsoil treatment. Densities in the nonirrigated-topsoil treatment increased substantially due to the exceptionally wet winter and spring. No significant differences were evident between the fall/spring irrigated with topsoil and the fall/spring irrigated with no topsoil treatments.

Significant differences were also detected among treatments for several species. Differences are depicted for the five most abundant species in figure 6. Individual species responded differently to the various treatments. For example, shadscale emerged and/or established best in the fall/spring-topsoil treatment; whereas, winterfat, Nevada jointfir, and Indian ricegrass emerged and/or established best in the spring-topsoil treatment. Densities of Indian ricegrass in the spring-topsoil and nonirrigated-topsoil treatments increased by 1.3 and 2.4 plants/m^2, respectively (fig. 6).

Wildlife Use

Several wildlife species have been documented using the reclaimed area as evidenced by direct animal observations and presence of sign (e.g., scat, tracks). These data are entered in a database to document wildlife use on the site.

During plant density sampling in 1997, 72.0 percent of the quadrats sampled contained black-tailed jackrabbit (*Lepus californicus*) pellets and 2.3 percent contained pronghorn antelope (*Antilocapra americana*) scat. Also, 36.0 percent of

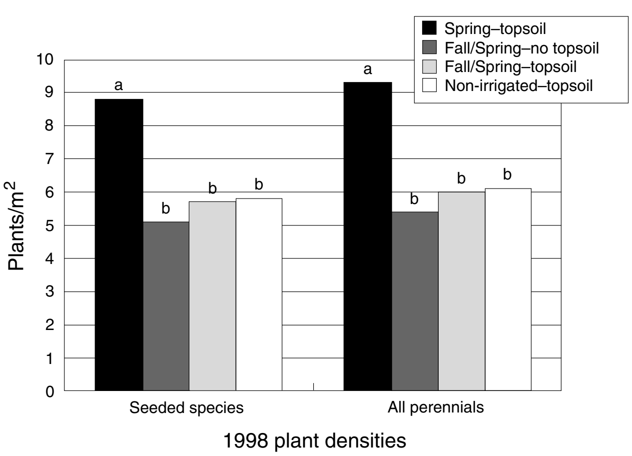

Figure 5—Total seeded and total perennial plant response to four treatments, June 1998.

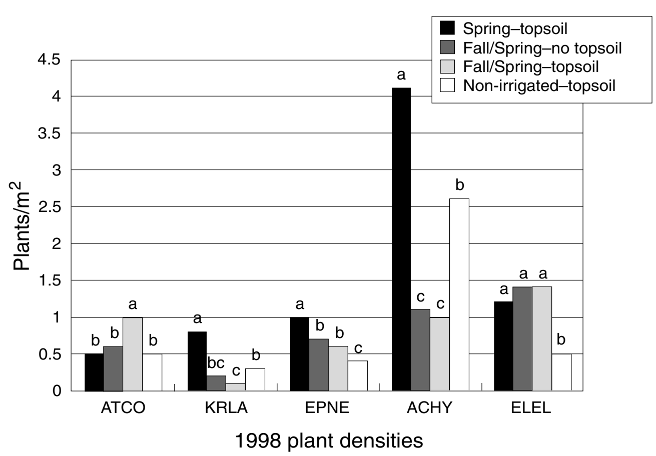

Figure 6—Plant response of five species to four treatments, June 1998.

the quadrats sampled contained at least one or more plants that showed signs of herbivory. In 1998, 36.0 percent of the quadrats sampled contained black-tailed jackrabbit pellets and 1.3 percent contained pronghorn antelope scat. Only 0.7 percent of the quadrats sampled contained plants that showed signs of herbivory.

Conclusions and Future Monitoring

Results from this study show that irrigation significantly increases seedling densities during years of average precipitation. Wallace and others (1980) determined that about 2 out of every 6 years are conducive to new seedling establishment on the Nevada Test Site based on precipitation records in their study. Because it is impossible to predict when the above-average precipitation years will occur, irrigation maximizes the potential for reclamation success. Results also indicate that spring irrigation was adequate for successful seedling emergence, but certain species like shadscale and squirreltail emerged best when irrigated both in the fall and spring.

Reclamation Success Criteria and Future Monitoring

Plans for future monitoring include sampling the reference area and the reclaimed area during the third, fifth, and tenth years following reclamation and comparing vascular plant density, cover, and diversity data between the two areas at each sampling period. If after 10 years vascular plant density, cover, and diversity of the reclaimed area are 60 percent of that measured on the reference area, reclamation of the Double Tracks site will be considered successful.

Sampling during the third and fifth years allows scientists to track the progress of the reseeded disturbed remediation site in comparison to the native vegetation. If after 5 years, vascular plant density is less than 2.1 plants/m^2 or vascular plant cover is less than 50 percent of the amount of cover on the reference area, remedial action such as reseeding or transplanting may occur to ensure successful reclamation by the tenth year (Anderson and Hall 1997).

References

Anderson, D. C.; Hall, D. B. 1997. Double Tracks revegetation and monitoring plan. DOE/NV/11718-104, UC-708. U.S. Department of Energy, Nevada Operations Office, Las Vegas, NV.

Church, H. W. 1969. Cloud rise from high-explosives detonations. SC-RR-68-903. Sandia National Laboratories, Albuquerque, NM.

Kelley, O. J. 1944. A rapid method of calibrating various instruments for measuring soil moisture in situ. Soil Science. 58: 433-440.

Leavitt, V. D. 1978. Soil surveys and profile descriptions of plutonium-contaminated areas on the test range complex in Nevada, 1970-1977. In: White, M. G.; Dunaway, P. B., eds. Selected environmental plutonium research reports of the NAEG. DOE/NV Operations Report NVO-192. Las Vegas, NV.

Ludwig, A. E.; Hergert, G. W.; Franklin, W. T. 1976. Irrigation water quality criteria. Colorado State University Extension Service. Service in Action Sheet No. 506. 2 p.

Office of the Nevada State Climatologist. 1991-1998. Unpublished data.

Shreve, J. D., Jr. 1964. Operation Roller Coaster, April 1964 conference data presentation and evaluation. Sandia National Laboratories, Albuquerque, NM.

Shreve, J. D., Jr. 1965. Operation Roller Coaster, scientific director's summary report. DASA-1644. Sandia National Laboratories, Albuquerque, NM.

Wallace, A.; Romney, E. M.; Hunter, R. B. 1980. The challenge of a desert: revegetation of disturbed desert lands. In: Soil-plant-animal relationships bearing on revegetation and land reclamation in Nevada deserts. Great Basin Naturalist Memoirs, Vol. 4. Brigham Young University, Provo, UT.

Wilkinson, L.; Hill, M.; Welna, J. P.; Birkenbeuel, G. K. 1992. Statistics. Evanston, IL: Systat, Inc. 750 p.