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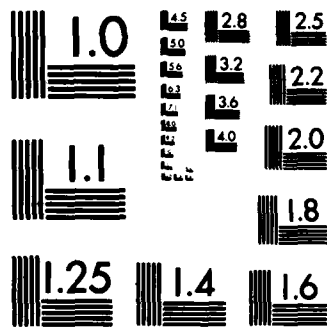
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER A132 912	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Revegetation Study of Adobe Dam, Phoenix Arizona TASK #3 Revised	5. TYPE OF REPORT & PERIOD COVERED FINAL	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) Catesby Moore Dr. Duncan T. Patten	8. CONTRACT OR GRANT NUMBER(s) DACW 09-80-M-1205	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Center for Environmental Studies Arizona State University Tempe, AZ	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Los Angeles P.O.Box 2711 Los Angeles, CA 90053	12. REPORT DATE August 1983	
	13. NUMBER OF PAGES	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for Public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are obtainable from the National Technical Information SVCS Springfield, VA 22151		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Revegetation Arid Lands		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Task No 2. "A review and Analysis of three Revegetation Projects by the U.S. Army Corps of Engineers." This report presents an analysis of revegetation projects at Dreaming Draw Dam, Cave Buttes Dam, and Bend Wash, Phoenix Arizona, and presents recommendations for arid lands revegetation.		

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Task No. 3 "Revegetation Methods for Arid Areas".

This report presents a comparison of methods of revegetation used by the Arizona Department of Transportation, mining companies in the Phoenix area, and the Desert Botanical Garden.

Task No. 4 "Site Characteristics."

This report describes the site characteristics of the Adobe Dam Study Area.

Task No. 5 & 7 Seeding Success on Topsoiled and Hard Topsoiled Slopes at Adobe Dam".

This report presents a statistical analysis of the relative success of several seeding methods used at the Adobe Dam site.

Task No. 6 "Evaluation of three watering and Molding Techniques on Transplanted Trees at Adobe Dam."

This report evaluated the relative success of alternative watering regimes and types of water used on transplanted trees of Adobe Dam.

Task 8. "Final Evaluation and Recommendation on Reclamation at Adobe Dam."

This report summarizes the findings of Tasks 2 through 7 and presents a series of specific recommendations for achieving success in arid lands revegetation projects.

Report to the U.S. Army Corps of Engineers
Los Angeles District

Task No. 3
Revised 8-18-1983

Revegetation Methods
for Arid Areas

by
Catesby Willis
and
Duncan Patten

Center for Environmental Studies
Arizona State University
Tempe, Arizona

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INTRODUCTION

In many areas in the Southwest deserts conditions favoring reestablishment of vegetation may only occur every four to seven years (Hassell 1977, Cook et al. 1974). For this reason, successful revegetation of disturbed desert lands requires special methods to prolong or take advantage of favorable moisture periods. In addition to moisture stress, soil fertility and toxicity problems are also common on areas in need of revegetation. Several agencies deal successfully with these problems. Most notable in terms of large scale revegetation efforts, are the highway departments and mining companies. Smaller organizations specialize in various aspects of revegetation such as transplanting techniques or seeding operations. This paper reviews reclamation practices currently used by the Arizona Department of Transportation, and methods recommended for revegetation of surface mining operations. In addition, transplanting techniques used by the Desert Botanical Garden in Phoenix, Arizona are briefly discussed.

Arizona Department of Transportation

Along Arizona's highways, disturbed areas are revegetated to minimize erosion and sediment damage. In addition to controlling erosion, vegetation serves to improve the aesthetic quality of the roadways. Information on the methods utilized by the Arizona Department of Transportation to establish vegetation was obtained through personal communication with E. LeRoy Brady, the Manager of Roadside Development Services for the Arizona Department of Transportation. Mr. Brady supplied his own opinions and a copy of a seeding specification for one of their many projects. Additional information was gathered from a paper by Martin Mortenson (1979), Natural Resource Planner, for the Arizona Department of Transportation.

Whenever possible, steep slopes are reduced by grading. Although the primary motive in grading steep slopes may be erosion control, conditions favoring seedling establishment are also enhanced. When steep slopes are reduced, the rate of runoff flow is slowed and there is greater water percolation into the soil. The resulting improvement in moisture conditions enhances seedling establishment.

