



RECLAMATION INVESTIGATIONS ON DISTURBED
LANDS AT GLEN CANYON NATIONAL
RECREATION AREA

FINAL REPORT

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INTRODUCTION

The U. S. National Park Service retained Thorne Ecological Institute to establish experimental test plots for evaluation of reclamation techniques in the pinyon-juniper woodland and sagebrush-grassland vegetation types within Glen Canyon National Recreation Area, Utah. This information is desired because of proposed tar sand development within the Tar Sand Triangle Special Tar Sand Area. The objective of this research is to test various treatments for rehabilitating disturbed areas within Glen Canyon National Recreation Area and the surrounding environs to their former state using native species and non-irrigation techniques of vegetation establishment.

LITERATURE REVIEW

ECOLOGY OF PINYON-JUNIPER WOODLANDS OF THE COLORADO PLATEAU

Climate and Soils

Weather on the northern Colorado Plateau is uniform due to the surrounding high mountains which deflect low pressure systems (Sherrier 1933). Blue skies are typical throughout the year (Issacson 1967). Precipitation is generally between 25 and 38 centimeters annually (Tueller and Clark 1975). Most precipitation falls in winter and early spring, with some occurring in July and August. The dry season occurs in late spring and early summer. June is particularly dry. Most summer precipitation is lost via evaporation and runoff (Tueller and Clark 1975), therefore, pinyon and juniper depend greatly on soil moisture stored from winter precipitation for their growth.

In pinyon-juniper woodlands of the Colorado Plateau in Utah, the annual mean maximum temperature is 19.3° C. The annual mean minimum temperature is 2.3° C, and the mean annual temperature is 11° C (Randles 1949). The mean July temperature is 20.4° C (Woodbury 1947). Annual evaporation rates are between 76 and 102 centimeters (Pearson 1931), and the frost free period is 120 days (Woodbury 1947).

In the northern part of the Colorado Plateau, soils form mainly from residual, colluvial, and alluvial sandstone and shale parent materials (Issacson 1967). Although the character and geological origin of the soils do not limit the woodland distribution (Emerson 1932), the soils influence the growth and development of individual trees (Tueller and Clark 1975).

Synecology

The pinyon-juniper woodland is a community characteristic of semiarid environments between the Sierra Nevada and Rocky Mountains (Zarn 1977). It extends from Idaho southward to Mexico. On the Colorado Plateau, pinyon-juniper is generally found at elevations between 1,523 and 2,133 meters. Known as the pygmy forest, the pinyon-juniper woodland occupies 32.9% of the Colorado Plateau (West et al. 1975).

Pinyon-juniper woodlands predominate on ridges, rough slopes, and shallow, coarse, rocky soils (Arnold et al. 1964; Burkhardt and Tisdale 1969; Christensen and Johnson 1964; Woodbury 1947). The distribution of pinyon-juniper is discontinuous where the landscape is interrupted by washes, valleys, mesas, and canyons.

Utah juniper (*Juniperus osteosperma*) Torr., and pinyon pine (*Pinus edulis*) Engelm. are the two dominant species in the canyonlands region of the Colorado Plateau. Tree density of the pinyon-juniper woodland varies with elevation. The densest stands occur just below the upper elevational limit. There trees grow fastest and achieve maximum development and size. Crown cover and crown:root ratios may reach 40%. The upper ecotone is abrupt, whereas at the lower elevational limit, the stands are more open and the ecotone is broad (Woodbury 1947). Their elevational distributions reflect their temperature preferences (West et al. 1975). Pinyon pine occurs at higher elevations and comprises from 17 to 90% of the pinyon-juniper woodland of the Colorado Plateau in Utah (Hardy 1937; Woodbury

1947). Utah juniper dominates the woodland at lower elevations where it forms homogenous stands in locations too arid for the pinyon pine to survive (Zam 1977).

At low elevations, juniper gives way to desert shrub communities. In northern regions of the Colorado Plateau, these communities are dominated by big sagebrush (Artemesia tridentata). In southern regions, blackbrush (Coleogyne ramosissimum) forms the dominant shrub community. Big sagebrush is found at elevations between 914 and 3,047 meters. Its densest stands occurring between 1,371 and 2,133 meters. In general, big sagebrush is located in valleys, on mesas and gentle slopes, and on fine deep soils.

The vegetation structure and floral composition of the pinyon-juniper woodland is relatively simple. Except for pinyon and juniper, there are no other species endemic to the woodland; all may be found in adjacent communities (West et al. 1975). Understory herbaceous cover reaches its maximum development at the upper and lower elevational limits of the woodland, and even at its maximum development it is often less than 1% (West et al. 1975). Species diversity is low, and there are few forb species.

The distribution of vegetation is determined primarily by the availability of soil moisture during the growing season, and secondarily by slope and aspect. In deeper soils of the pinyon-juniper woodland, a relatively diverse understory may occur that may include big sagebrush, green Mormon tea (Ephedra viridis), roundleaf buffaloberry (Shepherdia rotundifolia), and other shrubs. Perennial forbs and grasses are sparse. Shallow soils support a sparse understory. Big sagebrush communities may include winterfat (Ceratoides lanata), fourwing saltbush (Atriplex canescens), and blue grama (Bouteloua gracilis).

Extensive communities of cryptogams, primarily fungi and blue-green algae, form soil crusts which help to stabilize sandy soils against wind and water erosion, and to enhance water infiltration in the pinyon-juniper woodlands. By decreasing the impact of erosion, the cryptogams also prevent the loss of nutrients and organics from the upper soil layer.

Pinyon and juniper are strong competitors for environmental resources. Juniper intercepts 40% of the precipitation (Skau 1960) and 80% of the direct sunlight (Tueller and Clark 1975) that falls on its canopy. Thus, it limits the moisture and light available to the understory species. Juniper also produces and releases phenolic compounds which may inhibit the growth of plants beneath it. (Arnold 1964). Blue grama, for example, is negatively affected by juniper litter (Jameson 1961).

The extent of the pinyon-juniper woodland community has increased in recent years by invading shrublands and grasslands (Arnold et al. 1964; Ellis and Schuster 1968; Smith and Rechenthin 1964; West et al. 1975). When good seed production is accompanied by plentiful moisture, pinyon and juniper can easily invade established grasslands. Juniper is the initial invader. Once juniper is established, it dominates the environment until faster growing pinyon moves into all but the lowest elevations (Jameson 1965).

Overgrazing probably has enhanced successful establishment of pinyon and juniper in former grasslands (Burkhardt and Tisdale 1969). By reducing competition, overgrazing has opened up sites for seedling establishment (Burkhardt and Tisdale 1976). A study of historical records by Cottam and Stewart (1940) suggest that unrestricted sheep and cattle grazing between the late 1800's and 1935 and drought, followed by rains which created gullies and drained meadows, caused the grasslands to change to desert shrub communities of big sagebrush and rabbitbrush (Chrysothamnus spp.).

Juniper has moved into sagebrush but not into rabbitbrush dominated stands (Zarn 1977). In valley bottoms, competition from deep root systems of sage and rabbitbrush have prevented establishment of juniper. However, in the foothills, a lack of competition for space has allowed juniper to move into and replace the sagebrush; there the shallow roots of the juniper give it a competitive advantage.

Arnold et al. (1964) compared grazed and protected sites in pinyon-juniper woodlands of Arizona. He found that on the protected sites, shortgrass cover decreased and cover of midgrasses and palatable shrubs, such as fourwing saltbush and cliffrose (Cowania mexicana), increased. Prostrate species, half shrubs, such as snakeweed (Xanthocephalum sarothrae), and annual grasses and forbs were favored on the grazed sites.

Grasslands within pinyon-juniper woodlands are thought to be subclimax communities maintained only temporarily by fire (Leopold 1924; Humphrey 1958). The ability of pinyon and juniper to invade established grasslands indicates succession towards the true pinyon-juniper woodland climax (Arnold et al. 1964). After fire, pioneering annuals colonize an area. Then, within 3 to 4 years, native perennials become established. The perennial community then develops into either a perennial shrubland of sagebrush, rabbitbrush, and snowberry (Symphoricarpos spp.), or into a perennial grassland in about 35 years. Fire will cause the shrubland to revert to a grassland, and a lack of fire will allow invasion of both pinyon and juniper which may become dominant within 70 years (Barney and Frischknecht 1974).

Some additional factors thought to be responsible for the invasion of grasslands by pinyon-juniper woodlands include the use of the horse by the American Indian (West et al. 1975), and a wetter and warmer climate between 1850 and 1940 which favored the production of tree seed and tree dominance over understory species (LaMarche 1974).

MANAGEMENT OF PINYON-JUNIPER WOODLANDS

Historically, pinyon-juniper woodlands have been managed for production of wood products, wildlife habitat and grazing. Improved grazing, however, has been the primary management goal in pinyon-juniper woodlands. A locally stable livestock industry may be achieved by the enhancement of palatable grasses and forbs to their optimum, sustainable productivity. Improved forage production often results from overstory removal. Although tree and shrub removal increases available moisture and insolation, increased production of grasses and forbs is highly variable and depends on initial canopy cover, soil nitrate, calcareous soil (Clary and Jameson 1981), availability of the preferred species propagules, and the method and timing of overstory removal.

After pinyon and juniper removal in Arizona, average annual production varied from 715 to 3,703 kg/ha - a maximum increase of greater than 500% (Clary and Jameson 1981). Grasses increased from 46% to 73%, while forbs decreased from 21% to 19%. Half-shrubs and shrubs decreased from 33% to 8%. The dominant grasses after treatment were blue grama, sideoats grama (Bouteloua curtipendula), and squirreltail (Sitanion hystrix). Arnold et al. (1964) and Jameson (1961) found herbage production had increased 350% five to ten years after juniper control without additional seeding. Other studies have shown that little or no increase in production may occur if initial canopy cover is low and soil calcium carbonate levels are high (Brown 1965; Jameson 1966; O'Rourke and Ogden 1969). Soil disturbance by bulldozing or chaining also may reduce potential productivity. When

productivity of a site does increase, maximum productivity peaks about 5 to 10 years after treatment (Arnold et al. 1964). It may maintain this productivity for many years even as juniper reinvades the site (Kruse et al. 1979). Eventually the shrub and tree canopy will reduce the grass and forb understory unless the canopy is removed.

Tree and shrub removal techniques include burning, mechanical removal, and herbicides. Specific techniques will differ with respect to costs, secondary environmental damage and ease of application.

Burning may be used as an initial treatment to kill and partially remove the tree and shrub canopy. It also may be coordinated with mechanical removal to remove slash or with herbicide treatment to remove the standing dead. It is the least expensive method of removal but nonspecific in its action. Productivity is reduced immediately, however, after fire and may take 2 to 5 years to return to original productivity (Dwyer and Pieper 1967). Proper management of burned areas (e.g., protection of burned areas from livestock for one full year, light grazing the second year, and at medium rates thereafter) may significantly increase production (Vallentine 1980). If preferred species do not successfully establish either naturally or through management practices, the area is susceptible to reinvasion by trees, shrubs and annual weeds.

Mechanical removal, such as manual tree cutting or girdling and brush grubbing is slow and costly, but specific species can be controlled and environmental damage minimized. Bulldozers can be used to uproot and remove trees and crush and kill brittle brush species. This method is less costly than manual removal but results in some damage to the soil and preferred species. Chaining and cabling removes trees and shrubs by dragging heavy anchor chain or cable between two crawler tractors traveling in a parallel direction. This is the quickest and least expensive of mechanical removal methods but is the least specific in its effect. Some preferred species may be damaged and young trees or flexible shrubs may not be removed (Arnold et al. 1964). The slash from chaining may be left in place or burned. Depending on management goals, a secondary removal technique may be needed to remove young trees either manually or with herbicides.

Herbicide removal of tree and shrub canopy is more costly than burning and less costly than mechanical removal methods. Herbicides are not species specific, so some preferred shrubs and forbs will be effected. Environmental damage is minimized because the soil and native grasses are not disturbed.

Regardless of the tree and shrub removal method that is employed, if the existing grass population is not sufficient for quick natural reseeding, then additional seeding is recommended. Broadcast seeding in pinyon-juniper stands after wildfire has been successful (Koniak 1983).

Species selected for range improvement should be palatable to livestock and environmentally adapted to the site. Post-disturbance use should also be considered during development of an appropriate seed mix. If an area is to be grazed primarily in the spring and early summer, cool-season grasses should dominate the mix. If grazing is in the late summer and fall, then warm-season grasses should dominate. If year-round grazing is anticipated or no definite plan is determined, a mix of cool and warm-season grasses would be best. Year-round grazing and wildlife habitat may be enhanced by the addition of useful forbs, legumes and shrubs.

NATIVE REVEGETATION AND RECLAMATION TECHNIQUES FOR PINYON-JUNIPER WOODLANDS

Introduction

The severity of disturbance in the pinyon-juniper woodland influences the direction of secondary succession. Less disturbed sites, such as roads or drill pads, may revegetate naturally (Jaynes and Harper 1978). On drastically disturbed lands, such as abandoned mines, natural revegetation has been sparse (Narten et al. 1983). If extreme soil erosion, water and air quality deterioration, and scenic impairment are to be prevented, the rate and direction of secondary succession on drastically disturbed lands must be managed.

Reclaimed lands must be physically stabilized. Backfilling and simultaneous compaction of the spoils helps prevent landslides. Contour furrows, ditches, benches and sophisticated drainage channels can prevent mass wasting. In arid climates spoil saturation is a relatively minor problem.

Post-mine topography can influence revegetation potential of reclaimed lands. Spoils should be contoured, roughened and covered with the best available plant growth medium. This is usually the pre-mine, native soil. Beneficial textural, structural and biological properties of native topsoils have prompted state and federal regulations that require topsoil salvage and replacement over mine spoils (CMLRD 1980; SMCRA 1977; USDI 1981; WDEQ 1981b). In the pinyon-juniper ecosystem, topsoils may be very thin and infertile. Subsoils should be analyzed prior to disturbance to evaluate their potential as a topsoil substitute.

Topsoiled surfaces should have a variety of microtopographical features, such as, basins, furrows and pits (Hodder 1977). Mulches may be necessary for surface stabilization and to increase soil moisture.

Revegetation of disturbed sites depends on climate, soil, desired post-mine land use and species availability. Species and varieties selected for revegetation should be adapted to the site environment. Planting should occur prior to the longest period of favorable growing conditions (Vallentine 1980). Drill seeding of reclaimed lands is usually the most effective method of seeding (Packer et al. 1979).

Native Revegetation

Native revegetation or secondary succession on drastically disturbed sites in pinyon-juniper woodlands has been sparsely documented. However, successional patterns have been investigated during range improvements.

Many abandoned or infrequently used roads exist in Utah canyon country. Jaynes and Harper (1978) studied bladed roadways in the Kaiparowits Basin, Utah. In disturbed sandy loam soils, galleta grass (Hilaria jamesii), indian ricegrass (Oryzopsis hymenoides), globemallow (Sphaeralcea coccinea) and snakeweed were the initial colonizers. Fineleaf hymenopappus (Hymenopappus filifolius) colonized both sandy loams and sandy clay loams.

Similar results were observed at Glen Canyon National Recreation Area (Meyer per. observ.). Snakeweed was the dominant colonizer of abandoned drill pads, and hymenopappus was common on three drill pads on Gordon Flats. Rabbitbrush, green Mormon tea, Douglas's senecio (Senecio douglasii) and lobeleaf senecio (Senecio multilobatus) were abundant on drill pads in Glen Canyon National Recreation Area, whereas they apparently do not readily

invade roadways in the Kaiparowits Basin (Jaynes and Harper 1978).

Natural revegetation of abandoned, underground, coal mine wastes in central Utah has been extremely poor. Mixed coal fines and shales have been abandoned without reclamation at the Weber and Chappel mines. On 30 year-old coal wastes, high surface temperatures on most ungraded slopes have precluded natural plant invasion. On north-facing slopes and in gullies between piles, big sagebrush and indian ricegrass are sparse. On leveled, 50 year-old coal wastes, heavy growth of big sagebrush has been reported (Narten et al. 1983). Similar results have been observed on 30 year-old, coal wastes at the abandoned, underground, Helco and Reminger coal mines. The wastes only were sparsely vegetated with indian ricegrass and oregon-grape (Mahonia repens) (Narten et al. 1983).

Reclamation Techniques

Site Preparation.

