QA: NA

Yucca Mountain Site Characterization Project

RECLAMATION IMPLEMENTATION PLAN

YMP/91-14

Revision 2

Date: March 1, 2001

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Las Vegas, Nevada

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CHANGE HISTORY

Revision Number	Interim Change No.	Effective Date	Description of Change
0	0	01/07/1992	Initial Issue
1	0	08/11/1995	Revised for editorial, format changes
2	0	03/01/01	Changes were incorporated to comply with new procedural requirements and the requirements of the Integrated Safety Management System (ISMS), Information regarding the project area, existing surface disturbances, and results of reclamation feasibility studies were added. The Reclamation Implementation Plan was reorganized to follow the steps that occur at disturbed sites before, during, and after the use of those sites. The approved "Reclamation Standards and Monitoring Plan" was added.

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ACRONYMS

AP	Administrative Procedure
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
CRWMS M&O	Civilian Radioactive Waste Management System-Management and Operating Contractor
DOE	U.S. Department of Energy
EA	Environmental Assessment
EC	Electrical Conductivity
ECD	Environmental Compliance Department
ECRB	Enhanced Characterization of the Repository Block
EMP	Environmental Management Plan
ESF	Exploratory Studies Facility
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act of 1982, as amended
QAP	Quality Administrative Procedure
QARD	Quality Assurance Requirements and Description
RIP	Reclamation Implementation Plan
ROWR	Right of Way Reservation
SAR	Sodium Adsorption Ratio
SCP	Site Characterization Plan
USC	United States Code
USDA	U.S. Department of Agriculture
YMP	Yucca Mountain Site Characterization Project

ACRONYMS CONTINUED

YMSCO	Yucca Mountain Site Characterization Office

1. INTRODUCTION

The United States Department of Energy (DOE) has been tasked to develop the first repository for permanent disposal of high-level nuclear waste. The Nuclear Waste Policy Act of 1982 (NWPA), as amended, specifies the process for siting, constructing, operating, closing, and decommissioning a repository. This legislation directed the DOE to characterize the Yucca Mountain site for possible development of this nuclear waste repository. During the site characterization phase, the DOE is conducting both surface and subsurface activities to determine whether geologic and hydrologic conditions at the site will safely support construction and operation of a repository. Subsurface activities include the Exploratory Studies Facility (ESF), the Busted Butte Drift, and the Enhanced Characterization of the Repository Block Cross Drift (ECRB). Surface activities include drill pads, trenches, roads, pavement studies, and support facilities.

It is the policy of the DOE to conduct site characterization activities in an environmentally safe and sound manner. To support this commitment, the DOE's Yucca Mountain Site Characterization Office (YMSCO) has developed an environmental program. This environmental program is structured to satisfy the statutory requirements of the NWPA, the National Environmental Policy Act, the Atomic Energy Act, other applicable statutes, regulations, DOE Orders, and Bureau of Land Management (BLM) Right-of-Way Agreements.

The *Environmental Management Plan* (EMP) (YMP 1998a) establishes the environmental program for the Yucca Mountain Site Characterization Project (YMP). The EMP is the higher level plan in the YMP document hierarchy that dictates the specific need and the requirement for this Reclamation Implementation Plan.

This plan has been determined to be non-Quality Affecting in accordance with QAP-2-0, *Conduct of Activities*. This report is covered by the Activity Evaluation for Terrestrial Ecosystem Monitoring (CRWMS M&O 1997a). The information will not be used to support any quality affecting activities. Therefore this plan is not subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) document (DOE 2000).

1.1 SCOPE AND OBJECTIVES

As part of the environmental program, the YMSCO has developed a program to reclaim sites disturbed by the YMP. The objective of this reclamation program is to return land disturbed by site characterization activities to a form and productivity similar to the predisturbance state. This Reclamation Implementation Plan describes the process of planning, implementing, and monitoring activities required to meet this reclamation objective.

This process can be categorized into four parts: 1) pre-disturbance activities; 2) interim reclamation activities; 3) site closure and final reclamation activities; and 4) post-reclamation monitoring, remediation, and site release.

Pre-disturbance activities are discussed in Section 3 and are associated with gaining land access and ensuring that all surface disturbing activities comply with pertinent environmental regulations. Surveys or reclamation inventories are conducted on areas proposed for disturbance to document existing vegetation and soils, to recommend actions to minimize disturbance, and to conserve resources for future use.

Section 4 describes the interim reclamation activities. These activities include documentation of the types and extent of disturbance at the site, interim stabilization of salvaged topsoil, and topsoil monitoring to monitor soil erosion.

Site closure and final reclamation are described in Section 5 and involve gaining approval to access and decommission sites that are no longer needed for site characterization, preparing sites for reclamation, and then reclaiming them. Section 6 discusses the final step in the reclamation process. This step includes monitoring reclamation progress, remediating sites that may not meet the success criteria, and releasing sites that meet established success criteria.

1.2 REGULATORY REQUIREMENTS FOR RECLAMATION

A major tenet of Integrated Safety Management is the identification of the necessary and sufficient requirements to complete work in a safe and environmentally sound manner. Several environmental requirements set forth by federal laws and regulations, Executive Orders, and DOE orders are applicable to the YMP reclamation program. Additionally, several DOE documents contain commitments to reclaim sites disturbed by site characterization activities associated with the YMP. A brief summary of these requirements and commitments is given below.

The Nuclear Waste Policy Act of 1982 (NWPA) (42 U.S. Code [USC] 10101)

> The NWPA establishes the need to reclaim the Yucca Mountain site after completion of site characterization, if the site is found unsuitable for repository development. In implementing the NWPA, DOE issued 10 CFR 960, *General Guidelines for the recommendation of Sites for Repositories*. Section 960.3-4 states that DOE is to mitigate significant adverse environmental impacts throughout site characterization, site-selection, and repository development. Compliance is in part through reclamation of disturbed areas, which mitigates significant adverse environmental impacts related to site characterization activities.

The National Environmental Policy Act (NEPA) of 1969

> NEPA describes the basic federal environmental policy. Regulations were issued for implementing NEPA by the Council on Environmental Quality (CEQ) (40 CFR 1500 through 1508). According to 40 CFR 1508.20 "mitigation may include. . . rectifying the impact by repairing, rehabilitating, or restoring the affected environment." This includes reclamation as a form of mitigation and is applicable to site characterization.

Federal Land Policy and Management Act; Bureau of Land Management Right-of-Way Reservation (ROWR)

> The ROWR is subject to the conditions in the "Plan of Development" (Exhibit A of the Right-of-Way Reservation). The Plan of Development stipulates that "Mitigation and

reclamation will be used to return lands disturbed by site characterization to a stable ecological state with a form and productivity similar to the predisturbance state".

Title 42 U.S.C. 7401, The Clean Air Act and Title 40 CFR Part 50, National Primary and Secondary Ambient Air Quality Standards

A Class II Air Quality Operating Permit (#AP9611-0573) has been obtained for YMP activities. This permit states that soil erosion and windblown dust shall be controlled in part by chemical, short-term topsoil stabilization and in the long term via reclamation or re-vegetation of disturbed sites that are no longer needed for site characterization. Therefore, timely closure and reclamation of sites that are no longer being used provides an important means of dust control and compliance with the requirements of the air quality permit.

DOE Order 5400.1, General Environmental Protection Program

DOE Order 5400.1 provides general direction for DOE programs to assure compliance with environmental protection laws and regulations, Executive Orders and DOE policies. The YMP reclamation program helps to comply with this DOE order by meeting requirements stated in The Endangered Species Act, the Clean Air Act, and the Invasive Species Executive Order.

The Biological Opinion for Yucca Mountain Site Characterization Studies (Buchanan 1997), in accordance with section 7 of the Endangered Species Act of 1973, as amended (ACT)(16 U.S.C 1531 *et seq*.) sets forth terms and conditions for mitigating effects of site characterization activities on the threatened desert tortoise (*Gopherus agassizii*). The terms and conditions include revegetation of areas disturbed by site characterization activities that are no longer needed by the project. Site specific reclamation plans are required that include specifications for contouring, relieving soil compaction, treating and/or spreading topsoil, and planting. Additionally, the biological opinion required that DOE develop a Reclamation Standards and Monitoring Plan to evaluate the success of reclamation efforts.

Yucca Mountain Environmental Assessment (DOE 1986)

Commitments to reclaim areas disturbed by site characterization are made in the Environmental Assessment (EA) for the Yucca Mountain site (DOE 1986, Sections. 4.1.1.4 and 4.1.2.6). The adoption of these reclamation practices by DOE was used as justification for the conclusion reached in the EA (Sec. 4.2.5), that no significant adverse environmental impacts would result from site characterization activities. Within the EA DOE commits to stockpile topsoil, backfill excavated areas and seal boreholes, remove man-made materials and waste, ameliorate compaction, recontour sites to reestablish drainage, revegetate disturbed area with native or adapted species, and study the effectiveness of habitat restoration techniques.

Yucca Mountain Site Characterization Plan (DOE 1988)

Section 8.7 of the Site Characterization Plan (SCP) contains descriptions of reclamation activities to be conducted at Yucca Mountain. Specific types of reclamation activities include: 1) actions taken prior to land disturbance to stockpile topsoil and control erosion, and 2) actions taken to reclaim a disturbed area after site characterization activities are complete and a determination has been made that the area is no longer needed for the program. Specific actions are described for pre-disturbance and after site use. Predisturbance activities include: gather information on soil depth and plant cover during pre-construction surveys, remove and stockpile topsoil, install erosion control devices, establish vegetative cover over topsoil stockpiles where appropriate, and develop site specific reclamation guidelines. After site use activities include: analyze topsoil and amend if necessary, ameliorate soil compaction, backfill excavated areas and seal boreholes, regrade area to approximate original contours, redistribute topsoil, prepare seedbed and revegetate area with native or adapted species, and monitor reclamation success.

