Revegetation Plan: Pluess-Staufer (California), Inc. Mining Operations on USDA Forest Service Land, San Bernardino National Forest San Bernardino County, California

19 November 1996

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TMC 94-024

CERTIFICATION: I hereby certify that the statements furnished in this report and in the attached exhibits present the data and information required for this biological evaluation, and that the facts, statements, and information presented are true, correct, and complete to the best of my knowledge and belief.

Tierra Madre Consultants, Inc.

[signature]

Stephen J. Myers
Consulting Biologist

Date: 19 Nov 1996

Revegetation Plan: Pluess-Staufer (California), Inc. Mining Operations on USDA Forest Service Land, San Bernardino National Forest San Bernardino County, California

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Acceptance and Approval Statements

Acceptance Statement

Pluess-Staufer (California) Inc. accepts ownership of this Revegetation Plan, prepared by Tierra Madre Consultants, Inc., dated 19 November 1996. We accept this plan as our revegetation plan for quarry operations on U.S.D.A. Forest Service land, San Bernardino National Forest.

Signed: [signature] Date: 11-25-96
JIM REDDY
President
PLUESS-STAUFER (CALIFORNIA) INC.
[signature] 11-25-96

Approval Statements

The San Bernardino National Forest hereby approves the Revegetation Plan for Pluess-Staufer (California), Inc. mining operations on U.S.D.A. Forest Service land, San Bernardino National Forest, San Bernardino County, California, prepared by Tierra Madre Consultants, Inc., and dated 19 November 1996.

Signed: [signature] Date: 12-11-96
DANIEL CRAIG
District Ranger, Big Bear Ranger District
San Bernardino National Forest

The County of San Bernardino Planning Department hereby approves the Revegetation Plan for Pluess-Staufer (California), Inc. mining operations on U.S.D.A. Forest Service land, San Bernardino National Forest, San Bernardino County, California, prepared by Tierra Madre Consultants, Inc., and dated 19 November 1996.

Signed: [signature] Date: 12/18/96
For VALERY ~~FILMER~~ PILMER
Director of Planning
County of San Bernardino Planning Department

REVEGETATION PLAN: PLUESS-STAUFER (CALIFORNIA), INC.
MINING OPERATIONS ON USDA FOREST SERVICE LAND,
SAN BERNARDINO NATIONAL FOREST SAN BERNARDINO COUNTY, CALIFORNIA

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TIERRA MADRE CONSULTANTS, INC.
19 November 1996

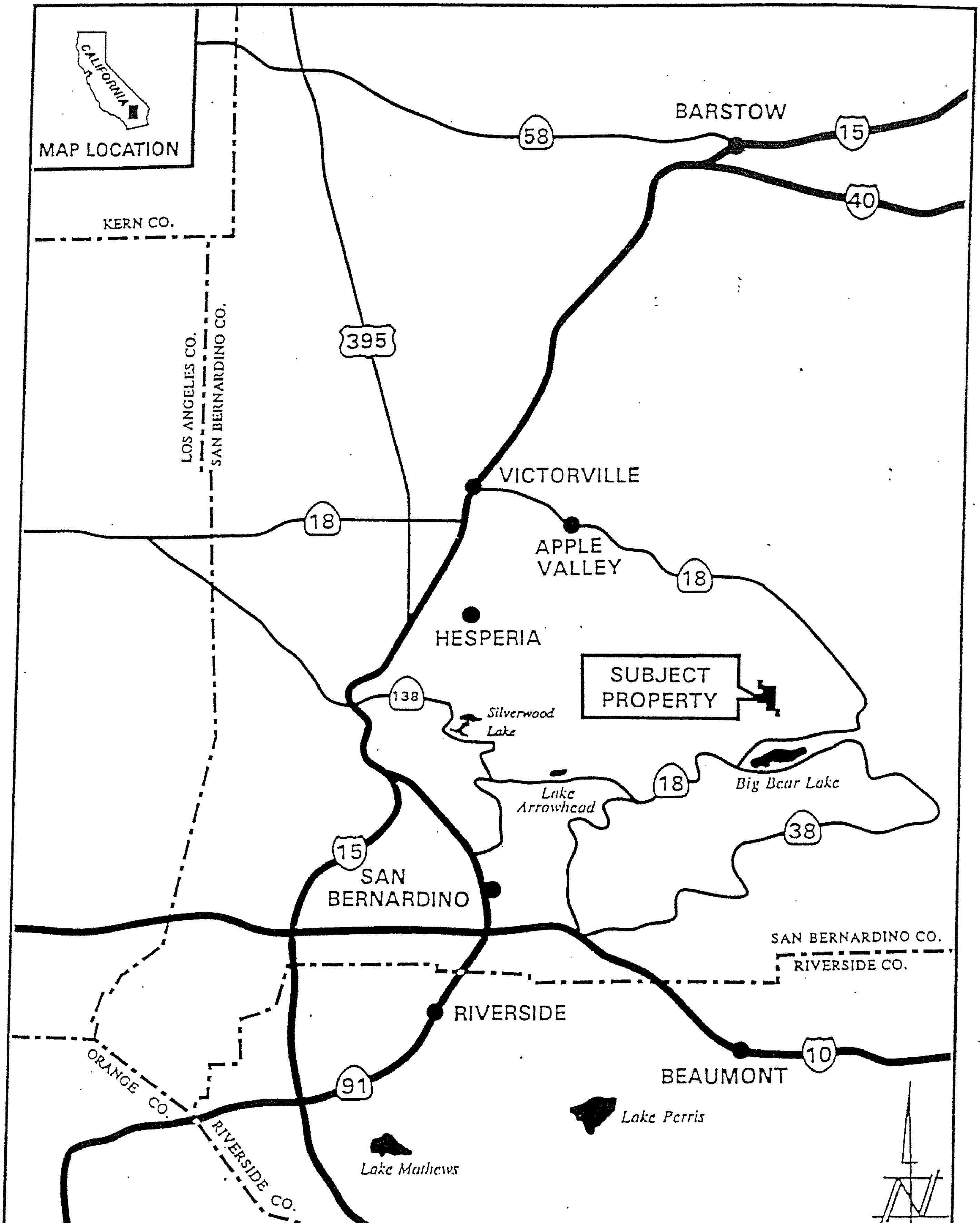
INTRODUCTION

This plan was contracted to supplement the Pluess-Staufer (California), Inc. *Reclamation Plan for Mining Operations on USDA Forest Service Land, San Bernardino National Forest, California* (1994). Pluess-Staufer operates a series of quarries and supporting facilities on the San Bernardino National Forest Big Bear Ranger District (Maps 1 and 2). Pluess-Staufer must reclaim and revegetate quarries and associated sites to meet standards of the Big Bear Ranger District (1991, in accordance with the National Forest Management Act) and the California Surface Mining and Reclamation Act (SMARA; standards in California Code of Regulations Article 9). Each site's activity status, reclamation schedule, final grading contours, and soil salvage/stockpile/replacement has been listed in the *Reclamation Plan* (pp. 41-42 and accompanying schedule).

We note that ecological restoration is a dynamic field and that new techniques are continually developed. Agency-mandated success criteria and the techniques and schedule provided here need not be revised after approval. But since this revegetation plan will be implemented over a period of many years, we recommend that Pluess-Staufer and the Forest Service review pertinent literature and consider new techniques, as they become available, which may reduce costs or improve success. Several periodicals, including *Journal of Arid Environments, Restoration Ecology* and *Restoration and Management Notes,* regularly publish applicable research articles. We also recommend maintaining contact with the California chapter of the Society for Ecological Restoration (SERCAL), which is a rich source of local expertise.

OBJECTIVES AND RATIONALE

The goals of this revegetation plan are (1) to meet standards required under SMARA and by the Big Bear Ranger District, and (2) to restore critical elements of biological communities to the extent practicable, so that natural processes will operate to more fully restore ecological function. SMARA requirements are stated in general terms, subject to interpretation, but make clear that revegetated sites should resemble pre-disturbance vegetation. For example, SMARA requires that reclaimed sites provide wildlife habitat "at least as good as that which existed before ... mining," and that reclaimed sites must be "similar to naturally occurring habitats in the surrounding area." The Big Bear Ranger District provides quantitative success criteria requiring that revegetated sites reach 50% of pre-disturbance vegetation cover and 15% of



MAP 1. PLUESS-STAUFER REVEGETATION PLAN: Vicinity.

MAP SOURCE: Tierra Madre Consultants, Inc.

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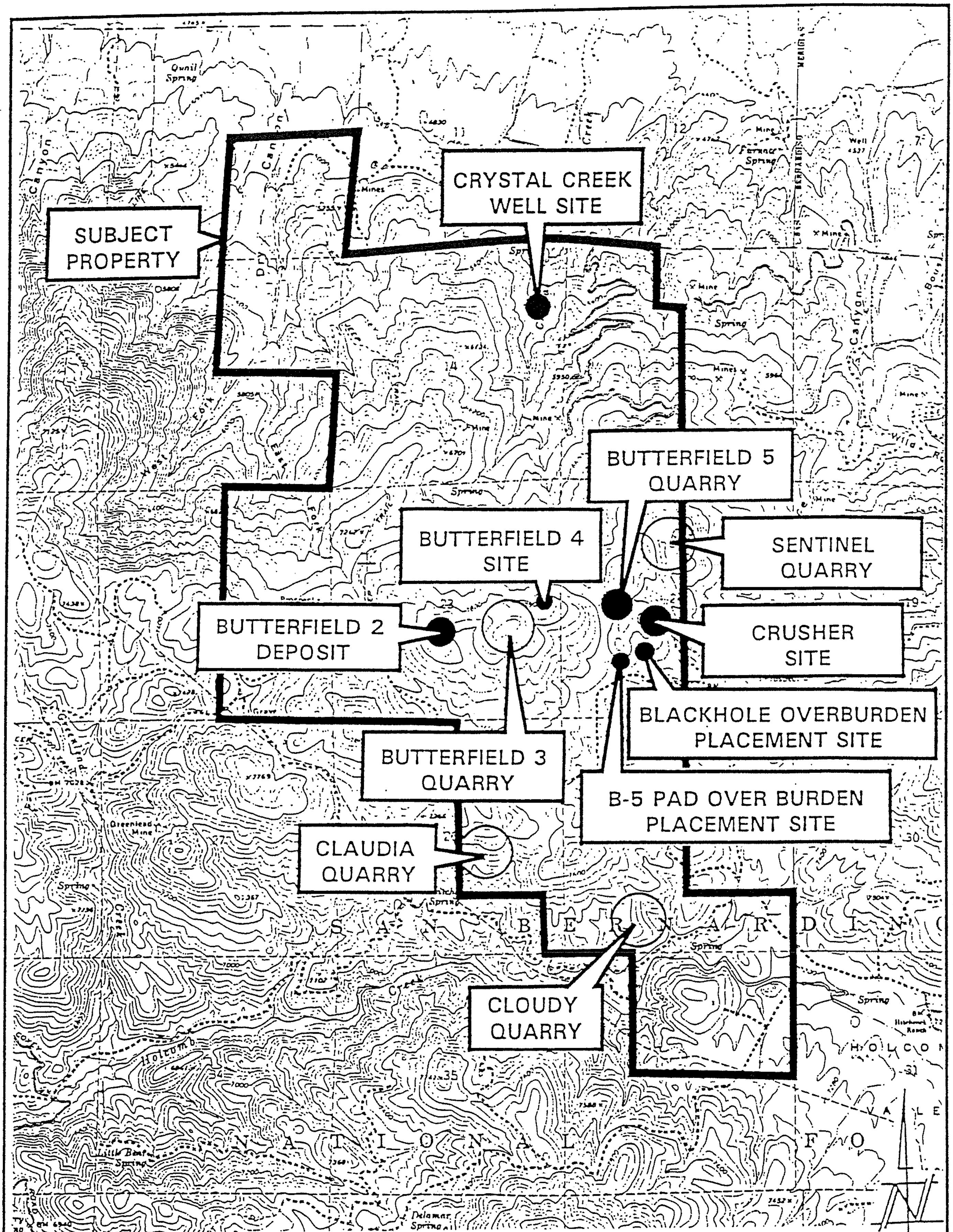

MAP 2. PLUESS-STAUFER REVEGETATION PLAN: Location.