Grading and Contouring: Water harvesting should be considered when shaping spoils. Creation of gentle, northeast slopes may create a more beneficial environment for plant establishment by reducing solar insolation and soil surface temperatures (McKell 1978). Ridges constructed perpendicular to the prevailing wind may increase snow accumulation in the leeward drainages or gullies. Toe slopes and basins may benefit from runoff provided that the surface flow is reduced by established plant cover. Intense rainstorms and erosion may bury desirable plants in the drainage if the velocity of the overland flow is not reduced (Meyer 1984).

Topsoil: It is generally recognized that topsoil is the best plant growth medium available for reclamation of disturbed lands. Soil organic matter (Black 1968), soil microorganisms (Alexander 1977) and plant (Iverson and Wali 1982) and fungal propagules (Trappe 1981) are beneficial characteristics of native topsoil. If properly utilized, native topsoil may improve disturbed land reclamation.

Topsoil quantity and quality available for reclamation must be determined by site specific evaluations. Guidelines for evaluating specific soil and overburden parameters have been developed for Wyoming (WDEQ 1981b). These principles are applicable to other semiarid regions. After the depth, volume and quality of available topsoil has been calculated, a topsoil handling plan is developed. Immediate or direct replacement of stripped topsoil over regraded and contoured spoils is desirable. If direct topsoil replacement is not possible, then topsoil can be stored for later use (SMCRA 1977).

The presence of soil organic matter is an important difference between topsoil and spoil material. Soil organic matter improves the plant environment by providing a nutrient source that sustains microbial populations. Soil organic matter decomposition and mineral cycling by microbes frees nutrients for plant utilization (Alexander 1977).

Most plants of the arid west exist in a symbiotic plant root-fungal associaton, known as vesicular-arbuscular endomycorrhizae (VAM) (Lindsey 1983; Trappe 1981). VAM fungi increase plant growth primarily by increasing phosphorus absorption by plants (Christensen and Allen 1980; Mosse 1973a, 1973b) VAM fungi may affect plant water uptake (Allen 1982; Allen et al. 1981b; Safir et al. 1972) and plant nutrient uptake (Jensen 1982). Christensen and Allen (1980) reported that VAM fungi may increase photosynthetic rates of blue grama. Colonization by beneficial

VA mycorrhizal fungi can occur by spores or by infected root fragments (Rives et al. 1980). A reservoir of VAM exists in undisturbed soil.

Immediate replacement of stripped topsoil will increase the probability of a viable population of VAM propagules on reclaimed lands. If immediate reapplication of stripped topsoil is unmanageable, topsoil may be stored for three years without a serious reduction of VAM propagule populations (Allen 1984; Meyer 1985). Research to date on the effects of topsoil storage on VAM generally indicate that, as storage time increases, mycorrhizal infection potential decreases, particularly in the upper layers of the stockpile (Christensen and Allen 1980; Reeves et al. 1980; Rives et al. 1980). Singleton and Williams (1980) found that populations of VAM drop rapidly after four or five years of storage and that after twelve years VAM were absent. Gould and Liberta (1981) studied the same stockpile as Rives et al. (1980), and reported that VAM inocula decreased from the third year to the fourth year of storage.

In arid and semiarid regions, establishment of a diverse, native plant community capable of succession depends on achieving a viable population of VAM fungi. Topsoil is the best resource for reestablishing VA endomycorrhizae on reclaimed lands.

Stripped topsoil is a potential source of native seeds for surface mine reclamation. The number and species of viable seeds in native soil may enhance vegetation cover, species diversity and the direction of succession on reclaimed lands (Barbour and Lange 1967; Beauchamp et al. 1976; Howard and Samuel 1979; King 1981; Knipe and Springfield 1972).

The germinable seed load in soils depends on several factors; history of the soils, reproductive potential of the vegetation community, dispersal mechanisms, dormancy patterns, and environment (Iverson and Wali 1982). These factors must be considered when evaluating a site for natural revegetation potential.

Iverson and Wali (1982) compared species composition of native topsoils to that of revegetated post-mined lands in North Dakota. Weeds were the only species common to both native and two-year-old reclaimed sites. However, a four-year-old reclaimed area contained several species that were present in the native prairie. Their study suggests that plant propagules from native topsoils influence the post-mined vegetation, mainly after the initial colonization by weeds.

Cultural Treatments: Movement, grading and contouring of spoils and topsoils result in severely compacted materials. Ripping is usually necessary to disrupt the compacted spoil and topsoil layers. Ripping improves drainage, infiltration and root penetration (Richardson and Packer 1979; Verma and Thames 1978). Ripping along the contour ameliorates slumping problems. Topsoil may be disked to pulverize clods. Subsequent harrowing smooths and firms the soil prior to seeding (Richardson and Packer 1979).

Fertilization--An assessment of soil or spoil fertility must be addressed on a site-specific basis. Topsoil and overburden sampling should detail fertility and toxicity problems prior to mining (Portle 1983). Topsoil should be salvaged and replaced over mine spoils (CMLRD 1980; SMCRA 1977; USDI-BLM 1984; WDEQ 1981b). Spoils may only be substituted for topsoil if topsoil volume and quality are inadequate to support an effective vegetation cover and if the spoil material is of better quality than topsoil (WDEQ 1981b). The best available plant growth medium should be used for reclamation.

Nitrogen (N) and phosphorus (P) are frequently deficient in soils and mine spoils of arid climates, whereas potassium levels are usually sufficient (Aldon et al. 1979; Bauer et al. 1978). Nitrogen deficiencies negatively affect long-term productivity of post-mined vegetation, whereas phosphorus deficiencies may limit plant establishment (DePuit and Coenenberg 1979). These deficiencies often have a greater effect on grasses than on forbs. Because reclamation seed mixtures usually are predominantly grasses, fertilization of the plant growth medium may be necessary to correct these deficiencies.

The amount of available soil moisture influences the beneficial effects of fertilization. Nitrogen and phosphorus must be in soluble forms for plant uptake. On arid sites fertilization may not be beneficial to plants, because after precipitation events plants may utilize the moisture before it can dissolve the fertilizer.

McKell and Van Epps (1980) and Van Epps and McKell (1980) studied nitrogen and phosphorus fertilizer treatments on containerized transplants in northeastern Utah. They found little positive response to fertilizer by big sagebrush, fourwing saltbush and winterfat. They suggested that any positive response was caused by supplemental water and not fertilizer additions. They also studied similar species on the Henry Mountain coal field in south central Utah. Little shrub response to fertilizer was observed. In slightly more mesic environments, however, plant growth may be stimulated by nitrogen fertilization. If precipitation is sparse later in the growing season, fertilized plants may deplete the available soil moisture (Van Epps and McKell 1980).

Seed mixtures may influence fertilization rates because different species and growth forms have specific environmental tolerances. Native, perennial species are often less competitive than many introduced annual species. On fertilized mine spoils in Montana, yield of cereal grains (Meyn et al. 1975) and introduced grasses (DePuit and Coenenberg 1979) was greater than native perennials. Fertilization may also stimulate annual weed production such that they out compete native seedlings (Van Epps and McKell 1980). Weed invasion may be reduced if nitrogen fertilization is postponed until the second growing season, at which time native perennials should be established (DePuit and Coenenberg 1979). Shrub seedlings do not readily respond to nitrogen fertilization because of internal nitrogen conservation and cycling (Charley 1977). Redente et al. (1984) found little response to high (112 kg N/ha, 56 kg P/ha) and moderate (56 kg N/ha, 28 kg P/ha) levels of fertilization by fourwing saltbush, cliffrose and green Mormon tea on retorted oil shale. Winterfat, however, exhibited slight response to the heavy fertilizer treatment.

In the Northern Great Plains DePuit and Coenenberg (1979) suggest that if high plant productivity is the desired reclamation goal, then high rates of fertilizer should be applied to perennial grasses. Low rates or no fertilizer should be applied if stand diversity is desired. Shrub establishment, at least on semiarid and arid reclaimed lands in Utah, probably will not be enhanced by fertilization (Van Epps and McKell 1980).

Water Harvesting and Retention Techniques—Limited precipitation and high temperatures inhibit plant growth in arid regions. Water harvesting can increase plant available moisture in specific locations by collecting water and concentrating it for plant use.

Relatively mesic microenvironments can be created on semiarid and arid reclaimed lands by selectively grading and contouring mine spoils. Runoff catchment basins can accumulate snow and direct runoff to designated

areas (Thames and Verma 1975). Growth of fourwing saltbush, for example, was increased when planted in post-mine floodways (Aldon and Springfield 1975). Similarly, cooler and moister environments may be created by constructing northeast facing slopes (McKell 1978).

Dozer basins and large depressions are smaller scale water harvesting techniques. Dozer basins have been used to simulate mini-drainage areas on reclaimed lands in Montana (Hodder 1977). In south central Utah McKell and Van Epps (1980) sampled runoff in five foot diameter basins that had various rates of polyvinyl acetate applied to their slopes. They found that if the basin continued to slope to the bottom of the basin, e.g., no sloughing or leveling, accumulated runoff was increased with or without a stabilizing agent application. High polyvinyl acetate application rates (3800 liters concentrate/hectare) significantly increased runoff over lower rates (1900 liters concentrate/hectare) and untreated plots.

Various soil stabilizing agents also have been tested in an attempt to harvest water on 10:1 slopes (McKell and Van Epps 1980). Only polyvinyl acetate improved the integrity of the water basin slopes. However, the positive effect was maintained for only seven weeks. After one year, all surface treatments were ineffective. It is suggested that high temperatures and intense rainstorms may have negatively affected the soil stabilizing agents. Aldon and Springfield (1977) tested ground paraffin and black polyethylene in basins that contained fourwing saltbush and Siberian peashrub (Caragana arborescens) transplants. Plant growth was greater in the black polyethylene plots than in the ground paraffin plots. Both treated plots, however, stimulated more plant growth than the untreated plots. These studies indicate that water harvesting may be a useful technique for improving plant growth on reclaimed lands in arid and semiarid regions.

Surface manipulation techniques, such as deep chiseling, off-set listering, gouging and contour furrowing, may increase soil moisture on reclaimed lands by impeding runoff, increasing infiltration and increasing snow accumulation (Dollhopf et al. 1977; Hodder 1977). Water retention in surface microtopographical features may provide relatively mesic microenvironments for plant growth. The duration of their effectiveness is a function of soil texture. Microtopographical features last longer in fine to medium textured soils than in coarse soils (Hodder 1977; Vallentine 1980).

Deep chiseling loosens compacted soil to 15 to 20 centimeters. It produces a series of parallel contour furrows that retard overland flow. Off-set listering creates alternately arranged, elongated pits that effectively impede runoff. Gouging produces a series of depressions approximately 25 centimeters deep.

Contour furrows have been applied more extensively than the above treatments. The effectiveness of contour furrows depends on the width, length, and depth of the furrow, as well as soil texture. Furrows moderate surface runoff, improve water retention and infiltration, increase snow accumulation and forage production on existent rangelands in salt-desert shrublands (Hancock 1968; Wein and West 1971) and in the Northern Great Plains (Barnes 1950; Wight et al. 1978). Branson et al. (1966) reported that furrows were successful on nuttall saltbush (Atriplex nuttallii) sites but not on winterfat or black grama (Bouteloua eriopoda) sites nor on blue grama sites on coarse soils in the southwest and intermountain regions.

Lavin et al. (1981) studied effects of contour furrowing at five pinyon-juniper sites in northern Arizona. They found that furrows (5 cm

deep) increased penetration and retention of soil moisture and lowered seeding-zone temperatures. However, no significant difference was detected between furrow seeding and surface drilling. Similar results were reported by Lavin et al. (1973) and Wein and West (1971). Deeper furrows (10-15 cm) would probably have more effect on the soil moisture regime than relatively shallow furrows (5 cm). Deeper furrows may collect more precipitation and reduce solar insolation. However, sloughing from furrow sides may bury seed too deeply for germination (Lavin et al. 1981).

In desert saltbush communities of eastern Utah, 30 centimeter deep furrows appeared to stimulate plant growth and seed yield of galleta grass, mat saltbush (*Atriplex corrugata*), and nuttall saltbush (Wein and West 1971). Seed production by plants adjacent to furrows may provide a continuous natural seed source in saltbush ecosystems. Gifford et al. (1977, 1978) studied similar contour furrows in eastern Utah. Contour furrows controlled runoff and sedimentation for a brief period but because of structural failure no increase in forage production was detected near the furrow.

Mulch—Mulch serves a dual role; it ameliorates the soil environment from high temperatures and evapotranspiration while protecting the soil from erosion prior to establishment of a permanent and effective vegetation cover (Aldon et al. 1979). Mulch aids plant establishment by reducing wind and water erosion, reducing evaporation, controlling soil temperatures, increasing soil moisture, enhancing infiltration, and protecting seedlings (Aldon et al. 1979; Lavin et al. 1981; Hansen et al. 1984; Sindelar et al. 1974; Springfield 1972). In arid climates many feel mulch is often necessary for plant establishment (Packer and Aldon 1978; Thornburg 1982).

Several types of mulch are available commercially. Straw, hay, woodchips, gravel, excelsior, jute, plastic film, and hydromulch have proven effective in various environments. Advantages and disadvantages of each are summarized in Aldon et al. (1979) and Kay (1977, 1978).

Selection of mulch materials depends on site characteristics, cost, mulch effectiveness, and the plant materials used. Slope, topography, and roughness will determine the degree of taccification necessary. Excelsior blanket and jute need to be physically affixed to the soil. Straw or hay mulch may need a chemical tacifier to stabilize it on steep slopes or windy sites.

Mulch may be quite expensive in remote areas because of transportation costs. Natural materials in the site proximity, such as slash, may be inexpensive alternatives. In northern Arizona juniper slash increased the effective length of the plant growing season by increasing penetration and retention of soil moisture and decreasing surface soil temperatures. However, it did not noticeably improve seedling emergence or long-term species survival relative to bare soils (Lavin et al. 1981).

Straw is the most widely used mulch because of its cost effectiveness. In New Mexico straw mulch reduced stress and increased survival of transplanted fourwing saltbush (Aldon 1973; Aldon and Springfield 1975). Straw (2240 kg/ha) that was rototilled into mine spoils increased establishment of fourwing saltbush and alkali sacaton (*Sporobolus airoides*) (Aldon 1975). Springfield (1972) reported that straw and a white petroleum resin tacifier reduced soil moisture loss and temperatures in the top 2.5 centimeters. Crimping of straw mulch into the soil is another means of stabilizing the soil. Packer and Aldon (1978) recommend that in the

southwestern United States hay mulch (3360 kg/ha) should be crimped into mine spoils twice.

Although straw mulch has been shown to improve native plant establishment, competition from introduced grains and weeds may be detrimental to the native species. Clean straw and hay should be used to avoid unnecessary competition between weedy species and desirable seedlings (Gould et al. 1975).

Crimping or rototilling straw or hay into disturbed soils may affect soil microbial cycling and nitrogen availability to plants. Straw and hay are composed mainly of carbon. Carbon additions to soils provide an energy source for microbial populations. A rapidly expanding microbial population temporarily may immobilize existing soil nitrogen (Alexander 1977). If additional sources of nitrogen are not added to the soils, plants may experience nitrogen deficits and plant growth may be limited.

The degree of nitrogen immobilization depends in part on the soil moisture regime. In mesic environments microbial populations have a greater potential for nitrogen immobilization than in xeric environments. In semiarid climates similar to Gordon Flats, it is unlikely that the negative effect of microbial nitrogen immobilization will outweigh the positive effects of mulch on plant growth.

Revegetation.

Species Selection: Species suitability for land reclamation is determined by site characteristics, species adaptability and availability, and past land use (Coenenberg 1981; Power et al. 1979; Thornburg 1982). Climate and soils determine the macroenvironment that influences plant geography. Environmental factors such as slope, aspect and elevation modify plant distribution by creating microenvironments within the landscape.

Drought tolerance is a critical plant adaptation in semiarid regions (Vallentine 1980). Seasonal drought and low annual precipitation produce long periods of soil moisture deficits. Prolonged drought, in conjunction with high temperatures, create a high evapotranspiration potential. Reclamation species must be selected for physiological and morphological adaptations to prolonged drought.

Soil properties of a site strongly influence plant community composition. Plant growth is affected by soil texture, salinity, alkalinity (Vallentine 1980), water holding capacity, depth and available nutrients (Black 1968). Indian ricegrass and sand dropseed (Sporobolus cryptandrus), for example, are better adapted to coarse, sandy well-drained, infertile soils, whereas blue grama is adapted to fine clay soils as well as coarse to medium sandy soils (Brown and Wiesner 1984).

