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Clean Slate 1 Revegetation and Monitoring Plan

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CLEAN SLATE 1 REVEGETATION AND MONITORING PLAN

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July 1997

MASTER

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CLEAN SLATE 1
REVEGETATION AND MONITORING PLAN

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1.0 INTRODUCTION

This document constitutes a reclamation plan for the short-term and long-term stabilization of land disturbed by activities associated with the cleanup of radionuclide-contaminated surface soil at the Clean Slate 1 site. This document has been prepared to provide general reclamation practices and procedures that will be followed during restoration of the cleanup site. The results of reclamation trials at Area 11, Area 19 and more recently the reclamation demonstration plots at the Double Tracks cleanup site, have been summarized and incorporated into this reclamation and monitoring plan. The plan also contains procedures for monitoring both the effectiveness and success of short-term and long-term soil stabilization.

1.1 Physical Location and Setting of Cleanup Site

The Clean Slate 1 cleanup site is located on the Tonopah Test Range (TTR), which is approximately 64 km (40 miles) from Tonopah, Nevada (Figure 1). Typical access to the cleanup site is through the north entrance (main gate) to TTR, south on Main Road for approximately 11 miles, east on Brownes Lake Road for approximately 4.5 miles, then south off of Brownes Lake Road for less than one mile.

Clean Slate 1 is located northeast of Antelope dry lake. Elevations at the site range from 1,637 m (5,370 ft) to 1,640 m (5,380 ft). Common shrubs found inside the fenced area include bud-sage (*Artemisia spinescens*), winterfat (*Ceratoides lanata*), and shadscale (*Atriplex confertifolia*). Common grasses are galleta grass (*Hilaria jamesii*) and Indian ricegrass (*Oryzopsis hymenoides*). Soils are predominantly gravelly sandy loams (Leavitt, 1978). Average annual precipitation at Goldfield, located 30 miles to the west of TTR, is 11.8 cm (5.22 in) (unpublished, Office of the Nevada State Climatologist).

1.2 Project Description

The Clean Slate 1 fenced area is approximately 160 m (525 ft) wide and 1,300 m (4,265 ft) long. The surface soils at Clean Slate 1 were contaminated as a result of the detonation of a device containing plutonium (Pu) and depleted uranium using chemical explosives (Church, 1969; Shreve, 1965). Excavation of contaminated soils at Clean Slate 1 will follow procedures similar to those used during the cleanup of the Double Tracks site (Bechtel Nevada, 1996). A maximum of approximately 15 cm (6 in) of the surface soils will be excavated and removed from the site. Near ground zero, where contamination levels are highest, approximately 91 cm (36 in) of soil may be removed. The maximum area to be excavated is estimated to be 3.9 hectares (9.5 acres). In addition to the disturbance associated with soil excavation, approximately 2.0 hectares (5.0 acres) will be disturbed by the construction of staging areas and placement of support facilities.

LEGEND

- Primary highway
- State boundary
- County boundary
- City

Figure 1. Location of Tonopah Test Range.

Figure 2. Location of Clean Slate 1, 2 and 3 on Tonopah Test Range.

1.3 Objective

The primary objective of this document is to provide general procedures for short-term and long-term stabilization of soils that will be disturbed during the cleanup of contaminated soils at Clean Slate 1. Stabilization is critical to prevent any resuspension of residual Pu and to reestablish wildlife habitat. Short-term or interim stabilization consists of the application of a chemical soil stabilizer that is applied immediately following excavation of the contaminated soils to minimize Pu resuspension, thus reducing health hazards for workers and the public.

Long-term stabilization, which is accomplished by the establishment of a permanent vegetative cover, will also reduce Pu resuspension, and is critical in returning the site to predisturbance conditions, thus providing habitat for local wildlife and complementing the other actions being taken to release the site for future use.

A secondary objective is to establish procedures for monitoring the success of both short-term and long-term stabilization. The criteria and methodology for evaluating the effectiveness of the chemical soil stabilizer in reducing resuspension of soil particles and the criteria for determining if revegetation has been successful are part of this plan.

2.0 CONSTRUCTION RECOMMENDATIONS

Removal of topsoil during the excavation process leaves a soil low in organic matter and thus soil nutrients. In addition, the pool of seeds from native plants commonly found in the surface soils is lost. These two factors result in a sterile soil and difficult conditions for reestablishing a viable plant community. The following actions are recommended to ameliorate the effects of the loss of the topsoil during the cleanup process.