MAP SOURCE: USGS 7.5' Fawnskin Quad.

Tierra Madre Consultants

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pre-disturbance species richness. Under these criteria, some revegetated sites that do not resemble pre-disturbance conditions would be considered successful. Quantitative success criteria, based on these guidelines, are described in the monitoring section of this plan.

Reclamation sites will not provide the same environmental conditions (soil texture and composition, slopes, etc.) which were present prior to mining. Natural vegetation characteristics depend largely on site conditions. Even after successful reclamation, vegetation will not necessarily develop the height, density and species composition now present. This plan is not designed to reproduce pre-disturbance vegetation. Instead, it should eventually establish structure and diversity comparable to natural vegetation on similar soils in the area, composed primarily of locally dominant native species, with minimal non-native weed cover.

The plan's main objective is to establish native perennial grasses, shrubs and trees on reclamation sites. Once established, these plants will trap windborne seed of other native species, enhancing natural dispersal to the site. They will attract birds and small mammals, enhancing natural dispersal of seed and mycorrhizae spores by animals. Plantings will provide "nurse shrubs" and a ready source of locally-adapted root mycorrhizal associates for newly germinating plants.

Five plants occurring on carbonate soils in the San Bernardino Mountains were recently listed as Threatened or Endangered under the federal Endangered Species Act (USDI Fish and Wildlife Service 1994). None of these five taxa have been observed on Pluess-Staufer's existing or proposed quarry sites, but may have occurred on the Crystal Creek Haul Road route before construction (M. Neel pers. comm.). A population of Parish's rock-cress (Forest Service designated sensitive plant) was impacted by construction of the Claudia quarry haul road. This revegetation plan does not include specific measures to introduce these species to revegetation sites, but we anticipate that some of the sites will provide suitable habitat for one or more of them. This plan does not preclude introduction of special-status plant species to reclamation sites if regulatory agencies and Pluess-Staufer wish to introduce them in the future, perhaps as part of a region-wide habitat conservation plan.

Planning Considerations

Vegetation and Carbonate Soils

Soils derived from carbonate parent material provide distinct environments where species occurrence and vegetation structure differ from species and structure on nearby soils formed from different parent material. To maximize revegetation success, prescribed plant materials must be suited to these soils.

To date, comparisons of carbonate and non-carbonate sites in the San Bernardino Mountains have examined elevations below most of the Pluess-Staufer site and have emphasized habitat of two Endangered plants not occurring at Pluess-Staufer (Gonella and Neel in press). Carbonate soils and their vegetation have been described at numerous other sites in the western US. Studies in the Bear River Range, Utah (Neely and Barkworth 1984), the Big Horn Mountains, Wyoming (Despain 1973), northeastern Nevada (Jensen 1989) Arizona's Santa Catalina Mountains (Whittaker and Niering 1968) and Mule Mountains (Wentworth 1981), the White Mountains of California and Nevada (Marchand 1973, Mooney 1966, 1973), the Kingston Range in California (Castagnoli et al. 1983) and ranges of the eastern Mojave

Desert in California (Thorne et al. 1981) were reviewed to provide a basis for revegetation planning.

Limestone and dolomite soils generally have greater silt content than granitic soils, and lower coarse sand content. Silt particles contribute to a somewhat higher water holding capacity in carbonate than in granitic soils. Carbonate soil Ph is generally neutral to slightly basic (between about 7.0 and 8.2) while nearby granitic soils are slightly acidic (Ph around 6.0). Carbonate soils often have higher mineral nutrient content than nearby granitic soils, though they may also have similar or lower nutrient contents. High pH reduces solubility of certain minerals, keeping them chemically bound to soil particles (Bradshaw and Chadwick 1980, Hausenbuiller 1978, Larcher 1980). Iron, manganese and phosphate availability are lower on limestone soils than on more acidic substrates, even if these minerals occur in equal or greater abundance.

Vegetation on carbonate soils is often more open than on other soils, though evidently not in the San Bernardino Mountains (Gonella and Neel in press). Some plant species are either restricted to carbonate soils, or grow in greater numbers on carbonate than other soils. Their distributions may result from tolerance of poor conditions where dominant plants of granitic soils cannot grow. Some carbonate-restricted plants can grow on other soils but seem unable to persist, perhaps due to competition from other plants.

Carbonate soils support distinctive plant communities in all studies reviewed here. Gonella and Neel (in press) found 48 species occurring only on carbonate soils and 81 never found on carbonate soils at 191 randomly selected plot sites. They recognized 5 species as "indicators" of carbonate soils in the San Bernardino Mountains, based on their regular occurrence on sampled carbonate sites and relatively infrequent occurrence on non-carbonate sites. Kruckeberg (1969) reviewed literature on plants restricted to certain soils, pointing out that widely distributed species often develop localized races, or "ecotypes," adapted to specific soil types. The likelihood of locally adapted "ecotypes" are an important consideration in selecting seed sources for revegetation.

Native Plants in Arid Habitats

MINERAL NUTRITION AND SOIL MICRO-ORGANISMS: Successful revegetation will require assured mineral availability for plantings on harsh calcareous soil. Most native plants have symbiotic relationships with soil microorganisms (primarily mycorrhizal fungi), which enhance their ability to extract mineral nutrients from soil water. Other potential methods of enhancing nutrient availability are fertilizer application or natural production of nutrients (nitrogen compounds) by particular plants.

Broad application of fertilizers has mixed results in restoration projects. High nutrient availability increases growth rates but discourages plants from forming symbiotic relationships with micro-organisms. Fertilization often increases growth of undesired weeds which may outcompete native species for water (e.g., Clary 1987). Also, high nutrient concentrations raise the osmotic potential of soil water, reducing water availability to plant roots (inorganic nutrients occur in the soil as salts). Bradshaw and Chadwick (1980) recommend phosphorous application on revegetated calcareous soils.

Some plants, especially in the legume family, supply nitrogen compounds to soil through the action of symbiotic microorganisms. Bradshaw and Chadwick (1980) recommend nitrogen application on revegetated calcareous soils where legumes are not planted. They caution, however, that fertilization tends to produce a sudden flush of new growth followed by browning or die-back after plants use the nitrogen supply. They recommend planting legumes to provide nitrogen in more constant concentrations. Only a few legumes occur naturally on the Pluess-Staufer site, and even these do not occur at high density. Therefore, rather than planting legumes, we recommend using slow-release fertilizers, following Bainbridge and Virginia's (1990) recommendation.

Microscopic fungi, especially "vesicular-arbuscular mycorrhizae" (VAM) are important in nutrient (especially phosphorous) acquisition and water uptake. Some plants, including conifers and manzanitas, form symbiotic relationships with *ecto*mycorrhizal fungi, while most other plants have *endo*-mycorrhizal VAM species associated with their roots. Comparative studies have shown increased growth and survival of plants with mycorrhizal root associates compared to the same species grown without mycorrhizae. Emphasizing the importance of soil microorganisms to successful restoration, St. John (1992) stated that "restoration is primarily a mycorrhizal pursuit."

Carbonate soils limit nutrient availability to plants, suggesting that mycorrhizal associates are probably more important in these environments than elsewhere. Successful revegetation will require that plants acquire suitable VAM organisms. This plan depends on inoculated nursery stock to (1) assure their successful establishment and (2) as a VAM source for other plants which disperse to the site (seedlings acquire mycorrhizae when their roots come into contact with the roots of other plants, of the same or different species, which already have VAM organisms). The plan also attempts to create conditions attractive to small animals which may distribute mycorrhizae spores in their feces (Allen 1989).

SEED DISPERSAL, GERMINATION, AND SURVIVAL: Natural establishment requires that seed (1) reach the site, (2) germinate, and (3) grow to maturity. These aspects of a plant's life history affect its suitability in revegetation planning. For example, some species may be well-adapted to reach a site by wind dispersal while others may require direct seeding. In other cases, young plants may require protection from wildlife or competing weeds. Inducement of germination may require supplemental watering or other seed treatment.

Plant seeds reach new sites by a variety of mechanisms. Examples include long-distance wind dispersal of light, tufted seed. Many species of the aster family are wind-dispersed. Animals, including scrub jays and pinyon jays, cache acorns and pinyon seed as food storage. Some of the stored seed is not collected and later germinates. Many grass and herb seeds have spines or hooks which catch in fur or feathers, resulting in dispersal from the parent plant to the site where the animal grooms. Seeds within berries are ingested when animals feed on fruits, then deposited elsewhere (sometimes many miles away) in feces. Finally, seed may simply drop from the parent plant, dispersing only a few feet.

Following dispersal, seed may remain dormant until a cue (e.g. rainfall or soil disturbance) induces germination. Some species' seed remains dormant for many years. The natural accumulation of seed in soil is known as "seed banking" and can provide a natural seed source for revegetation (Glass 1989). Seed germination is usually initiated by rainfall and temperature cues which vary among species and among individual seeds produced by any one species (reviewed by Inouye 1991). Locations of individual seeds also leads to variation in germination conditions. Seed in a drainageway or furrow may germinate in a dry year while other seed on an exposed site may not germinate until a wet year.

Seedling survival depends largely on rainfall and is often very low, especially for shrubs (Inouye 1991, Ackerman 1979). Plant populations could become locally extinct if all seed germinated after spring rainfall but died in the following weeks due to a late freeze or long dry period. Variations in germination requirements and microsite characteristics prevent local extinctions since some seed remains dormant each year, assuring a future seed source even if no plants survive a given year. Revegetation planning can reduce need for reseeding by exploiting these characteristics. Successful restoration can result from partial germination with some survival each year, spread over several years. In contrast, if 100% germination in the first year were followed by complete mortality, then reseeding would be needed.

Seedlings are often more successful beneath established "nurse shrubs." These associations may result from more windblown seed deposited beneath shrubs than in open areas, increased organic material or fine soil beneath shrubs, reduced water stress due to shading, or the ready availability of VAM root associates near established shrubs (Inouye 1991, Bloss 1985). Initial establishment of shrub cover on revegetation sites is likely to enhance future recruitment of "volunteer" seedlings.

Natural post-fire succession in pinyon-juniper woodlands is slow (Eddleman 1986, Gottfried 1986, Ronco 1986, West and Van Pelt 1986). Both pinyon and juniper seem to become established more readily beneath nurse shrubs. Therefore, natural regeneration on open sites tends to follow initial establishment of shrubby species (e.g., mountain mahogany). Pinyon and juniper seeds are dispersed primarily by animals. Clark's nutcrackers and pinyon jays "cache" pinyon seed; some goes uneaten and germinates the following spring. Juniper seed is eaten (with the berry-like fruit) and later egested, sometimes onto a site suitable for germination and establishment. Dispersal tends to be patchy, and eventual tree establishment is unreliable in the short-term. Natural dispersal and growth will not restore pinyon or juniper to mine sites for many years. Tierra Madre Consultants recommends greenhouse propagation and transplantation of both trees to the sites.