1.3 SITE LOCATION AND DESCRIPTION

The YMP area is in southern Nevada, approximately 160 km (100 mi.) northwest of Las Vegas, Nevada. For the purposes of this document, the YMP area is a block of land approximately 20.5 x 29 km (potential land withdrawal area) that encompasses most of the existing site characterization activities (Figure 1). This area is located exclusively within lands controlled by the federal government. Administration and use of the YMP area is divided among three federal entities: the DOE, the U.S. Air Force, and the BLM. The DOE administers and uses the eastern half of the YMP area through land withdrawn for use as the Nevada Test Site (NTS). The U.S. Air Force uses the northwestern portion of the site through land withdrawn for the Nellis Air Force Range, the surface of which is administered by the BLM. The BLM administers the southwestern portion of the site as public trust lands. Locations outside of the YMP area also have been used for site characterization activities. These disturbances will be reclaimed according to this document as well.

The YMP area lies within the southern part of the Great Basin subprovince of the Basin and Range Physiographic Province (Civilian Radioactive Waste Management System Management and Operating Contractor [CRWMS M&O] 1998a). The topography of Yucca Mountain and the surrounding region is typical of the Great Basin and the larger Basin and Range Province which are generally characterized by more or less regularly spaced, generally north-south trending mountain ranges and intervening alluvial basins that were formed by faulting (CRWMS M&O 1998a). Elevation changes and variations in topographic relief are considerable within the YMP area. The Yucca Mountain crest ranges in elevation from approximately 1,400 m (4,600 ft) to 1,500 m (4,900 ft). Adjacent valley bottoms reach their lowest elevation (850 m, 2,788 ft) in Jackass Flats near the southwest corner of the NTS.

Yucca Mountain is an irregularly shaped volcanic upland that is part of a volcanic plateau known as the Southwestern Nevada volcanic field which formed between 14 million and 11.5 million years ago (Sawyer et al. 1994). Soils in the YMP area are derived from underlying volcanic rock and mixed alluvium dominated by volcanic material. According to soil survey data (GS960408312212.005 1996) and research conducted by Resource Concepts (1989), these soils are classified as Aridisols and Entisols. Aridisols are the most widespread, usually occurring on mesa tops, piedmont remnants, and old alluvial fans (CRWMS M&O 1999a). Entisols are generally found on steep slopes and areas of more recent alluvium. Entisols are considered to be young soils with little horizon development, unlike Aridisols, which tend to have well-developed soil horizons (CRWMS M&O 1999a). As elevation increases from stream channels and alluvial fans to the ridge tops, soil depth generally decreases (YMP 1996a). Lower elevation soils are typically 170 cm deep. Mid-elevation soils on fan piedmonts and within steep narrow canyons have soil depths of up to 75 cm while soils on the ridge tops may reach depths of 45 cm. Soils in all topographic positions generally have coarse to medium textures and are modified by rock fragments (dominantly gravels and cobbles). Most of the soils are calcareous and it is common to find calcic horizons either near the surface or as buried soil horizons. The soils are moderately to strongly alkaline (pH ranging from 8.0 to 8.6) and generally have low water holding capacities (YMP 1996a).

The Yucca Mountain region is arid and warm. The climate of the YMP area is characterized by strong solar insolation, limited precipitation, low relative humidity, and large diurnal temperature ranges (YMP 1996b). The overall weather patterns are influenced primarily by continental air masses, which contain limited amounts of moisture. Total rainfall is typically less than 254 mm (10 inches) per year. The eleven-year precipitation average at Yucca Mountain is 126 mm (4.97 inches) (CRWMS M&O 1997b). Mean nighttime and daytime air temperatures range from 22-34° C (72-93° F) in the summer and 2-10.5° C (34-51° F) in the winter (CRWMS M&O 1997b)

Vegetation in the YMP area is classified into two vegetative formations (Mojave Desert and Great Basin Desert) and nine vegetation associations: *Ambrosia* (bursage), *Ambrosia-Atriplex* (bursage-shadscale), *Ambrosia-Larrea* (bursage-creosotebush), *Ephedra-Ambrosia* (jointfir-bursage), *Larrea-Ephedra* (creosotebush-jointfir), *Menodora* (Menodora), *Artemisia* (sage brush), *Coleogyne* (blackbrush), and *Eriogonum-Ericameria* (buckwheat-rabbitbrush) (CRWMS M&O 1998b). The last three vegetation associations listed are categorized in the Great Basin Formation because of structural differences when compared to the Mojave Desert Formation. Shreve (1942) described the Great Basin Desert as having a single vegetative stratum of small, flexible stemmed shrubs, and the Mojave Desert as more structurally complex due to the presence of larger stemmed shrubs such as creosotebush (*Larrea tridentata)*. The Mojave Desert also has a group of low growing, prostrate shrubs such as range ratany (*Krameria erecta)* and spiny menodora *(Menodora spinescens*). However, due to the range of elevation at Yucca Mountain, which is typically considered a transition between the two deserts, plant species from both formations or deserts are frequently found in the same area. Each vegetation association is actually a mosaic of subassociations consisting of dominant, codominant, and less abundant species of shrubs, grasses, and forbs.

The vegetation in the Yucca Mountain area has been impacted by factors other than planned DOE activities. A portion of the Yucca Mountain ridgetop (77 ha) burned shortly before or during 1978 (DOE 1986) and an area in Midway Valley north of Yucca Mountain also burned in the late 1980's. Vegetation has established on the burned area on Yucca Mountain ridge; however, the species composition and density is still different than the surrounding areas. The burned area in Midway Valley currently does not have a well established vegetative cover. Both

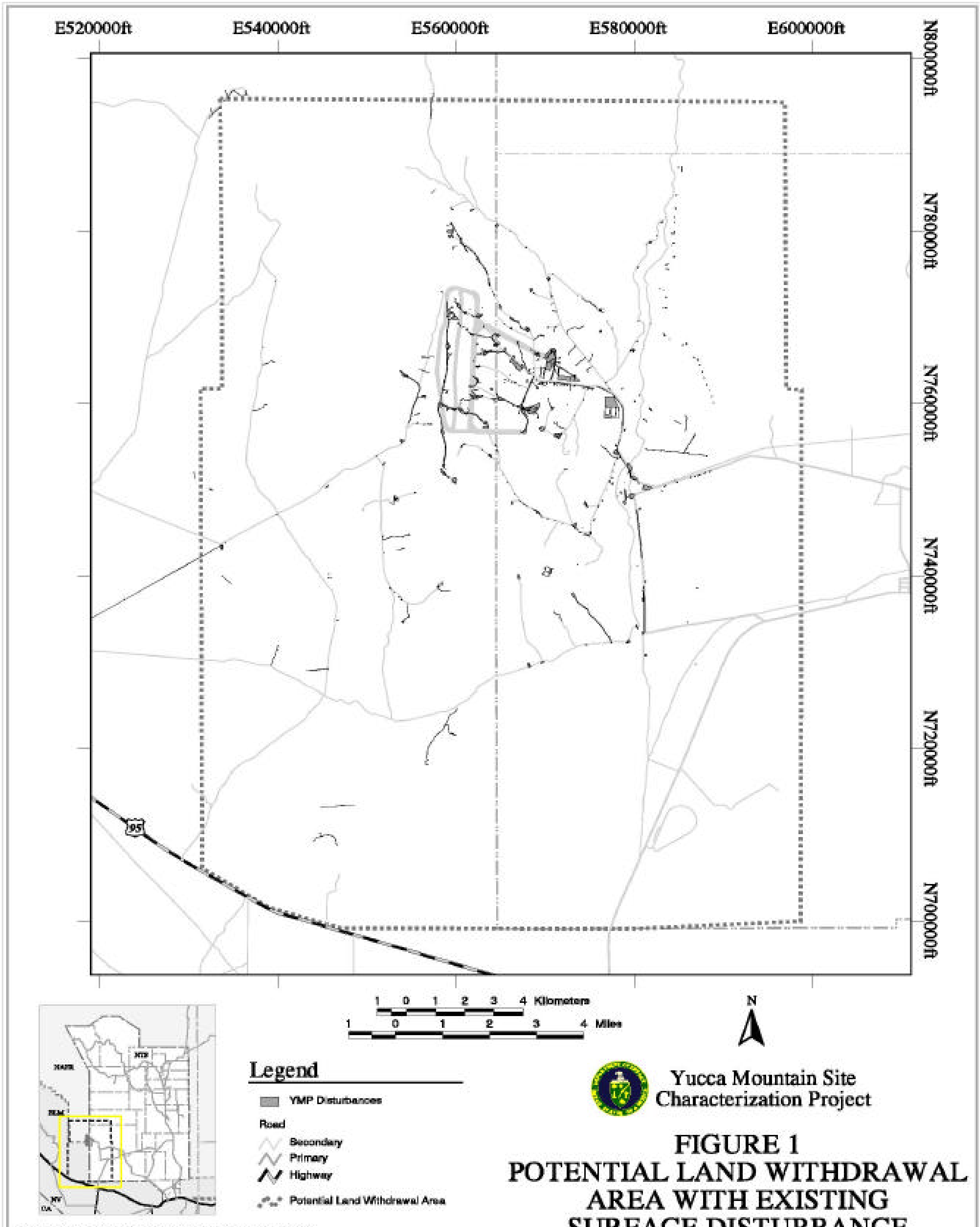

FIGURE 1
POTENTIAL LAND WITHDRAWAL AREA WITH EXISTING SURFACE DISTURBANCE

of these areas are adjacent to blackbrush (*Coleogyne ramosissima*) communities and may have been dominated by this species.