- Salvage the topsoil from the staging areas and the equipment loading/unloading zone, and any other major disturbances.
- Stockpile the salvaged topsoil on the up-slope side of the disturbed area, where possible, in areas shown on Figure 2.
- Topsoil stockpile should not exceed 2 meters (6 feet) in depth to maintain soil microbiological viability.
- During construction of new roads, any topsoil that is removed should be salvaged and stockpiled along side the road in berms not exceeding 2 meters (6 feet) in depth.
- During construction of topsoil stockpiles, traffic of earth moving equipment on top of the topsoil stockpile should be minimized.
- Topsoil stockpiles will be stabilized with a chemical stabilizer until soils are redistributed over disturbed areas.
- Reclamation scientist(s) should be on site during construction activities to assist in locating topsoil stockpiles and minimizing impacts to the environment.
- Construction equipment and all other vehicles on site should travel on existing roads; no off-road travel should occur.
- Due to the hydrophobicity of the soils at Clean Slate 1, water applied to the plume and ground zero prior to excavation will be treated with a wetting agent. The wetting agent will be applied at a rate of 2 gallons/acre and will be used as frequently as needed.

The reclamation scientist(s) will coordinate with the construction foreman to ensure that these recommendations are implemented.

Figure 3. Potential Locations for Topsoil Stockpiles and Areas to be Revegetated at Clean Slate 1 Cleanup Site.

3.0 SHORT-TERM STABILIZATION

Short-term stabilization will be conducted after contaminated soils are excavated and verified to be within the established cleanup concentration levels of Pu. The duration of this phase will be as long as the excavation and verification processes may take. Short-term stabilization must remain effective until long-term stabilization occurs. To maintain effectiveness, reapplication of the soil stabilizer may continue until revegetation of the site occurs. The window for long-term stabilization (revegetation) is between October 1 and November 30. If excavation is completed outside this window, then short-term stabilization must continue until the site is revegetated.

3.1 Areas to be Stabilized

The highest priority for short-term soil stabilization will be the excavation area, which includes the area around ground zero, and the plume. Next in priority is the stockpile of the soils excavated from ground zero and the plume. The stockpile will be located after mobilization of equipment and during excavation. Stockpiles of topsoil may be created during the construction of the staging area inside the fenced area. Topsoils may be bladed and stockpiled for later use in final reclamation (Section 2.0). These stockpiles will be located up-slope and along the edge of the staging areas (Figure 2). The excavated areas and the stockpiles of soils will be stabilized as soon after disturbance as possible, to minimize any fugitive dust. The chemical soil stabilizer, AGRI-LOCK, will be used.

Short-term stabilization may also occur on miscellaneous disturbances during the excavation process, at the bagging operation, and after demobilization. Miscellaneous disturbances will include those areas disturbed prior to or during cleanup support activities. Some of the miscellaneous disturbances may become stabilized by natural soil crusting. These types of disturbance generally would not receive short-term soil stabilization unless it is deemed necessary to reduce fugitive dust and minimize the health risk to workers. Construction of the staging areas, inside and outside the fenced area constitute the majority of the miscellaneous disturbances (Figure 2). Portions of these disturbances may be stabilized with AGRI-LOCK as may be requested by the project manager and/or construction foreman. The temporary equipment loading and unloading area directly to the south of the staging area will be stabilized when all of the equipment has been moved off of the the site. After stabilization this area will be closed to vehicular traffic.

After demobilization of excavation and bagging equipment, the soil surfaces in the staging areas inside and outside the fence will be ripped to alleviate the compaction of the soil (Section 4.6, Site Preparation) and disked to break up larger soil clods. Following ripping and disking, the soils may be stabilized again using AGRI-LOCK. Interim stabilization is necessary at this point because final stabilization will not occur until October or November and demobilization is tentatively scheduled for June.

3.2 Product Selection

AGRI-LOCK, a synthetic chemical soil stabilizer, was selected to be used for interim reclamation. Over the past couple years, numerous organic mulches, inorganic mulches, chemical stabilizers, soil surface manipulation treatments and windbreaks were evaluated. Each product or treatment was evaluated for its ability to 1) control wind erosion, 2) remain effective for at least five months, 3) be compatible with eventual revegetation of the site, 4) not introduce hazardous materials to the environment, 5) not pose a risk to workers, 6) show resistance to traffic, 7) not impede the verification process, 8) be compatible with the excavation process, 9) show compatibility with different soil types, and finally 10) be cost effective. Of the numerous products available in each of the aforementioned groups, eight representative products were field tested for erosion control capabilities, longevity of effectiveness, and effect on the emergence of seedlings. Based on the results of the original screening and the field trials, AGRI-LOCK was selected to be used for short-term stabilization.

Interim stabilization does not include active roads. AGRI-LOCK may not be the appropriate product for stabilization of disturbances that receive vehicular traffic. Examples of traffic resistant products include: petroleum byproducts, wood byproducts, and salts. These products should be applied to a compacted soil surface. Most require a pre-wetting treatment, although some products must be incorporated into the soil. This would reduce costs associated with hauling water for dust suppression. These products require much less water than a water-only soil-stabilization treatment and have an effective longevity of one to several months.