Pre-disturbance Vegetation

Natural vegetation in the area includes pinyon woodland, pinyon-juniper woodland, and Jeffrey pine forest growing on residual carbonate and granitic soils. Vegetation data collected at a series of sites in the area are shown in Table 1. Descriptions below are based on these data and on informal observations throughout the area.

Single-leaf pinyon pine (*Pinus monophylla*) is probably the most characteristic plant throughout the area, occurring as a dominant or important overstory plant at every site visited. Western juniper (*Juniperus occidentalis*) is less common but still characteristic throughout the mining area and upper slopes along the Crystal Creek haul road. It is replaced by Utah juniper (*J. osteosperma*) on the lower slopes. Jeffrey pine (*Pinus jeffreyi*) is common at the Cloudy, Claudia, and west

Table 1. Undisturbed vegetation throughout Pleuss-Staufer operation on San Bernardino National Forest.

Species	Cover class[1] (herbs) or percent cover[2] (shrubs and trees)									
Plot no.:	1	2	3	4	5	6	7	8	9	10
Soil characteristics[3]:	R, L	R, L	R, L	R, L	R,L	R,L	R,G	R,G	R,L	C,L
HERBS										
Achnetherum hymenoides (*Oryzopsis h.*)	O	O	R			O				
Achnetherum parishii (*Stipa coronata depauperata*)					O	O				
Arabis pulchra		O			O					
Argemone munita	R									
Artemisia dracunculus						O	O			
Artemisia ludoviciana										F
Bromus tectorum	F	F		F	O	F				
Caulanthus major						O				
Chenopodium sp.						R				
Cryptantha sp.							O			
Cordylanthus nevinii										A
Delphinium sp.						R				
Descurainia pinnata		O								
Elymus elymoides (*Sitanion hystrix*)	A	O			O			F	F	F
Elymus cf. glaucus						O				
Eriogonum parishii							O		O	
Erysimum capitatum	R									
Gayophytum sp.		O					O			
Gilia sp.		O								O
Malacothrix glabrata	R	R								
Phacelia cf. imbricata								O		O
Poa fendleriana		F	R		O				O	
Poa secunda						F				
Swertia neglecta										O

1. Cover classes: R = rare, O = occurs, F = frequent, A = abundant, D = dominant.
2. Based on ocular estimates, 0.1-acre circular plots.
3. Soil characteristic codes: C = colluvial, L = carbonate, G = granitic, R = residual.

Table 1, continued.

Species	Plot no.: Soil characteristics[3]:	1 R, L	2 R, L	3 R, L	4 R, L	5 R,L	6 R,L	7 R,G	8 R,G	9 R,L	10 C,L
		Cover class[1] (herbs) or percent cover[2] (shrubs and trees)									
SHRUBS											
Amelanchier utahensis			1				5		1	2	<1
Arctostaphylos patula		<1							<1		
Artemisia tridentata		2	<1	<1	3		5		3	10	20
Astragalus douglasii		2									
Castilleja applegateii							<1				<1
Ceanothus greggii		5		<1			<1				
Cercocarpus ledifolius		10	10		20	5		22	25	20	20
Chrysothamnus nauseosa					<1		2	<1	<1		
Eriodictyon trichocalyx		1									
Eriogonum microthecum corymbosoides			<1			3	<1				
Eriogonum umbellatum											2
Eriogonum wrightii subscaposum								3			<1
Eriophyllum confertiflorum							<1				
Fremontodendron californicum		10	1	15	20					1	
Galium sp.							<1				
Gutierrezia microcephala									<1		<1
Monardella australis (*M. odoratissima*)								<1			
Opuntia basilaris		<1	1	<1						<1	<1
Penstemon grinnellii		<1					2	<1	±2		
Phlox austromontana		10	2			3	<1		<1	<1	1
Prunus virginianus							2				
Salvia pachyphylla							1				1
Solanum xanti		<1									
TREES											
Abies concolor								<1			
Juniperus occidentalis		3	10	10	10	15	8		30	5	5
Pinus jeffreyi							3	40	25	3	2
Pinus monophylla		10	40	40	20	50	<1	<1	10	20	2
Quercus chrysolepis			10	10					<1	<1	

uncommon near the Sentinal and Butterfield 5 sites. Small canyon live oaks (*Quercus chrysolepis*) occur occasionally, at relatively low cover, throughout the area. These overstory trees seem to be characteristic of both granitic and carbonate soils throughout the area.

Some areas not disturbed by mining support dense cover of curl-leaf mountain mahogany (*Cercocarpus ledifolius*) and California fremontia (*Fremontodendron Californica*) beneath a scattered overstory of relatively small pinyon and juniper trees. In other areas, overstory trees are far more dominant, and shrub cover is sparse. These differences in vegetation structure probably result from wildfire some 50 years ago. Mountain mahogany and fremontia seem to do well in open areas following disturbance (such as fire), and overstory trees recolonize more slowly.

Perennial grasses, including Indian ricegrass (*Achnatherum hymenoides*), bottlebrush squirreltail (*Elymus elymoides*), Fendler's bluegrass (*Poa fendleriana*), and Parish's needlegrass (*Achnatherum parishii*) occur on both substrates. They tend to be most common where forest cover is open, and only Fendler's bluegrass seems to occur regularly in closed canopy forests. Other understory species occurring occasionally throughout the general area include Great Basin sagebrush (*Artemisia tridentata*), common rabbitbrush (*Chrysothamnus nauseosa*), snakeweed (*Gutierrizia microcephala*), greenleaf manzanita (*Arctostaphylos patula*), and antelope bush (*Purshia tridentata*).

Some understory species tend to be associated with either granitic or carbonate soils, following the pattern described by Gonella and Neel (in press). Curl-leaf rabbitbrush (*Chrysothamnus viscidiflorus*) and San Bernardino Mountains buckwheat (*Eriogonum microthecum*) occur primarily or exclusively on carbonate soils. California buckwheat (*Eriogonum fasciculatum*) and Wright's buckwheat (*E. wrightii* ssp. *subscaposum*) occur primarily on granitic soils.

Anticipated Post-Mining Conditions

After completion of mining, quarry surfaces will be bare carbonate rock on steep slopes, level benches, and floors. Drainage from adjacent facilities sites and the quarries themselves will not accumulate because fractured limestone bedrock will allow fairly rapid percolation. Inaccessible quarry walls and benches are not proposed for revegetation. Quarry bottoms and perhaps some benches will be accessible to equipment for revegetation, and the Pluess-Staufer reclamation plan proposes to revegetate 30% of accessible level areas. The only soil or growth media available in reclaimed quarries will be material transported to accessible sites from existing stockpiles or from newly disturbed ground at the Sentinal quarry. The Cloudy quarry was mined to the water table and standing water now covers its floor. It will be backfilled with overburden material to cover the pool before revegetation begins.

Overburden placement sites will be composed primarily of non-commercial quality carbonate rock, granitic rock, and crusher fines (waste limestone powder and chips). These sites will present harsh plant environments due to soil compaction, texture, alkalinity, absence of organic material or biological activity, and poor water holding capacity. In certain respects, overburden sites will resemble alluvial fans composed of carbonate material occurring elsewhere in the northern San Bernardino Mountains (e.g., below Marble Canyon). Both substrates are composed of fairly coarse-textured, well-drained carbonate material.

Roads and facilities sites are all accessible for reclamation. These sites have compacted soils of carbonate and/or granitic origin which will be ripped prior to revegetation.

Revegetation Efforts and Results to Date

Pluess-Staufer has seeded and/or planted several sites as part of reclamation efforts or experimental plots, documented in a series of internal reports prepared by Charles Johnson and Howard Brown. These reports and current conditions are summarized here for three sites. Current conditions were evaluated by walking linear transects across each site, censusing all living perennial plants. Transect areas were 210 feet x 6 feet (distances estimated by pacing), or 0.3 acres. These data are not intended to constitute monitoring reports for revegetation sites; instead, they are reported here to indicate relative success of previous treatments, as a guide to current revegetation planning.

Butterfield 4

Soil was removed from the site to allow mineral exploration in 1979. The site was never mined commercially, and was reclaimed beginning in 1988. It was revegetated by direct seeding and seedling planting in spring and fall 1989 (Table 3). Topsoil was transferred from newly opened quarry areas at the Sentinal site with no extended storage period. Two species seeded onto the site were not recorded on the transect: four-wing saltbush and California fremontia. Four-wing saltbush does not occur naturally on mining claims at these elevations and did not perform well on other sites where it was seeded. Tierra Madre Consultants concludes that it is poorly suited to revegetation on the Pluess-Staufer sites, except on the haul road at lower elevation. California fremontia is common on recently disturbed pinyon-juniper sites nearby, and should be suitable for revegetation. Germination in California fremontia is induced by fire or treatment imitating fire (e.g., brief immersion in hot water: Nord 1974, Emery 1988). Johnson did not describe seed treatments, and this plant's failure on the Butterfield 4 site may be a result of inadequate treatment prior to seeding.

Total vegetation cover of native plants in 1994 (i.e., 5 years after seeding and planting) is roughly comparable to undisturbed areas nearby, but species composition is markedly

Table 3. Seeding/planting and current density at Butterfield 4 site.

Species	Application	Transect census (28 June 94)	Estimated density (no./acre)
Indian ricegrass (*Achnatherum hymenoides* [syn. *Oryzopsis h.*])	seeded Mar 89	60	2000
Douglas's milk vetch (*Astragalus douglasii*)		1	30
Four-wing saltbush (*Atriplex canescens*)	seeded Dec 89	0	0
Curl-leaf mountain mahogany (*Cercocarpus ledifolius*)	seeded Dec 88, Mar 89; planted nursery stock Nov 89	19	630
Common rabbitbrush [*Chrysothamnus nauseosus* (two subspecies)]	seeded Dec 89	354	11,000
Curl-leaf rabbitbrush (*Chrysothamnus viscidiflorus*)		5	160
Bottlebrush squirreltail (*Elymus elymoides* [syn. *Sitanion hystrix*])	seeded Mar 89	160	5300
California fremontia (*Fremontodendron californica*)	seeded Mar 89	0	0
Needle and thread (*Hesperostipa comata* [syn. *Stipa comata*])	seeded Mar 89	21	690
Western juniper (*Juniperus occidentalis*)		1	30
Giant blazing star (*Mentzelia laevicaulis*)		1	30
Grinnell's penstemon (*Penstemon grinnellii*)		51	1700

different. The revegetated Butterfield 4 site is dominated by shrubs and grasses (common rabbitbrush, bottlebrush squirreltail, and Indian ricegrass) whereas an adjacent undisturbed site is covered primarily by pinyon pine and western juniper. Note also that much of the rabbitbrush seed came from a commercial source, and that most rabbitbrush on the site does not match descriptions of locally-common subspecies. The revegetation site supports 3 native species of the 9 noted on a sample plot in adjacent pinyon-juniper forest (Table 1, plot 5): bottlebrush squirreltail, curlleaf mountain mahogany, and western juniper.