Grading operations are preceded by soil analyses. Based on this information, required soil amendments are determined. For example, sodic conditions are treated. Mortenson (1979) reports that soils with percent exchangeable sodium in excess of ten are often often treated with 400 lbs/acre of gypsum. Given sufficient quantities of lime in the soil, 79 lbs/acre of sulfur may be used alternatively. The Department of Transportation has corrected sodic soils with exchangeable sodium as high as 39 percent by application of up to 8000 lbs/acre of gypsum or 400 lbs/acre of sulfur (Mortenson 1979). Amendments of such large quantities are rarely necessary, and when they are, burying

the excessively sodic soil with nonproblematic soil might prove to be the cheaper solution.

After ameliorating unfavorable soil conditions, fertilizer and topsoil, if available, may be applied. Mortenson (1979) stresses that site conditions vary, but nitrogen and phosphorous in amounts up to 20 lbs/acre are usually tilled into the seedbed. Caution should be exercised, because he reports that excessive fertilizer additions induce lush vegetation stands that can not be supported by the limited moisture available in roadside planting.

Tilling mixes the fertilizer into the top few inches of soil. If the site is extremely rocky, tilling depth is reduced. Tilling may even be eliminated on steep slopes. Disk harrowing, chiseling or other approved methods provide tillage for the seedbeds.

Seed mixes are specifically designed for each site and contain grasses, forbs and shrubs of indigenous species whenever possible. An exact list of species used by the Arizona Department of Transportation was not obtainable; however, many species commonly used for arid revegetation are presented in Table 1. Research on individual tolerance ranges and ecological requirements should be conducted to determine suitability to a particular site.

The combined seeding rate of the primary seedmix ranges from 20 to 60 pure live seeds per square foot. This rate may be increased for sites with harsher conditions. These sites include areas where seed is broadcasted or the seedbed is not mulched (Mortenson 1979)

Broadcast seeding is typically reserved for small seeded species. Following broadcasting, these seeds are covered by dragging or hand raking the area. However, in general, drilling is the preferred method for seeding along Arizona highways. Drilling allows control of seed planting depth, which for large seeded species is from one half to one inch (Mortenson 1979). Because proper seed coverage is crucial in germination and subsequent seedling growth, drill seeding usually results in a higher percentage of seed germination. When seeds are broadcasted, the accepted rule is to double the seeding rate (Cook et al. 1974).

In areas with high erosion potential, or low probabilities of vegetation establishment, mulch is used. A mulch cover provides soil stability and can both prolong and improve soil moisture conditions. Its positive effects result from reduction in runoff velocity and increases in water percolation into the soil. Addition of mulch will also decrease evaporation potential and reduce soil temperatures. Typically, straw or hay mulch is used by the Department of Transportation. Applied at a rate of two to two and a half tons/acre, these mulches are anchored by crimping

or tacked into place using 400 gals/acre of emulsified asphalt (Mortenson 1979; Brady, personal communication).

In special cases, transplants may be used in revegetating disturbed roadside areas. Specifications place emphasis on the health of the plant materials. They may further specify that holes for planting transplants be filled to capacity with water and allowed to drain three times prior to planting. Planting dates must occur shortly after the final filling (Anonymous 1980). This practice greatly improves soil conditions and, coupled with the addition of water directly following transplanting, can ensure favorable moisture conditions for the first few days.

Mortenson (1979) reports that over 5,000 acres of disturbed lands around Arizona's roadways were treated by the Department of Transportation over a four year period. During this period, average costs per acre for revegetation ranged from \$500 to \$700 dollars. Mortenson (1979) thinks that this initial cost can be justified by an expected reduction in long term maintenance.

Mining Companies

There are probably as many approaches to revegetating mine wastes as there are mining companies in the Southwest. Soft rock mining companies, such as those which mine coal, are required to revegetate disturbed areas and must follow strict government regulations in doing so. Hardrock mines with patented lands, such as copper mines, are not regulated as closely and revegetation, when not required, is usually not attempted. Fortunately, most mining companies are now responding to public pressure for reclaiming mine wastes. The erosion control, dust reduction and aesthetic enhancement produced through revegetation provide motivation for establishing vegetation on mine wastes. Those companies who do attempt revegetation generally utilize some or all of the following techniques for arid land revegetation as reported in a survey conducted by the Soil Conservation Service's Plant Materials Center in Tucson during a meeting of the Southwest Mine Reclamation Group (unpubl.).