3.3 Product Application

AGRI-LOCK will be applied with a hydromulcher at a minimum rate of approximately 55 gallons/acre. The product will be diluted at a ratio of from 1:10 to 1:20 parts product to water. The ratio selected will be based on the crust strength desired. A ratio of 1:10 would be appropriate for areas where additional light traffic might be expected. A ratio of 1:20 would be used on the stockpiles and on areas where excavation activities are completed. Application of AGRI-LOCK, like most chemical stabilizers, requires a pre-wetting of the soil. If soils exposed after excavation are not adequately wet, they may have to be wetted prior to application of AGRI-LOCK. A curing time of one to three hours is required, depending on the wetness of the soil, air temperature and wind. After curing, the soil surface should be resistant to some light traffic. Repeated vehicular traffic may require reapplication. A wood fiber treated with a chemical dye may be used to act as a tracer or indicator of areas treated. The wood fiber should be applied at a rate of approximately 50 lbs/1,000 gallons of water:product mixture.

4.0 LONG-TERM STABILIZATION: REVEGETATION

The primary objective of long-term stabilization is to establish a stable plant cover that will reduce wind and water erosion, and reestablish wildlife habitat. Long-term stabilization is critical for minimizing fugitive dust and Pu resuspension, restoring the site to predisturbance conditions, and reestablishing habitat for wildlife. The potential for successful reclamation is enhanced by identifying soil plant growth potential, selecting appropriate plant species, using appropriate site preparation techniques, amending the soil, if needed, and implementing a tested arid-land revegetation strategy. The following sections outline the areas to be revegetated and the procedures to be used for revegetation at the Clean Slate 1 cleanup site.

4.1 Areas to be Revegetated

The following areas are to be revegetated during the reclamation window.

Table 1. List of areas to be revegetated at the Clean Slate 1 cleanup site (See also Figure 3).

Description	Number of Hectares (Acres)
Inside Fenced Area:	
Area to be excavated: Ground Zero and Plume Area	3.85 ha (9.50 a)
Staging Area	0.21 ha (0.52 a)
Loading Area	0.86 ha (2.12 a)
Outside Fenced Area:	
Staging Area	0.64 ha (1.58 a)
Temporary Equipment Loading/Unloading	0.14 ha (0.34 a)
Water loading area	0.19 ha (0.48 a)
TOTAL ACREAGE TO BE REVEGETATED	5.89 ha (14.54 a)

Some roads may also be revegetated, as determined by the project manager, or they may be revegetated at a future date when monitoring activities are completed.

4.2 Plant Growth Potential of Soils

The layer of exposed soil on the excavated areas at Clean Slate 1 has physical and chemical characteristics that will support plant growth. The uppermost layer (30 cm [12 in]) of soil after excavation will have parameters consistent with those in the good suitability class (USDA, Forest Service, 1979; USDA, Soil Conservation Service, 1978). The results of soil analyses conducted by EG&G (1995) and Leavitt (1978) on soils at Clean Slate 1 were used to assess soil suitability. Overall the soils are slightly alkaline, pH was 8.5, and organic matter is

low, less than 1%. However, the plants in the area have adapted to such conditions and soil amendments to ameliorate the higher pH would change conditions such that native species may not reestablish.

Soils in the Mojave and Great Basin deserts are generally low in organic matter. Soils collected near the Clean Slate 1 cleanup site contain about 0.12% organic matter, below the desired level of 0.5 to 1.5%. Since the top portion of the soil at Clean Slate 1 will be removed, most or all of the organic matter will be lost. The low percentage of organic matter results in a reduction in nutrients available to plants and the soil water holding capacity is lowered. To improve the poor water holding capacity of the exposed soils, several actions will be taken. First, a polyacrylamide gel will be applied, which can potentially improve the water holding capacity in the upper layer of the soil (Section 4.7.1). Second, to increase the organic matter in the soil, a straw mulch will be used following seeding (Section 4.7.3). The mulch will be crimped into the soil. Although some may blow from the site, much of the straw will become incorporated into the soil, thus improving the amount of organic matter in the soil. Finally, the topsoil that is salvaged during the construction of the staging areas will be returned to the site, when cleanup activities are completed (Section 4.6). This action will return to the site needed nutrients and seeds, which are important elements of the restoration process.

4.3 Plant Species Selection

Vascular plant species native to the Clean Slate 1 area will be used to revegetate the cleanup area. To determine naturally occurring plants at the Clean Slate 1 site, vascular plant density and cover data were collected in July 1995 from 15 permanent, 50-m (164 ft) transects located in the southern-most corner of Clean Slate 3. The vegetation at Clean Slate 1 is similar to that found at Clean Slate 3. Vegetation data collected at Clean Slate 3 will serve as a reference for both Clean Slate 3 and Clean Slate 1. Density (absolute) was determined by averaging the number of plants occurring in five random 2 x 2-m quadrats on each of the 15 transects (Table 2). Relative percent density was calculated for each species by dividing the absolute percent density for a particular species by the total absolute percent density for all species combined. Relative density can be used to identify the proportion of an individual species' density in the total plant density of a site.