Blackhole

About 10,000 square feet on the Blackhole overburden site were covered with stockpiled growth medium and hydroseeded in 1986. Vegetation now present is summarized in Table 4. Of 19 species recorded in nearby undisturbed vegetation (Table 1, plot 2), four (21%) occur on the revegetated site.

Butterfield 5

An experimental plot was seeded at the Butterfield 5 overburden site in 1989. Current conditions at the site are summarized below, in Table 5. Density and species diversity are comparable to that described above for the Blackhole site.

Conclusions

All revegetation efforts described here have successfully established two native perennial grasses (bottlebrush squirreltail and Indian ricegrass) at high density. The Butterfield 4 site also supports common rabbitbrush at high density. None of the sites resembles undisturbed vegetation, but all may marginally meet Forest Service criteria for cover and

Table 4. Seeding/planting and current density at Blackhole site, by species. Seeded in 1986.

Species	Application	Transect census (28 June 94)	Estimated density (no./acre)
Indian ricegrass (*Achnatherum hymenoides* [syn. *Oryzopsis h.*])	seeded (8 lb)	122	4100
Four-wing saltbush (*Atriplex canescens*)	seeded (2 lb)	10	330
Cupleaf ceanothus (*Ceanothus greggii*)	seeded (1 lb)	1	30
Common rabbitbrush (*Chrysothamnus nauseosus*)	seeded (3 lb)	0	0
Bottlebrush squirreltail (*Elymus elymoides* [syn. *Sitanion hystrix*])	seeded (5 lb)	313	10,000
California buckwheat (*Eriogonum fasciculatum*)	seeded (6 lb)	21	690
California fremontia (*Fremontodendron californica*)	none	1	30
Needle and thread (*Hesperostipa comata* [syn. *Stipa comata*])	none	1	30
Lewis's flax (*Linum lewisii*)	seeded (1½ lb)	35	1200
Giant blazing star (*Mentzelia laevicaulis*)	none	19	630
Grinnell's penstemon (*Penstemon grinnellii*)	none	64	2100
Heliotrope (*Phacelia tanacitifolia*)	seeded (1½ lb)	0	0
Fendler's bluegrass (*Poa fendleriana*)	none	2	70
Antelope bush (*Purshia tridentata*)	seeded (2½ lb)	3	100

Table 5. Seeding/planting and current density at Butterfield 5 site (all seed planted Fall 1989).

Species	Application	Transect census (28 June 94)	Estimated density (no./acre)
Indian ricegrass (*Achnatherum hymenoides* [syn. *Oryzopsis h.*])	seeded (8 lb)	111	3700
Prickly poppy (*Argemone munita*)	seeded (1 lb)	0	0
Great Basin sagebrush (*Artemisia tridentata*)	none	11	360
Four-wing saltbush (*Atriplex canescens*)	seeded (9 lb)	0	0
Curl-leaf mountain mahogany (*Cercocarpus ledifolius*)	nursery stock (200)	4	130
Common rabbitbrush (*Chrysothamnus nauseosus*)	seeded | 60 lb	58	1900
Curl-leaf rabbitbrush (*Chrysothamnus viscidiflorus*)	seeded | combined	3	100
Bottlebrush squirreltail (*Elymus elymoides* [syn. *Sitanion hystrix*])	seeded (2 lb)	555	18,000
California buckwheat (*Eriogonum fasciculatum*)	none	1	30
California fremontia (*Fremontodendron californica*)	seeded (1 lb)	0	0
Needle and thread (*Hesperostipa comata* [syn. *Stipa comata*])	seeded (1 lb)	1	33
Wild lettuce (*Lactuca serriola*)	none	1	30
Giant blazing star (*Mentzelia laevicaulis*)	none	3	100
Grinnell's penstemon (*Penstemon grinnellii*)	seeded (15 lb)	55	1800
Nodding (Sandberg) bluegrass (*Poa secunda* [syn. *P. sandbergii*])	seeded (3 lb)	76	2500

species richness. Recommendations that follow make use of species which have been successfully established, while modifying species composition, seed treatment, and planting techniques to enhance success for additional species. This approach is intended to increase (1) vegetation's establishment rate, (2) diversity on reclamation sites, and (3) similarity to undisturbed sites.

REVEGETATION PLAN

Public Safety Fence

Consistent with San Bernardino National Forest guidelines, Pluess-Staufer's reclamation requires fencing at closed mines to reduce potential danger to hikers. We note, however, that wire fences present a hazard to bighorn sheep (D. Ramirez, D. Armantrout pers. comm.). If sheep hook their horns on the wire as they crawl beneath the fence, they cannot escape and eventually die of exposure, starvation, or dehydration. Bighorn sheep occur in the northern San Bernardino Mountains and are regularly observed in limestone quarries. They are a management emphasis species on the San Bernardino National Forest.

Tierra Madre Consultants recommends that Pluess-Staufer and the Forest Service develop a mutually agreeable alternative to the proposed barbed wire fence. We list potential alternatives below:

- eliminating the fence requirement, and providing signs or other measures for public safety
- fencing only at likely access routes, such as trails or abandoned roads
- placing large rocks at periodic intervals so that bighorn can climb over the fence, or leaving periodic openings for bighorn access, especially at existing wildlife trails
- standard wire fence without modification
- the "Helvie" fence design, using steel or wooden rails at specified heights (lower rail 20" above ground, middle and upper rails at 8" intervals)

Topsoil Conservation

Wherever logistics allow, salvaged soil and growth media should be transported directly from mine expansion areas to revegetation sites rather than stockpiled for future use. This will maximize the benefit of biologically active topsoil to revegetation success and will minimize soil handling, since soil will be transported only once. Existing stockpiles should be used in place wherever possible (e.g., at the Claudia overburden site) rather than transported to new locations. A possible drawback of this soil management procedure is that storage time would be extended for existing stockpiles. We believe that potential benefits outweigh drawbacks because:

- Comparison of the Butterfield 4 site with other revegetation sites suggests that newly salvaged topsoil can enhance revegetation success.
- Topsoil and growth media now stockpiled at the Claudia overburden site has been colonized by native plants. Leaving this soil undisturbed will allow continued development of a native seed bank and soil microorganism populations.

SMARA standards require analyses of growth medium to determine availability of mineral nutrients and occurrences of soluble toxic materials where material other than native topsoil is not used. Soil analyses from one revegetation site are reported in the Pluess-Staufer reclamation plan (p. 112). These values are generally comparable to carbonate soils elsewhere (e.g., Jensen 1989). There is no reason to anticipate toxic material in these growth media (i.e., mine spoils have not been treated with toxic materials and

Pluess-Staufer is not mining ores that contain heavy metals or other toxins). Tierra Madre Consultants recommends no further soil analyses.

SMARA also requires "Topsoil and suitable growth media stockpiles shall be planted with a vegetative cover or shall be protected by other equally effective measures to prevent wind and water erosion and to discourage weeds." Pluess-Staufer has described measures to minimize erosion in the Reclamation Plan (p. 73).

Tierra Madre Consultants recommends collecting and storing topsoil from future quarry expansion at the Sentinal site as follows:

1. Where possible, salvage perennial grasses and any other plants likely to survive transplantation for storage or nursery propagation and eventual outplanting onto revegetation sites.

2. To the extent feasible, woody material and other plant material should be removed from the collection site before topsoil collection. Shrubs and small tree limbs should be chipped and mixed with low quality soil before applying it to reclamation sites (below). Larger diameter material should be stockpiled or moved directly to reclamation sites in accordance with Pluess-Staufer's reclamation schedule.

3. Topography at the mine expansion area prevents separate collection of topsoil and subsoil. Therefore, all available soil should be removed. The most effective use of salvaged soil will be to transfer it directly to revegetation sites, avoiding extensive storage periods. If it must be stockpiled for later use, it should be stored, preferably dry, and relatively cool (it should not be covered with black plastic) to minimize loss of seeds and microorganisms. Seed banks and microorganisms can remain viable for several years, but their numbers will decline during storage. Soil stockpiles may be used as storage sites for salvaged plant materials. Regardless of storage conditions, storage time should be minimized to retain topsoil viability.

4. If scheduling dictates that only a fraction of salvaged material can be used immediately at reclamation sites, then high quality material should be selected for immediate use and lower quality subsoil should be stockpiled.

Seed Collection and Storage

Effective revegetation will require a dependable seed supply. Pluess-Staufer should arrange for collection and storage of all species listed in Table 6, and additional species as they become available (even in small quantities). Some seed will be used for nursery propagation, but most will be sown onto revegetation sites to maximizing cover and diversity of native species. Consistent with Seed Zones adopted by the US Forest Service Region 5 (California) and by the California Department of Forestry and Fire Protection, all seed should originate in the San Bernardino Mountains, within ±500 feet elevation of the site where it will be planted. Seed zones apply formally only to trees, but research biologists with the Forest Service recommend using the same zones for shrubs and herbs (A. Dennis, A. Montalvo; pers. comms.).

Many species included in this revegetation plan occur commonly throughout the project area (e.g., pines, junipers, fremontia, and mountain mahogany). Others are especially common in disturbed areas, including natural drainageways, roadsides, and the logged Butterfield 2 deposit area. Grinnell's penstemon and purple mat are examples of species common to disturbed sites throughout the area. Greenleaf manzanita is common at the Butterfield 2 site. Snakeweed, Great Basin sagebrush, and rabbitbrush are fairly common in a natural drainageway which crosses the Claudia haul road near Turn 26. Perennial grasses are relatively common along the upper margin of the Cloudy quarry and in relatively open pinyon stands throughout the area. Revegetated areas at Butterfield 4, 5, and Blackhole can provide abundant sources of bottlebrush squirreltail and Indian ricegrass seed and live plants. Since the Sentinal expansion area will be sacrificed, we recommend exploiting this site as heavily as possible as a seed source. Other sources are scattered throughout the area.

Seed are collected, cleaned, and stored by various techniques (Young and Young 1986). Seed collectors should be mindful of the collection site, minimizing impacts to otherwise undisturbed vegetation (damaging habitat at an undisturbed site for the sake of revegetation elsewhere is a poor exchange). No seed should be collected from species whose populations might suffer from seed collection. No more than 50% of available seed should be collected from each species at any one collection site. Available seed will vary from year to year, and collecting adequate quantities will necessitate regular monitoring throughout summer to identify sites where various species are in seed. A supply of native seed should be established as soon as possible, and expanded each year. Detailed records of seed sources, including substrate (carbonate or granitic) and elevation, should be maintained so that seed will be reintroduced into appropriate environments. Pluess-Staufer may also wish to consider propagating native plants in a nursery for the purpose of seed amplification.

At planting, seed may either mixed or raked into the top layer (a few cm) of replaced soil, or applied during surface treatment. If seed is applied on the surface without raking, then application rate should be tripled to allow for loss to granivores.

Plant Propagation

On-site collection of plant propagules (seed and cuttings) is recommended because of their availability and the likelihood local ecotypes adapted to elevation and soils. Tierra Madre Consultants recommends that revegetation rely on a combination of greenhouse-grown stock, seeding, natural seed banks, and natural dispersal. Additional seeding will be used as a remedial measure if monitoring indicates that diversity is insufficient to meet San Bernardino National Forest success criteria (1991).