Plant Materials: In areas where precipitation is not limiting, seeding is recommended over transplanting because it is more cost effective. However, even in mesic environments seeding of shrubs and trees have exhibited only limited success (Aldon and Pase 1981; Plummer et al. 1968; Van Epps and McKell 1980). In arid environments fourwing saltbush (Gould et al. 1975; Aldon and Springfield 1975) and shadscale (Atriplex confertifolia) (Wein and West 1971) have been seeded successfully.

Transplanting live plant materials has been researched on disturbed sites. Live transplant materials include bare-root seedlings and saplings, cuttings, sod and containerized transplants. Live plant material should be planted in moist soil just prior to peak seasonal precipitation (Vallentine 1980; Jensen et al. 1979).

In most intermountain regions, soil moisture conditions are suitable for transplanting during spring and fall. July and August thunderstorms have replenished soil moisture after summer drought. Conversely, winter snow accumulation provides moisture for spring growth.

In south central Utah, McKell et al. (1980) found little difference between spring and fall transplants. Call et al. (undated) observed similar survival rates of spring and fall transplanted containerized shrubs. Frischknecht and Ferguson (1979), however, reported that spring transplanting of container-grown plants at Sand Wash, Utah was necessary to ensure establishment of chenopod shrubs.

Bare-root stock generally is shrub or tree species that have been grown in beds for 1 to 2 years. Harvesting and planting should occur while the plant material is dormant. In mesic areas (>30cm precipitation) bare root-stock has been shown to be equally as successful as containerized stock (Monsen et al. 1979).

Although more expensive than bare-root stock, containerized stock is preferred in arid environments, because the roots are already in contact with the soil. The root ball helps the plant to survive until environmental conditions permit root growth. Van Epps and McKell (1980) found that survival of containerized shrubs was greater than bare-root transplants in the salt desert of eastern Utah.

Cuttings are sometimes used in wet or moist sites. Willow (Salix spp.) cuttings may be quite successful if soil moisture is adequate during the growing season (Plummer et al. 1968; Monsen et al. 1979). Oldman wormwood (Artemisia abrotanum) cuttings establish readily on disturbed sites within its range (Plummer et al. 1968).

Seeding: Seedings of native perennial grasses in pinyon-juniper ecosystems generally have been successful in areas with greater than 30 centimeters precipitation. In sites that receive less than 30 centimeters of precipitation, seeding results have been inconsistent (Gould et al. 1975; Van Epps and McKell 1980).

Seeding of a selected seed mixture should consider seedbed preparation, proper planting season, seeding method and seeding rate. Seedbed preparation has been discussed above with site preparation.

Season—Seedings generally should occur prior to the longest period of favorable growing conditions (Vallentine 1980). In the pinyon-juniper woodlands, the wettest months are July to October. Precipitation events consist primarily of intense thunderstorms. Late spring and early summer seedings may be washed out if the seedbed has not been properly prepared. High temperatures may allow germination of warm-season species but preclude germination of cool-season species. Warm-season species, including fourwing saltbush and winterfat, probably should be planted in late spring (Lavin et al. 1968; Springfield 1970).

Late fall seedings have been recommended for cool-season species in the southwest (Lavin et al. 1968; Plummer et al. 1968). Soil moisture accumulates during winter and is available for seed germination when temperatures are suitable. Fall seeding allows cold stratification, which is often necessary for shrub seed germination (Plummer et al. 1968; Vories 1981). Loss of seed to rodents also is reduced by late fall seeding. Fall seedings, however, may be subjected to winter wind erosion if mulch has not been applied or if soil has not been compacted over the seed (Packer and Aldon 1978).

Seed mixtures of cool- and warm-season species may be planted during late fall or in late spring depending on their respective species

composition. If time and resources permit, phased seedings would probably enhance reclamation success. Forbs, shrubs and warm-season species could be seeded in late spring and cool-season species interseeded one to three years later. Phased seedings minimize competition from cool-season grasses prior to establishment of warm-season species.

Seeding Method—Seeding success depends on good seed to soil contact, proper seed covering and soil compaction (Hansen et al. 1984; Packer et al. 1979; Vallentine 1980). Drill seeding is usually preferred over broadcast seeding because it theoretically achieves more precise planting depth and seeding rate, more uniform seed cover, and better contact between seed and soil. It is a one-step process and uses less seed than broadcasting (Plummer et al. 1968; Thornburg 1982; Packer et al. 1979; Vallentine 1980).

Broadcasting is more suitable in small, uneven or inaccessible terrain. Diverse seed mixtures, especially those with small fluffy seeds that often clog drill tubes, are more easily dispersed by broadcasting. Broadcasting may require mechanical covering of the seed and seeding rates twice that of drilling (Vallentine 1980). Both techniques have been successful in various environments but drill seeding has been preferred in the southwestern U.S. (Currier 1973), probably for historical and traditional reasons.

Seeding Rate—Seeding rate influences stand density and development. A heavy rate may intensify intra- and interspecific competition, whereas a light rate may not adequately protect the soil from erosion.

Seeding rate depends on seed size, seed purity, the desired plant density, seeding method and site characteristics. Broadcast seeding rates should be double those of drill seeding (Packer and Aldon 1978; Thornburg 1982; Vallentine 1980). Unfavorable sites generally require more seed than favorable sites (Plummer et al. 1968). The U.S. Soil Conservation Service (Thornburg 1982) has published an excellent publication on semiarid and arid land seeding and planting characteristics which includes appendices on seed sizes and seeding rates.

DESCRIPTION OF THE AFFECTED ENVIRONMENT

The Tar Sand Triangle Special Tar Sand Area is located on the Colorado Plateau in south central Utah (Figure 1). It is situated north and west of the Colorado River and between the Dirty Devil River to the west and the Green River to the east. Forty-five percent of the lease unit lies within Glen Canyon National Recreation Area. It lies west of and above the Orange Cliffs area. The lease boundary is 5 to 10 kilometers west of Canyonlands National Park.

The area is characterized by flat-topped mesas, vertical cliffs, and deep canyons that have resulted from the differential erosion of geologic strata. Mesa tops, between 914 and 2011 meters in the lease unit, are Wingate Sandstone capped by the Kayenta Formation. Outcrops of these two formations form the Orange Cliffs. The Chinle and Moenkopi Formations form steep slopes below the Orange Cliffs. The White Rim Sandstone of the Cutler Formation forms broad mesas at the base of the Moenkopi Formation.

The tar sand is located in the White Rim Sandstone. It is composed of fine quartz grains and is very friable. Stratigraphic studies indicate that the White Rim Sandstone is probably a nearshore, shallow water marine sandstone (Baars & Seager 1970). The White Rim Sandstone with a maximum thickness of 92 meters is exposed below the Orange Cliffs and dips northwest at 18 meters per kilometer.

In about 6% of the lease unit, mesa tops are covered with Begay soils. They are coarse, loamy, mixed, mesic Ustollic Camborthids, 114-178 centimeters deep. Sagebrush and grasses dominate these well-drained soils on Flint and Gordon Flats.

Begay soils have low reclamation potential due to their shallow depths, infertility, poor seeding potential, and inability to retain water. If disturbed, they are susceptible to wind erosion (USDA-SCS 1983).

In approximately 32% of the lease unit, mesa tops have shallow Mellenthin soils. They are loamy-skeletal, mixed, mesic, lithic Ustollic Calciorthids. Pinyon-juniper woodland characteristically occurs on this soil type.

All soil types support cryptogamic soil crusts. Cryptogams are composed of nitrogen-fixing bacteria and algae that help to stabilize the soil against erosion and improve soil fertility. There is a positive correlation between crust development and soil silt content. The soil crusts are most extensive in valley bottoms.

The Tar Sand Triangle has a semiarid climate modified by topography and elevation. Three year averages (1981-1983) for precipitation and temperature at Hans Flat Ranger Station in Glen Canyon National Recreation Area reflect short-term climate in the lease unit (Table 1). No long-term data is available for Hans Flat (USDI 1984). Annual average precipitation is 30 centimeters. The majority falls in March and July through October. The average minimum temperature is -5.7°C in January.

Topography strongly influences local surface air movement. Air flows down through the canyons and river drainages during the cool nights and early mornings and rises in the afternoons. The wind direction is generally southwest. Canyonlands National Park is downwind from the proposed tar sand development.

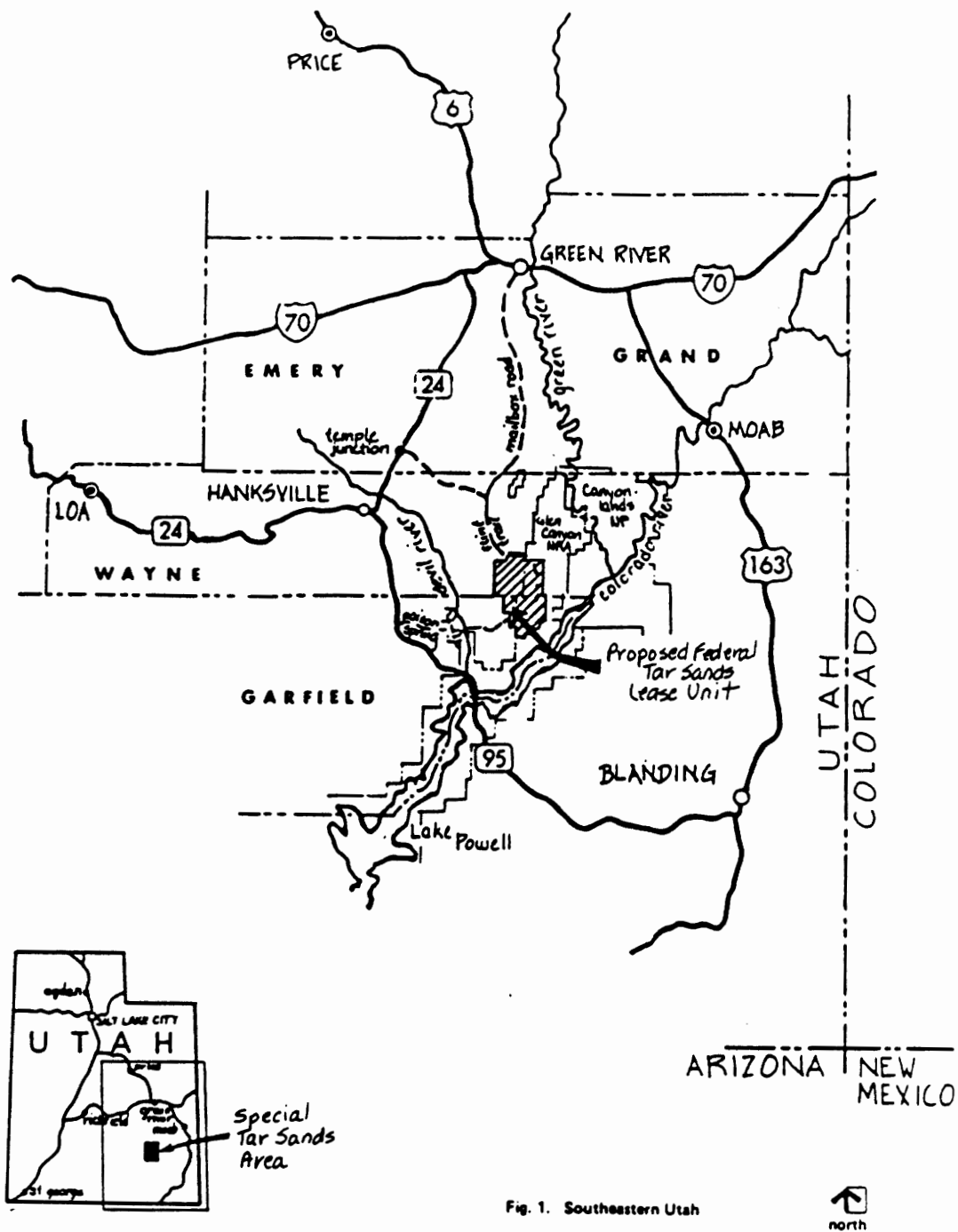


Fig. 1. Southeastern Utah

Figure 1. Regional setting of the Tar Sand Triangle Special Tar Sand Area.

Table 1. Three-year (1981-1983) temperature (°C) and precipitation (cm) averages at Hans Flat Ranger Station, Glen Canyon National Recreation Area, Utah (3643 m).

Climate	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.*	Oct.	Nov.	Dec.	Annually
Precipitation	1.1	0.8	3.1	1.7	1.4	2.2	3.9	3.8	4.2	3.9	2.9	1.3	30.3
Temperature													
Mean	-0.8	1.0	3.9	8.0	13.0	19.5	22.7	22.2	18.7	10.1	4.4	0.9	9.8
Mean Maximum	4.1	6.1	9.0	14.0	19.5	26.6	29.6	28.7	24.8	15.6	8.7	3.8	15.6
Mean Minimum	-5.8	4.1	1.2	1.9	4.5	12.4	15.7	15.6	12.7	4.5	-0.1	-5.6	4.0

* September data was estimated (U. S. Dept. of Commerce 1983).

EXPERIMENTAL RECLAMATION PLAN

SITE DESCRIPTIONS

Four disturbed sites on Gordon Flats were chosen for the reclamation study (Figure 2). All sites are located in Township 30S, Range 16E, 38°10'N, and 110°10'W. Three disturbed sites are located in the pinyon-juniper woodland and the fourth site is located in a big sagebrush-blue grama community.

Site One

The drill pad in Township 30S, Range 16E, Section 3, NE1/4 is estimated to be 20 to 30 years old. Its elevation is 2020 meters, and its topography is level (Figure 3). The area of disturbance is 0.12 hectares.

Native vegetation of Site One is pinyon-juniper woodland. Pinyon pine and juniper dominate the landscape with big sagebrush, rabbitbrush (Chrysothamnus viscidiflorus), green Mormon tea, roundleaf buffaloberry, and snakeweed as the most common shrubs. Blue grama and sandhill muhly (Muhlenbergia pungens) are the dominant grasses. Galleta grass and indian ricegrass are also common.

The drill pad has been invaded by native species since the initial disturbance. Several junipers have successfully established on the site. The largest juniper is seven feet tall. Pinyon pines have also established. The oldest is approximately seven years old. Rabbitbrush (Chrysothamnus viscidiflorus and C. nauseosus) are the dominant shrubs. Big sagebrush is also present. The dominant forbs include fineleaf hymenopappus, Douglas' senecio, and snakeweed. Lobeleaf senecio and hymenoxys are also common. Narrowleaf yucca (Yucca angustissima) is abundant at the western edge of the pad. Astragalus spp., owllover (Orthocarpus spp.) and hoary townsendia (Townsendia incana) occur occasionally. Blue grama and sandhill muhly are present, but infrequent.

Undisturbed and disturbed soils are sandy loams. These soils are deficient of nitrate-nitrogen (Table 2). Undisturbed soils belong to the Mellenthin Series (USDI 1984). No cryptogams were noted, possibly because the soil has been trampled by cattle. The site has been moderately grazed.

Site Two

This site (T30S, R16E, S10, N1/2) is a road that was cut in an east-southeast direction from the county road through pinyon-juniper down to a blue grama flat. (Figure 4). The elevation ranges from 1965 to 2002 meters along the 350 meter long road. The disturbed area is approximately 0.28 hectares with a slope of 15°.

Vegetation of the area is a pinyon-juniper woodland very similar to that of Site One. Although shrub diversity is similar, shrub density is less. Big sagebrush is more abundant than at Site One. Single-leaf ash (Fraxinus anomala) is also present. The tree canopy is denser than at Site One. The dense overstory reduces the understory noticeably. Cryptogams are abundant here, possibly because of greater soil moisture and clay content of the site and reduced cattle trampling.