Plant cover was determined using a point-intercept method. Cover (absolute), defined as the percentage of ground surface area covered by the canopy of a particular species, was recorded for each perennial species along the transects (Table 2). Relative percent cover was calculated for each species by dividing the absolute percent cover for a particular species by the total absolute percent cover for all species (Table 2).

Density and cover data were used in determining the species and proportion of each species to be included in the seed mix, and/or transplants used in revegetation of the Clean Slate 1 site. Annual plant species are not included because they do not provide constant vegetative cover. Other criteria used to select species for revegetation include 1) previous success in establishing

the species either by seeding or transplanting, 2) the ability to collect seed from native species in environments similar to the Clean Slate 1 site, and 3) the commercial availability of seed from species adapted to the Clean Slate 1 environs.

Table 2. List of perennial plants found in the reference area established in the southeast corner of the Clean Slate 3 fenced area on the TTR. Percent density and cover values are given for species encountered on fifteen transects established in the reference area.

Scientific Name	Common Name	Density		Cover (%)		Seed Commercially Available	Seed Collection Feasible
		Absolute (plants/m ²)	Relative (%)	Absolute	Relative		
Perennial species							
<i>Artemisia spinescens</i>	Budsage	0.7	9.0	2.1	13.8	no	yes
<i>Atriplex confertifolia</i>	Shadscale	0.4	5.6	2.5	16.5	yes	yes
<i>Ceratoides lanata</i>	Winterfat	1.0	13.2	5.1	34.4	yes	yes
<i>Opuntia pulchella</i>	Sand Cholla	<0.1	<0.1	0.0	0.0	no	no
<i>Aristida purpurea</i>	Purple Threeawn	<0.1	<0.1	0.0	0.0	yes	yes
<i>Hilaria jamesii</i>	Galleta	4.9	66.9	2.7	17.9	yes	yes
<i>Oryzopsis hymenoides</i>	Indian Ricegrass	0.3	4.6	2.6	17.4	yes	yes
<i>Sitanion hystrix</i>	Bottlebrush						
	Squirreltail	<0.1	0.6	0.0	0.0	yes	yes
Totals		7.3		14.9			

The seed mix for the Clean Slate 1 cleanup site will contain a minimum of three species of shrubs, four grasses and one forb (Table 3). The ratio of the different lifeforms in the seed mix is similar to that found on the reference sites, four shrubs and four grasses. No perennial forbs were encountered, but desert globemallow (*Spaeralcea ambigua*) was added to the species mix because it is found frequently in the area.

Seed collected from within the same geographical region is available from commercial seed collecting companies for all species except budsage. Seed for budsage will be collected from within a 2-3 mile radius of the Clean Slate 1 cleanup site. Seed purity and viability will be determined for budsage after it is cleaned. Seed purchased from native seed companies will be on a pure live seed (PLS) basis. Specifications for the purchase of native seeds will require collection from the Mojave and/or Great Basin desert environments and recent (within six months) certification of seed purity and viability.

4.4 Site Access Requirements

The Clean Slate 1 site should have an access with a width of at least 5 m (16 ft). Equipment that will be required at the site includes a tractor, road graders, disks, a harrow, flat bed truck, four wheel drive trucks, a seed drill, a hydromulcher, and a straw blower.

4.5 Timing of Reclamation

Long-term stabilization will occur between October 1 and November 30. During this period, conditions are more favorable for meeting germination requirements of the seeded species. Seeding may occur later depending on climatic conditions, but seeding earlier is not recommended.

Table 3. Composition of seed mix to be used for revegetation of Clean Slate 1 cleanup site.

Lifeform	Scientific Name	Common Name	% of Seed Mix	PLS kg/ha (lbs/ac)
Shrub	<i>Artemisia spinescens</i>	Budsage	1.0	0.3 (0.3)
	<i>Atriplex confertifolia</i>	Shadscale	1.0	7.8 (7.0)
	<i>Ceratoides lanata</i>	Winterfat	51.5	16.8 (15.0)
	<i>Chrysothamnus nauseosus</i>	Rabbitbrush	1.7	0.6 (0.6)
Grasses	<i>Aristida purpurea</i>	Purple Threeawn	1.3	0.4 (0.4)
	<i>Hilaria jamesii</i>	Galleta	8.3	2.8 (2.5)
	<i>Oryzopsis hymenoides</i>	Indian Ricegrass	10.0	3.4 (3.0)
	<i>Sitanion hystrix</i>	Bottlebrush Squirreltail	3.3	1.1 (1.0)
Forbs	<i>Sphaeralcea ambigua</i>	Desert Globemallow	1.0	0.3 (0.3)
Total PLS kg/ha (lbs/ac)				33.6 (30.0)