Revegetation at treated sites will require a dependable supply of locally-collected native plants and a site to store plants salvaged from remediation sites. We recommend that Pluess-Staufer contract with a local nursery to store and propagate plant materials. Plants grown for the landscaping trade will not be suitable for harsh sites to be planted under this program. Plants must be grown with minimal fertilization and watering, in containers designed to maximize root:shoot ratios. All nursery-grown plants destined for outplanting onto carbonate soil should be raised in similar soil. They must be "hardened off" under arid montane conditions (we recommend building a "lath house" or similar structure on-site for this purpose), and ready for outplanting on the project's schedule, with maximum root lengths but not rootbound within containers.

Plant production must be coordinated

with revegetation planning to assure an adequate supply of the necessary species as they are needed for planting. There is no existing inventory of locally-collected nursery stock for sites to be planted within the first few years of this plan (old Sentinal and Blackhole overburden sites, Cloudy quarry, and any replanting at Butterfield 4 or other sites already revegetated). In order to revegetate these sites on schedule, Pluess-Staufer and the Forest Service should agree to either (1) plant the sites with nursery stock originating elsewhere in the region, or (2) delay outplanting nursery stock until material grown from locally-collected seed is available. If appropriate species are available from comparable elevations in the northern San Bernardino Mountains then we recommend proceeding with revegetation on schedule. If no stock originating in the region is available, then we recommend proceeding with soil treatment and seed application, and delaying outplanting of nursery stock until locally-collected material is available. In either case, we recommend collecting seed from plant species listed in Table 6 beginning in 1995.

Nursery practice

Shrubs and grasses will be propagated in advance, and outplanted as established stock. They will provide (1) vertical structure, including shade and shelter from elements, and (2) a source of mycorrhizae for seeds germinating on the site. We recommend a mix of shrubs and native perennial grasses for this purpose. All nursery stock must be inoculated with mycorrhizae suitable to the area. It can be cultured on-site or purchased from commercial vendors; potential sources are listed in the appendix. Plants salvaged before remediation will also be planted onto restoration sites.

Size of nursery stock will vary according the site's accessibility. In general, large, well-established nursery-grown plants have a higher likelihood of survival than small plants, but are more expensive to produce and store, and are more difficult to transport to remote sites. Successful revegetation can result from outplanting either small numbers of large plants, or large numbers of small plants (i.e., quality vs. quantity). The first approach depends on successful establishment of nearly all plants. The second anticipates high mortality but invests little money and effort in each plant so that overall success results when a small proportion of plants become established. We recommend using relatively small nursery stock for quarries and overburden sites that will be accessible throughout the monitoring period. Haul roads, in contrast, should be planted with relatively large, well-established nursery stock. Pluess-Staufer may wish to use a combination of container sizes at early revegetation sites to develop familiarity with materials and identify preferences. Monitoring will determine relative success (note that success will not be measured as survival rates).

Small, readily accessible sites lend themselves to large, well-established plants. They should be grown in "tall pots" made of PVC pipe or similar material to assure deep rooting, following methodology of the Center for Arid Lands Restoration (Joshua Tree National Monument). These containers are heavy and awkward, and planting requires a deep hole (dug with either a tractor-mounted auger or labor-intensive hand digging).

Larger and less-accessible sites are better suited to planting with large numbers of smaller plants. A variety of containers is available from forestry and nursery suppliers; regardless of a plant's size, it should be grown in a relatively tall and narrow container. Standard horticulture pots (e.g., 1-gallon and 5-gallon stock available at commercial nurseries) are not suitable for revegetation on arid sites. Commercially-available containers include "super-cells" (plastic tubes about 2½ cm x 20 cm) and "plant bands" (foil-, plastic-, or wax-lined cardboard; dimensions similar to a 1-qt. milk carton). Depending on their size, these can be planted in holes dug with a shovel, manual soil auger, or chainsaw-powered auger. As before, smaller containers allow production and transport of more plants; larger containers enhance survivorship. Regardless of containers, all plants must be inoculated with mycorrhizae, must have actively growing vertical roots, must not be rootbound in the container, must not have been recently fertilized, and must have minimal leaf area compared to root length.

PREPARATION OF NURSERY STOCK:

Greenleaf manzanita is one of several burl-forming manzanitas. In nature, these species are very long-lived, surviving fire and other disturbance. They propagate largely vegetatively as lateral branches reach down to the soil and take root. Naturally-occurring seedlings are uncommon, and seem to occur mainly after wildfires. Because of the relative rarity of natural seedlings, we recommend introducing greenleaf manzanita to revegetation sites as nursery stock. It can be propagated from seed, by soaking mature seed in sulfuric acid for four hours, followed by 120 days cold treatment. Manzanitas are generally more easily propagated from cuttings (Berg 1974), and we recommend this method.

Table 6. Recommended plant species, usage, and site criteria.

Perennial grasses for application as seed and mycorrhizal nursery stock: minimum 5 species per site; greenhouse propagation by seed or cutting, outplanted as mycorrhizal "plugs," to provide mycorrhizae at sites not reclaimed with biologically active topsoil; direct seeding total 40 lb. per acre elsewhere.

Common name	Latin name	Application
Indian ricegrass	*Achnatherum hymenoides* (*Oryzopsis h.*)	All sites
Desert needlegrass	*Achnatherum speciosum* (*Stipa speciosa*)	Haul road below 6000 ft.
Parish's needlegrass	*Achnatherum parishii* (*Stipa coronata depauperata*)	All sites
Squirreltail	*Elymus elymoides* (*Sitanion hystrix*)	All sites
Fendler's bluegrass	*Poa fendleri*	All sites
Nodding bluegrass	*Poa secunda*	All granitic soil sites

Shrubs for application as nursery stock: minimum 2 species per site, greenhouse propagation by seed or cuttings; outplanted as "deep pot" stock.

Common name	Latin name	Application
Greenleaf manzanita	*Arctostaphylos patula*	All sites above 6000 ft.
Curlleaf mountain mahogany	*Cercocarpus ledifolius*	All sites
Blackbush	*Coleogyne ramosissima*	Haul road below 6000 ft.

Shrubs for application as seed: 8 species minimum per site, total shrub seed application 60 lb./acre minimum; pre-treatment *per* Emery 1988 and/or USDA Forest Service 1974.

Common name	Latin name	Application
Bigberry manzanita	*Arctostaphylos glauca*	Haul road below 6000 ft.
Great Basin sagebrush	*Artemisia tridentata*	All sites
Douglas's rattleweed	*Astragalus douglassii*	All sites above 6000 ft.
California fremontia	*Fremontodendron californicum*	All sites
Desert ceanothus	*Ceanothus greggii*	Haul road below 6000 ft.
Curlleaf mountain mahogany	*Cercocarpus ledifolius*	All sites
Common rabbitbrush	*Chrysothamnus nauseosus*	All sites
Curlleaf rabbitbrush	*Chrysothamnus viscidiflorus*	All carbonate soils
California buckwheat	*Eriogonum fasciculatum*	All granitic soils
San Bernardino Mtn. buckwheat	*Eriogonum microthecum* var. *corymbosoides*	All carbonate soils
Sulfur buckwheat	*Eriogonum umbellatum*	Granitic soils
Wright's matted buckwheat	*Eriogonum wrightii* ssp. *subscaposum*	Granitic soils above 6000 ft.
Snakeweed	*Guitierrizia sarothre*	All sites
Purple mat	*Nemophila rothrockii*	steep granitic soils only
Grinnell's penstemon	*Penstemon grinnellii*	All sites

Trees for application as nursery stock: minimum 3 species per site; greenhouse propagation from seed, outplanted as "deep pot" stock.

Common name	Latin name	Application
Utah juniper	*Juniperus osteosperma*	Haul road below 6000 ft.
Western juniper	*J. occidentalis*	All sites
Jeffrey pine	*Pinus jeffreyi*	Haul roads s of Sentinal quarry, Butterfield 2 and 3 sites, Claudia quarry
Pinyon pine	*Pinus monophylla*	All sites
Canyon live oak	*Quercus chrysolepis*	All sites

Curlleaf mountain mahogany is an important shrub of steep rocky terrain, and is more likely to grow successfully on steep slopes than other species. It eventually may account for much of the slopes' vegetation cover. Because of its anticipated importance, Tierra Madre Consultants recommends a focused efforts to ensure its establishment. Its seeds have long plumes that likely function in wind dispersal, but the seeds seem heavy enough that wind probably would not carry them far. Some mountain mahogany seed will reach revegetation sites by natural dispersal, but this should be supplemented by direct seeding and probably by planted nursery stock.

Mountain mahogany can be grown from seed. Germination is enhanced by soaking seed for 20 minutes in concentrated sulfuric acid and/or a 2 to 3 month cold-stratification period. (Deitschman et al. 1974a, Emery 1988). Seedlings are outplanted after about 2 years of growth and an on-site acclimation period.

Mountain mahogany stock had a very low survival rate at the Butterfield 4 and Butterfield Pad reclamation sites. Poor success may have been caused by absence of root mycorrhizae or by poor rainfall after planting. Tierra Madre Consultants anticipates better success by outplanting mycorrhizal nursery stock and supplying these plants with drip irrigation, described below.

Blackbush, which occurs occasionally on limestone alluvium/colluvium at near the haul road, is likely to grow successfully on the reclaimed road. It is grown in cultivation at the Center for Arid Lands Restoration (Joshua Tree National Monument, no date) and propagation techniques should follow theirs (S. Chaney, personal communication). Seed germinates during one-month cold-stratification in moist medium (e.g., sphagnum moss). Germinated seed is transplanted to tall pots for growth to outplanting size (minimum 8 inches height). Seedlings are especially vulnerable to fungal root infections and must not be overwatered. Blackbush is mycorrhizal, and outplantings should be inoculated to assure association with suitable microorganisms.

Juniper: Three juniper species occur on the north slope of the San Bernardinos: western juniper (*Juniperus occidentalis*), Utah juniper (*J. osteosperma*), and California juniper (*J. californica*). Utah juniper is relatively common at lower elevations on the haul road, and western juniper is common at the quarries and other facilities. Their propagation from seed is described by Johnsen and Alexander (1974). Ripe fruits are collected in the field, then cleaned from the seed. Juniper seed is heat-stratified, then cold-stratified to break dormancy. (These treatments mimic natural temperature fluctuations. Storing seed in a protected, dark, moist container exposed to daily and seasonal temperature should provide equivalent results). Seed should be germinated during spring or summer, ¼ inch deep in sandy soil.

Juniper roots are associated with both ecto- and endomycorrhizae (Klopatek and Klopatek 1986). Nursery stock should be grown with mycorrhizal inoculant to assure that seedling trees become associated with appropriate mycorrhizae.

Germination and 1 to 2 years of growth should take place in a nursery. Before transplanting to the revegetation site, potted juniper seedlings should be "acclimated" in a partially-protected structure. Junipers should be planted beneath nurse shrubs to simulate conditions under which natural establishment is most successful.

Perennial grasses: To maximize survival and assure presence of root mycorrhizae, Tierra Madre Consultants recommends large-scale propagation of perennial grasses from material collected on-site. Grasses will provide shade, shelter and root mycorrhizae to new seedlings. Perennial bunch-grasses should be salvaged from the proposed expansion area at the Sentinal quarry, and seed can be collected throughout the area. Seed need no special treatment to induce germination.

Leaves and root masses of salvaged plants should be broken into several bunches, each 1 to 2 inches diameter. After potted plants have grown to suitable size, they should be separated again into small bunches, and each bunch transferred to a new pot with its soil and root mass. This process can be repeated as often as necessary to provide an adequate supply of planting stock. Bunch grasses used in propagation should be grown in high-carbonate soil containing mycorrhizae inoculum, in suitable pots for further vegetative propagation. Those to be outplanted should be grown in pots selected to maximize root depth.