Mining wastes are often associated with special soil fertility and toxicity problems. These conditions are dependent on the mining and milling operations as well as on geological site conditions. In extreme cases, where massive soil amendments are necessary, the waste material may be capped or buried by a thick layer of less problematic soil material.

Topsoil is often applied over subsoil materials which provides a seedbed higher in organic matter and fertility. In addition, it serves as a source of native seed materials specifically adapted to the site which may be otherwise unobtainable. In some cases, available topsoil materials are of low quality and may be saline or sodic in nature. When suitable topsoil is not present, subsoils are used (Cook et al. 1974).

Topsoil benefits are site dependent and proper use can best be established from soil analyses of subsoil and topsoil materials.

The extensive grading required on mine disturbances make favorable slope angles readily obtainable. Packer and Aldon (1978) recommend slopes of 20 percent or less on these recontoured areas. These slope angles favorably affect moisture conditions and reduce erosion. In addition to slope adjustments, soil surface modifications will also improve water retention. Small basins, pits or trenches create depressions for runoff collection and naturally conserve moisture. These surface modifications promote seedling establishment and are effective in arid land revegetation (Cook et al. 1974).

Fertilizers most often used in Southwest mine reclamation are combinations of nitrogen and phosphorous. They are not used in all cases, however, and the time of application is more in question than the amount. For desert sites, Cook et al. (1974) recommend the addition of 800 lbs/acre of nitrogen applied at the time of planting or at the end of the first growing season. However, Packer & Aldon (1978:443) state that a "mixture of fast and slow release fertilizers provides both immediate and longer lasting effects." They do not recommend applying fertilizer immediately following seedling emergence in dry areas.

Mining regulations often require that species indigenous to the premining site be included in the revegetation seed mix. These species are adapted to site conditions and when practical should be used. Care should be exercised because many native plant species have special germination requirements. Cook et al. (1974) recommend 20-25 pure live grass seed per square foot drilled in desert areas where special basins or pits have been constructed. Moreover, when forbs and shrubs are included in the mix, they should be seeded at three to five seeds per square foot and one to two seeds per square foot respectively. The amount of grass seed should be slightly reduced when forbs and shrubs are included in the seed mix. In addition, these rates for favorable sites should be increased by 50-100 percent for more critical sites, such as west and south facing slopes (Cook et al. 1974)

For best seeding results, seeding should be accomplished just prior to the season which receives the most dependable rainfall (Cook et al. 1974, Jordan 1981). The season to seed then will depend on the climate of the particular site to be seeded. Species typically used in arid land revegetation are listed in Table 1.

Drill seeding is more frequently used in mine reclamation than other seeding methods. A rangeland drill is preferred in the Southwest because of its high clearance and rugged construction; however, it can not be used for seeding trashy species (Packer and Aldon 1978). Broadcast seeding has also been used in establishing vegetation on mine spoils (Day and Ludeke 1980).

Various mulches are applied to seeded mine spoils depending on site conditions. The favored mulch is hay or straw crimped with a sheeps-foot roller, mulch tiller, or lightly disked into the soil. When these operations are not feasible, an asphalt emulsion is commonly used to stabilize the mulch (Cook et al. 1974). A disadvantage to using straw or hay is the introduction of weed species contained in this type of mulch. These weedy species compete for the limited moisture with seeded species. To reduce this problem, Kay (1978), recommends specifying 'clean' straw and stating a maximum weed content of 0.5 percent by weight. Another way to circumvent this problem is to use rice straw. Seeds of weedy species contained in rice straw will not usually germinate in nonirrigated areas. However, the application of rice straw is often uneven, due to a tendency for it to clump (Kay 1978).

Straw or hay can be successfully applied to a site by a straw-blowing machine or by hand. Kay (1978) found the former technique to be most effective. The rate of application by a straw-blower can be readily adjusted and the spread achieved is more uniform than with the hand broadcasted method. Recommended rates for straw or hay mulches are from 2.5 to 3.4 metric tons/acre depending on the site. It is possible, however, to apply the straw so heavily that seedlings can not penetrate the mulch layer. As a rule, some soil should be visible between the mulch fibers (Kay 1978).