Burros and cattle have been observed in the Yucca Mountain area; however, the affects of grazing have not been documented. No grazing leases have been issued for Yucca Mountain (DOE 1986). Thus cattle grazing has most likely been limited during the past 50 years to a small number of animals migrating onto the site from other locations. Burro tracks and scat have been observed throughout the mid and upper elevations of the Yucca Mountain area. The highest concentrations were observed in Solitario Canyon (DOE 1986). A small herd of burros currently occupies the Crater Flat area near well VH-2 where free standing water occurs.

Of approximately 268 plant species identified during site characterization studies at Yucca Mountain, 10 species are exotic. All of these species have been documented in undisturbed areas; however, only foxtail brome (*Bromus rubens*) and redstem stork's bill (*Erodium cicutarium*) have been measured in more than trace amounts (> 0.1% cover) across the Yucca Mountain Landscape (CRWMS M&O 1996). On disturbed sites Russian thistle (*Salsola* spp) is common.

1.4 ARID LAND RECLAMATION RESEARCH

Secondary succession on disturbed-arid lands is a very slow process. Research indicates that decades to centuries may be required for the vegetation in disturbed areas to return to its original state (Vasek 1983; Carpenter et al. 1986; Angerer et al. 1994). However, several studies have demonstrated that reclamation of disturbed lands in arid ecosystems (including the Mojave Desert) is achievable. The following paragraphs briefly summarize this past research including research conducted at Yucca Mountain.

During the 1970's, the California Department of Transportation established revegetation trials at six locations in the south and east portion of San Bernardino County within the Mojave Desert (Clary 1983). Sites were chosen along a precipitation gradient (100-180 mm) that were representative of the conditions most likely encountered during highway construction. Several species of grasses, legumes, and shrubs were evaluated for survival, erosion control, and aesthetics. Species were drill seeded and broadcast seeded into plots and also transplanted into plots as containerized plants. Additional treatments included mulching versus no mulching, mulching type (straw, woodfiber, paper) and amount, application of fertilizer, fencing transplants, and irrigation frequency of transplants (once during planting or monthly through the summer). The best suite of revegetation methods from this study included drill seeding, fertilization during seeding, mulching with straw, and tackifying to anchor the straw to the soil surface.

In these revegetation efforts, several species indigenous to the Yucca Mountain area were successfully established on disturbed lands. Those species that were successfully established from direct seeding included cattle saltbush (*Atriplex polycarpa*), fourwing saltbush (*Atriplex canescens*), and Eastern Mojave buckwheat (*Eriogonum fasciculatum*). The most successful transplant species included cattle saltbush, fourwing saltbush, Eastern Mojave buckwheat, rubber rabbitbrush, creosotebush, and shadscale. Recommendations for transplanting included placing grazing exclosures around all plants, planting in late winter/early spring, and not irrigating. Irrigating did not result in increased plant survival.

The effects of grazing by rodents on transplants have been studied on the NTS (Hunter et al. 1980). During one study, 14 native shrubs species were transplanted to bare areas of a Mojave desert shrub community in Frenchman Flat. Plants were either fenced or unfenced. Each plant received supplemental water monthly through the summer (10 to 20 liters of water per plant per month). Survival rates six years later were 42 and 23 percent for fenced and unfenced shrubs, respectively.

Several other transplant studies were reported during the 1970s and early 1980s. Species that had the highest survival in these studies included: cattle saltbush, fourwing saltbush, rubber rabbitbrush (*Ericameria nauseosa),* and Nevada ephedra (*Ephedra nevadensis*) (Smith et al. 1978); white bursage (*Ambrosia dumosa)* and creosotebush (Romney et al. 1981a, 1981b); and white bursage (Graves et al. 1978).

To control dust in the Antelope Valley of southeastern California, approximately 1,070 ha were seeded using a variety of methods (Grantz et al. 1998). Results indicated that 1) direct seeding can lead to plant establishment during favorable rainfall years, but is likely to fail during any given year, 2) direct seeding should be implemented with little soil disturbance to minimize the potential establishment of invasive annual species, 3) fourwing saltbush is the species most likely to become established in the study area, and 4) unpredictable rainfall and temperature require that direct seeding be backed up with alternative strategies to achieve dust control in arid environments.

To minimize the effects of the arid Mojave Desert climate, techniques such as water harvesting, mulching, and supplemental watering have been used. Techniques that modify soil microtopography such as imprinting have been used successfully in the arid southwest (Clary 1989; Winkel and Roundy 1991). Various mulches have been shown to reduce evaporation, stabilize soils, and increase seedling establishment (Kay 1978; Fraser and Wolfe 1982). However, mulch application rates that are too high can reduce seedling emergence (Packer and Aldon 1978) and use of mulch can introduce unwanted weedy species to the site (Gould et al. 1975).

Perennial plant establishment at the NTS under natural conditions usually occurs only during above average rainfall years (Wallace and Romney 1972; Beatley 1975), which occur approximately 20% of the time (Ries and Day 1978). This low and unpredictable precipitation is a factor limiting successful revegetation in the arid/semi-arid West (May 1975). Application of supplemental water has been studied as a method to increase seedling emergence and provide better conditions for plant establishment on a more consistent basis.

Research on supplemental watering has provided mixed results. Balzer et al. (1975), working in an area receiving 210 mm of precipitation annually, concluded that supplemental water was crucial to successful seedling establishment. Gould et al. (1975) found that irrigation on mine spoils near Farmington, New Mexico resulted in suitable stands of all species as compared to no

emergence on non-irrigated plots. In contrast to these examples, Powell et al. (1990) showed that supplemental water may temporarily benefit perennial grass establishment, but this benefit diminishes over time. Ferraiuolo and Bokich (1982) also found that non-irrigated plots had better plant establishment than irrigated plots; however, low quality water was used in this study and may have caused this result. While supplemental water has been demonstrated to be useful, care should be used during its application. Used in excess, supplemental water promotes the growth of exotics, can cause salt accumulation at or near the soil surface and can produce plant densities that cannot be supported after the irrigation is halted (Bainbridge et al. 1995).
Another limiting factor in arid land reclamation in the Mojave Desert is the lack of a suitable substrate or growth medium (Wallace et al. 1980). Topsoil salvage is a common practice during reclamation because it saves the media in which plants previously grew. Little research on the effects of topsoil depth on reclamation success has been conducted in the southwest. Based on studies in other areas, as little as 10 to 15 cm of topsoil increased plant establishment (Anderson, 1987; Claassen and Zasoske 1993).

Because topsoil is limited, the suitability of fill and borrow material as a replacement for topsoil has also been studied. Crofts et al. (1987) showed that subsoil and topsoil treatments performed similarly after nine years. Since materials used for topsoil substitutes are often nutrient deficient, fertilizer has been used to amend the soil. Unlike crop plants and many exotics, many native plants are adapted to low nutrient conditions and have limited ability to respond to fertilization. Fertilizer tends to increase competition between annual exotic species and native species (Heady and Child 1994), thus reducing native plant establishment. Desert herbivores may also prefer plants with high nitrogen levels (Bainbridge et al. 1995).

While salvaging topsoil is generally considered to be a necessary reclamation practice, moving/salvaging soil harms soil structure (including soil aggregates), soil microflora, plant nutrients, and the seed bank. If the salvaged soil is immediately placed on a site to be reclaimed, the damage is minimized. However, in many reclamation programs the soil cannot be replaced immediately and must be stored for months or years. In arid areas, topsoil storage can lead to loss of microflora, particularly arbuscular mycorrhizae inoculum potential. At the Bridger mine in the northern Great Basin in Wyoming, Miller et al. (1985) found that the longer the piles were stored and the more moisture present in the pile, the more detrimental the effects of storage. After 24 months of storage, the mycorrhizal inoculum potential of the piles was severely damaged. When these soils were placed on reclamation areas, most native plants could not establish. Conversely, at Castle Mountain Mine in the East Mojave Desert, inoculum potential of storage piles was not directly correlated with age, and piles from 1 to 4 years old all had reduced, but significant inoculum potentials (Viceroy Gold Corporation 1995).

1.4.1 Reclamation Research at Yucca Mountain

From 1992 through 1995, the DOE conducted a series of reclamation feasibility studies in the YMP area to determine the suitability of reclamation techniques documented in previous studies and to address specific areas where information was lacking. Studies were focussed on identifying and improving the effectiveness of site preparation, revegetation, and topsoil stockpiling techniques. Site preparation studies included investigations of soil type, soil depth, and topsoil/subsoil mixing prior to seeding (CRWMS M&O 1999b; CRWMS M&O 1998c). To develop cost-effective combinations of revegetation techniques, studies were implemented to evaluate irrigation timing; irrigation frequency; seeding methods and seeding rates; species performance; mulches; water harvesting techniques; soil amendments including fertilizer, organic matter, and polyacrylamide gel; and use of transplants (CRWMS M&O 1998c; CRWMS M&O 1999b; CRWMS M&O 1999c). Maintenance of stockpiled topsoil viability through establishment of vegetation was also examined (CRWMS M&O 1999d). From these studies, an array of reclamation techniques were identified that could be selected from and applied to Yucca Mountain sites based on type of disturbance, soil type and depth, vegetation community, and topography.

1.4.2 Reclamation Research Needs

Upon potential approval and construction of the repository, large amounts of spoil will be generated from the drift excavation. These materials are comprised of crushed rock from varying depths underground that has no soil structure or soil microflora. Additionally, this material may contain nutrients that are detrimental to plant growth, such as heavy metals or unoxidized sulphur compounds. Thus, studies are still needed to determine what is required to successfully revegetate this spoil.