Two grasses associated with carbonate soils in Jensen's Arizona study (1989) occur on the sites: Indian ricegrass (*Oryzopsis hymenoides*) and bottlebrush squirreltail (*Sitanion hystrix*). These two species have done well on the Pluess-Staufer's other revegetation sites, Gonella and Neel (in press) regularly recorded these species and Parish's needlegrass [*Achnatherum parishii* (*Stipa coronata* ssp. *depauperata*)] on carbonate soils in the San Bernardinos. Tierra Madre Consultants recommends that propagation efforts focus largely primarily on these three plants. Other perennial grasses now growing on the site (Table 1) should also be propagated for outplanting to the revegetation project, but at lower numbers.

Jeffrey pine cones are collected in late summer and early fall when seeds ripen just before the cones open. Mature cones can be recognized by their dull purple to light brown color, whereas immature cones are black or dark purple. Cones are air dried and seed is removed by shaking. Fresh seed needs no special pre-germination treatment, but germination rate may be enhanced by cold stratification (soak in water for 1-2 days, then chill in moist air at 33-41°F up to 60 days. Seed stored over an extended period should be cold-treatment before germination. Seed is planted in spring, ¼ to ³/₈ inch deep in sandy soil without mulch, and outplanted after 1-2 years (Krugman and Jenkinson 1974).

Pinyon pine cones should be collected as they ripen, before seed it is collected by birds or small mammals. If cones have already opened, seed can be collected by shaking the tree's limbs after spreading a tarp beneath them. Otherwise, cones are collected and air dried to open them, then seed is removed by shaking. Pinyon seed is cold stratified in a moist mulch for 28 to 90 days (simulating winter conditions). It is planted at about ½ inch depth and mulched. Seedlings are outplanted to the site after 2 years (Krugman and Jenkinson 1974). Pinyons have *ecto*mycorrhizae root associates (Klopatek and Klopatek 1986), rather than the *endo*mycorrhizae of most plants. To ensure that seedlings are inoculated with appropriate microorganisms, they should be grown in potting soil with appropriate mycorrhizal inoculant. Pinyons should be outplanted following 1 to 2 years growth and an on-site acclimation period in a partially-protected structure.

Canyon live oak seed does not have a dormancy mechanism. Oaks are propagated by fall planting (in a nursery) in seedbeds at 10 to 35 per square foot, covered with up to 1 inch of soil, and mulched. Buried acorns need to be protected from animals. Mulch is removed after winter frosts are past. Young oaks are outplanted at ages 1 to 2 years (Olsen 1974).

SEED TREATMENT:

Bigberry manzanita is not a burl-forming manzanita, and seedlings are common after fire. We anticipate effective establishment by seeding revegetation sites with treated seed. Seed is cleaned and soaked in sulfuric acid 4 to 15 hours to break dormancy (Berg 1974).

Great Basin sagebrush will germinate without treatment, but germination is enhanced by cold treatment (Deitschman 1974). At the Pluess-Staufer sites, seed will likely germinate late in the first winter after seeding.

Desert ceanothus seed is soaked in boiling water for one minute, then cold treated for 30 to 60 days to induce germination (Reed 1974).

California fremontia seed is collected in late summer just as the capsules begin to open. The fruit is covered by fine bristles, and gloves should be worn during collection and cleaning. Seed is removed from the capsules and heat treated (soaked in water at ±180°F for 1 to 5 minutes), then cold-stratified (2 to 3 months) to induce germination (Nord 1974, Emery 1988).

Purple mat seems to be an effective colonizer of disturbed soils (mainly granitic) in the mining area. It grows as a spreading ground cover and dies back to rootstocks annually. A related plant, *Nemophila lobbii*, is said to be an aggressive root competitor, and may inhibit conifer establishment (Nord and Leiser 1974). *N. rothrockii* probably has similar characteristics. Thus, it may be useful in revegetation because of its success on disturbed sites, but it should not be allowed to dominate reclamation sites. Nord and Leiser (1974) described seed collection and treatment for *N. lobbii*, and treatment for *N. rothrockii* should be similar. Seed heads are collected late in the season (e.g., late September and after). The material is dried and threshed to separate seeds from capsules. Seed does not germinate well until they are leached 2 to 3 days in running water and then soaked in gibberellic acid (a plant hormone). Treated seeds should be included in seed mixes sown onto granitic soils where steep slopes prevent access for tree planting or other treatments.

Prickly poppy: Emery (1988) recommends fire treatment to induce seed germination, but prickly poppies occur on roadsides and other disturbed sites where there have been no fires. Presumably, a proportion of the seed has no dormancy mechanism, or dormancy can be broken by other means (perhaps mechanical disturbance).

Rabbitbrush, snakeweed, Grinnell's penstemon, sulfur buckwheat, and **Wright's matted buckwheat** do not require treatment to induce germination (Deitschman et al. 1974b, Emery 1988, personal observations).

Douglas's rattleweed and **San Bernardino Mountain buckwheat:** Pretreatment requirement unknown; some *Astragalus* species germinate without treatment, others require scarification of seed coat (Young and Young 1986). Most buckwheat species seem to germinate without pretreatment (Emery 1988).

SITE PREPARATION

On quarry benches and floors, soil and growth media should be spread to a depth of two feet, as proposed in the Reclamation Plan. If salvaged material is insufficient to provide two feet at all sites, then available soil and growth media should be spread to only one foot depth at overburden sites. Beneath the growth media, overburden surfaces should be ripped to provide greater rooting depth. This measure will maximize salvaged soil and growth media for use in quarry areas where only fractured rock will be available beneath salvaged material.

STOCKPILED SOIL: Where reclamation will use stockpiled soil already on the site which now supports native plants (e.g., Claudia overburden site), we recommend minimizing soil disturbance and handling. By the time these stockpiles are used for revegetation, biological activity (e.,g., seed banks and microorganisms) in the surface layers may begin to approach activity of undisturbed soils. Stockpiled soil should be spread to the appropriate depth and, only as needed, moved to "island" sites specified in the Reclamation Plan. If "island" locations were designated arbitrarily, then plans should be revised to use soil stockpiles in place.

If topsoil and subsoil ("growth medium") will both be used at a single site, they should be spread with the low quality material beneath topsoil. If a site will be reclaimed using a mix of stockpiled soil and newly salvaged soil, the new material should be spread above stockpiled soil. Surfaces should be slightly compacted to reduce erosion, but should *not* be compacted to engineering standards, because over-compacted soils inhibit root growth. Total depth of growth media should bring the surface to its final planned contour.

Stockpiled soil and subsoil will contain abundant seed of non-native weedy plants. Reducing weed seed abundance can be accomplished by inducing germination (by watering) and then destroying young plants by mowing before they produce more seed. Burning or herbicide application might also be attempted, but these methods require special permitting and any advantage over mowing is unlikely to justify permit processing. If newly salvaged soil is to be spread on top of stockpiled soil, then weed seed treatment may not be necessary, since most seeds germinate in response to light availability. If the layer of new soil will be thin or uneven, then weed seeds should be destroyed before application of newly salvaged topsoil.

SOIL TRANSFERRED FROM SALVAGE SITE: If soil can be transferred directly from a salvage site, revegetation sites should be contoured to meet stability and engineering requirements to within 24 inches of the intended final surface. Salvaged growth medium and chipped organic material should be transported and spread over the surface. It should be slightly compacted to reduce erosion, but should *not* be compacted to engineering standards, because over-compacted soils inhibit root growth. The highest quality material should be applied at the surface. Total depth of growth media should bring the surface to its final planned contour.

NO SOIL TRANSFER (haul roads, facilities sites): These sites should be ripped as deeply as possible and downslope berms pulled onto road surfaces as proposed in the Reclamation Plan. Surfaces should be left uneven. Haul road revegetation should proceed concurrently with surface treatment, since ripping will prevent future access onto the road.

SURFACE TREATMENT AND SEED APPLICATION

Soil surfaces should be treated by imprinting (Dixon 1988), pitting (Slayback and Cable 1979), or equivalent techniques. These techniques use modified rollers, pulled behind tractors, to imprint mounds and hollows on the soil surface. The imprint pattern increases rainwater infiltration, improves gas exchange between soil and the atmosphere, reduces erosion, and improves contact between seeds and soil water (transported up the sides of imprints by capillary action). These conditions enhance development of soil microorganisms, seedling survival, and establishment of young plants (St. John in prep.). Modified imprinters can also apply seed or microorganism inoculant while treating soil surfaces. Local contractors with imprinters are listed in the appendix. If no imprinter or pitter is available, alternate techniques include:

- Hand-operated imprinter: R. Dixon has experimented with manually-operated imprinting, using a device that resembles a pogo-stick. One person can imprint about one-quarter acre in a day. The imprinter should be custom-built, following Dixon's design (appendix).
- Sheep's foot roller: should only be used if soil is relatively dry, and with a minimum number of passes to avoid compaction. The technique is preferred to no treatment, but surface impressions are not correctly shaped to provide benefits of proper imprinting.
- Caterpillar tracks: Also preferred to no treatment, but surface impressions are not correctly shaped to provide benefits of proper imprinting.

Seed should be sown before or during surface treatment so that a proportion of the seed will be buried or pressed into the soil surface. Recommended species and estimated application rates are listed in Table 6. There is no dependable method for determining seeding rates. Two methods are summarized here: Seed quantities can be determined numerically, from intended density of each species, by working backward to seed numbers necessary to establish that density. The following example assumes an intended density of 100 plants per acre, and estimates proportional survival at each step between seed application and plant establishment as 80% loss to granivores, 80% loss upon germination, and 80% loss between germination and establishment. Sowing 12,500 live seed per acre would result in 2500 seeds avoiding granivores; 500 of these would survive germination; and 100 would become established plants. The initial rate, 12,500 live seed per acre, is converted to pounds of seed by determining (1) average weight of seeds, and (2) proportion of seeds in a given lot which are viable. Seed suppliers report this value as "pure live seed." It should be determined experimentally for each lot of seed collected. In the example above, if there are 1000 seeds per pound, and 80% are viable, then 15.6 pounds per acre would be applied.

The second method begins with a total value (e.g., 100 lb. per acre), divided proportionally among species to be seeded, based on intended densities and judgements of each species' likelihood of survival to become an established plant. Both of these methods rely on numeric estimates or professional judgement to determine survivorship from seed to established plants, and neither can account for unpredictable variations in weather or rodent populations. Tierra Madre Consultants recommends that on-site planners consider these numeric approaches along with recommendations from a seed supplier. Actual seeding rates will largely be determined by budget and seed availability. Monitoring data from early revegetation sites should be used to plan seeding densities at later sites.

After seeding and surface treatment, woody material should be scattered onto the revegetation site. Rocks, limbs, furrows, and crevices in the surface will provide "safe sites," increasing the probability that seed will be located in suitable sites for germination and long-term survival. This material will also attract birds or small mammals (which will disperse seed and microorganisms to the site) and, as it decomposes, provide nutrients in small (but meaningful) quantities over many years.

Soil surfaces should be examined to

determine whether they are vulnerable to erosion, and control measures taken if needed. Hay is a suitable mulch for arid land revegetation, even though it may introduce non-native seed to the site, because the dry climate will prevent crop species and associated weeds from becoming established after their first year. Chipped yard waste, logging slash, rice hulls, or rice straw are also suitable mulches.