4.6 Site preparation

Site preparation will be completed prior to the October 1 to November 30 revegetation window. It is assumed that the soils will be compacted, which will require alleviation for good plant establishment. Heavily compacted soils will be ripped using a grader equipped with 16-inch ripper teeth. Depth of ripping will be below the compacted soil layers, usually from between 12 and 16 inches. Less compacted areas will be ripped using a chisel-tooth plow, again to a depth below compaction. Disking and/or harrowing may follow ripping or it may be delayed until just before planting. The delay will allow a natural breakdown of the soil clods and negate the need for disking. Ripping and disking, if necessary, increase water infiltration, and provide a firm seedbed for good soil-to-seed contact (Munshower, 1994). After ripping and disking the staging areas, the area will be recontoured to approximately pre-disturbance conditions. Working the soil will be minimize so soil structure may be maintained.

Any non-contaminated topsoils that were removed and stockpiled during construction or cleanup activities will be returned to the site prior to recontouring. The topsoil will be evenly distributed over the site not to exceed 10-15 cm (4-6 in) deep.

4.7 Revegetation

The reclamation strategy that will be employed at the Clean Slate 1 site will include a combination of seeding and supplemental irrigation to increase the potential for the establishment of a native plant community during the first few years. The possibility of establishment occurring without seeding is remote because the native seed source in the native soils has been removed. Leaving the excavation area to reseed naturally would only promote an influx of annual species. The abundance of annual species often gives the appearance of restoration success, but their effectiveness in controlling erosion is short lived and undependable. Annual species are dependent on good growing conditions. Based on climatic conditions experienced during the past decade, several years may pass in this region without good growing conditions and consequently the absence of annual plant species.

The overall objective of artificially seeding disturbed sites is to accelerate the natural restoration process by establishing a viable, native, perennial plant community. The establishment of perennial species will provide a more permanent means of controlling wind and water erosion throughout the growing season. Wildlife should adapt to the newly revegetated area because species native to the area will be used in revegetation efforts.

4.7.1 Soil Amendments

The only soil amendment that will be used is a polyacrylamide gel. Polyacrylamide gels (cross-linked polymer gels) can absorb 40 to 500 times their weight in water. At NTS, polyacrylamide applications have been successful in increasing the numbers of germinating perennial species over areas not receiving the polyacrylamide application (EG&G/EM 1994; EG&G/EM 1995). The gel will be applied at a rate of 24 kg/ha (20 lbs/ac) using a drill seeder. Application will be concurrent with the seeding process (Section 4.7.2).

4.7.2 Seeding

The Clean Slate 1 site will be seeded during the reclamation window, which is between October 1 and November 30. The preferable month for seeding is November. Seeding at this time ensures that dormancy-breaking requirements for germination of most seeded species would be met. Additionally, seed would be in the ground prior to winter precipitation and freezing temperatures.

The seed will be broadcast-seeded at a rate of approximately 36.2 pure live seed (PLS) kg/ha (32.3 lbs/ac). The area will be seeded with a tractor-drawn seed drill having seedboxes that accommodate intermediate and fluffy seeds. The seed tubes will be disconnected from the disk

openers, thus allowing the seed to be broadcast over the soil surface. A drag bar with ten 30-inch chains attached, will be fitted onto the walkboard at the rear of seeder. The length of the chains will be adjusted so seeds are covered by the chains. The length of the chain that is allowed to drag will be adjusted according to the soil structure. In coarser soils the chain should drag 8-10 inches on the ground in order to adequately cover the seed. However, in finer soils, which is the case at Clean Slate 1, the length of chain should be shorted, so seed is not buried too deep. This process improves soil-seed contact and places the seed in the surface few inches of soil. Seeding will be perpendicular to the slope or at an angle to the slope to avoid gullyng or rilling in the event of excessive runoff that may occur during intense precipitation events.

4.7.3 Mulching

Immediately after seeding, the site will be mulched with a grain (wheat or barley) straw. The mulch is secured to the soil surface by crimping, which creates a vertical barrier to both wind and water erosion. The incorporation of the mulch into the soil also increases the percentage of organic matter in the soil, thus creating a more favorable micro-environment for seedling establishment and plant growth.

The straw is applied evenly to the soil surface with a straw blower at a minimum rate of 4,500 kg/ha (4,000 lbs/ac). The exposed soil surface should be less than 5% and the thickness of the straw mulch should not exceed 7.5 cm (3 inches). The length of the stem length of the straw should be maximized, preferably 15-25 cm (6-10 inches). This is accomplished by adjusting the number of chains attached to the hammermill.

A tractor drawn disk-crimper will be used to punch the straw into the soil. Weights are added to the disk-crimper so that disk and straw penetration into the soil is 4-6 inches. The direction of crimping will be perpendicular to the slope of the site.