2. DESCRIPTION OF ACTIVITIES AT YUCCA MOUNTAIN THAT REQUIRE RECLAMATION

From 1977 to 1988 the DOE sponsored studies to assist in the site-selection process for a potential geologic repository (DOE 1999). These studies, which involved the development of roads, boreholes, trenches, seismic stations, and support facilities, along with non-Yucca Mountain activities, disturbed approximately 250 hectares (620 acres) (YMP 1998b). The non-Yucca Mountain activities that are part of the 250 ha area include many of the existing roads and power lines in the Forty-Mile Wash area, and roads that were constructed in the Bare Mountain, Crater Flat, and Amargosa Valley areas. These roads and facilities were not constructed to support the YMP, thus the YMSCO is not responsible for reclaiming them.

Site characterization activities to evaluate the suitability of Yucca Mountain as the site for a repository began in 1989 and will continue until 2001 (DOE 1999). Site characterization activities include surface excavations, excavations of exploration drifts, and subsurface excavations and borings. However, for this Plan only surface disturbances will be considered. As of February, 2000, site characterization activities have disturbed 126 hectares (312 acres, McCann 2000). By 2001, an additional 24 hectares (64 acres) may be disturbed (DOE 1999).

Many surface-based activities resulting from site selection and site characterization will be reclaimed while others will not. Activities that typically will not require reclamation include meteorological monitoring, radiometric monitoring, geodesy, seismic monitoring, evapotranspiration studies, geologic and surficial deposits mapping, and geophysical surveys. For these types of activities, no new roads were constructed and off-road travel was kept to a minimum. The disturbances were minor and short-term in nature. Only those activities that may be reclaimed are described below.

2.1 FACILITIES

In general, support facilities are located on level ground to accommodate construction and access, and to minimize disturbance (Table 1). Exceptions to this are the portal pads, the Fran Ridge heater block test facility, the water supply system, and the Busted Butte drift pad. For these activities, cut and fill processes were implemented to create a level working area. Most of the support facilities (ex., Subdock equipment storage) were surfaced with fill material to create a smooth working surface. Permanent and semi-permanent buildings with concrete foundations have been erected on sites such as the North Portal ESF and the two water wells. Temporary storage and office trailers or boxcars on temporary foundations have been placed on some of the remaining sites. Additionally, electricity and water have been supplied to some of these facilities.

2.2 ROADS

Roads are defined as routes used for repeated vehicle access to field sites, for the purpose of conducting or supporting site characterization activities. Infrequent off-road vehicle use is not included in this definition because vegetation is not damaged to a level that requires reclamation.

Table 1. Existing surface facilities, roads, and site characterization activities at Yucca Mountain that have been constructed as part of site selection activities and site characterization activities. Adapted from DOE 1999 and the 1997 Site Atlas (DOE 1997).

Disturbance type		Number of sites
Facilities	Portal pads	2
	Busted Butte drift pad	1
	Concrete batch plant and precast yard	2
	Borrow pits and screening plants	6
	Subdock equipment storage	1
	Equipment/supplies laydown yard	1
	Hydrocarbon management facility	1
	Boxcar equipment and supplies yard	1
	Water wells J-12 and J-13	2
	Topsoil and rock storage pile	1
	Water supply and booster pump system	1
	Heliport	1
	Septic system	1
	Fran Ridge heated-block test facility	1
	Meteorological monitoring stations	8
Roads	Light-duty-paved[1]	13.8 km
	Unimproved-graded	unknown
	Trails-not graded	unknown
Pavements/Exposures		14
Boreholes	Engineering design	44
	Geologic	45
	Geophysical	78
	Hydrologic	35
	Natural infiltration	120
Trenches/Pits	Quaternary faulting	81
	Volcanic	10
	Paleoflood	2
	Soil trench	21
	Soil and rock	112

[1]Within withdrawal area excluding road to Gate 510

Before construction to support the YMP, the only access into the Yucca Mountain area was by unimproved dirt roads and rough jeep trails (DOE 1988). As a result of site investigation and site characterization, a network of roads has been constructed, consisting of: 1) light-duty, paved roads, 2) unimproved roads, and 3) one-lane dirt tracks or trails (Table 1). There are three light duty paved roads, the main access road to the Yucca Mountain area (H-road) which ends slightly northwest of the Subdock equipment storage area, and two spurs off H-road to the North and South Portal, respectively. These roads have two lanes with established drainage ditches and are approximately 7 meters wide.

The unimproved roads are wide enough for two-lane vehicle traffic. These roads are typically graded roads. The use of road-base material or gravel for these roads is dependent mainly on the terrain and the existing surface materials. Most of these roads do not have drainage ditches and average about 5-6 meters wide. Most of the general purpose roads in the Yucca Mountain area are included in this category.

One-lane trails or two-tracks are used to access infrequently visited or short-term field sites, such as trenches, streamflow monitoring stations, seismic stations, and bedrock pavement sites. Some of these trails are bladed, but most, consist of two vehicle tracks where the vegetation has been killed and the soil compacted by repeated use. The need to blade a track to provide access to a field site is dependent on the terrain. Disturbance width for these roads is generally three to four meters wide.

2.3 DRILLING

The Viability Assessment (DOE 1998) documents the following types of boreholes: 1) Engineering Design, 2) Geologic, 3) Geophysical, 4) Hydrologic, and 5) Natural Infiltration. Approximately 320 boreholes were drilled to study a variety of characteristics of Yucca Mountain and to aid in the design of the repository (Table 1). In terms of surface impacts these boreholes can be separated into two broad categories based on drilling depth and associated drilling equipment. Shallow boreholes, typically less than 60 m (200 ft) in depth, were drilled using an all-terrain, rubber-wheeled, truck-mounted drill rig. Drilling of these holes required little, if any, surface preparation. In some situations a small pad (large enough for the truck-mounted drill rig) was constructed to provide a level place for drilling. Disturbances associated with this type of drilling usually included repetitive overland driving which compacted the soil and killed vegetation. At some boreholes, there is no visible evidence of disturbance except the drill stem. This type of drilling was done for the Geophysical and Natural Infiltration boreholes.

Deeper boreholes, such as the Geologic and Hydrologic boreholes, required construction of a drill pad. Site preparation for drill pad construction involved providing an area that was level and cleared of vegetation. The extent of surface disturbance was dependent on the site location and the type of drilling, or drill rig used. Larger drill pads may cover an area 70 to 100 meters on a side while moderately sized drill pads are 30 to 40 meters on a side. Disturbances vary from vegetation clearing and minor grading for drilling and support equipment, to cut and fill construction on steep slopes to provide a level working area. For these drill pads, additional fill material was imported to create a smooth surface work area.

Prior to 1989 topsoil was not salvaged for any drilling activity. After 1989, topsoil from drill pad locations was usually salvaged and stored for later use. Many of the shallow boreholes dug after 1989 did not require topsoil salvage because drill pad construction was not required.

2.4 TRENCHES AND PITS

The trenches and pits excavated during site characterization were separated into five categories based on the characteristics they were used to study: Quaternary Faulting, Volcanic, Paleoflood, Soil, and Soil and Rock (Table 1). The disturbances resulting from these excavations were similar. Disturbances included the pit or trench, subsoil (spoil) and topsoil stockpiles, a parking area, and in some cases a two-track road. The size of the pits and trenches ranged from 3 x 5 m up to 15 - 18 x 80 - 90 m.

Prior to 1989, the large trenches were dug primarily with a bulldozer. Trenches were created by pushing the material to one or both ends of the trench. This method covered over any topsoil that could be used for reclamation during decommissioning. After 1989, most of the trenches were dug with a backhoe. Topsoil was generally placed along one side of the trench and spoil was placed on the opposite side.

Because many of the trenches were located in remote areas, two-track roads were created for access. These roads were created by repetitive vehicle travel and compacted the soil and crushed vegetation. The disturbance areas associated with the access roads were often comparable or larger than those of the excavations because many of the roads were long (200 m or greater).

2.5 PAVEMENTS AND EXPOSURES

Pavements and exposures were used to study surface fractures and faulting networks and involved the mapping and measurement of fracture and fault patterns in the surface bedrock (Table 1). Pavements and exposures were generally located where the bedrock was relatively close to the ground surface. The thin layer of soil was removed to expose the bedrock fractures leaving an area devoid of any soil material.

Reclamation will not be undertaken for some of these sites because they are located on hilltops and are located away from existing roads. Additionally, the soil removed from these sites was not salvaged. Thus, topsoil would need to be imported long distances across undisturbed areas and steep grades to reclaim them. The new disturbances that would be created to reclaim these relatively small pavement sites have been deemed to outweigh the benefits of reclaiming them.

3. PRE-DISTURBANCE ACTIVITIES

Before any new or expanded field activity is initiated, the Affected Organization must receive environmental clearance following DOE procedure AP-EM-002, *Land Access and Environmental Compliance*. This procedure establishes the process for submittal, review, and approval of land access requests. It supports compliance with applicable environmental, regulatory, and monitoring and mitigation requirements. Additionally, it ensures that all necessary permits are identified and obtained, the location is evaluated for threatened and endangered species and antiquities, and that requirements of the land manager/owner are met.

To initiate the land access process, the Affected Organization submits a description of the proposed work/activity including access routes; types of disturbance; start and end dates; estimate of land area to be disturbed; and a list of any projected emissions, effluents, toxic or hazardous materials, and chemicals. Additionally, the Affected Organization is responsible for staking the proposed disturbance area. Once the request is submitted, all environmental surveys are performed.