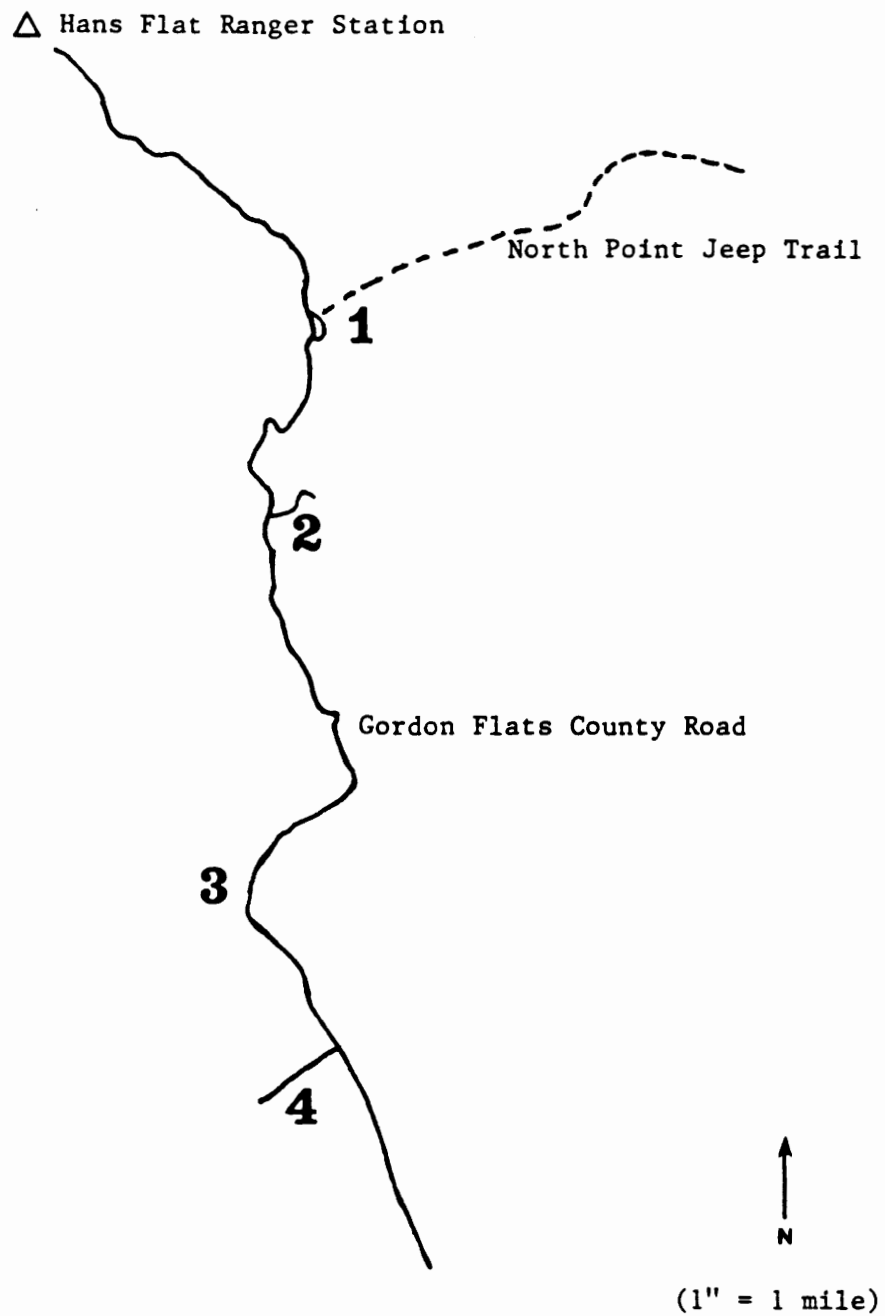


Figure 2. Experimental reclamation site locations on Gordon Flats in Glen Canyon National Recreation Area, Utah.

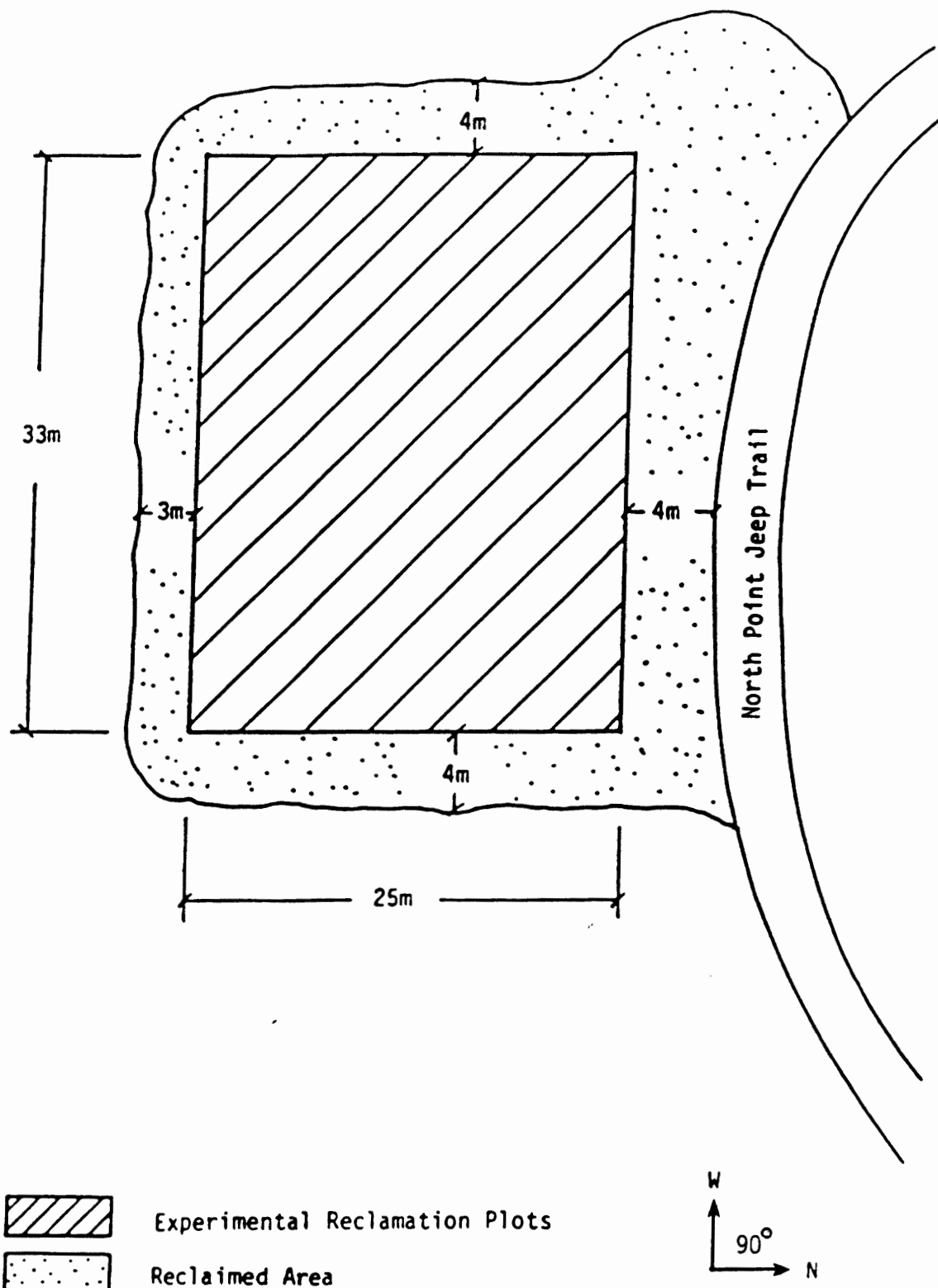


Figure 3. Experimental reclamation plots and reclaimed area at Site One on Gordon Flats in Glen Canyon National Recreation Area, Utah.

Table 2. Native and disturbed soil analyses of four experimental reclamation plots on Gordon Flats in Glen Canyon National Recreation Area, Utah.

Soil Parameters *	Native Soils				Disturbed Soils			
	Site One	Site Two	Site Three	Site Four	Site One	Site Two	Site Three	Site Four
pH	8.3	8.2	8.0	8.0	8.2	8.2	8.4	7.8
Electrical Conductivity (mmhos/cm)	0.2	0.3	0.3	0.3	0.4	0.3	0.4	6.3
Calcium Carbonate Equivalent (%)	2.5	0.9	12.2	2.1	3.4	2.0	8.8	2.2
Organic Matter (%)	0.3	0.4	1.8	0.6	0.5	0.5	0.4	0.5
Nitrate-Nitrogen (ppm)	<1	<1	1.0	1.0	3.0	<1	3.0	16.0
Phosphorus (ppm)	0.5	2.1	1.8	2.1	2.5	0.6	0.8	3.7
Potassium (ppm)	34.0	86.0	130.0	279.0	86.0	32.0	161.0	218.0
Zinc (ppm)	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2
Iron (ppm)	2.1	3.0	4.6	2.0	4.4	2.2	1.6	1.9
Manganese (ppm)	1.5	0.9	2.5	0.7	1.5	0.6	0.7	0.9
Copper (ppm)	0.2	0.5	1.0	1.1	0.5	0.2	0.3	1.1
Calcium (meq/l)	2.0	2.3	2.6	2.3	3.5	2.2	1.7	26.0
Magnesium (meq/l)	0.5	0.5	1.3	0.8	1.3	1.1	1.9	10.6
Sodium (meq/l)	0.1	0.1	0.2	0.1	0.2	0.1	0.4	27.4
Sodium Adsorption Rate	0.1	0.1	0.1	0.1	0.1	0.1	0.3	6.4
Texture	SL	SCL	SCL	SCL	SL	SCL	SCL	SCL

*Legend

mmhos/cm: micromhos per centimeter

%: percent

ppm: parts per million

meq/l: milliequivalents per liter

SL: sandy loam

SCL: sandy clay loam

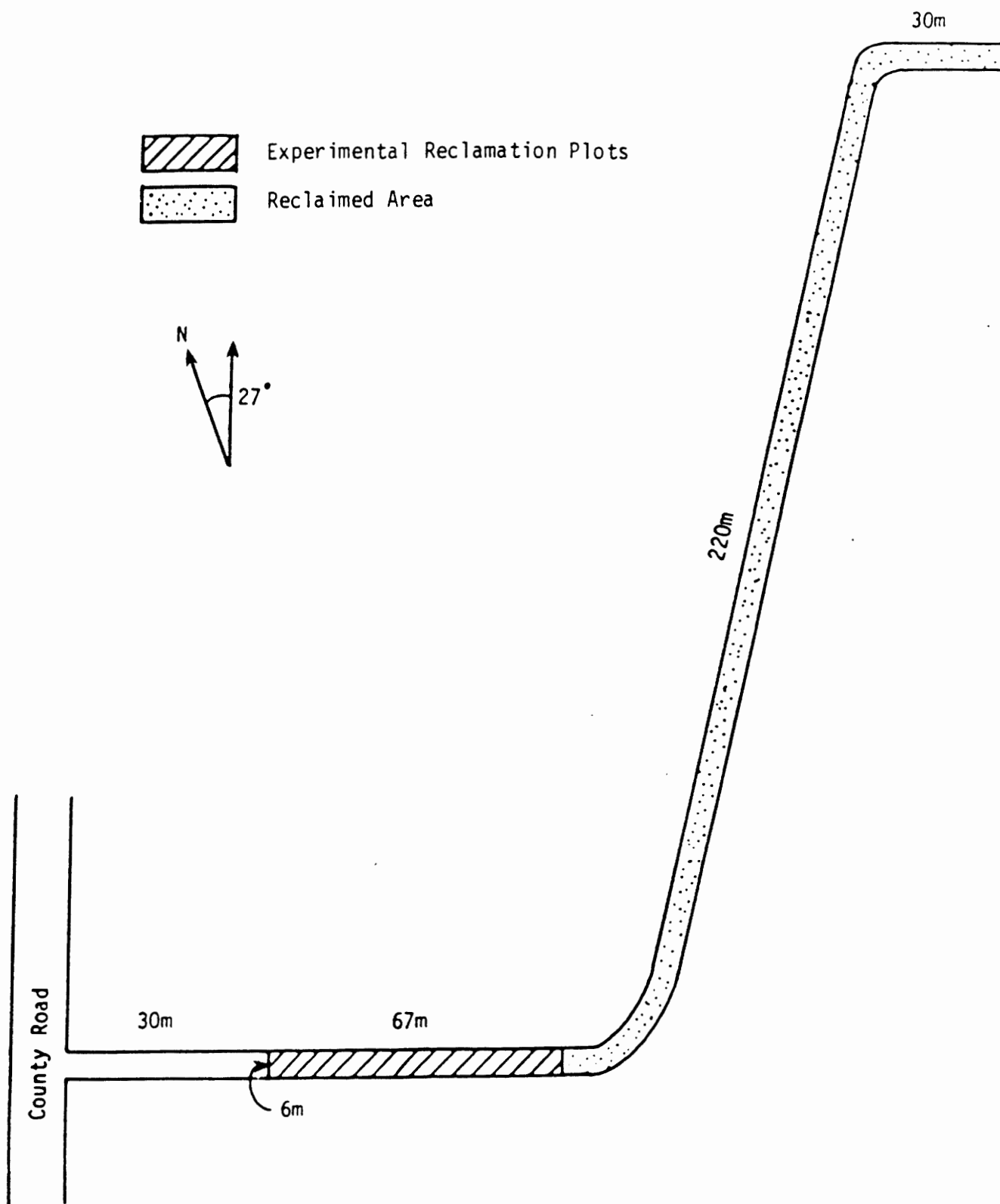


Figure 4. Experimental reclamation plots and reclaimed area at Site Two on Gordon Flats in Glen Canyon National Recreation Area, Utah.

Undisturbed soils of Site Two belong to the Mellenthin Series (USDI 1984). The sandy clay loams exhibit little structure or horizonation and lack nitrate-nitrogen. Little difference, except for potassium, is observed between the native and undisturbed soils (Table 2).

Site Three

The site (T30S, R16E, S22, NW1/4) is located in a pinyon-juniper woodland. This drill pad was cut near the head of a drainage channel on Gordon Flats. Elevation is approximately 1938 meters. The site is fairly level, and the disturbed area is about 0.40 hectares (Figure 5). Vegetation of the surrounding area is similar to that found at Sites One and Two.

Undisturbed soils near this site belong to the Mellenthin Series (USDI 1984). They are more developed, however, than those at the other pinyon-juniper sites. A calcic horizon exists below 23 centimeters in the deeper soils, whereas sandstone is encountered at 15 centimeters in the shallower soils. The soils are browner, less red, and contain more clay. Potassium is somewhat higher in the disturbed soils than in the native soils (Table 2).

Site Four

This drill pad (T30S, R16E, S27, NW1/4) disturbance occurs in a big sagebrush-blue grama community. The elevation is 1974 meters, and the site is fairly level and heavily grazed. Total disturbed area is approximately 0.70 hectares (Figure 6).

Big sagebrush is the dominant shrub on both the disturbed and adjacent native areas. However, snakeweed, a sub-shrub, is quite abundant on the disturbed area. The most common forbs are yellow beeplant (Cleome lutea), lobeleaf senecio, and globemallow. Dragonhead (Moldavica parviflora) is locally abundant along the edge of the disturbed area. Although big sagebrush is the dominant shrub in the native community, fourwing saltbush and winterfat are common locally. Plantain (Plantago purshii) is abundant in this community. Snakeweed, lobeleaf senecio, and Opuntia sp. occur occasionally. Blue grama is the dominant grass. It may form dense mats that dominate between sagebrush individuals. Pure blue grama stands, some 0.10 hectares, occur to the east of the disturbed site. Sandhill muhly is present, but uncommon.

The native soils of the big sagebrush-blue grama community belong to the Begay Series. They are deep, fine, sandy clay loams of depositional origin. The cambic horizon occurs from 1 to 33 centimeters. A hard B_{3ca} horizon was observed at 33 centimeters. Blue grama roots do not appear to reach below this level. Big sagebrush roots, however, do attain this and greater depths. Like the Mellenthin soils, the Begay soils are very deficient in nitrate-nitrogen and phosphorus. The electrical conductivity and the sodium adsorption rate are noticeably higher in the disturbed soils than in the native soils (Table 2).