4.7.4 Transplants

Transplants are not planned to be used during initial revegetation. Transplanting may occur in subsequent years to increase species diversity on the site, if certain dominant species such as budsage are not reestablishing on the site. The number of transplants per hectare for budsage and other species that may be identified, would be determined from: 1) relative cover and density (Table 1) of the species in the native plant community, 2) desired percentage of a species density as transplants, 3) past success in establishment of the species from seeding or transplanting, and 4) the availability of transplants from either commercial nurseries or contract growers. Budsage is not available from plant nurseries, and it is unlikely that any of the other species are available either. If transplants are to be used it would be necessary to collect local seed and contract with a nursery to grow the desired number of plants. The decision to use transplants will be made the third or fifth growing season following initial revegetation.

4.8 Irrigation

One of the most limiting factors for successful seed germination and plant establishment is the availability of water. Precipitation amounts fluctuate from year to year at the Clean Slate 1 site, and extended periods of drought conditions could result in the complete failure of long-term soil stabilization attempts. Preliminary results from reclamation field study plots established at Double Tracks and at other sites on NTS suggest that irrigation improves seedling densities, which eventually results in the establishment of a stable perennial plant community. Results from these studies also suggest that irrigation during the late spring and early summer months improves survival of seeded species over the summer months.

Approximately 98% of the seedlings on study plots that were irrigated with 25 mm (1 inch) of water seven different times at intervals of 2-3 weeks during the late spring and early summer, survived the hot, dry summer months of 1995. About 95% of the seedlings on plots irrigated with 50 mm (2 in), instead of 25 mm (1 inch) of water, survived, indicating that 25 mm (1 inch) is just as effective as 50 mm (2 in). Seedling survival on the two irrigated treatments was higher than on the plots that were not irrigated: 84% survival on non-irrigated plots as opposed to 95% on irrigated plots. Although the non-irrigated plots did not receive any supplemental irrigation, natural precipitation during the late spring and early summer was 83.6 mm (3.3 in), which created optimal growing conditions. In addition, temperatures during the summer of 1995 were moderate, and high temperatures did not occur until late in the summer. Under below-normal precipitation and poor growing conditions, irrigation would have had a more dramatic effect on seedling survival over the dry summer months.

Another study was conducted during the fall of 1995 and spring of 1996 to evaluate different irrigation strategies. One strategy tested was to irrigate in the fall to recharge the soil water levels, thus providing an environment more conducive to seed germination requirements. Another strategy was to irrigate just prior to seed germination in the spring of the year to provide an immediate source of water to ensure seed germination. A third strategy was a combination of the two. Results of the study suggest that seedling emergence is enhanced by fall or spring irrigations, as well as the combination of the two. In fact, seedling densities on non-irrigated plots were near zero. It was not possible to determine if different levels or intensities of irrigation were better than others. The study does, however, suggest that during years of poor growing conditions, irrigation is essential for establishing native plant species on disturbed sites.

4.8.1 Irrigation Water Quality

The assumption is made that the quality of the available water will be sufficient for use in irrigation. To ensure this, a sample of water from the water source will be tested to determine the quality of the water. If the water quality is poor, actions must be taken to amend the water to improve the quality, or seek an alternative source. Ludwig et al. (1976) lists four basic criteria for evaluating water quality for irrigation purposes:

- 1) total soluble salt content (salinity hazard),
- 2) relative proportion of sodium cations to other cations (sodium hazard),
- 3) bicarbonate anion concentration as related to calcium plus magnesium cations, and
- 4) the concentration of elements that may be toxic.

Total soluble salt is measured by electrical conductivity (EC). For irrigation water, the EC should not exceed 1.5 mmhos/cm (Ludwig et al., 1976). However, soil solutions should not have an EC greater than 4 mmhos/cm (Ries and Day, 1978).

The relative proportion of sodium cations is measured by the sodium adsorption ratio (SAR). Ludwig et al. (1976) recommend that the SAR for irrigation water not exceed 10. Water high in bicarbonate will tend to precipitate calcium carbonate and magnesium carbonate when the soil solution concentrates through evapotranspiration. This increases the SAR, which in turn, will increase the sodium hazard of the water to a level greater than that indicated by the SAR value. No upper limits were found for bicarbonates.

Devitt (1989) lists boron as one micronutrient that is essential for plant growth, but it becomes toxic to plant growth at levels exceeding 1 ppm. Fluoride is another element that limits plant growth when levels exceed 1 ppm (U.S. Environmental Protection Agency, 1983).

4.8.2 Irrigation System Design and Implementation

It is assumed that water will be available at the Clean Slate 1 site to irrigate the revegetated areas. The irrigation system used at the Clean Slate 1 site will be a solid-set sprinkler-type system designed to produce an even distribution of water across the entire reclaimed area. Sprinkler heads will be selected so as to apply water at the optimal rate and spray pattern. The sprinkler heads chosen will have a droplet size that maximizes distribution of water to the soil, minimizes runoff, and reduces wind drift.