Wood fiber is another commonly used mulch. It is significantly more expensive to use than straw or hay but in general requires no anchoring. Kay (1978) observed that the benefits of using a tackifier with wood fiber could be duplicated by simply increasing the mulch rate. Recommended rates of application for wood fiber are from 1,000-3,000 lbs/acre.

For all mulches, Kay (1978) notes that fiber length is a major factor in mulch stability. In general longer fibers provided greater erosion control than shorter fibers. For greatest effectiveness mulch must be used properly. Mulch cover should not be substituted for soil cover over a seeded area. For dry areas, maximum success is obtained when mulch is applied after seeds are properly covered with soil (Kay 1978).

On many mined sites irrigation may be used to guarantee adequate moisture. Without the addition of supplemental water, revegetation efforts may fail during severe drought periods unless revegetation attempts are repeated (Cook et al. 1974). However, the use of irrigation should be limited to sites where data on seasonal distribution of rainfall indicate the necessity (Verma, Thames 1975).

Transplants may be used in mining revegetation. These should be planted when soil moisture is optimum and high probabilities for weekly rainfall are high. Supplemental water may be necessary to increase transplant survivorship. Packer and Aldon

(1978:447) reported significantly lower survival of nonirrigated transplants. In addition to increased survivorship, briefly irrigated transplants were double the size of their nonirrigated counterparts.

Transplanting, as done by the Desert Botanical Garden, is highly successful. Typically, containerized transplants, one gallon in size are used. These are planted with the addition of a slow release fertilizer in a compost and sand mixture. Hose watering and drip irrigation are utilized to ensure proper moisture for all transplants. During summer months these transplants may receive daily watering to promote survival. It should be noted, however, that plant specimens in the Garden are carefully maintained for maximum show (Victor Gass personal communication).

From a brief examination of arid land revegetation practices, it can be seen that the Arizona Department of Transportation and mining companies differ only slightly in their approach. The majority of their efforts are aimed at mitigating moisture problems. These problems are dealt with through reducing slope gradients, modifying the soil surface, mulching, selecting drought hardy species and adding supplemental water if necessary. These methods, properly executed, can enhance chances of success in revegetation of arid Southwest lands.

Comparative Costs and Success

The relative success achieved by the Arizona Department of Transportation (ADOT) and the mining companies is tied directly to the costs of the revegetation projects. Costs are relative and exact figures per acre are so variable as to be difficult to compare. However, different procedures such as seeding or seed selection each carry different costs, depending on the management decision. Table 2 presents the relative cost levels and potential for improving revegetation success used by the different organizations studied. These are compared to those procedures used at Adobe Dam.

ADOT frequently uses high cost techniques but in so doing increases the potential for success. By combining slope reduction with drill seeding, mulch with tackifiers and site specific seed species, success is almost assured. These procedures are costly. However, ADOT also does soil analyses, a relatively low cost procedure that ensures success when using the other high cost revegetation procedures.

The mines have very difficult conditions and therefore must use costly revegetation procedures. Because the substrates are often very toxic, even costly operations do not guarantee success. Selection of indigenous seed species increases plant success in the macroenvironment of the mined area; however, the chemistry of the mine spoils is often so specific that site specific seed selection would enhance revegetation. Mines also use transplants but, for aesthetic reasons, large transplants with irrigation are most commonly planted. This is a costly form of transplanting and does not have the potential for success that

one finds with smaller transplants. The transplant record at the Desert Botanical Garden attests to success with small plants; however, the constant manual care of the plants is costly.

The Adobe Dam project used only a limited number of the procedures for revegetation. Most of the procedures were in the moderate range in cost, although eliminating procedures such as surface modification and retaining the natural rough surface of the fill, not only would have saved funds but improved revegetation success. One low cost procedure, soil analyses, would have allowed a more selective process for choice of seed species and thus enhance seeding success. Because certain procedures that are only moderate in cost and success were used at Adobe Dam the potential for long-term success can only be rated as moderate. This is true for both reseeding and transplants. This analyses has proven correct for reseeding, but transplanting has been highly successful in part due to favorable climatic conditions during the year following transplant and irrigation, a set of conditions one cannot always count on.