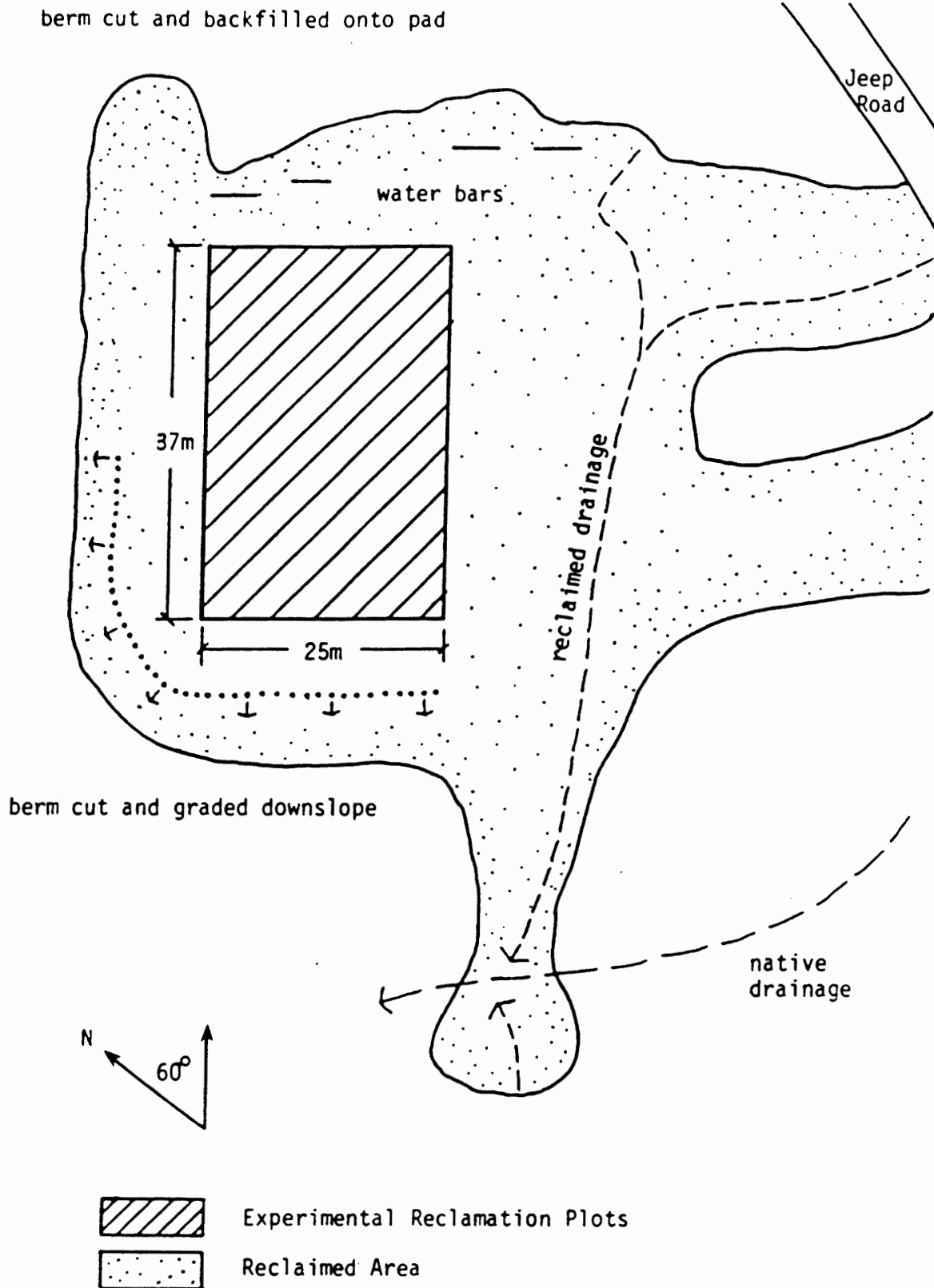


Figure 5. Experimental reclamation plots and reclaimed area at Site Three on Gordon Flats in Glen Canyon National Recreation Area, Utah.

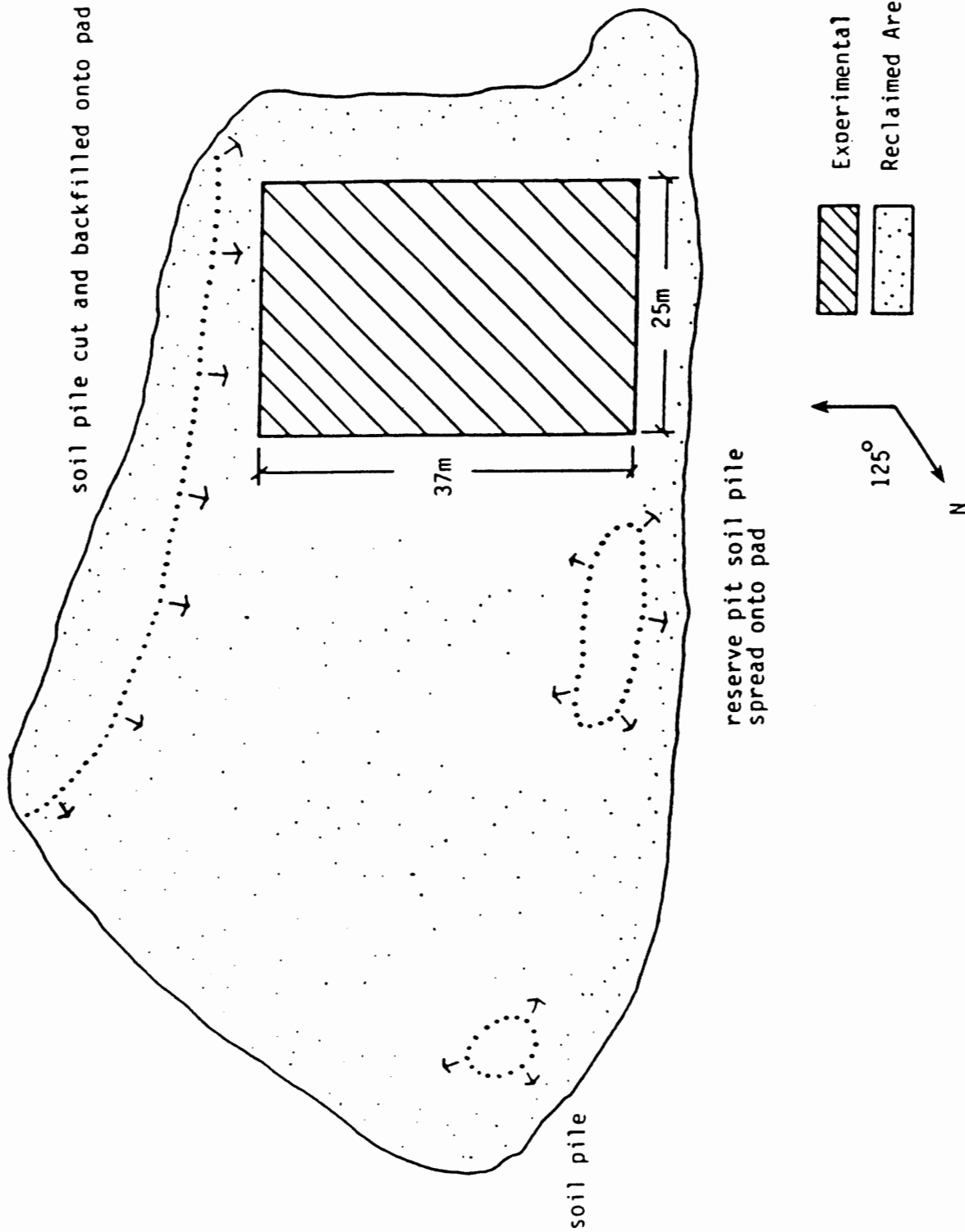


Figure 6. Experimental reclamation plots and reclaimed area at Site Four on Gordon Flats in Glen Canyon National Recreation Area, Utah.

METHODS

Experimental Design

Site Preparation. The experimental reclamation sites were graded to approximate the natural topography and were ripped and harrowed following removal of existing vegetation from the site. The intensive study areas were fenced with five strands of barbed wire. Two and one-half centimeter wire mesh was attached to the bottom 60 centimeters of fence to exclude large rodents. Planting occurred between November 15 and December 12, 1984.

The enclosed areas were 825 square meters at Site One, 402 square meters at Site Two, 925 square meters at Site Three, 925 square meters at Site Four. Seeding Experiment. The seeding experiment examines species responses to two seeding rates (14 kg/ha PLS, 28 kg/ha PLS), three mulch treatments (no mulch, straw mulch (3360 kg/ha), slash), and two methods of seeding (broadcast, drill). The species mix and rates that were planted are presented in Tables 3 and 4. The seeding rates were determined on a pure live seed (PLS) basis. Pure live seed is a product of the purity and germination of a seed lot. The experimental design is a split-split-plot with three replications. There are twelve treatments per block. The experimental design is repeated at sites One (Figure 7), Two (Figure 8), and Three (Figure 9). At Site Two the block has only one replication (Figure 8). At Site Four (Figure 10) the same treatments are replicated three times, except that a different species mixture is used (Table 4). Keys to the treatment symbols are presented in Table 5.

Control plots on disturbed areas are located at Sites Three and Four. Data that is collected from the control plots is combined and compared to the various treatments.

Dependent Variables: The U.S. National Park Service has directed this study's emphasis towards restoration of the landscape to approximate its native condition. In the experimental plots species responses to various treatments is tested. Cover and frequency of each species is evaluated within and between sites.

Two trees, seven shrubs, one forb, and four grass species have been selected for the four reclamation sites (Table 6). The ecological characteristics of these species have been reviewed in Appendix A. Littleleaf mountain-mahogany (Cercocarpus intricatus), Culter's Mormon tea (Ephedra culteri), roundleaf buffaloberry, grizzlybear pricklypear (Opuntia erinacea), narrowleaf yucca and sandhill muhly frequently occur in the area. They were not included in either the seeding or transplant experiment because seeds or containerized transplants were unavailable.

Independent Variables: Three variables were selected for the seeding experiment: seeding method, seeding rate, and mulch. These variables were selected because of their importance to reclamation practices. Fertilization, another often utilized reclamation treatment, was not selected for this experiment. Fall seeding was chosen over spring seeding. A review of each variable's significance to reclamation is presented above in "Reclamation Techniques" (p. 12). Only key references and principles are illustrated below.

Late fall seeding provides several advantages relative to spring seeding. Fall seeding allows soil moisture accumulation during winter, so that it is available for seed germination when temperatures are suitable. Plant growth then may be sustained through summer drought by stored soil

Table 3. Seeding rates for Sites One, Two, and Three of the seeding experiment on Gordon Flats in Glen Canyon National Recreation Area, Utah.

Species	Seeding Rate PLS (kg/ha)				Species Composition	
	Rate A		Rate B		% by weight	% by # of seed
	Broadcast	Drill	Broadcast*	Drill		
<i>Bouteloua gracilis</i>	2.80	2.80	5.60	5.60	20.00	0.23
<i>Hilaria jamesii</i>	1.12	1.12	2.24	2.24	8.00	0.02
<i>Oryzopsis hymenoides</i>	2.24	2.24	4.48	4.48	16.00	0.04
<i>Sporobolus cryptandrus</i>	0.22	0.22	0.45	0.45	1.61	0.14
<i>Sphaeralcea coccinea</i>	0.11	0.11	0.22	0.22	0.78	6.10
<i>Artemisia tridentata</i>	0.23	0.23	0.45	0.45	1.61	64.33
<i>Cercocarpus montanus</i>	1.68	1.68	3.36	3.36	12.00	8.39
<i>Cowania mexicana</i>	1.68	1.68	3.36	3.36	12.00	12.12
<i>Ephedra viridis</i>	2.24	2.24	4.48	4.48	16.00	6.21
<i>Pinus edulis</i>	1.68	1.68	3.36	3.36	12.00	2.42
	14.00	14.00	28.00	28.00	100.00	100.00

* Seed mix also seeded on unexclosed, disturbed areas.

Table 4. Seeding rates for Site Four of the seeding experiment on Gordon Flats in Glen Canyon National Recreation Area, Utah.

Species	Seeding Rate PLS (kg/ha)				Species Composition	
	Rate A		Rate B		% by weight	% by # of seed
	Broadcast	Drill	Broadcast*	Drill		
<i>Bouteloua gracilis</i>	2.80	2.80	5.60	5.60	20.00	0.19
<i>Hilaria jamesii</i>	1.12	1.12	2.24	2.24	8.00	0.02
<i>Oryzopsis hymenoides</i>	2.80	2.80	5.60	5.60	20.00	0.04
<i>Sporobolus cryptandrus</i>	0.22	0.22	0.45	0.45	1.61	0.12
<i>Artemisia tridentata</i>	0.23	0.23	0.45	0.45	1.61	56.19
<i>Atriplex canescens</i>	2.24	2.24	4.48	4.48	16.00	11.29
<i>Ceratoides lanata</i>	1.68	1.68	3.36	3.36	12.00	20.03
<i>Ephedra viridis</i>	2.80	2.80	5.60	5.60	20.00	6.79
<i>Sphaeralcea coccinea</i>	0.11	0.11	0.22	0.22	0.78	5.33
	<u>14.00</u>	<u>14.00</u>	<u>28.00</u>	<u>28.00</u>	<u>100.00</u>	<u>100.00</u>

* Seed mix also seeded on unexclosed, disturbed areas.

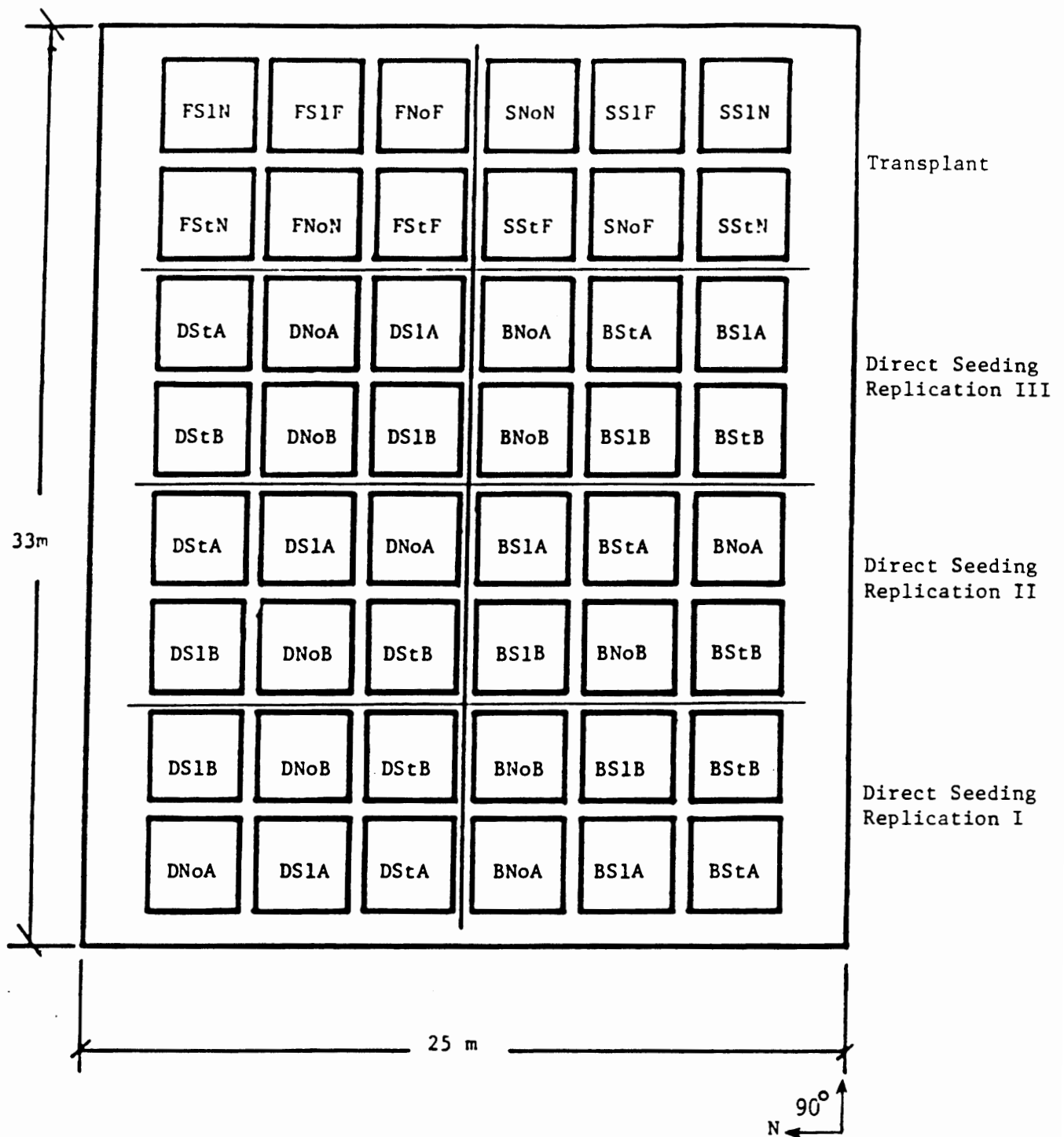


Figure 7. Experimental reclamation plot design for Site One on Gordon Flats in Glen Canyon National Recreation Area, Utah.