Application of irrigation will include three implementation periods: pre-germination irrigation, germination irrigation, and establishment irrigation. Pre-germination irrigation is the application of water to recharge the soil profile prior to germination of the seeded species. This recharge will encourage deep rooting and establishment of the seeded plants. Pre-germination irrigation will be implemented during late fall or winter after seeding, and will consist of the addition of approximately 80 mm (3.15 in.) of water to the soil over a 2 to 3-week period. Amount and frequency of application may vary based on climate conditions at the time of implementation.

Germination irrigation is defined as supplemental irrigation applied to initiate germination and seedling emergence. Germination irrigation can be adjusted by changing the amount applied during an irrigation event, the frequency of the events, and the duration of an irrigation event. Soil moisture cells will be placed in the upper 5 cm (2 in) of soil to determine optimal application levels. Germination irrigation would begin in March and continue through May.

Approximately 40 mm (1.6 in) of water would be applied over a 4 day period each of the three months.

Establishment irrigation is the application of supplemental water following germination and seedling emergence. Establishment irrigation is used to supplement pre-germination irrigation by recharging the soil profile to encourage deep-rooting and survival of seedlings. As with germination irrigation, optimal application levels for establishment irrigation are dependent upon soil and climatic parameters. Typically, establishment irrigation would be initiated soon after seedling emergence and consist of the application of approximately 25 mm (1 in) of water every two weeks until July.

Irrigation is not scheduled to continue past the first growing season. The objective of irrigation is to create optimum conditions for the establishment of perennial shrub and grass species during the first growing season. After the first growing season perennial plants should be well enough established to adapt to and survive growing conditions that may follow.

4.8.3 Soil Moisture

Soil moisture data provides a means to monitor amounts and frequency of germination and establishment irrigation, and to determine possible causes of reclamation failure. Soil moisture cells (resistance blocks) will be used to measure soil moisture in the surface soils (2.5 cm [1 in]) and at a depth of 25 cm (10 in). Soil moisture data are recorded daily and downloaded as necessary, approximately every 3 months.

4.9 Fencing

The fence currently surrounding the contaminated area at Clean Slate 1 should be left in place to reduce the effects of herbivores on plant establishment. This fence would primarily exclude horses and burros, but would not exclude rabbits and small rodents. The fence should remain in place for a minimum of five years, which should be sufficient time for plants to become established and able to withstand the effects of herbivory. Fencing may also be necessary around the staging area located outside the fenced area.

The effects of herbivores on new seedlings at the excavation area will be monitored during the growing season for the first two years. If herbivory is detected and is determined to be severe, i.e. may lead to the mortality of the majority of the plants, corrective action may be taken. If rabbits are noted to be the dominant herbivore, then a 1.2 m (4 ft) tall wire netting fence would be installed at the base of the existing fence.

5.0 SOIL STABILIZATION AND REVEGETATION SUCCESS MONITORING

The objectives of monitoring both short-term and long-term (revegetation) soil stabilization are to document the control of erosion, track the successful establishment of a stable vascular plant community on the disturbed site, and document the use of the site by wildlife. The success of revegetation will be determined by comparing plant and animal communities on the revegetated area with those on adjacent reference or undisturbed areas.

5.1 Short-term Soil Stabilization

The effectiveness of short-term or interim soil stabilization will be monitored monthly. A staff scientist will conduct a meandering survey of the excavation area every four weeks following the initial application of AGRI-LOCK. The excavation area will be surveyed for signs of soil erosion, the occurrence of loose soil particles on the soil surface, major soil cracking thus exposing subsurface soil layers, and active rodent burrows, which usually result in subsurface soils being moved to the surface. The scientist will determine whether reapplication of AGRI-LOCK is necessary for the entire site, or for specific areas, such as recent rodent activity. AGRI-LOCK will be reapplied within two days of the survey. The same methods of application will be used. The rate of application may or may not be altered depending on the recommendation of the scientist conducting the survey.

A second evaluation of the effectiveness of interim soil stabilization may be made by the Desert Research Institute (DRI). The resuspension of soil particles will be measured using a wind tunnel. Measurements will be taken prior to interim soil stabilization and at different intervals after stabilization. DRI scientists will evaluate the results of the wind tunnel. If resuspension of soil particles reaches a level considered to be excessive by DRI scientists, then reapplication of AGRI-LOCK will occur or some other form of corrective action will be taken.

5.2 Long-Term Soil Stabilization: Revegetation Success

Revegetation success will be evaluated by comparing conditions on the cleanup site with predetermined success criteria or standards, developed specifically for Clean Slate 1. Revegetation will be considered successful if, after ten years, plant density and cover on the revegetated area, are 60% of that measured on the reference areas during the same year. This percentage is based on the fact that complete restoration of the site would naturally take several decades (Angerer, et al. 1996) and that after one decade, if the site is within 60% of the native undisturbed reference area, it would appear to be on track for successful restoration.