If biologically active topsoil is not moved onto the site, replanting will require new establishment of mycorrhizae and seed banks. These sites will be planted at high density with inoculated native grasses as mycorrhizae carriers, and will be heavily seeded with native species. If viable topsoil has been replaced onto the site, the need for seed bank establishment and high-density perennial grass plantings is avoided.

OUTPLANTING

PLANTING DENSITIES: Intended densities of established plantings should be based on undisturbed vegetation, described earlier, and intended density upon completion of monitoring. The following example uses cover of pinyon pine in undisturbed vegetation near the Sentinal quarry. Pinyon cover ranges from about 10% to 40% cover; 30% is the approximate mean. It will be intended as a major component of revegetated sites, and should reach at least half the density and cover of undisturbed vegetation.

Estimating diameter of a mature pinyon at 4 m, each mature tree will cover about 12 m^2 (130 $ft.^2$), so eventual density should be about 1 tree per 40 m^2 (430 $ft.^2$), or 250 per hectare (100 per acre). Planting densities are calculated from intended densities, based on anticipated survival. If large, well-established plants are used and high survival (e.g., 90%) is expected, then a site should be planted with about 110 pinyons per acre to allow for 10% mortality. If small plants are used and only 50% survival is anticipated, then it should be planted with 200 pinyons per acre.

During the monitoring period, pinyons will not grow to pre-disturbance sizes and their cover will not reach even 50% of pre-disturbance values. Other shrubs and trees planted on each site are intended to make up the difference in total cover, and planting densities estimated here for pinyon pine should be adequate to meet success criteria.

Using similar methodology, we recommend planning for establishment of 50 mountain mahogany (it also will be included in seed mixes), 50 western juniper, and 50 canyon live oak per acre, 50 greenleaf manzanita per acre (above 6000 feet), 50 Jeffrey pine per acre (specified sites), 200 blackbush and 50 Utah juniper per acre (below 6000 feet). Planting densities will be calculated according to size of nursery stock and anticipated survival.

RECLAMATION SITES WITH STOCKPILED OR COMPACTED SOIL AS PLANTING SURFACE: These soils will not have adequate mycorrhizae inoculum to support vigorous plant growth. After surface preparation, cultivated perennial grasses with mycorrhizal roots should be planted in a grid pattern on ±5 foot centers (±1800 plants per acre). Plantings should include a mix of grass species but will primarily be made up of Indian ricegrass and bottlebrush squirreltail. It is not this plan's intent to permanently establish dense grass cover on revegetation sites. Instead, the major objective of planting mycorrhizal grasses in a dense grid is to reintroduce microorganisms to the soil so that they will be available to newly germinating seeds.

These grasses will be shaded or crowded out by shrubs and young trees within a few years. Grass plantings will be accompanied by shrub and tree plantings, described above.

All nursery stock will be planted into moist soil, supplied with slow-release nitrogen and phosphorous fertilizer capsules, and perforated irrigation pipes to provide occasional deep irrigation (Figure 1). Data for all outplantings will be kept in a log book, showing propagation conditions, species and height for each plant. Plants will be permanently tagged with a number for identification throughout the monitoring period.

RECLAMATION SITES WITH NEWLY SALVAGED SOIL AS PLANTING SURFACE: Where biologically active soil (i.e., the top ±1 foot) has been transferred directly from a salvage site, there will be no need to reestablish mycorrhizae populations. Thus, we do not recommend planting perennial grasses in the dense grid pattern described above. Seeding and shrub planting techniques and densities should be the same.

MAINTENANCE AND IRRIGATION

IRRIGATION: Nursery stock will be watered plentifully upon planting. If there is no natural precipitation during the first few weeks after planting, additional irrigation water may be applied at the soil surface. After plants are established, they will be irrigated by pouring water into the deep pipes periodically during the first two to three growing seasons. Irrigation schedules will be determined by professional judgment, based on natural rainfall and soil conditions. The objective of irrigation is *not* to maximize growth rates, but instead to maximize establishment to the point where artificial irrigation is no longer needed. In dry years, frequent watering may be necessary, but in wet years there should be little (if any) supplemental watering.

A drip system may be used to supply water to the irrigation pipes, but no further irrigation water will be applied at the surface. In addition to the corrugated pipe irrigation system, Pluess-Staufer may wish to provide supplemental surface watering, either with overhead sprinkler system or by watering from a truck. If this method is used, it must be applied sparingly, again only supplementing natural rainfall.

REMEDIAL WORK: When monitoring indicates that weeding is needed, it will be carried out by a work crew supervised by a qualified biologist. Weeding will occur either (1) while weeds are still in flower during the year they are detected, or (2) after weed seedlings emerge the following spring. Removing weeds after they have released seed would provide no benefit to revegetation success. The crew will be trained to recognize non-native weeds, particularly Russian thistle and brome grasses, which must be removed. Mitigation plantings and volunteer native species are not to be removed. The biologist will be available on site throughout all work to identify plants and oversee the work crew.

Supplemental planting will be needed if survival, seed germination, or volunteer rates are low. Replacement grasses and shrubs will be planted to raise overall survival and cover to meet success criteria. Replacement plantings may use the same proportions used initially, or these may be modified according to the success of particular species. If the diversity of native annual and herbaceous

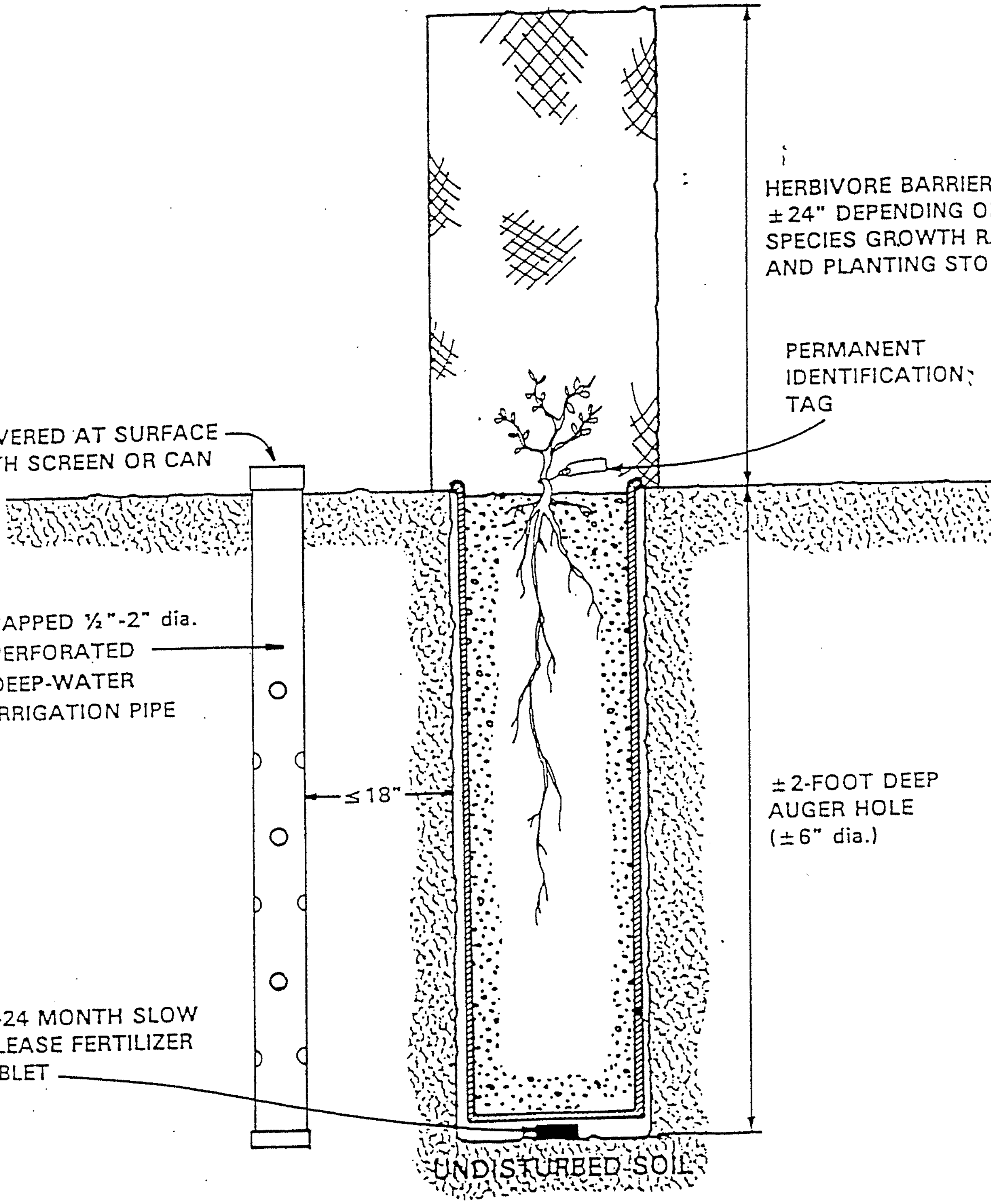

FIGURE 1. Conceptual sketch of planting procedures and plant protection.

NOT TO SCALE

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plants is low, then restored areas will be reseeded using seed of native herbs and grasses collected locally and using techniques to avoid damaging plantings and volunteers. Specific details of remedial planting or seeding should be planned by a biologist, depending on the particular shortcomings noted during monitoring.

MONITORING

Success Criteria

SMARA requires that reclaimed sites provide wildlife habitat "at least as good as that which existed before ... mining," and that reclaimed sites must be "similar to naturally occurring habitats in the surrounding area." SMARA also requires the operator to demonstrate that vegetation on reclaimed sites has been self-sustaining without irrigation, fertilization, or weeding for a minimum of two years prior to release of performance bond. The Big Bear Ranger District requires that revegetated sites reach 50% of pre-disturbance vegetation cover and 15% of pre-disturbance species richness by the end of a ten year monitoring period for release of the performance bond.

Based on these guidelines, Tierra Madre Consultants recommends the following quantitative success criteria for revegetation sites at Pluess-Staufer operations on the National Forest. Criteria 1 and 2 are intended to meet National Forest requirements; the remaining criteria are intended to meet subjective SMARA requirements. Criterion 3 will gauge wildlife habitat quality, and Criteria 4 and 5 will assure that revegetated sites are similar to nearby undisturbed habitat.

1. Average total native plant cover on revegetation sites will be at least 50% of the average total native plant cover on undisturbed natural vegetation within the Pluess-Staufer mining area.

2. Species richness of locally indigenous plants on revegetation sites will reach at least 15% of average species richness of locally indigenous plants on equal acreage of undisturbed natural vegetation within the Pluess-Staufer mining area.

3. Species richness and density of native bird species occurring in revegetated areas during the breeding season will equal or exceed average species richness and density of native bird species occurring in equal acreage of undisturbed natural vegetation within the Pluess-Staufer mining area during the breeding season.

4. Total native shrub cover at revegetated sites will reach 50% of the average total native shrub cover occurring in equal acreage of undisturbed natural vegetation within the Pluess-Staufer mining area.

5. Density (number of trees per acre) of native tree seedlings and saplings (all species combined) in revegetated sites will be at least 50% of the average density of mature trees in equal acreage of undisturbed natural vegetation within the Pluess-Staufer mining area.