3.1 RECLAMATION INVENTORIES

Reclamation inventories are used to assess and inventory the site conditions, and the vegetative and edaphic resources of an area prior to disturbance. Gathering site-specific information prior to an activity is an important step in the reclamation process (Hansen and McKell 1991; USDA 1979a). The information gathered generally focuses on soil and vegetative resources and landscape characteristics (Hansen and McKell 1991). Knowledge of the specific activity that will cause land disturbance, is also important for reclamation planning. The reclamation inventory may also identify construction or site access alternatives that minimize disturbance area or severity.

Reclamation inventories have five objectives:

- Identify site characteristics and project activities that may affect soil erosion
- Identify practices that will help reduce soil erosion on areas that will be disturbed and the area where salvaged topsoil will be placed
- Document the plant species and their respective cover on areas that will be disturbed.
- Determine the presence and amount of soil and vegetative resources that are suitable for salvage and use in reclamation of disturbed areas
- Determine the location where salvaged topsoil and vegetative resources will be used or stored

Information obtained during the reclamation inventory is used to develop site-specific reclamation recommendations that minimize impacts to natural resources during site construction. These recommendations focus on Interim Reclamation (section 4.0) and include information regarding topsoil and plant salvage, practices to reduce wind or water erosion of soil (e.g., advising against locating an activity in an ephemeral drainage), and the need for chemical or vegetative stabilization of the topsoil. These recommendations are incorporated into the Land

Access and Environmental Compliance Approval Letter from DOE as stipulations that the Affected Organization is required to follow to ensure compliance with all pertinent environmental regulations.

3.2 SOIL ASSESSMENT

Topsoil salvage is an important step in the reclamation process (Chambers 1989; Hargis and Redente 1984). Due to the limited amount of topsoil (A horizon soils) in arid ecosystems and the sites where soil was not salvaged during site investigation activities, subsoils (B and C horizons) will also be used during reclamation. Therefore, site-specific assessments of soil suitability and depth of soil materials are made at selected activity locations.

The soil properties and associated quality ratings in Table 2 provide some general guidelines regarding soil suitability for salvage. Generally, the coarse rocky texture of the soils in the Yucca Mountain area are either poor or unsuitable for reclamation. The USDA Forest Service (no date) states that for coarse textured or rocky soils, increased depths of replacement soils (up to 24 inches) are usually beneficial. It should be noted that reclamation has been successful when using these coarse soils (CRWMS M&O 1998c; CRWMS M&O 1999b).

During the reclamation inventory, information on the quantity and quality of soil suitable for salvage is gathered. The reclamation specialist uses this information when formulating site-specific reclamation requirements, particularly those requirements dealing with selection of appropriate plant materials and management of stockpiled soil. If soil quality is sufficiently poor, amendments may be considered during interim or final reclamation.

3.3 VEGETATION ASSESSMENT

An assessment of the vegetation is conducted prior to any surface disturbance. Information gathered includes vegetation association, plant species and their abundance, and the presence of exotic species. This information is used to identify plant species for reclamation (USDA, 1979b), salvage, or avoidance. Currently, no plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the land withdrawal area (DOE 1999).

Plants that may be candidates for salvage and transplanting will be identified. Because of the lack of root pruning under natural conditions, salvaging deep rooted shrubs and trees is not recommended. Several species of cacti and yucca, all of which are protected by the State of Nevada from commercial collection, are found in the withdrawal area. Joshua trees and cacti are the most suitable species for transplanting because they have adventitious root systems which generally adjust well to transplanting.

Table 2. Soil properties that affect the quality of a soil for reclamation.

	Soil Quality			
Soil Property	**Good**	**Fair**	**Poor**	**Unsuitable**
Texture	sandy loam loam silt loam	sandy clay loam silty clay loam clay loam[2]	loamy sand sandy clay silty clay sand	clay
Rock & Gravel (% by volume)	0-10	10-20	20-40	>40
pH	6-8	5-6; 8-8.5	4.5-5[1]; 8.5-9[2]	<4.5; >9
Sodium Adsorption Ratio (SAR)	<4	4-8	8-16	>16
Electrical Conductivity (EC) (milli-mhos/cm)	<3	3-7	7-15	>15

[1]check for excessive concentration of heavy metals
[2]check for excessive boron or lime
(adapted from USDA Forest Service–no date)

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4. INTERIM RECLAMATION ACTIVITIES

4.1 SITE PREPARATION FOR INTERIM RECLAMATION

Site preparation for interim reclamation is the process of salvaging and storing vegetation and soils for use during final reclamation. Site preparation also includes practices to help maintain the hydrologic drainage of a disturbed site to the extent practical. The extent of site preparation is determined on a site-specific basis during the reclamation inventory (See Section 3.1). This information is documented in the site-specific reclamation recommendations that are subsequently included in the letter of approval for land access (see section 3.1). Any vegetation that is identified for salvage will be marked, and instruction will be given for its handling and removal. The plan for salvaging topsoil includes details on depths of soil to which soil is salvaged and appropriate stockpile placement.

4.1.1 Vegetation Salvage

Past experience indicates that situations requiring vegetation salvage are limited. Seeding has been successful at Yucca Mountain, therefore costly salvage operations are not currently warranted. When significant stands of salvageable material exist (yucca and cacti), they can sometimes be avoided by modifying the activity.

If site preparation does not include soil disturbance, but requires removal of vegetation, plants will be cut and cleared by hand from the site with no additional disturbance of the soil. By minimizing the disturbance to vegetation and soil resources during construction, many native plant species can re-establish more quickly from seed and root materials remaining in the soil.

4.1.2 Soil Removal

Following any removal of vegetation, all suitable soil material will be salvaged. Various methods and types of equipment have been developed specifically for clearing vegetation and soil resources for land reclamation (USDA 1979a); however, typical earth moving equipment, such as bulldozers, front-end loaders, dump trucks, scrapers, and graders will be used during site characterization because the amount of site preparation is relatively small (as compared to a strip-mining project), and the types of disturbances consist of several small sites (i.e., drill pads and trenches) rather than large contiguous tracts of land. The type of equipment used for a particular disturbance will be determined by the construction management personnel based on the size and type of disturbance, the physiographic location, the amount of topsoil present, and the location of the topsoil stockpile.

If topsoil is stored adjacent to the site, bulldozers are best suited for removing topsoil. Bulldozers also are more suited to salvaging topsoil on steep slopes. Scrapers or trucks can move soil more efficiently than bulldozers if haul distances are long and areas of disturbance are large.

4.1.3 Drainage Control

Drainage control is defined as measures which minimize disturbance to the prevailing flow of surface and groundwater systems due to surface disturbances from site characterization activities.

Drainage control will be implemented to divert overland water flow away from disturbed areas. Temporary or permanent diversions may be used to minimize erosion and prevent sedimentation and debris deposition downstream. Diversions include channels, ditches, culverts, embankments, berms, or other manmade structures constructed to divert water from one area to another. The following practices are appropriate when diversions are used:

- Grading and recontouring disturbed sites so natural drainage patterns are re-established, undue ponding of runoff is avoided, and erosion is minimized.
- In the event that a diversion consists of rerouting or altering an existing stream channel (including ephemeral drainages), the capacity of the diversion will be at least equal to the capacity of the channel.
- Channel linings, if necessary, shall be designed to withstand expected water flows and rip-rap will be used where necessary to minimize channel erosion.
- Minimum side slopes of 2h:1v will be constructed for all ditches and channels.
- Culverts will incorporate the use of end sections or concrete headwalls and tailwalls when deemed necessary.
- Rip-rap or energy dissipaters will be installed at discharge points where diversions intersect natural channels at velocities greater than that of the receiving stream and, as needed, at the toe of cut and fill slopes.

Drainage control measures will be determined for each site characterization activity prior to site preparation. Drainage controls are considered part of site preparation, and are maintained as necessary throughout site characterization until final reclamation occurs. However, in some instances, it may be necessary to leave a drainage control in place until reclamation has sufficiently stabilized a site. Eventually those controls will be reclaimed.

4.2 TOPSOIL MANAGEMENT

Topsoil management includes topsoil evaluations, salvaging, redistribution, and topsoil preparation for reclamation. These aspects of topsoil management are discussed in other sections of this Reclamation Implementation Plan (Pre-activity Survey-reclamation inventory [section 3.2], Site Preparation for Interim Reclamation [section 4.1], and Site Preparation for Final Reclamation [section 5.2.2]). Discussed in this section are methods for topsoil handling, topsoil stabilization to retain maximum utility, and topsoil monitoring. The two methods of topsoil handling are (1) direct lifting and replacement of topsoil, and (2) topsoil stockpiling. Depending on how the topsoil is handled, different topsoil stabilization techniques are used.

4.2.1 Topsoil Handling

For the YMP, topsoil is defined as any soil (including subsoil) that is deemed suitable as a growth medium for vegetation. Soil material that is removed from an activity site must be protected from erosion and biological degradation if it is to retain its utility for reclamation (USDA 1979a). Topsoil handling techniques, stockpile depth, erosion protection, and timing of stockpiling are important parameters in maintaining a viable topsoil (Chambers 1989; Colorado Natural Areas Program 1998)

4.2.1.1 Direct Lifting and Replacement of Topsoil

This method involves removing topsoil from one site and placing it directly on a different site. Topsoil is best preserved using this method because fresh topsoil contains plant nutrients, microflora, seeds, and rhizomes that will aid in stabilizing the site. Although any disruption of topsoil is detrimental, direct replacement minimizes loss of live propagules including mycorrhizal fungi, seeds, and rhizomes (USDA, 1979a; Hargis and Redente, 1984). The applicability of this method is limited because another site without salvaged topsoil that has similar physiographic, edaphic, and biotic properties must be available.