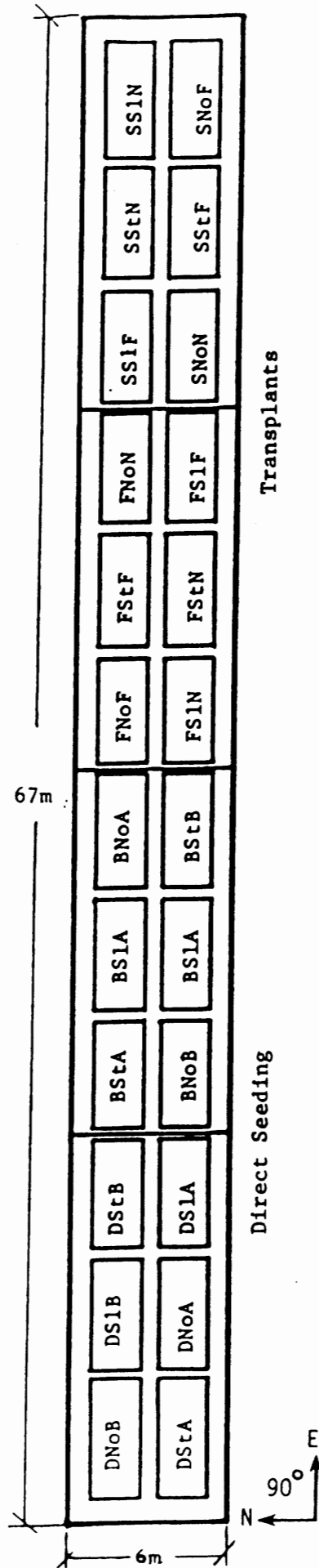


Figure 8. Experimental reclamation plot design for Site Two on Gordon Flats in Glen Canyon National Recreation Area, Utah.

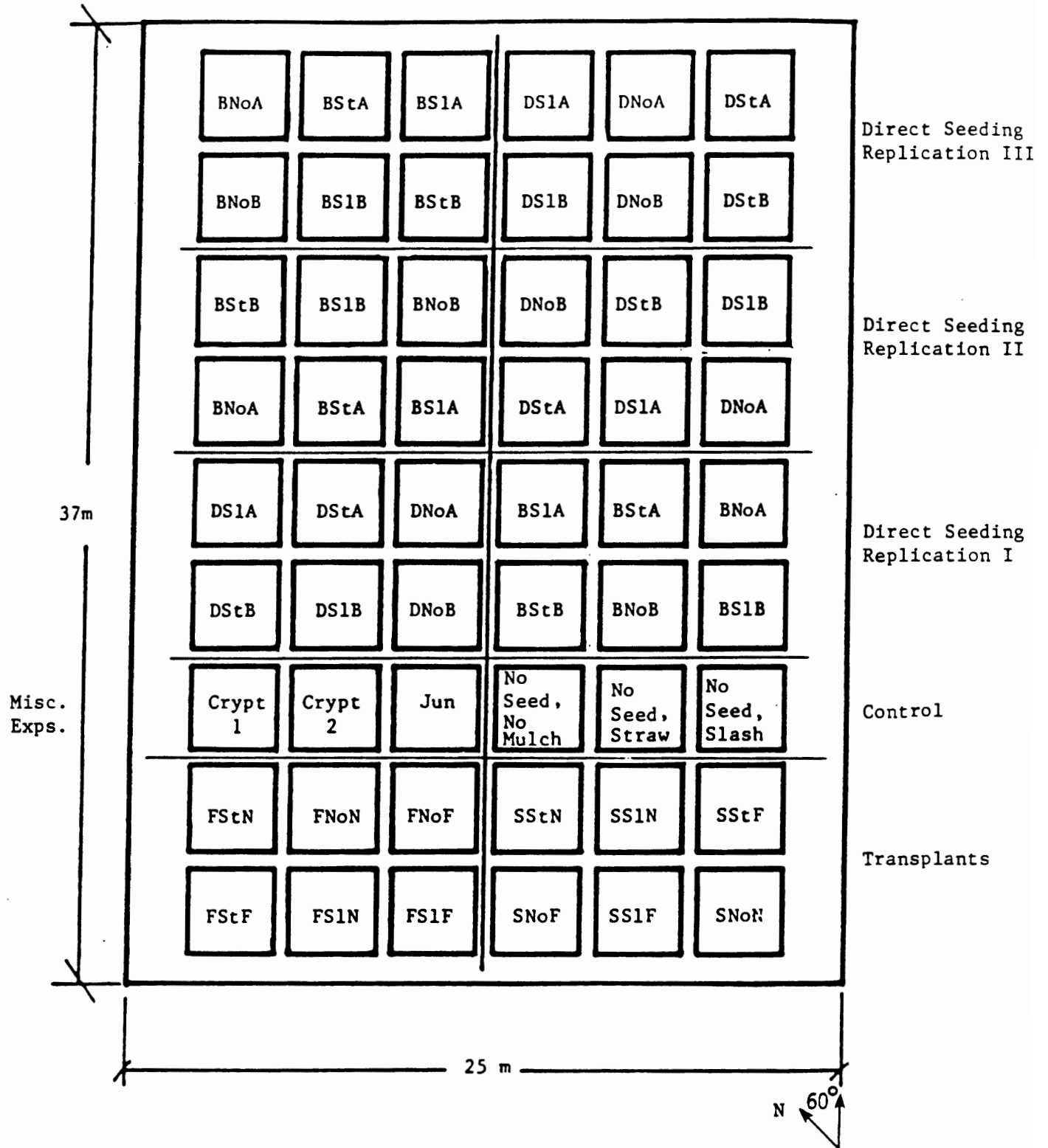


Figure 9. Experimental reclamation plot design for Site Three on Gordon Flats in Glen Canyon National Recreation Area, Utah.

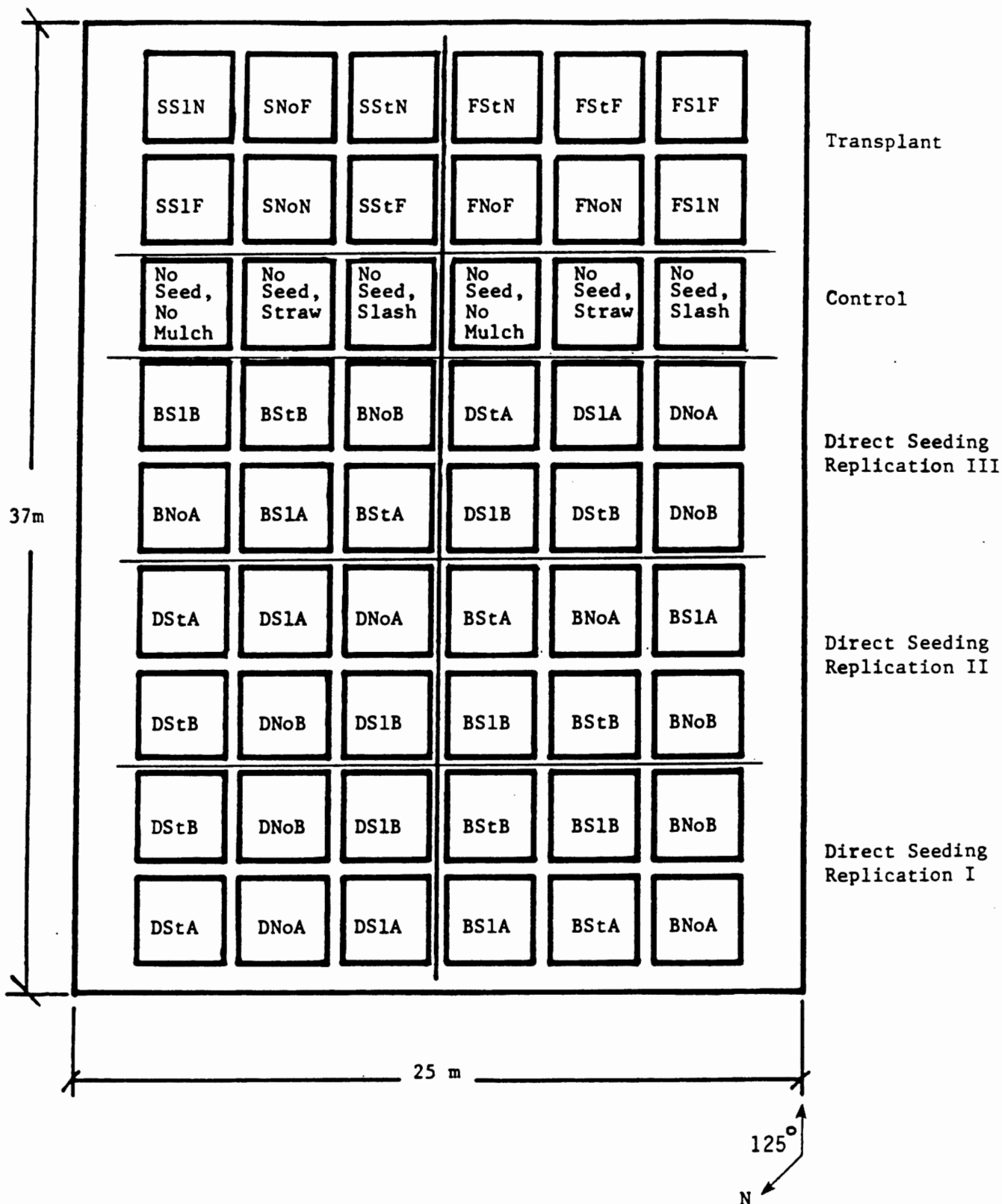


Figure 10. Experimental reclamation plot design for Site Four on Gordon Flats in Glen Canyon National Recreation Area, Utah.

Table 5. Key to treatment symbols for experimental reclamation plots on Gordon Flats in Glen Canyon National Recreation Area, Utah.

TRANSPLANT EXPERIMENT

Acronym:Description

FNoN: Fall; No mulch; No furrow
 FNoF: Fall; No mulch; Furrow
 FStN: Fall; Straw mulch (3360 kg/ha); No furrow
 FStF: Fall; Straw mulch (3360 kg/ha); Furrow
 FSIN: Fall; Slash; No furrow
 FSIF: Fall; Slash; Furrow
 SNoN: Spring; No mulch; No furrow
 SNoF: Spring; No mulch; Furrow
 SStN: Spring; Straw mulch (3360 kg/ha); No furrow
 SStF: Spring; Straw mulch (3360 kg/ha); Furrow
 SSIN: Spring; Slash; No furrow
 SSIF: Spring; Slash; Furrow

SEEDING EXPERIMENT (Fall Only)

Acronym:Description

ENoA: Broadcast; No mulch; Rate A (14 kg/ha PLS)
 ENoB: Broadcast; No mulch; Rate B (28 kg/ha PLS)
 BStA: Broadcast; Straw mulch (3360 kg/ha); Rate A (14 kg/ha PLS)
 BStB: Broadcast; Straw mulch (3360 kg/ha); Rate B (28 kg/ha PLS)
 BSlA: Broadcast; Slash; Rate A (14 kg/ha PLS)
 BSlB: Broadcast; Slash; Rate B (28 kg/ha PLS)
 DNoA: Drill; No mulch; Rate A (14 kg/ha PLS)
 DNoB: Drill; No mulch; Rate B (28 kg/ha PLS)
 DStA: Drill; Straw mulch (3360 kg/ha); Rate A (14 kg/ha PLS)
 DStB: Drill; Straw mulch (3360 kg/ha); Rate B (28 kg/ha PLS)
 DSlA: Drill; Slash; Rate A (14 kg/ha PLS)
 DSlB: Drill; Slash; Rate B (28 kg/ha PLS)

MISCELLANEOUS EXPERIMENTS*

Acronym:Description

Crypt1: Cryptogams (1 shovelful/m²)
 Crypt2: Cryptogams (2 shovelfuls/m²)
 Jun: Juniper (11.1 seeds/m²)

* These plots are present only at Site Three.

Table 6. Species planted in experimental reclamation plots on Gordon Flats in Glen Canyon National Recreation Area, Utah.

<u>Species</u>	<u>Transplant Experiment</u>	<u>Seed Mix Sites 1,2,3</u>	<u>Seed Mix Site 4</u>	<u>Miscellaneous Experiments</u>
<u>Trees</u>				
Pinus edulis	X	X		
Juniperus osteosperma				X
<u>Shrubs</u>				
Amelanchier utahensis	X			
Artemisia tridentata	X	X	X	
Atriplex canescens	X		X	
Ceratoides lanata			X	
Cercocarpus montanus	X	X		
Cowania mexicana		X		
Ephedra viridis	X	X	X	
<u>Grasses</u>				
Bouteloua gracilis		X	X	
Hilaria jamesii		X	X	
Oryzopsis hymenoides		X	X	
Sporobolus cryptandrus		X	X	
<u>Forbs</u>				
Sphaeralcea coccinea		X	X	
<u>Cryptogams</u>				X

moisture until peak precipitation occurs in late summer and early fall (Table 2). Cold stratification, especially for shrubs, often is necessary for seed germination (Plummer et al. 1968). Winter wind erosion, however, may damage fall seedlings if the soil is unprotected by mulch or compaction (Packer and Aldon 1978). Spring seeding may be less successful because of difficult seeding conditions, such as wet soils and bad weather, that adversely affect accurate seeding depths and rates. Frozen ground during late winter seedings preclude good seed to soil contact.

Seeding Method—Two methods of seeding are being tested: drill seeding and broadcast seeding. Both techniques have been successful in a variety of environments. Drill seeding is often preferred over broadcasting because of more precise planting depth, more uniform seed covering, and better contact between seed and soil (Plummer et al. 1968; Thornburg 1982). Broadcasting, however, is more suitable for small areas or inaccessible terrain. Small fluffy seeds that often clog drill tubes are more easily dispersed by broadcasting. Broadcast seeding achieves a more "natural" appearance because it does not leave rows on the landscape.

Seeding Rate—The seeding rate was determined by growth form, seed size, recommended seeding rates (Brown and Wiesner 1984; Hansen et al. 1984; Plummer et al. 1968; Redente et al. 1984) and the local environment (Table 1). Seeding rate is based on density of pure live seed (PLS) per square meter. The relatively light seeding rate (14 kg/ha PLS) is one-half of the heavier rate (28 kg/ha PLS). Seeding rate depends on seed size, seed purity, the desired plant density, seeding method and site characteristics. Broadcast seeding rates should be double those of drill seeding (Packer and Aldon 1978; Thornburg 1982; Vallentine 1980).

Mulch—This experiment tests three mulch treatments on species survival and development: no mulch, straw (3360 kg/ha), and slash. Straw is the most widely used mulch for soil stabilization mainly because of its relatively low cost. Straw enhanced fourwing saltbush survival at the Navajo Mine in New Mexico (Aldon and Springfield 1975). Gould et al. (1975) observed that weed seeds in straw mulch may inhibit establishment of native range plants. Therefore, clean straw should be used.

Slash is dead woody material, e. g., branches and stems. It is readily available after clearing of pinyon-juniper woodlands. Proximity of mulch material to disturbed areas suggests that slash may have potential in reclamation plans. In northern Arizona juniper slash did not noticeably improve seedling emergence or long-term species survival relative to bare soils. However, plants under juniper slash did experience a longer growing season (Lavin et al. 1981).

Non-Selected Variables—Disturbed soils of the four test sites are nitrogen deficient, suggesting, perhaps, that fertilization may improve plant growth. However, their respective native soils are also quite deficient of nitrate-nitrogen (Table 2). Because of its high application cost, the arid environment, published research results, and the reclamation objective, fertilizer was not selected as a treatment variable.

Transplant Experiment. The transplant experiment tests two water retention techniques (no furrow, furrow), three mulch treatments (no mulch, straw mulch (3360 kg/ha), slash) and two planting seasons (fall, spring) on shrub and tree transplants. The species transplanted were: big sagebrush, green Mormon tea, fourwing saltbush, pinyon pine, Utah serviceberry, and true mountain mahogany (*Cercocarpus montanus*) (Table 6). The experimental design is split-plot with one replication (Figures 7 - 10). Twelve treatments are being tested. The treatments were repeated at all sites. However, the

species planted at each site varied. At Sites One, Two, and Three, big sagebrush, green Mormon tea, pinyon pine, Utah serviceberry, and true mountain mahogany were planted. Only big sagebrush, green Mormon tea, and fourwing saltbush were planted at Site Four.

Planting Season: Spring outplanting of containerized plant material is recommended for most environments (Plummer et al. 1968). At Hans Flat, soil moisture should be sufficient for adequate root growth and plant establishment prior to the dry winter or summer months. Winter and spring snows replenish soil moisture for spring growth. At Hans Flat precipitation also is relatively plentiful from July through October (Table 1). Soil moisture is probably adequate for root development from mid-September through November. Either plants should be established prior to freezing temperatures, or they should be dormant prior to planting in order to minimize transplant mortality. Fall planting may be successful on Gordon Flats.

Research conducted in Bryce National Park (Call et al. undated) and in south central Utah (McKell et al. 1980) support this hypothesis. McKell et al. (1980) reported good fall transplanting survival ($\bar{X}=48\%$) of containerized shrub transplants. However, spring planting survival was greater ($\bar{X}=61\%$). Call et al. (undated), on the other hand, found that the survival rate of transplanted containerized shrubs was not different between fall planting and spring planting. Vastly different site environments and conflicting results in the literature, suggest that containerized transplants may be planted during late fall and early spring in the experimental reclamation plots on Gordon Flats.