To determine reclamation success, vascular plant cover and density will be measured on both the reclaimed area and the reference area over the next 10 years. Success for density will only consider those species that were seeded or native to the plant community surrounding the Clean Slate 1 site (Table 2).

During the first growing season after revegetation, 15 permanent, 50-m transects, similar to those in the reference area at Clean Slate 3 (Section 4.3), will be randomly located within the revegetated area Clean Slate 1. Vascular plant density, cover, and volumetric data on key perennial species will be measured along each of these transects and used for statistical comparisons with similar data collected from the reference area. These comparisons will be the basis for determining reclamation success.

The number of transects sampled will provide a level of precision that will allow the detection of a 10% change in the mean with 90% confidence. The formula is:

$$N_{\min} = (t_{.05})^2 2(S^2) \div [(10\%)(\bar{x})]^2$$

where t = the two-tailed t value at .10 significance with infinite degrees of freedom; S^2 = the variance; and $\bar{x}$ = the mean. Density estimates will be used to determine the minimum number of transects to sample. The total number of transects sampled will not exceed 15. If 15 are sampled, the confidence intervals will be determined and reported.

5.2.1 Vascular Plant Density

Plant density will be measured to determine numbers of established plants, seedling emergence and plant survival. Density will be determined by recording the number of individual plants of each species occurring within each of five 4-m² (43.1 ft²) quadrats randomly located along each permanent transect. Plant density will be sampled after each growing season during the first, third, fifth, and tenth year following reclamation. Composition data will be derived from density and/or cover data. Composition will be calculated for the reference and reclaimed areas in the third, fifth, and tenth growing season after revegetation.

5.2.2 Vascular Plant Cover

Ground cover is determined from the proportion of the ground surface covered by each of three categories: 1) living, above ground vegetation, 2) dead vegetative material (litter), and 3) bare ground. Each of these cover parameters is expressed as a percentage of the total area of measurement (Chambers and Brown, 1983). Ground cover data will be collected during the third, fifth, and tenth growing seasons.

Cover is determined using a cover-point optical point projection device (COPPD) (Buchner, 1985). The COPPD is positioned approximately 1 m (3.3 feet) above the ground and the plant species, litter, or bare ground that is intercepted by the theoretical vertical line is recorded. Cover parameters will be determined from four line intercepts or points recorded at two meter intervals along each 50-m (163 ft) transect, or 100 points along each transect (4 points at 25 locations).

5.3 Reestablishment of Wildlife Habitat

One of the objectives of reclamation of the Clean Slate 1 site is to return the site to provide habitat for wildlife. To document that the site is being used by wildlife, the presence of wildlife and/or signs of wildlife will be recorded during vegetation sampling. Wildlife observed on site will be noted as will signs of the presence of wildlife, such as scat, burrows, and browsed vegetation. These passive animal indicators will serve as a means to monitor use of the revegetated site by wildlife.

5.4 Remediation Criteria

Remediation, which involves some site preparation, reseeding, and remulching, will only be considered if reclamation of the site is not on track to meet the success criteria. Both vascular plant density and cover will be considered in determining the need for remedial reclamation.

5.4.1 Vascular Plant Density

Plant density for the area surrounding the Clean Slate 1 site is approximately 7.3 plants/m² (0.69 plants/ft²). There were approximately 2 shrubs/m² (0.19/ft²) and 5 grasses/m² (0.46/ft²).

To attain this density by the fifth growing season, a density of at least 10 shrub seedlings/m² (0.93 seedlings/ft²) and approximately 20 grass seedlings/m² (1.86/ft²) of seeded or native species is necessary after the first growing season. If seedling density is significantly less than this after the first growing season, or less than 7.3 plants/m² after the third or fifth growing season, some form of remediation may be necessary to ensure successful reclamation of the site.

5.4.2 Vascular Plant Cover

Vascular plant cover will be measured in the third, fifth, and tenth years after reclamation. Data collected in year five will be used to evaluate the need for remedial reclamation. If vascular plant cover is below approximately 50% of the amount of cover on the reference area, remedial action may be necessary to ensure that reclamation success criteria are met.

5.4.3 Soil Properties

Soil on the reclaimed area may change over time as plants become established, soil amendments are added, or as salts build up from irrigation waters and rainfall. Soils from the reclaimed area will be monitored for conditions that may cause poor vascular plant establishment and/or growth. If such conditions are observed, soil samples may be retrieved from the top 30 cm (12 in) of soil and analyzed for key physical and chemical properties. The soil analyses will be used to identify the cause of poor growing conditions and to assist in developing remedial action(s).

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