PROCEEDINGS:
High-Altitude Revegetation Workshop no. 5

Edited by

Robin L. Cuany and Julie Etra

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PROCEEDINGS
HIGH ALTITUDE REVEGETATION WORKSHOP
NO. 5

Colorado State University
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March 8-9, 1982

Edited by

ROBIN L. CUANY and JULIE ETRA
Department of Agronomy, Colorado State University

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PREFACE

The Fifth High Altitude Revegetation Workshop is now history. The early history of the group is explained in one of the papers presented and the composition of the High Altitude Revegetation Committee is printed after the Table of Contents. The Committee started as an ad hoc group and has grown along with its sponsored activities such as the Workshops and the annual summer Field Tours. One of us has been Chairman since 1974, and prevailed on the Committee to hold an election during the March, 1982 workshop. As a result, Larry F. Brown (who had been Vice-Chairman) was elected to the Chairmanship and Wendell Hassell was elected to be Vice-Chairman. Most of the committee membership continues, as an invaluable source of advice and strength, and the thanks of all who are interested in High Altitude Revegetation are gratefully offered to these persons and to their parent agencies and companies, whose names are recognized on the title pages.

The editors also realize, and wish to point out, that the Workshop could not have been as successful as it was (with 243 participants) without the valuable contributions of three groups: the participants who attended contributed their resources and knowledge in the discussions; the chairmen and panelists who likewise guided the thoughts and questions of the group; and the speakers who contributed their skills and time in the preparation and delivery of their papers.

One paper, by Richard Hallman, was not given orally but the value of the text and photographs made it a worthy addition to the sequence. On short notice, William Mitchell volunteered a progress report from Alaska which we transcribed and have printed here at the end of the first afternoon session. Our efforts to record and transcribe the panel discussion were foiled by technical problems, for which we tender apologies.

We acknowledge the help and organizational abilities of Dean Bressler and the staff of the CSU Office of Conferences and Institutes. Our thanks also extend to Randall and Blake, Inc. for their generous sponsorship of the social hour.

A special feature of the Banquet this year was the thought-provoking tape/slide show on the eruption of Mt. St. Helens. The magnitude of this disturbance and the scope of natural succession and revegetation efforts is humbling to those of us involved in this field.

Robin L. Cuany
Julie Etra

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The Principles of Ecology as a Framework for a Total Ecosystem Approach to High Altitude Revegetation Research*

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Like many other fields of scientific endeavor, modern ecology has been developed around a set of fundamental principles which have, over the years, guided the ways in which theories have been developed and studies designed to test specific hypotheses. As originally put-forth by Odum (1959, 1971), these principles have also proved to be useful as a means of providing a framework for various applied problems associated with growing concerns for environmental impact assessment and prediction.

Over the years, it has been the author's experience that the fundamental principles of the field of modern ecology have been a useful point of departure for designing research and making useful assessments in a variety of areas of environmental concern. It is the

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*Portions of this article are based on a presentation, "The Principles of Ecology and Their Application to Environmental Problems Associated with the Production and Utilization of Energy," in _Population and the Environmental Crisis_ (S. White, Ed.), as originally published in 1975 by the Research Advisory Council of East Tennessee State University, Johnson City, Tennessee, and reproduced here with permission.

purpose of this presentation to examine these basic principles of the field of modern ecology and to suggest ways in which they may provide a frame of reference for environmental concerns associated with the revegetation of high altitude environments.