4.2.1.2 Topsoil Stockpiling

Topsoil stockpiling is required when direct lifting and placement of topsoil is not an option. This method of handling topsoil is used in most situations at Yucca Mountain. Topsoil handling and stockpiling has been shown to negatively impact the physical, chemical, and biological properties of soil. Some of these impacts include: 1) increased compaction (Ramsay 1986); 2) decreased soil stability, increased bulk density, and decreased soil porosity (McQueen and Ross 1982); 3) increased ammonium concentrations (Harris and Birch 1987); 4) decreased numbers of aerobic bacterial and fungal spores with increased depth (Harris et al. 1989); 5) decreased numbers of viable seeds in the seedbank as stockpile depth and age increase (Dickie et al. 1988); and decreased mycorrhizal fungal inoculum potential (Miller et al. 1985; Stark and Redente 1987). While most of these impacts cannot be avoided, they can be minimized by proper handling, stockpiling, and stabilization techniques.

The location of the topsoil stockpile will be determined by the reclamation specialist during the reclamation inventory. Topsoil may or may not be stockpiled adjacent to the site depending on the topography of the site, other adjacent planned activities, the length of time the site will be active, and the size of activity. The design or shape of topsoil stockpiles will be determined for each site based on the location, size of disturbance, amount of topsoil salvaged, available space, potential for erosion, and the length of time the topsoil will be stored. Topsoil can be stockpiled to depths of two meters with little effect on soil viability (CRWMS M&O 1999d).

While salvaging topsoil is important for reclamation success, this value is minimized if the soil is not stored properly. Maintenance of microbial populations (including mycorrhizal fungi) in stockpiled soil is influenced by the amount of organic material in the soil (Elkins et al. 1984; Visser 1985), the amount of water in the soil (Miller et al. 1985), and the length of time the soil is stockpiled (Miller et al. 1985; Viceroy Gold Corporation 1995). Mycorrhizal vegetation can be planted on the stockpiled soil to maintain microbial populations and organic matter; the re-established vegetation also helps to minimize erosion (BLM 1992; Brown and Hallman 1984; USDA 1979a).

If possible, the topsoil will be salvaged and stockpiled when it is relatively dry to minimize compaction (Hansen and McKell 1991); however, some moisture may be desirable to help maintain soil structure (Chambers 1989). To minimize compaction, heavy equipment will not be operated on the top of the stockpile while it is being built. The topsoil will be dumped and subsequently pushed into place to the desired depth.

For improved and unimproved access roads, forming windrows of salvaged topsoil along the edge of the road is the least costly; however, in some cases water erosion or subsequent road maintenance causes the loss of topsoil when it is stored adjacent to the road. If possible, the topsoil from a road will be salvaged and placed at a central location(s), eliminating the possibility of accidental use during road maintenance. This also minimizes the amount of area requiring subsequent reclamation because the topsoil can be stockpiled higher, thus taking up less space than placing it adjacent to the road.

4.2.2 Topsoil Stabilization

Stockpiled topsoil is stabilized to minimize soil erosion and maintain soil viability. Soil erosion is a two-step process: (1) detachment, or breaking away of individual soil particles or small aggregates at the surface; and (2) transportation, which results in the actual loss of soil material from the site. Both wind and moving water provide energy for particle detachment and transportation. Materials and techniques for erosion control on disturbed lands of arid regions include chemical products (ex. asphalt emulsions, resin-in-water emulsions, co-polymers, and latex)(Armbrust and Dickerson 1971) and erosion control blankets (ex straw mats, polyethylene nets, and jute mats)(Fifield et al. 1987). Engineered erosion control structures such as terraces and vegetative erosion control practices also can be used (BLM 1992).

Physical, chemical, and vegetative treatments are used at Yucca Mountain to minimize soil erosion and maintain soil viability. The specific treatment(s) will depend on the stockpile's size and the length of time the topsoil will be stored. Physical treatments are used on stockpiles large enough for equipment to access. Chemical treatments are used for short-term stockpiles (in place less than 1 year) or stockpiles created outside the seeding window (i.e., the period when seeds can be planted prior to the onset of reliable precipitation. At Yucca Mountain, this period is from October – December). Vegetative treatments are implemented on long-term topsoil stockpiles (in place one year or longer) to stabilize the stockpile and maintain soil viability.

4.2.2.1 Physical Treatments

The topsoil stockpile will be located to minimize erosion potential and subsequent disturbance. The topsoil stockpile will be located on level ground, if possible, and not in a drainage or wash. The topsoil also will be marked to ensure it won't be subsequently used during the activity.

If the stockpile is created on a slope greater than 20% (5h:1v), the top of the stockpile will be stepped to keep it level to reduce erosion and increase water infiltration. If slope lengths for the top of the stockpile exceed 30 m (100 feet) (depending on slope angle) terraces, benches, or other slope breaks should be considered to minimize erosion (BLM 1992). It may be necessary to place a berm or ditch around the base of a stockpile to protect it from disturbance and prevent loss of soil material from erosion due to runoff. Straw dikes, rip-rap, check-dams, water bars, vegetative sediment filters, and other measures will be placed as necessary to reduce overland water flow velocity, reduce runoff volume, or trap sediment.

The surface of the stockpile will be leveled and then ripped to alleviate compaction and create a rough microtopography. A rough microtopography provides catchments to increase water infiltration and creates shelter for seeds and seedlings. The side slope of a topsoil stockpile should not exceed 5h:1v to allow for seeding (Ferris et al. no date). However, hand broadcasting or hydroseeding can be used to seed steeper slopes. Using steeper sideslopes decreases the amount of area covered by the stockpile. With steeper sideslopes, surface scarification techniques that promote moisture retention and reduce the rate and volume of runoff become more critical.

4.2.2.2 Chemical Treatments

Chemical soil binding polymers are applied to protect topsoil stockpiles from erosion by water and wind for short-term storage of topsoil. These polymers also are used on long-term stockpiles when it is not practical to seed them because of low probability of seeding success. For example, if a stockpile is created in March, it would be chemically stabilized, then seeded and mulched in the fall to establish a vegetative cover for long-term stabilization.

Stockpiles will not be sprayed with water to control dust because increasing the soil water content causes decreases in microbial viability (including mycorrhizal fungi), the seedbank, organic material, and nutrient availability.

4.2.2.3 Vegetative Treatments

Long-term topsoil stockpiles (soil that will be stored greater than 12 months) are stabilized by mulching and establishing of a vegetative cover. Mulches provide protection for the soil against erosion, retard evaporation, and increase infiltration of precipitation (Slick and Curtis 1985; Brown and Hallman 1984). The vegetative cover acts as a long-term erosion control measure that also maintains microbial activity, organic matter, and nutrient cycling within the soil. Perennial species will be used that provide a quick cover and are mycorrhizal. The methods used to establish a vegetative cover on topsoil stockpiles are the same as those used during final reclamation (section 5.2.3).

4.2.3 Topsoil Monitoring

Topsoil stockpiles are monitored annually to assess their condition. For stockpiles that were chemically stabilized, integrity of the soil crust is monitored. If the crust is not intact, the chemical stabilizer may be re-applied. For long-term topsoil stockpiles, signs of soil erosion are noted and the cover and density of the vegetation is estimated. Based on these observations, either no action is taken or the stockpile is re-stabilized. In some instances only a portion of a stockpile requires re-stabilization, such as an area where gully erosion has occurred. For these areas the appropriate drainage control techniques such as decreasing slope steepness, creation of drainages covered with rip rap, and water spreading may be used.

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5. SITE CLOSURE AND FINAL RECLAMATION

Once a site is no longer needed for site characterization it is proposed for closure and reclamation. Site closure includes 1) obtaining concurrence from appropriate participants to close a site, 2) gaining land access approval, and 3) decommissioning the site. Once the site has been decommissioned, final reclamation may proceed. Final reclamation activities include 1) development of a final reclamation plan, 2) site stabilization, including recontouring and installation of any final erosion and drainage controls, 3) distribution of any stockpiled topsoil, and 4) revegetation.

5.1 SITE CLOSURE

5.1.1 Site Closure Approval

Sites proposed for closure are first reviewed by the principal investigators and the YMSCO. This review process ensures that there are no ongoing activities at the sites, and that any data collected at the sites have been properly reviewed and reported. The YMSCO then submits the list of sites to the Nuclear Regulatory Commission for further review and approval. Once it has been determined that field sites, facilities, or access roads are no longer needed for YMP purposes, land access approval for decommissioning can begin.

Site closure may be postponed for several reasons. For some sites, final reports may not be completed. These sites will remain active until the report is finalized and the conclusions regarding the data are approved. For other sites, the data from a completed activity may require comparison to an ongoing activity, and because of that comparison, additional data may be required from the completed activity in the future. Other sites may be retained for repository monitoring if Yucca Mountain is deemed suitable for storing nuclear waste.

5.1.2 Land Access

As with pre-disturbance activities (Section 3.0), the land access process (AP-EM-002, *Land Access and Environmental Compliance*) is initiated to ensure compliance with applicable environmental, regulatory, and monitoring and mitigation requirements. This process also ensures that the requirements of the land manager/owner are met. A final reclamation survey is conducted as part of the land access process. The information gathered during the final reclamation survey is used to develop a final reclamation plan, which is attached to the Land Access and Environmental Compliance Approval letter (See section 5.2.1).

As part of the land access process, and as a condition of the right-of-way agreement between the DOE and BLM, the DOE will consult with BLM regarding the disposition of roads and activity sites that are on BLM-administered land. Prior to reclaiming these sites, an attempt will be made to identify an alternative use for a particular road or activity site. For example, the main access road and some secondary access roads may be left in place to provide access to the Yucca Mountain area in the future, or boreholes that penetrate the water table may be left for future use.