Mulch: Three mulch treatments (described on p. 51 above) were applied to the containerized shrub transplant plots. Mulch reduces soil temperatures, increases soil moisture, and stabilizes the soil (Lavin et al. 1981; Springfield 1972). Straw mulch reduced stress of transplanted fourwing saltbush seedlings (Aldon 1973).

Furrow: Contour furrows were utilized as a water retention technique in the transplant experiment. The furrows were approximately 12 centimeters deep, 15 centimeters wide and 3 meters long. The furrows were oriented along the contour.

Contour furrows may increase soil moisture by collecting precipitation and decrease evaporation by reducing solar insolation (Bertrand 1965). Plants growing in contour furrows may experience reduced evapotranspiration rates which, in turn, may positively affect plant growth and seed production. Even plants growing near contour furrows may grow faster and produce more seed than plants 3 meters away (Wein and West 1971).

Non-Selected Variables: As earlier mentioned, native and disturbed soils of the four test sites on Gordon Flats are nutrient deficient (Table 2). Application of fertilizer, especially nitrate-nitrogen, may alleviate the depauperate nutrient status of these soils.

Research of containerized shrub response to fertilization is limited on the Colorado Plateau. Generally, fertilization has little effect on growth and survival of containerized field transplants. However, research has been limited to only a few species.

Van Epps and McKell (1980) and McKell et al. (1980) studied fertilizer treatments on containerized transplants in northeastern Utah and on the Henry Mountain coal field in south central Utah, respectively. They found little positive response to fertilizer by big sagebrush, fourwing saltbush and winterfat. They suggested that any positive response probably was caused by supplemental water and not fertilizer additions.

The literature suggests that fertilization of containerized shrub transplants does not improve plant survival. This study does not test species responses to fertilization.

Miscellaneous Experiments. In addition to the transplant and seeding experiments, two less sophisticated experiments were initiated at Site Three (Figure 9). These experiments could not be repeated at all sites because of the different site dimensions.

Cryptogams: Cryptogamic soil crusts were collected to a depth of 5.0 centimeters with a shovel from native, undisturbed sites and placed on two, 9 square meter plots at relatively light (1 shovelful/m²) and heavy rates (2 shovelfuls/m²). The cryptogams were mixed with the disturbed soil to a depth of 5.0 centimeters and raked smooth.

Utah Juniper: Native juniper seeds were harvested from nearby trees in December. The pericarps were removed, and the seed coats were scarified with a file. One hundred scarified seeds were seeded 2.5 centimeters deep on one, 9 square meter plot. The plot was raked to cover the berries.

Implementation

Site Preparation. Earth-moving on the four reclamation sites began on November 9, 1984 by Carl Hunt of Hunt Services, Inc., Hanksville, Utah. Using a D-7 caterpillar dozer, existing vegetation was bladed off Site One. Earth was moved from the uphill side to the downhill side of the site. Topsoil depth then was at least 25 centimeters throughout the site. The pad was ripped to approximately 41 centimeters. Sandstone was encountered and broken at the lower end of the site. Rocks that were brought to the surface were removed from the area to be fenced.

The dozer work left an uneven soil surface crossed by dozer tracks. The surface was smoothed by dragging chains that were weighted by a log behind the dozer. Because some dozer ruts were still present, an I-beam was chained to a pickup and driven over the site. A weighted harrow is also useful for this purpose. During surface ripping and smoothing, some soil compaction occurred. Soil compaction could be reduced if the processes were accomplished concurrently. Furthermore, a smooth soil surface is not as important on large disturbed areas, as it was for the experimental plots. In fact, surface modifications may be desirable to enhance water retention.

Earth movement at Site Two was begun and completed on November 9, 1984. First, berms adjacent to the road were pulled back onto the road with the dozer. Second, the road surface was ripped to approximately 61 centimeters and graded. Several deep cat tracks remained near the bottom of the road because of deep, soft sand. They were smoothed out by pulling an I-beam and chains behind the dozer on its last uphill pass.

Site preparation at Site Three was accomplished on November 9 and 10, 1984. Grading began by removing the existing vegetation from the exclosure area only. Small trees and large shrubs on the adjacent disturbed area were not disturbed. Berms that were created during drill pad construction were pulled back onto the site and the dirt spread out. An existent drainage channel was regraded and diverted away from the experimental plot area. All edges between disturbed and undisturbed areas were smoothed. Finally, the site was graded to blend in with the undisturbed topography.

After earth movement was completed, the former drill pad was cross-ripped from 40 to 60 centimeters deep. The adjacent disturbed areas were ripped along the contour to an equal depth. The soil surface was smoothed by an I-beam pulled behind the dozer.

Hunt's Service, Inc. prepared Site Four on November 10 and November 11, 1984. Sagebrush and snakeweed were scraped off the experimental plot area, but were left on adjacent disturbed areas. Large earth piles that were created during pad construction were reduced and spread over the entire disturbed area. The earth was graded to approximate the native topography. Soil depth on the reclaimed site was 30 to 40 centimeters.

Subsurface and surface compaction was disrupted by ripping. The experimental plot area was cross-ripped, whereas adjacent disturbed areas were ripped along the contour. Because of the moist loose soil, cat tracks were still present after ripping, even though an I-beam and chains were pulled behind the dozer. A harrow pulled behind a pickup smoothed most of the depressions.

During the grading and ripping sequence, the dozer teeth ripped and uncovered the drilling mud reserve pit. In addition to the drilling mud, the reserve pit contained many lengths of drilling rig cable. As the dozer passed over the pit, the cable and mud clods were spread above and below the soil surface of the site. The drilling mud and the cable continuously interrupted reclamation efforts. It is suggested that reserve pits be sufficiently deep to prevent their being unearthed during reclamation of drill pads.

Fence Construction. Fence construction of the four exclosures was completed between November 10 and November 12, 1984 by Hunt Services, Inc., Hanksville, Utah. A five strand, barbed wire and an H-type, corner post, construction was utilized. Corner post holes were dug 0.6 to 1.0 meter deep. Juniper posts were placed in the holes and earth compacted around them. Metal fence posts were driven 0.3 to 0.6 meters deep at 4 meter intervals along the exclosure sides. Five strands of barbed wire were wired at 15 centimeter increments to the fence posts. Large rodents were excluded from the exclosure by 2.5 centimeter diameter, wire mesh fencing attached to the lower 60 centimeters of the exclosure. The lower 15 centimeters of fencing was bent outward and covered with earth.

Revegetation. The seeding, transplant (fall planting season only) and miscellaneous experiments were implemented between November 15 and December 9, 1984. Disturbed areas adjacent to the reclamation exclosures were seeded concurrently. Implementation procedures were similar at all sites, except where noted. The reclamation sub-contractor was Mountain West Environments, Inc. of Steamboat Springs, Colorado. Plant materials were purchased from Native Plants, Inc., Salt Lake City and Weddle Native Gardens, Palisade, Colorado.

Reclamation treatment plots were delineated within exclosures by string laid across the length and width of the exclosure. Then nine meter square plots were located and marked first with lath and later with rebar. Plot layouts are depicted in Figures 7 to 10. Treatment plots were raked prior to planting to level the surface and to remove rocks.

Drill seeding was accomplished by maneuvering a Truax rangeland drill with a small garden tractor. The drill was calibrated on site at 14 kg/ha PLS. Initially, the drill was backed onto the appropriate treatment row. Then the drill tubes and seed agitator were engaged. The tractor pulled forward and drilled three treatment plots consecutively, before the drill was disengaged. Two passes over the treatment row by the drill were made for the higher seed rate (28 kg/ha PLS). Seed drilled between plots was removed with a shovel.

The seed mixture for Site Four could not be drill seeded at the minimum rate of 14 kg/ha PLS using standard calibration techniques because the

light, fluffy winterfat seeds clogged the seed tubes. Rice hulls were added to the seed mix to increase seed flow but the attempt failed. To attain the minimum seed rate, the wheel drive shaft had to be advanced manually while the drill was moving. This procedure increased the seed flow. Several trials on the adjacent disturbed area were needed to calibrate the procedure properly. If disturbed areas within big sagebrush-blue grama ecosystems are to be drill seeded, a separate seed box for winterfat may be necessary.

Broadcast seeded treatment plots were hand seeded with premeasured seed (14 and 28 kg/ha PLS) of the appropriate seed mix (Tables 3 and 4). Then the seed was raked into the soil to cover it.

After seeding, straw (3360 kg/ha) and slash (10-20% cover) were applied by hand to their respective treatment plots. Plastic netting was placed over the straw and stapled in place. Juniper and pinyon branches were the slash material used at Sites One, Two and Three. Big sagebrush debris was stapled to slash treatment plots at Site Four.

After the treatment plots were raked, they were delineated into a grid of equally spaced units. Furrows (15 cm wide, 3 m long, 12 cm deep) were dug in rows along the contour in the appropriate treatment plots. Containerized shrubs and trees were planted equidistant from one another in the furrows and in treatment plots without furrows. Straw mulch and slash was applied to the appropriate treatment plots.

Containerized Utah serviceberry, big sagebrush, mountain mahogany, green Mormon tea, and pinyon pine were planted in the experimental reclamation, transplant plots at Sites One, Two and Three. Seven plants of each species were planted in each nine square meter plot. Plant density was 1 plant/0.25 square meter. Containerized big sagebrush, fourwing saltbush and green Mormon tea were planted at Site Four. Six plants per species were planted in each treatment plot. Plant density was 1 plant/0.50 square meter. Transplant density was less at Site Four than the other three sites, because Site Four occurs in a big sagebrush shrubland-blue grama grassland ecotone.

Spring transplanting occurred between March 7 and March 11, 1985. At each site the species planted in spring were identical to those planted in the fall. The lone exception was green Mormon tea. Because of winterkill in the nursery, it was not available for the spring planting season.

The cryptogam treatment plots were installed at Site Three on November 18 as described on page 56. The Utah juniper experiment was implemented on December 9 using methods described on page 56.

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APPENDIX A

AUTOECOLOGICAL CHARACTERISTICS OF SPECIES
SELECTED FOR RECLAMATION EXPERIMENTS
AT GLEN CANYON NATIONAL RECREATION AREA, UTAH

Presented below and annotated in Table 8 are descriptions of native species selected for reclamation experiments at Glen Canyon National Recreation Area. Species selection was based on synecological and autecological analyses of the Tar Sand Triangle at Glen Canyon National Recreation Area and the literature. These and other potential reclamation species may be obtained from suppliers listed in Crofts and McKell (1977).

Utah juniper, Juniperus osteosperma (Torr.) Little, is a small tree 3 to 6 meters tall that grows from 1300 to 2750 meters in medium to coarse, shallow soils. It produces more foliage and fruit per crown area on upland, shallow hardpan soils than on mesic soils. Its root system is adapted to various edaphic conditions. Lateral roots can compete with grasses for moisture, and its taproot is capable of rapid elongation into rock crevices (Emerson 1932). Mature trees average 92 years old and are 0.6 to 4.0 meters tall with pointed crowns. Decadent trees average 240 years old, are 2.4 to 6.1 meters tall, 15 to 26 centimeters in diameter, and have round, flat crowns (Blackburn 1967).

Juniper produces its first seeds after ten years and bears heavily every 2 to 5 years (Tueller & Clark 1975). Seed germinates in spring after a period of cold stratification.

Pinyon pine, Pinus edulis Engelm., can grow up to 15 meters tall (Cronquist et al. 1972) in areas that receive 25 to 46 centimeters precipitation annually. Generally, soils of pinyon stands are alkaline, calcareous, rocky, unproductive (Howell 1941) and do not hold moisture (Tueller & Clark 1975). Pinyon may be the slowest growing of all pine species (Zarn 1977). It may mature in 75 to 200 years, and like junipers, its maximum recorded age is over 1,000 years. Such old trees are only found on steep, rocky slopes where they have been protected from fire (West et al. 1975).

Pinyon produces its first cones at about 25 years of age, and it produces seeds every fifth year thereafter. Unfavorable climate, seed infertility, declining germination rates, and seed predation limit its reproduction and establishment (Tueller & Clark 1975).

Utah serviceberry, Amelanchier utahensis Koehne, is a shrub common in southwestern Utah. It grows on dry, rocky slopes from 610 to 2,590 meters (Blauer et al. 1975). Maximum height may reach four meters (Harrington 1964). A. utahensis does well on medium to coarse, well-drained soils of moderate depth (Stark 1966) that have a pH of 5.3 to 7.8 (White 1968).

Seed should be planted in fall (Vories 1981) to ensure that it receives cold stratification of 3 to 5°C for 1.5 months (Heit 1970). A large percentage of the seeds may be infertile or insect-infested (White 1968).

Utah serviceberry provides good forage for cattle and good browse for sheep and goats in early spring. Deer utilize it during winter. Its persistent dried fruit feeds birds and small mammals in winter and spring.

Big sagebrush, Artemisia tridentata Nutt., is an evergreen shrub 40 to 400 centimeters tall (Harrington 1964). It grows on arid plains, valleys, foothills and mountain slopes from 500 to 3,400 meters (McArthur et al. 1979) that receive 20 to 36 centimeters of precipitation annually (Brown and Wiesner 1984).

Big sagebrush is found in well-drained, moderately deep, coarse to fine soils (Sutton & Johnson 1974). Generally, maximum growth correlates with deep fertile soil (Brown & Wiesner 1984; Sampson & Jespersen 1963). It does not tolerate saline soils and prefers pH of 6.5 to 7.4 (Sutton & Johnson 1974).

Table 7. Autecological characteristics of species selected for reclamation experiments at Glen Canyon National Recreation Area, Utah.

	Habit	Elevation Range (m)	Soil Type	Planting Season	Stratification Requirements	Precipitation Requirements (cm)	Seeding Depth	Notes
<u>Juniperus osteosperma</u>	tree 3-10 m	1300-2750	medium to coarse, shallow medium	fall	increased germina- tion with 5° C for 30-122 days	20-36	2-4 cm	acid or mechanical scarification improves germination
<u>Pinus edulis</u>	tree 5-15 m	1600-2750	coarse, well- drained, deep	fall	not required; in- creased germination soaked in 20° C water for 24 hours	25-46	2-4 cm	
<u>Amelanchier utahensis</u>	shrub ≤ 4m	610-2590	medium to coarse, well- drained, medium depth	fall	3-5° C for 1.5 months	30-50	6 mm	important wildlife browse
<u>Artemisia tridentata</u>	evergreen shrub 40-400 cm	500-3400	fine to coarse, well- drained, moderate depth	fall to spring	not required; increased germination with 60 days moist chill at 3-5° C; light increases germination	20-36	6 mm	
<u>Atriplex canescens</u>	evergreen shrub 20-250 cm	≤ 2400	medium, well- drained, deep	spring	none	15-38	≤ 1 cm	salt tolerant, fire resistant, frost may damage seedlings
<u>Ceratoides lanata</u>	subshrub 40-150 cm	660-2600	medium, well- drained, deep	spring or fall	none	15-48	6 mm	salt tolerant, frost may damage seedlings
<u>Cercocarpus montanus</u>	shrub ≤ 3 m	1220-3040	medium to coarse, shallow to deep	fall	0° to 3° C for 70 days	25-58	6-12 mm	highly fire tolerant important wildlife browse
<u>Cowanisia mexicana</u>	evergreen ≤ 6 m	1220-2440	coarse to rocky well-drained	late fall	moist chill 0° to 3° C for 1 month	28-46	6-12 mm	important wildlife browse
<u>Ephedra viridis</u>	evergreen shrub 50-100 cm	900-2400	medium to coarse, shallow to medium	spring	alternating temps 10-25° C day 3-5° C night	15-25	1-2 cm	effective soil stabilizer
<u>Sphaeralcea coccinea</u>	perennial forb	900-2100	fine to coarse	fall or winter	none	15-41	2.5 cm	moderately salt tolerant
<u>Bouteloua gracilis</u>	warm-season bunchgrass & sod-former	≤ 3150	medium to fine medium- to poor- drained	mid- summer	none	20-60	≤ 1 cm	needs additional H ₂ O 6 wks after germination
<u>Hilaria jamesii</u>	warm-season bunchgrass & sod-former	1100-2300	coarse to fine well-drained	mid- summer	none	10-50	1-3 cm	poor seed establishment
<u>Oryzopsis hymenoides</u>	cool-season bunchgrass	≤ 2850	coarse, well- drained	fall or early spring	30 days cold	25-45	4-8 cm	acid scarification improves germination
<u>Sporobolus cryptandrus</u>	warm-season rhizomatous bunchgrass	≤ 2550	coarse, well- drained, shallow	fall	not required; moist chill for 60 days enhances	25-90	≤ 1 cm	winter hardy

Although big sagebrush seed germinates well without stratification, percent germination increases with up to 60 days moist chill at 3 to 5°C (Goodwin 1956). Sabo et al. (1979) found that peak germination occurred with a constant temperature of 18.5°C. Slight moisture stress has no effect on germination (Sabo et al. 1979), whereas light increases germination (Deitschman 1974; Goodwin 1956; Shepherd 1937; Weldon et al. 1959). Seed should be planted at 6 millimeters (Deitschman 1974) and will not emerge if planted deeper than 25 millimeters (Goodwin 1956). Seed may be planted from fall through spring (Deitschman 1974).