For additional information on:

- (1) Mulches for dry areas (Kay 1978)
- (2) Surface modifications to improve moisture conditions (Hodder 1977)
- (3) Irrigation for dry areas (Ries and Day 1978)

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TABLE 1:—List of Plant Species Commonly used in Arid Land
Revegetation with the Numbered References.

Species	Common Name
Grasses	
<u>Aristida</u> sp. (6)	Three Awn
<u>Bouteloua</u> sp. (4,6)	Gram Grass
<u>Distichlis stricta</u> (4,6)	Desert Saltgrass
<u>Eragrostis Lehmanniana</u>	Lehman's Lovegrass
<u>Hilaria rigida</u> (4,6)	Big Galleta
<u>Muhlenbergia porteri</u>	Bush Muhly
<u>Oryzopsis hymenoides</u> (4)	Indian Ricegrass
<u>Schismus barbatus</u> (3)	Mediterranean
<u>S. arabicus</u> (3)	Grass
Forbs	
<u>Baeria chrysostroma</u> (6)	Goldfields
<u>Baileya multiradiata</u> (2,3)	Desert Marigold
<u>Eschscholzia</u> sp. (3)	California Poppy
<u>Lotus rigidus</u> (3)	Deer Vetch
<u>Plantago insularis</u> (3)	Indian Wheat
<u>Sphaeralcea</u> sp. (2,3)	Globe Mallow
Shrubs	
<u>Ambrosia deltoidea</u> (2,6)	Triangle Bursage
<u>A. dumosa</u> (2,6)	White Bursage
<u>Atriplex canescens</u> (2,4,5)	Four-wing Saltbush
<u>A. lentiformis</u> (2,5)	Quailbush
<u>A. polycarpa</u> (2,5)	Desert Saltbush
<u>Baccharis sarothroides</u> (2)	Desert Broom
<u>Calliandra</u> sp. (3)	Fairy Duster
<u>Cassia</u> sp. (3)	
<u>Chrysothamnus nauseosus</u> (4,6)	Rubber Rabbitbush
<u>Encelia farinosa</u> (2)	Brittlebush
<u>Larrea tridentata</u> (2,6)	Creosote
<u>Santolina chamaecyparissus</u> (5)	Gray Lavender Cotton
Trees	
<u>Cercidium microphyllum</u> (3)	Foothill Palo Verde
<u>C. floridum</u> (3)	Blue Palo Verde
<u>Nicotiana glauca</u> (1)	Desert Tobacco
<u>Prosopis juliflora</u> (1)	Velvet Mesquite

- (1) Day and Ludeke 1981
- (2) Hassell 1977
- (3) James, Dan personal communication
- (4) Long 1981
- (5) Nord 1977
- (6) Thornberg and Fuch 1978

Table 2.—A comparison of the relative costs (High - H; Medium -M; Low - L) of different revegetation processes, their potential for success (High - H, Medium - M, Low - L) and their use by the Arizona Department of Transportation (ADOT), hardrock mines, Desert Botanical Garden (DBG) and the Corps at Adobe Dam (Frequent - F, Common - C, Seldom - S, Used - X).

	Rel. Cost	Success	ADOT	Mines	DBG	Adobe
Grading (Slope reduction)	H	M	F	F	-	-
Surface Modification	M	H	S	F	-	X
Soil Analyses	L	H	F	C	S	-
Soil Capping >4"-6"	H	M	C	F	-	-
Soil Amendments						
Gypsum	H	M	C	S	-	-
Sulfur	H	M	C	S	-	-
Fertilizer (e.g.,N)	H	M	S	F	F	-
Top Soil	M	H	C	F	C	X
Tilling (Dragging)	L	H	C	C	-	X
Seed Selection						
Indigenous	M	M	S	F	-	-
Site Specific	H	H	F	C	-	X
Exotic	M	M	S	S	-	-
Seeding						
Broadcast	L	L	S	S	-	-
Drilling	H	H	F	F	-	-
Hydroseed	M	M	S	S	-	X
Mulch	M	M	S	F	C	-
Mulch w/tackifier	H	H	F	S	-	-
Transplants						
Small	L	H	S	S	F	-
Large	H	M	S	C	S	X
Irrigation For Transplants	H	H	S	C	F	X