5.1.3 Decommissioning Sites

Once land access has been granted (see section 3.2), the sites can be decommissioned. Site decommissioning includes those steps that will turn a site to a safe, non-operable condition (DOE 1988). Each particular site will be decommissioned according to the following measures as they apply to that site.

Decommissioning activities associated with the permanent closure of underground openings, including shafts, ramps, exploratory boreholes, and the ESF are discussed in the SCP, Section 8.3. If the Yucca Mountain site is selected and operated as an underground repository for high-level radioactive waste, the DOE is required by 10 CFR 60 to seal boreholes and shafts at permanent closure of a nuclear waste repository (DOE 1988). DOE will follow all current regulations regarding the closure of these openings. If the Yucca Mountain site is determined to be unsuitable for development as a repository, all underground openings will be sealed in accordance with applicable state and federal regulations, including Section 534 of the Nevada Administrative Code.

For surface activities that require decommissioning, hoisting equipment, generators, building materials, electrical and water distribution systems, and monitoring equipment, will be dismantled and removed from the site and salvaged; concrete pads and foundations will be reduced to rubble; pavement will be ripped up; and resultant debris and wastes disposed of at an approved landfill. Hazardous materials generated during site characterization shall be disposed of in accordance with applicable regulations. Buried water, electrical, and sewage lines will be disconnected below the surface and left in the ground. Excavated areas such as trenches, borrow pits and mud pits will be backfilled

The DOE will consult with federal and state agencies in an attempt to identify an alternative use for the ESF. If an alternative use is identified, the ESF would be left in place and periodic maintenance would preserve the structural integrity of the facility and physical security would be retained at the surface. If a future long-term alternative use for the ESF is identified, the strategy to preserve the facility should include temporarily capping the underground openings.

If no alternative use for the ESF is identified, abandonment of the ramps and/or shafts may include removing equipment and structures; leaving in place concrete liners and underground workings; material that was removed during excavation may be used as backfill; and permanent sealing of the openings in a manner that would prevent access by people, livestock, and wildlife, and to minimize disturbance to the hydrologic balance.

5.2 FINAL RECLAMATION

5.2.1 Reclamation Plan

The final reclamation plan describes how specific sites or series of sites will be prepared for revegetation (Sec. 5.2.2), and which revegetation methods will be used (Sec. 5.2.3). The prescriptions in the final reclamation plan are based on information from the reclamation inventories, and the soil and vegetation assessments.

5.2.2 Site Preparation for Final Reclamation

Wallace et al. (1980) presents three general "rules-of-thumb" for revegetating disturbed sites such as fill-slopes, compacted surfaces of old roadways and other facilities. These are: (1) stabilize soils, if necessary, before planting; (2) prepare a seedbed with a micro-topography that will "harvest" water as well as hold seed; and (3) use native or naturalized plant materials. USDA (1979b) and several researchers referenced therein also discuss the need for good seedbed preparation and proper selection of plant materials.

5.2.2.1 Recontouring and Erosion Control

Recontouring and erosion control practices include backfilling spoil material and grading disturbed sites, so that a stable land form is created that blends with the surrounding topography. Since erosion is an active natural process, it is not the intent of erosion control practices to eliminate erosion from those areas impacted by surface based activities, but rather to control and thus minimize erosion during site characterization and site decommissioning. If possible, reclaimed sites should be reconstructed in a manner that maintains unconcentrated flow and promotes infiltration.

Following site decommissioning, disturbed areas will be graded such that the natural drainage pattern (predisturbance drainage) is restored. The sites will be stabilized and recontoured to blend into the natural topography of the area. Recontoured slopes should be no steeper than 2h:1v, because revegetation efforts are rarely satisfactory on slopes steeper than this (USDA 1979a). Slopes will exceed 2h:1v only where natural terrain or some other limitation prohibits further reduction. Slopes should be 3h:1v or less if equipment will access the site (BLM 1992); however, slopes of 4h:1v or less are more conducive for vegetation establishment.

Slope length and slope shape will be considered while recontouring a site. The movement of sediment within the hillslope is an important part of the erosion process and minimizing offslope movement via rill and gully erosion is critical (Ferris et al. no date). Slope lengths that exceed 15.25 m (50 ft) to 30.5 m (100 ft) at 4h:1v or steeper may result in concentrated water flow, depending on soil texture and vegetative cover. In comparison, slopes of 5h:1v become problematic at lengths of 150 feet or greater (Ferris et al. no date). Cross-slope ditches and furrows can be incorporated into the hillslope to achieve the desired slope lengths to reduce concentrated flow. A minimum gradient of four percent should be established for all cross-slope ditches to reduce the probability of failure (Ferris et al. no date).

Most disturbances at YMP do not encompass all hillslope components (top, shoulder, arm, toe) from the top of a hill to the bottom; however, there are some sites that cover portions of two or three of these components. For these situations, effort will be required to reconstruct these components while staying within the disturbance boundaries and ensuring the disturbed area blends into the surrounding landscape. While not applicable in all situations, concave slopes optimize the economics of material movement and the goal of minimizing erosion and maximizing infiltration (Ferris et al. no date).

Recontoured surfaces will be roughened, as necessary through ripping or chiseling, to permit better contact and stability between the surface and soil materials that are applied as topsoil. As a general rule, the distance between the ripping shanks should equal the ripping depth. Areas of repeated vehicle use, such as parking areas may require deep ripping (to 3 ft) followed by ripping to a 1 foot depth in a perpendicular direction with a roadgrader to alleviate soil compaction.

For road reclamation, drainage structures will be removed as necessary. Road surfaces will be recontoured, including ripping to relieve compaction (final ripping should be at a 90-degree angle to the slope) and any shoulders, berms and drainage ditches will be regraded to blend in with the natural undisturbed topography. Natural drainage channels will be re-established.

5.2.2.2 Redistributing Topsoil

Topsoil that has been stockpiled or is available from other areas will be distributed over disturbed sites. The topsoil material may be used to create the cross-slope ditches for drainage control.

The method of spreading topsoil depends on the size of the disturbed area, the location of the topsoil stockpile in relation to the disturbed site, the amount of topsoil to be respread, and the slope of the recontoured site. For relatively small sites where the stockpile is adjacent to the site, such as drill pads, topsoil can best be spread by a bulldozer. For larger areas, where a large centralized stockpile is utilized, scrapers or a combination of dump trucks and bulldozers will be used for distributing topsoil. Available topsoil will be spread to a uniform depth over the disturbed site. Depth will be determined based on the amount of available topsoil and the substrate over which the topsoil is spread (CRWMS M&O 1998c; CRWMS M&O 1999b).

If topsoil was not salvaged at a site, soil samples will be collected from soil material at the site and analyzed to determine suitability as a topsoil substitute. If determined to be suitable (Table 2), these materials will be used as surface soils for reclamation purposes. If these surface soils are not suitable, soils may be borrowed from other disturbed areas that may have a greater volume of suitable soil than required for successful revegetation.

5.2.2.3 Seedbed Preparation

Following topsoil distribution, a suitable seed bed will be prepared. Seed bed preparation may include ripping the site to relieve soil compaction or compacted by moving a tracked vehicle over the area. The final surface of a site should be left in a roughened condition, such that small surface depressions are created in order to increase infiltration and decrease erosion.

5.2.3 Revegetation

Reclamation is the process of re-establishing vegetation on disturbed areas and is largely dependent on natural conditions that cannot be controlled. The most critical of these conditions for the Yucca Mountain area is rainfall. The total amount of precipitation and its distribution are key elements to successful revegetation in desert environments (Wallace and Romney 1972).

The DOE/YMSCO will attempt to establish native vegetation on disturbed areas to minimize erosion and keep exotic species from invading unvegetated areas. This action supports DOE Order 5400.1 which is intended to assure compliance with several environmental laws and regulations such as the Clean Air Act, Invasive Species Executive Order 13112, and the Endangered Species Act.

Native seed or transplants are used to revegetate areas disturbed by Yucca Mountain activities. Revegetation shall be accomplished through implementation of one, or a combination of techniques (broadcast seeding, drill seeding, hydroseeding, or transplanting). The techniques selected for revegetation will depend on factors such as the severity and extent of the disturbance, topography, and access to the site.

5.2.3.1 Seeding

Direct seeding is the simplest technique for re-establishing a plant community on disturbed sites. Seeding will be used initially to establish plants on all sites, unless only a small vegetative input is required for success, then transplanting may be used. Past experience at Yucca Mountain indicates that direct seeding during years of above average rainfall will generally result in successful vegetation establishment (CRWMS M&O 1999b). Additionally, there have been situations where below normal precipitation have also resulted in vegetative establishment. However, due to the unpredictability of precipitation in the Mojave Desert, varying degrees of seeding success are expected.

Results of studies at Yucca Mountain showed that broadcast seeding produced comparable or superior results to drill seeding (CRWMS M&O 1999b). Broadcast seeding is generally preferred over drill seeding at Yucca Mountain due to rough terrain where rocks and undulating soil surfaces make drill seeding difficult.

Seeding rates vary according to species and seed availability. Based on feasibility studies (CRWMS M&O 1999b), the target seeding rate is approximately 20 kilograms of pure live seed (PLS) per hectare. Native plant species will be used. The composition of the seedmix is based on vegetation assessments of the immediate area, Ecological Study Plots in the same vegetation association (CRWMS M&O 1996) and results from vegetation mapping efforts at Yucca Mountain (CRWMS M&O 1998b).