Big sagebrush is important forage on western winter livestock and game ranges. Browsers rely on it for food, while many birds and small mammals use it for cover (Brown & Wiesner 1984). Its palatability and digestibility vary widely between populations and subspecies. It is established readily from seed and transplants if moisture is sufficient. Therefore, it is useful in revegetating depleted winter game ranges and in stabilizing exposed sites (McArthur et al. 1979).

Fourwing saltbush, Atriplex canescens (Pursh.) Nutt., is a woody-based, evergreen shrub that grows from 20 to 250 centimeters tall (Vories 1981). It is found at elevations up to 2,400 meters in arid sites of the western states that receive less than 25 centimeters precipitation annually (Blauer et al. 1976). Fourwing saltbush is found on dry slopes, flats and washes probably because of its tolerance to saline and alkaline soils (Brown and Wiesner 1984) and its preference for medium textured soils (Stark 1966).

Fourwing saltbush is easily propagated from seed, transplants or stem cuttings (Blauer et al. 1976). Its seeds need no stratification and should be planted in spring when the soil temperature reaches 25°C. Warmer temperatures encourage mold and reduce germination (Brown & Wiesner 1984). Optimum seedling emergence occurs when seed is planted one centimeter deep (Williams et al. 1974). Light has no effect on germination (Springfield 1969).

Fourwing saltbush is an important forage species because of its abundance, evergreen nature, growth rate, palatability and nutritive value (Blauer et al. 1976; Plummer et al. 1968). Birds and small mammals eat its seeds, leaves, and stems. Hooved browsers, including pronghorn antelope, bison, mule deer, and mountain sheep use the plant for winter forage. The plant tolerates grazing pressure well but is better maintained if used for winter forage (Brown & Wiesner 1984).

Winterfat, Ceratoides lanata (Pursh) J. T. Howell, is a subshrub 40 to 150 centimeters tall and grows in areas that receive 15 to 48 centimeters of precipitation annually (Stark 1966). It prefers loamy soils that are 91 to 152 centimeters deep, well-drained (Stark 1966) and alkaline (Woodmansee & Potter 1971; Blauer et al. 1976).

Seed germinates best in moist environments (Hodgkinson 1975; Springfield 1968) that have a short period of cool or freezing temperatures (Stevens et al. 1977). Light has no effect on germination (Springfield 1974). Seed should be planted at a depth of 6 millimeters (Stevens et al. 1977; Springfield 1974; Statler 1967). Winterfat may be planted in late fall or early winter (Hodgkinson 1975) or in spring (Statler 1967).

Livestock, antelope, elk and deer use winterfat for winter browse (Blauer et al. 1976). It is relatively tolerant to grazing pressure. The species is a natural increaser and thus useful for increasing cover and forage, and stabilizing desert soils in Utah (Blauer et al. 1976).

True mountain mahogany, Cercocarpus montanus Raf., is a shrub, 1 to 3 meters tall (Harrington 1964), that occurs at elevations between 1,220 and 3,040 meters. It inhabits areas that receive 25 to 28 centimeters precipitation annually (Wasser 1982). It occurs on both coarse, shallow soils of south or west-facing slopes and ridges, and on moist, fertile, deep soils of canyon bottoms and north-facing slopes of lower elevations (Blauer et al. 1976).

Stratification and scarification are not necessary for germination, but alternating temperatures of 23°C (8 hours) and 11.5 to 15.5°C (16 hours) may enhance germination (Sabo et al. 1979). Light has no effect on germination, but moisture stress inhibits it (Piatt 1976). Dormancy may vary with ecotypes (Deitschman et al. 1974), and germination may vary with seed source (Piatt 1976). Seed should be planted between 6 and 12 millimeters deep in the fall (Deitschman et al. 1974).

Cercocarpus montanus is important browse for big game in the southwest (Sabo et al. 1979). It is grazed in summer and winter and is especially important winter browse for deer (Blauer et al. 1976).

Mexican or Stansbury cliffrose, Cowania mexicana var. stansburiana (Torr.) Jepson, is an evergreen shrub that grows up to 6.0 meters tall. It inhabits dry, rocky foothills and mesas, often in association with pinyon and juniper trees that receive 28 to 46 centimeters of precipitation annually (Blauer et al. 1976). It occasionally occurs in big sagebrush and salt desert shrub types (Blauer et al. 1976). Cliffrose prefers deep, well-drained, rocky to coarse soils (Sutton & Johnson 1974) which are dry and have a pH of 7.0 to 8.0 (Stark 1966).

Stratification may enhance germination. Moist chill for 1 month at 3 to 5°C increased germination (Heit 1970). Laboratory tests indicate that germination also occurs at constant temperatures of 12.2 to 13.9 °C (Springfield 1973) or at alternating temperatures between 30°C in the day and 10°C at night (Heit 1970). Germination does not require light (Heit 1968). Planting should be done in fall or early winter at a depth of 6 to 12 millimeters (Alexander et al. 1974).

Stansbury cliffrose is an important browse plant for cattle, sheep and deer in winter. However, phenolic compounds in certain populations make it unpalatable (Blauer et al. 1976).

Green mormon tea, Ephedra viridis Coville, is an evergreen shrub 50 to 100 centimeters tall (Harrington 1964), that occurs between 900 and 2,300 meters in precipitation zones of 15 to 25 centimeters (Stark 1966). Seed germination may be increased by after-ripening (Kay et al. 1977). Germination occurs when temperatures are alternated between 10 to 25°C in the day and 3 to 5°C at night.

Seed should be planted in spring (Stark 1966) at 1 to 2 centimeters deep (Kay et al. 1977; Williams et al. 1974). Green mormon tea prefers dry, medium to shallow, and medium to coarse soils (Stark 1966) but is often found on limestone cliffs. It is saline-alkaline tolerant (Stark 1966). Green mormon tea seeds successfully, and its deep, extensive root system make it useful for soil stabilization.

Galleta grass, Hilaria jamesii (Torr.) Benth., is a warm-season, native species which forms both bunches and sod. It is found in medium to heavy textured soils and will tolerate moderate salinity. It is drought tolerant. If summer precipitation is abundant, galleta grass can initiate several phenological cycles (Everett et al. 1980).

Germination occurs over a wide range of temperatures (West et al. 1972). Maximum germination was achieved when temperature was constant at

32° C, whereas 85% germination occurred with constant temperatures between 15° and 32° C (Knipe 1967; 1968). Light has no effect on germination (Sabo et al. 1979).

Scarlet globemallow, Sphaeralcea coccinea (Pursh) Rydb., is a small perennial forb that may grow to 25 centimeters. It grows from 900-2100 meters (McKell et al. 1979) in areas that receive 15 to 41 centimeters precipitation annually, and it inhabits most soil textures (McKell et al. 1979). Seed should be planted in fall or winter because cold stratification may enhance seed germination. Although it is not required, scarification, may also aid seed germination (Wasser 1982). Its widely spreading rhizomes help stabilize disturbed soils.

Indian ricegrass, Oryzopsis hymenoides (Roem. and Schult.) Ricker, is a cool-season, native perennial bunchgrass. It inhabits sandy soils on upland slopes and ridges that receive 25 to 45 centimeters of precipitation annually (Brown & Wiesner 1984). It is adapted to infertile, well-drained sites and neutral pH. It is moderately salt tolerant.

Seeds can remain dormant for several years. Cold stratification of 30 days is necessary for germination and therefore seeds should be planted in fall or early spring when temperatures are below freezing. Acid scarification also improves germination (Wasser 1982).

Indian ricegrass is a valuable forage grass on western rangelands. It is highly nutritious and palatable to livestock, big game, birds, and mammals, throughout the growing season and during the winter. Although it will tolerate grazing if carefully managed, this species is considered a decreaser (Brown & Wiesner 1984).

It is an important reclamation species on coarse infertile soils in arid and semi-arid regions (Brown and Wiesner 1984). Although indian ricegrass is not an effective soil stabilizer, it should be planted in conjunction with rhizomatous species.

Sand dropseed, Sporobolus cryptandrus (Torr.) A. Gray, is a warm-season perennial, rhizomatous bunchgrass. It is adapted to shallow, coarse, sandy, soils of low fertility and neutral pH. It may be found at elevations up to 2,550 meters where precipitation is between 25 and 90 centimeters annually. It is moderately tolerant of saline conditions, and it is drought tolerant and winter hardy (Brown & Wiesner 1984).

Alternating temperatures of 35 to 37°C for 8 hours and 11 to 27°C for 16 hours produced maximum germination. Light enhanced germination (Sabo et al. 1979). A two month-long cool, moist period enhances germination. Therefore, fall planting is recommended (Brown & Wiesner 1984). Although seedlings resist disease and insect infestation, they do not successfully compete with other species (Brown & Wiesner 1984).

Green growth is palatable and nutritious to livestock and large game animals but does not cure well. Sand dropseed tolerates grazing pressure and is useful in range seeding (Brown & Wiesner 1984; Sabo et al. 1979).

Blue grama, Bouteloua gracilis (H.B.K.) Lag. ex Steudel, is a warm-season perennial bunch and sod forming grass. It is one of the most common and important species of the short grass prairie. It is distributed from Canada to Mexico where precipitation is 20 to 60 centimeters annually. It occurs up to 3,150 meters in the central Rocky Mountains (Brown & Wiesner 1984).

Although it prefers fine textured soils, blue grama can grow on sandy uplands, lowlands, and slopes (Brown & Wiesner 1984). It often occurs on poorly drained sites but is intolerant of flooding. Blue grama is adapted to infertile soils, neutral pH and is tolerant of saline conditions.

Blue grama seed requires no stratification. Optimum germination occurs when temperatures alternate between 27 to 37°C for 8 hours and 35 to 37°C for 16 hours for 3 days (Sabo et al. 1979). Slight moisture stress does not inhibit germination, and light has no effect on germination (Sabo et al. 1979). Seed should be planted at depths of at least 1 centimeter (Brown & Wiesner 1984). Seedlings are not vigorous and often die between 6 to 10 weeks unless additional precipitation has stimulated adventitious root development. Seminal roots are not sufficient to support seedling establishment (Briske & Wilson 1978; Wilson & Briske 1979).

Blue grama is utilized by game, small mammals, and birds. It is the most important forage grass on the prairie, because of its rhizomatous nature and its tolerance to grazing. Blue grama roots may spread 60 centimeters laterally, thus effectively binding the soil and increasing spatially on heavily grazed land (Schuster 1964). Although production is low, its drought tolerance, palatability, grazing tolerance and rhizomatous nature, make it a desirable reclamation species.

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APPENDIX B

**IMPLEMENTATION COSTS AND CONTRACTORS
FOR THE RECLAMATION EXPERIMENTS
AT GLEN CANYON NATIONAL
RECREATION AREA, UTAH**

IMPLEMENTATION COSTS AND CONTRACTORS FOR THE RECLAMATION
EXPERIMENTS AT GLEN CANYON NATIONAL
RECREATION AREA, UTAH*

I. PROJECTED RECLAMATION COSTS

	<u>\$/Hectare</u>	<u>\$/Acre</u>
SITE PREPARATION (includes grading and contouring)	\$2,092	\$ 846
BROADCAST SEEDING (includes seeding, harrowing, materials)	916	370
TRANSPLANTING		
Labor (\$10/hour)	333	135
based on 30 transplants planted/hour and 1000 plants/hectare (405 plants/acre)		
Materials (\$0.64/plant)	640	259
TOTAL PROJECTED RECLAMATION COSTS	\$3,981	\$1,610

* Projected reclamation costs are based on large scale reclamation costs that were derived from actual costs and not from implementation costs for the experimental reclamation plots. The costs also do not include topsoil removal and replacement or crimping of mulch. Actual reclamation costs are detailed below.

II. ACTUAL RECLAMATION COSTS

A. SITE PREPARATION (Grading and Contouring)

Area (3.71 acre/1.50 hectare)

Reclamation supervisor (32 hrs @ \$20/hr) 640.00

Dozer travel to site (9 hrs @ \$65/hr) 585.00

Dozer and operator (21.5 hrs @ \$82.50/hr) 1,774.00

Dozer supervisor (4 hrs @ \$35/hr) 140.00

A. TOTAL (SITE PREPARATION)

3,139.00

B. FENCING

Area (1672')

Barbed Wire Fence (5 strand)

Labor, Materials and Equipment (\$2/ft) 3,344.00

Wire Mesh Fence

Labor (16 hrs @ \$17/hr) 272.00

Materials

24" Wire Mesh (\$25.81/roll) x 12 310.00

Tie Wire (\$3.95/roll) x 2 8.00

B. TOTAL (FENCING)

3,934.00

C. REVEGETATION

1. Subcontractor Mobilization and

Trip Preparation

Labor (55 hrs @ \$17/hr) 943.00

Equipment

4X4 Pickup (26.5 hrs @ \$13/hr), 2 604.00

Trailer, large (23.25 hrs @ \$10/hr) 232.00

Trailer, small (23.25 hrs @ \$8/hr) 186.00

Total (mobilization)

1,965.00

2. Experimental Reclamation Plot

Implementation (168 plots)

Reclamation Supervisor (92 hrs @ \$20/hr) 1,840.00

a. Plot Construction

Labor (20 hrs @ \$17/hr) 340.00

Materials

Stakes

Lath (\$6.90/100), 7 48.00

Rebar (#3) (\$0.13/f) 61.00

Flagging 3.00

Metal Tags (\$1.89/24) 15.00

b. Seeding (Drilling and Broadcasting)

Labor (84 hrs @ \$17/hr) 1,428.00

Materials

Seed 286.00

Straw (\$4.50/bale), 10 45.00

Netting (\$0.18/sq. yd), 500 sq. yd 90.00

Staples

9" (\$45.00/box) 45.00

6" (\$50.00/box) 50.00

Equipment

Tractor with drill (\$45/day) 225.00

c. <u>Transplanting</u>		
Labor		
Fall (63 hrs @ \$17/hr)	1,071.00	
Spring (93 hrs @ \$8/hr)	744.00	
(includes 40 hr travel)		
Materials		
Plants (including shipping)		
Fall	501.00	
Spring	447.00	
Straw, Netting, Staples		
included under Seeding		
<u>TOTAL (EXPERIMENTAL RECLAMATION PLOTS)</u>		7,239.00
3. <u>Reclaimed Areas (Broadcast Seeded)</u>		
Area (2.77 acres = 1.12 hectares)		
Reclamation Supervisor (8 hrs @ \$20/hr)	160.00	
Labor (\$17/hr)		
Seeding (7.25 hrs)	123.00	
Harrowing (1.5 hrs)	25.00	
Raking (6.5 hrs)	110.00	
Materials		
Seed	843.00	
Tractor with harrow (\$35/d)	35.00	
<u>Total (2.77 acres: 1.12 hectares)</u>		1,296.00
<u>C. TOTAL (REVEGETATION)</u>		10,500.00
D. <u>MISCELLANEOUS</u>		
Housing	32.00	
Per Diem (\$45/d)	1,215.00	
Truck Rental	742.00	
Gas	261.00	
Food	500.00	
<u>D. TOTAL (MISCELLANEOUS)</u>		2,750.00
<u>TOTAL RECLAMATION COSTS</u>		<u>\$20,323.00</u>

III. CONTRACTORS

Earth Moving and Fencing

Hunt's Service, Inc.
P. O. Box 215
Hanksville, Utah 84734-0215
(801) 54203241

Reclamation

Mountain West Environments, Inc.
P. O. Box 2107
Steamboat Springs, Colorado 80477
(303) 879-2313

Plant Material Suppliers

Native Plants, Inc.
9180 S. Wasatch Boulevard
Sandy, Utah 84092
(801) 943-3288

Weddle Native Gardens
3589 G Road
Palisade, Colorado 81526
(303) 464-5549