Revegetation sites will be monitored over a 10 year period to evaluate success or potential need for remedial work. Monitoring in the first few years will measure survival of planted nursery stock, need for weeding or replanting, and successful establishment of seeded and volunteer native plants (termed "growth and survivorship," below). In later years, monitoring will focus on the site's resemblance to undisturbed vegetation in terms of SMARA's subjective criteria and the Forest Service's quantitative criteria ("cover and species richness"). Bird surveys in years 8 and 10 will compare wildlife habitat quality with undisturbed sites. Each year's monitoring data will be available, and the final year's data will be used to evaluate project success or failure in terms of these standards. Monitoring data should be subject to verification by the Forest Service or an agency independent from Pluess-Staufer to assure objectivity.

Methods

GROWTH AND SURVIVORSHIP MONITORING: At years 1, 2, and 4, planted nursery stock survival will be measured to determine whether supplemental plantings will be needed and to provide feedback data for planning revegetation at future reclamation sites. Monitoring will occur in early spring or late winter. 200 plants per acre (originally planted as nursery stock) will be randomly selected to determine survival and condition of each one. For all living plants examined, height, sign of animal damage, reproductive condition (sterile, flower, fruit) and any other pertinent information will be recorded.

All seedlings within a 1 m^2 plot (a circle of radius 0.56 m), centered at each of 50 of the selected plants and at 50 additional randomly-selected points per acre between planted nursery stock, will be inventoried. All seedlings and herbaceous plants within the circular plots will be censused by species. Results will indicate germination success of seeds sown onto the site, occurrence of volunteer plants, and abundance of weeds.

These results will be used to adjust seed mixes for future sites, determine abundance and species of native plants volunteering onto the site, determine whether weeding is needed, and (by comparing data over several years) identify any trend in weed abundance. Results should be made available to the Forest Service, but growth and survivorship monitoring results will not document achievement of success criteria listed above. Instead, they are intended to judge general trends and any need for maintenance or remediation.

COVER AND SPECIES RICHNESS MONITORING: These criteria will be evaluated in years 3, 5, 7, and 10 after planting. Quantitative data collection will follow the methodology of Gonella and Neel (in press). On haul roads, belt transects (4 m x 100 m) will be substituted for circular plots. These data will be used to determine average height and cover of all species occurring on the site (including those planted as nursery stock, seeded, and volunteers). Vegetation structure and species richness will be compared to similar data collected on undisturbed and naturally-disturbed sites. Abundance of species volunteering onto revegetation sites will be used to evaluate need for adding or removing species in seed mixes at other sites, or perhaps reseeding the site as remediation. These data will also provide an index of weed cover, but will not be as reliable as the 1 m^2 circular plots described above.

Species richness, total vegetation cover, and tree seedling and sapling densities will be used to evaluate revegetation success in terms of the criteria listed above. SMARA requires that "Sample sizes must be sufficient to produce at least an 80% confidence level." We recommend applying methods described by Bonham (1988: pp 65-67) to determine sample size adequacy for estimates of cover and species richness. Bonham provides a formula to determine adequate sample size for comparing to means, but it assumes that samples and variances will be equal in both populations. We doubt that these assumptions are appropriate for Pluess-Staufer's revegetation sites, and we recommend against using the technique. Instead, adequate sample size should be determined by using existing data (Table 1 and any data collected by the Forest Service within the Pluess-Staufer area) in the following formula (Bonham 1988: p 66)

$$n = \frac{t^2 s^2}{(\bar{x} - \mu)^2}$$

where n = sample size, t is determined from a one-tailed Student's t-distribution where $p = 0.2$, s^2 = variance, $\overline{x}$ is the mean calculated from available data, and μ is the actual mean. Since the value of μ, is unknown, an acceptable difference between $\overline{x}$ and μ (e.g., 5%) is assigned. Thus,

$$n = \frac{t^2 s^2}{(0.05\ \overline{x})^2}$$

Calculating $\overline{x}$ (= 14) and s^2 (= 5.2) for species richness from 10 plots in undisturbed vegetation (Table 1), and using a confidence level of 80% ($t = 0.442$),

$$n = \frac{0.442^2 \times 5.2}{0.7^2} = 2.1 \text{ plots}$$

Thus, the existing 10 plots are sufficient to estimate mean species richness (μ) in undisturbed vegetation, assuming that the estimated mean ($\overline{x}$) is within 5% of μ. If additional plots are available from the Forest Service, this calculation should be verified using a larger sample.

Similarly, calculating $\overline{x}$ (= 0.58) and s^2 (= 0.19) for summed cover of shrubs and trees (an estimate of total vegetation cover), in the 10 plots

$$n = \frac{0.442^2 \times 0.19}{0.03^2} = 43 \text{ plots}$$

The 10 plots are not sufficient to estimate mean vegetation cover (μ) in undisturbed vegetation. Repeating the calculation with an acceptable error for ($\overline{x} - \mu$) of 10% instead of 5% results in

$$n = \frac{0.442^2 \times 0.19}{0.06^2} = 10.3 \text{ plots}$$

Again, this calculation should be repeated using a larger sample if additional plots are available. We believe that existing data probably provide a sufficient sample for the purpose of evaluating revegetation success.

Adequate sample size for revegetated sites should be calculated similarly. Note, however, that these sites will be small (Table 2), and only a few 0.1 acre (= 0.04 ha) plots will cover an area equal to an entire revegetation site. Thus, it will likely be more efficient to census small sites rather than sample them.

BIRD DENSITY AND SPECIES RICHNESS MONITORING: Bird occurrence in revegetation areas will be used to evaluate wildlife habitat quality in years 8 and (if needed) 10 after planting. We recommend calculating density and species richness of native birds by point-counts (Ralph et al. 1993: pp 30-35, Ralph et al. in press) in each revegetation site during five visits, one to two weeks apart, between 6:00 AM and 10:00 AM, during appropriate weather conditions, in the breeding season. During each visit, the observer should spend 30 minutes at the center of the revegetated area. This relatively long period was selected because bird density in arid montane woodlands is generally low. Surveys are intended to maximize likelihood of detecting birds passing through the site during foraging. Data should be separated according to birds detected during the first 5 minutes and those detected during the remaining 25 minutes, and according to birds seen flying over the site rather than detected within vegetation growing on the site. The same procedures should be followed on 4 reference plots in undisturbed vegetation nearby. Observers must be well experienced with identifying birds by their calls, and the same observer should monitor all sites during any one year.

After one or more years' data have been accumulated, modifications to this procedure may be necessary to improve its utility as an indicator of "wildlife habitat quality." In particular, the revegetation "islands" may have relatively low bird density and species richness due to surrounding unsuitable habitat rather than to habitat shortcomings within revegetation sites.

Bond Release Criteria

In accordance with SMARA and Forest Service policy, Pluess-Staufer has posted a performance bond for reclamation described here and in the Mining and Reclamation Plan. The Big Bear Ranger District directs release of the bond, as follows:

1. Work involving final shaping, drainage, ripping, growth medium placement, and vegetative material placement will be released at acceptable conclusion of all of these activities.

2. Colorization will be released at acceptable completion of this activity.

3. Revegetation will be released when the site has met the cover and diversity requirements at the ten year anniversary of the initial attempt, provided that the operator makes a good faith effort to establish vegetation, even to the extent that periodic replantings may be necessary.

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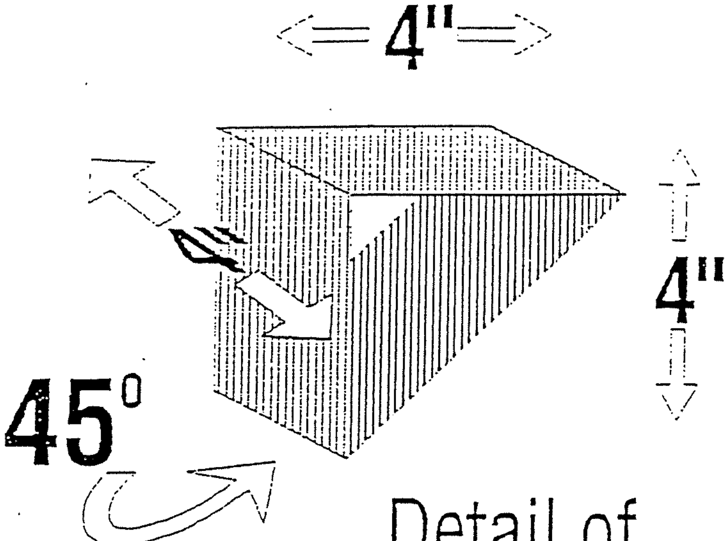
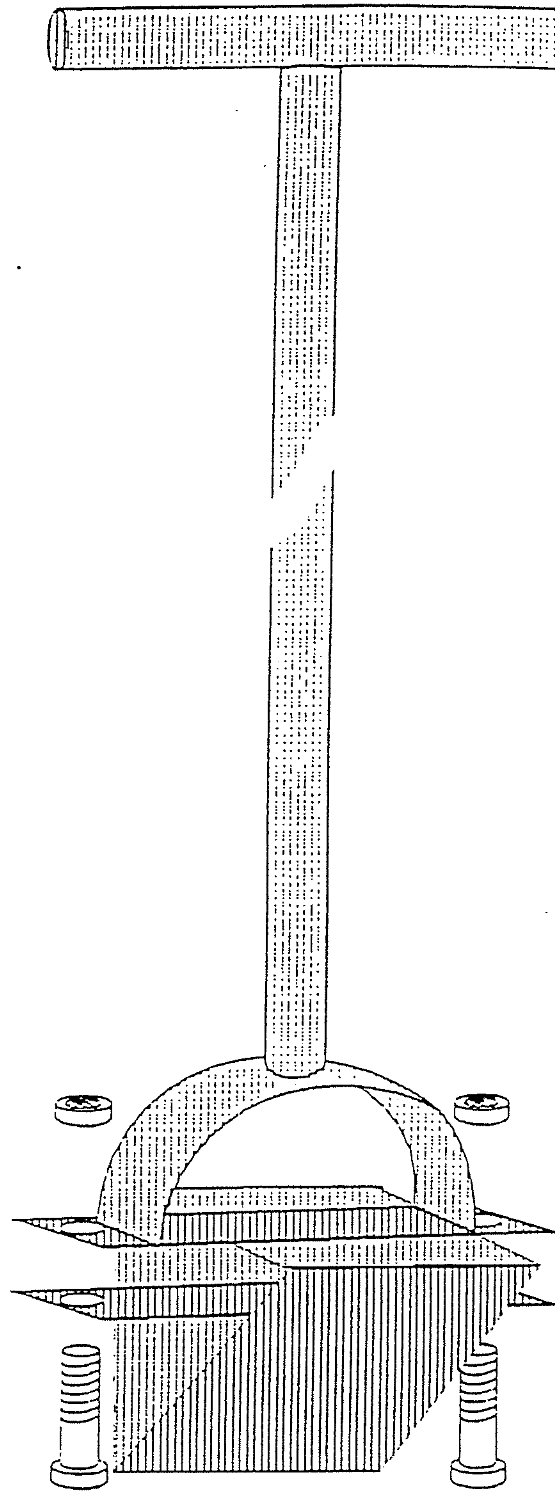
Hand Imprinter

Current Dixon design

Operator works uphill, backwards. Place imprints one foot on center.



Detail of angle



Angle attaches to handle with bolted plate

SOURCE: *T.V. St. John, Tree of Life Nursery.*