Results of studies (e.g., CRWMS M&O 1999b) and final reclamation efforts at Yucca Mountain have shown that Nevada ephedra, *Eriogonum fasciculatum* (Eastern California buckwheat), *Krascheninnikovia lanata* (winterfat), *Achnatherum hymenoides* (Indian ricegrass), and fourwing saltbush generally have high potential for establishment by direct seeding (i.e., consistent establishment of plants at relatively high densities across sites) and are therefore recommended for use. Species that have shown moderate success include blackbrush, rubber rabbitbrush, white bursage, *Atriplex confertifolia* (shadscale), and cattle saltbush. Use of these species should be evaluated based on occurrence in adjacent undisturbed areas as they don't tend to exhibit high potential for establishment across a wide variety of site conditions. Species that exhibit low potential for establishment include *Chrysothamnus viscidiflorus* (sticky leaf rabbitbrush), creosotebush, *Lycium andersonii* (Anderson desert-thorn), *Sphaeralcea ambigua* (desert globemallow), *Grayia spinosa* (spiny hopsage), and *Hymenoclea salsola* (white burrobrush). Consideration of germination requirements, time of seeding, and site characteristics should be evaluated when using these species.

Sites are generally seeded between October 1 and December 31. This period is prior to the timing of relatively predictable rainfall that occurs January through March. If necessary, this seeding window can be extended; however, later seeding efforts increase the probability that additional inputs may be required to generate vegetative establishment. In cases where seeding is followed by inadequate amounts of moisture, reseeding entire sites may be necessary. After seeding, the site is harrowed to cover the seed.

5.2.3.2 Transplanting

Planting live plants on disturbed sites is an alternative to direct seeding that has been used successfully in the Mojave Desert (Wallace et al. 1980; Clary 1983; CRWMS M&O 1999b). Transplanting involves higher initial input of labor and plant materials relative to the potential number of plants that can be established by direct seeding. However, transplants are in an advanced stage of development, which allows for more rapid and successful establishment.

Transplanting is useful for establishing plant species that either aren't available commercially as seed or are hard to establish by direct seeding. The focus of the transplanting effort at Yucca Mountain will be on species that are dominant components of the vegetation associations. The following species either have or will be used as transplants: creosotebush, Anderson desert-thorn, *Lycium pallidum* (wolfberry), blackbrush, spiny menodora, *Encelia virginensis* (Virgin River brittlebrush), *Achnatherum speciosa* (needleandthread grass), spiny hopsage, *Acamptopappus shockleyi* (Shockley's goldenhead), *Salizaria mexicana* (bladderpod) and *Ericameria cooperi* (Cooper's heathgoldenrod).

Populations of these species have been identified in the Yucca Mountain area and seed is stored for many of these species to grow out as transplant stock when needed. Additional species may also be used in the future depending on the sites and the vegetation.

5.2.3.3 Mulching

Studies at Yucca Mountain indicate that addition of wheat straw mulch increases plant density compared to not mulching (CRWMS M&O 1999b). Mulch aids in the establishment and growth of vegetation because it 1) reduces evaporation and conserves soil moisture, 2) reduces soil crusting, 3) modifies temperature extremes, 4) holds seed and small seedlings in place, and 5) enhances the microenvironment for seed germination (Vogel 1987). When seeding is completed, sites will be mulched with wheat straw, with the exception of 2-track access roads. Repeated travel on 2-track roads to seed, mulch, and then anchor the mulch causes recompaction, eliminates the effectiveness of site preparation, and decreases emergence of seedlings.

Straw mulch will generally be applied at rates of 1.5 to 2 tons/acre, depending on the method used to anchor the straw. Due to the rocky nature of the soils at Yucca Mountain, a tackifier is often used to anchor the straw mulch. The organic tackifying agent (psyllium, derived from a species of plantago) is mixed with water and woodfiber to form a slurry. This slurry is sprayed on the straw mulch and when dry, creates a hardened blanket comprised of straw, woodfiber, and psyllium. The application rate on level ground for the tackifying agent is about 220 kg/ha and between 400 and 500 kg/ha for the woodfiber. When applying mulch to steeper-sloped areas, both the tackifier and wood fiber application rates are increased to ensure the mulch stays in place.

Crimping maybe used to anchor straw mulch to the ground; however, this method requires less rocky soil to allow the crimping disks to penetrate the soil. Crimping requires heavier application rates of straw mulch (2 tons/acre) because the crimping disks push the straw into the ground which decreases the amount of straw covering the ground.

5.2.3.4 Soil Amendments

Based on previous research, fertilizer is not required or recommended for vegetation establishment on disturbed sites at Yucca Mountain (CRWMS M&O 1998c). However, the application of chemicals or organic materials may be necessary to ameliorate soil conditions. This would be determined by comparing the soil characteristics gathered during preactivity survey and pre-reclamation surveys. Amendments may be considered for soils with characteristics in the “poor” or “unsuitable” categories (Table 2). However, if soils are found to be unsuitable, importing soil from another location may be less costly than using soil amendments.

5.2.3.5 Irrigation

Studies at Yucca Mountain indicate supplemental irrigation can be used to extend the seeding window and under certain protocols can increase plant establishment (CRWMS M&O 1999b and 1999c). Irrigation also has differential effects on individual species depending on when the water is applied. However, irrigation doesn’t guarantee success and can be costly. For most species, seeding within the traditional seeding window (October-December) will result in similar establishment as compared to seeding later and irrigating. Thus, irrigation is not a standard practice and will only be considered if repeated attempts using standard revegetation methods prove unsuccessful.

5.2.3.6 Fencing

Newly revegetated sites, other than access roads and greater than 0.1 hectare will be protected from grazing by lagomorphs. Revegetated areas will be fenced using four foot wide, chicken wire fence with a two inch mesh.

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6. RECLAMATION SUCCESS STANDARD AND MONITORING

Reclamation success at each disturbed area is monitored following completion of reclamation activities. This monitoring is necessary to ensure that sites are progressing as desired and to make a final determination regarding reclamation success so that reclaimed sites may be released from further inputs by DOE.

6.1 RECLAMATION SUCCESS STANDARD

To ensure the objective of the reclamation program is met and to comply with the requirements of the biological opinion for Yucca Mountain site characterization studies (Buchanan 1997), DOE developed the following success standard (Dixon 1998):

> "Return land disturbed by site-characterization activities to a stable ecological state with a form and productivity similar to the predisturbance state."

To evaluate whether the standard is met the following guideline (Dixon 1998) was developed:

> "Reclamation will be considered successful if the cover, density, and species richness (i.e., the number of perennial plant species in each site) of native-perennial vegetation is equal to or exceeds 60% of the values of these parameters in undisturbed reference areas."

The following sections describe the monitoring program that was developed to determine whether reclaimed sites meet the parameter values in the guideline.

6.2 RECLAMATION SUCCESS MONITORING

6.2.1 Qualitative Monitoring

Qualitative monitoring will be conducted periodically at all reclaimed sites. The goal of qualitative monitoring is to document site conditions and evaluate the need for remediation to ensure that sites are progressing toward the success guideline. The year of seedling emergence (seedling density > 1 plant/m^2), species richness, cover and density of perennial vegetation, soil conditions, exotic species, and animal use are documented. The reclaimed sites are rated and determinations are made regarding remediation activities which could include reseeding the site, spot seeding, adding transplants, irrigating, erosion control, and fencing

Experience indicates that inoculum potential of the soil microflora at Yucca Mountain will usually not hinder reclamation, which is similar to the findings at other Mojave Desert sites (Viceroy Gold Corporation 1995). However, soil microflora are an integral part of plant communities and they are important to consider in arid land reclamation due to their fragile nature and slow recovery rates (Miller and Jastrow 1992). Thus soil inoculation of certain components of the soil microflora may also be a possible remediation action if deemed necessary. Arbuscular-mycorrhyzal fungi can be cultured from local soil samples or purchased from commercial suppliers and applied with seed (St. John 1996).

Photography will be used to help document the status of revegetation at all sites. Photographs are taken after site abandonment, following recontouring and revegetation, and during each monitoring visit. Follow-up photographs will be taken from the same location as the initial photograph.

6.2.2 Quantitative Monitoring

On reclaimed sites larger than 0.1 ha (0.25 acre), vegetation is evaluated using quantitative methods. Success parameters are measured on reclaimed sites in the sixth growing season (or sooner if deemed appropriate) and compared to undisturbed reference areas to determine if the reclamation guideline has been met. Sample locations within both the reference area and reclaimed area are randomly selected. Sample size adequacy (Bonham 1989) is calculated to ensure a sufficient number of samples are taken to estimate the means for success parameters with a given level of confidence. If the mean for a given success parameter is less than the guideline (60% of the reference area mean) a statistical comparison is made with a one-tailed *t*-test (Bonham 1989). Species richness is evaluated by comparing the total number of native perennial plant species encountered on a reclaimed site to that of the sample area within the reference area. Species richness from the reference area is based on the same amount of area that was sampled within the reclaimed site.

6.3 SITE RELEASE

For sites larger than 0.1 ha, reclamation is considered successful and sites are released from monitoring based on the guideline stated in section 6.1. For sites 0.1 ha or smaller, vegetation will be qualitatively compared to the associated reference area; however, these sites are released automatically six years after seedling emergence has been documented. Additional reclamation actions will be taken, as necessary, on sites larger than 0.1 ha that do not meet the standard, and those sites will be re-evaluated in subsequent years.

The DOE will use all reasonable methods, including remediation, to help ensure that the guideline is met on all disturbed sites. However, it is possible that some sites will be incapable of supporting adequate vegetation to meet the guideline because of natural or project-caused conditions. Reclamation efforts will cease on those sites after all reasonable measures to promote revegetation have been taken.

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7.3 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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10 CFR 960. 2000. Energy: General Guidelines for the Selection of Sites for Repositories. Readily available.

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