The basic principles of modern ecology as outlined by Odum (1959, 1971), center around a consideration of the natural world as a hierarchy of levels of varying complexity of organization. These levels of organization range from atoms though molecules, cells, organs, tissues and individual organisms (or "individuals"). Individual organisms however, are grouped into larger and still more complex units known as populations, which are grouped into biotic communities and these communities into ecosystems which are the most complex units of organization regularly considered in an ecological sense. An important aspect of this philosophy of viewing the natural world as systems of varying levels of complexity of organization is the fact that principles which operate at one level of organization also often operate in a similar fashion at other levels. Frequently however, a given principle may be more readily understood at one level of organization than would be the case at some other levels. As an example, the principle that systems at all levels of organization act as single unified wholes, is probably best understood, even by the lay public, at the individual level of organization. Few persons would doubt that the circulatory system, digestive organs, skeletal and nervous systems of an individual are organized into anything other than a single structurally and functionally integrated whole. Although comprised of many component parts, an individual organism (such as for example an individual human being) is thus considered to be a single unit acting in an integrated fashion. Less well understood however, are the ways in which a forest or other such ecosystem is also structurally and functionally integrated into a single unified whole. Frequently, vital component parts of ecosystems may be removed, "transplanted" or altered in a fashion which suggests that those responsible for such actions do not understand the complete ramifications of what is taking place in terms of the disturbance of the overall structural and functional integration of the whole. The extermination of the wolf from the eastern deciduous forest ecosystem for example, may be viewed in the same perspective as the removal of a kidney from a human patient on an operating table. In neither case does the "patient" die since individual human beings can live without one kidney and the forest can obviously continue to survive without the wolf. In neither case however, does the system continue to operate in the same fashion as prior to the removal "surgery". The forest is a distinctly different ecosystem without the wolf, and a patient minus one kidney is faced with a large number of considerations which did not exist prior to the surgery. In neither case would such "surgery" on either an ecosystem or an individual human being be wisely undertaken without good reason and without adequate forethought and planning.

Extending this analogy to the revegetation of high altitude ecosystems, it may be useful to consider high altitude ecosystems as "patients" for whom certain surgical actions are being contemplated. By this analogy the revegetation of disturbed high altitude ecosystems may be comparable to skin grafting and the regeneration of the body integument of an individual who was badly burned in an accident. It is important to realize that whether at the level of the individual organism or the ecosystem, this "skin grafting" is only one portion of the concern for the total welfare of the "patient" as a whole. Skin grafting on a human patient must be considered in the context of the cardiovascular, nutritional and psychic state of the person being treated. Ecosystem revegetation similarly must be considered in the context of the welfare of the total integration of producers (green plants), consumers (animals), decomposers and abiotic factors found in naturally occurring "healthy" high-altitude ecosystems. The process of revegetation of such an ecosystem should not take place without concern for the state of health of the other portions of the ecosystem any more than skin-graft surgery should take place on a patient whose general state of health is not continuously being monitored by means of determinations of body temperature, blood pressure, red blood cell count and other such indicators of general health. At the ecosystem level, unfortunately, our familiarity with indicators of the normal status of our total "patient" is much less complete than in the case of a human presented for skin graft surgery in a hospital.

Basic to an understanding of the hierarchy of levels of complexity of organization, is the fact that each of the levels consists of systems which may be considered as entities comprised of a series of interacting component parts. A description of these component parts at the ecosystem level is frequently best undertaken by the means of a systems-modelling approach. In these approaches, the component parts of the ecosystem are represented in terms of "boxes" which are storage compartments of either energy and/or matter within the ecosystem and "arrows" which indicate the directions and flux rates of matter and/or energy between the storage compartments within the system. A greatly simplified "boxes and arrows" diagram of an ecosystem is presented in Fig. 1. In this figure, energy, flowing in a one-way path from sunlight through the producers to the consumers and/or decomposers and eventually out of the ecosystem as lost respiratory heat, is used as the tool to describe the way in which the ecosystem components are interrelated. Matter, to the extent that it is interchangeable with energy, may also be used as the basis of describing the "boxes and arrows" of a specific ecosystem's organization.

In order to adequately understand the role and potential impact of revegetation on a given ecosystem therefore, it is necessary to understand how such revegetation procedures will effect not only the primary producer plant component but also the other ecosystem components which are interrelated to the producer group. These latter components include animals which may act as consumers in the system and decomposers which perform vital functions in the recycling of nutrients between the plants, animals and the abiotic portions of the ecosystem. Thus far however, the general approach to ecosystem revegetation seems to have centered mainly on the mechanics and details related to the green plant producer component and soils. If indeed, a total ecosystem approach is to be realized, it will be necessary to increase the attention which is given to the consumers and decomposers of these same ecosystems. The titles of papers presented in past symposia in this series suggest that this has not yet been done. While it may not actually be necessary to give equal treatment in terms of time and effort to consumers and decomposers of high altitude ecosystems which are being revegetated, it would seem

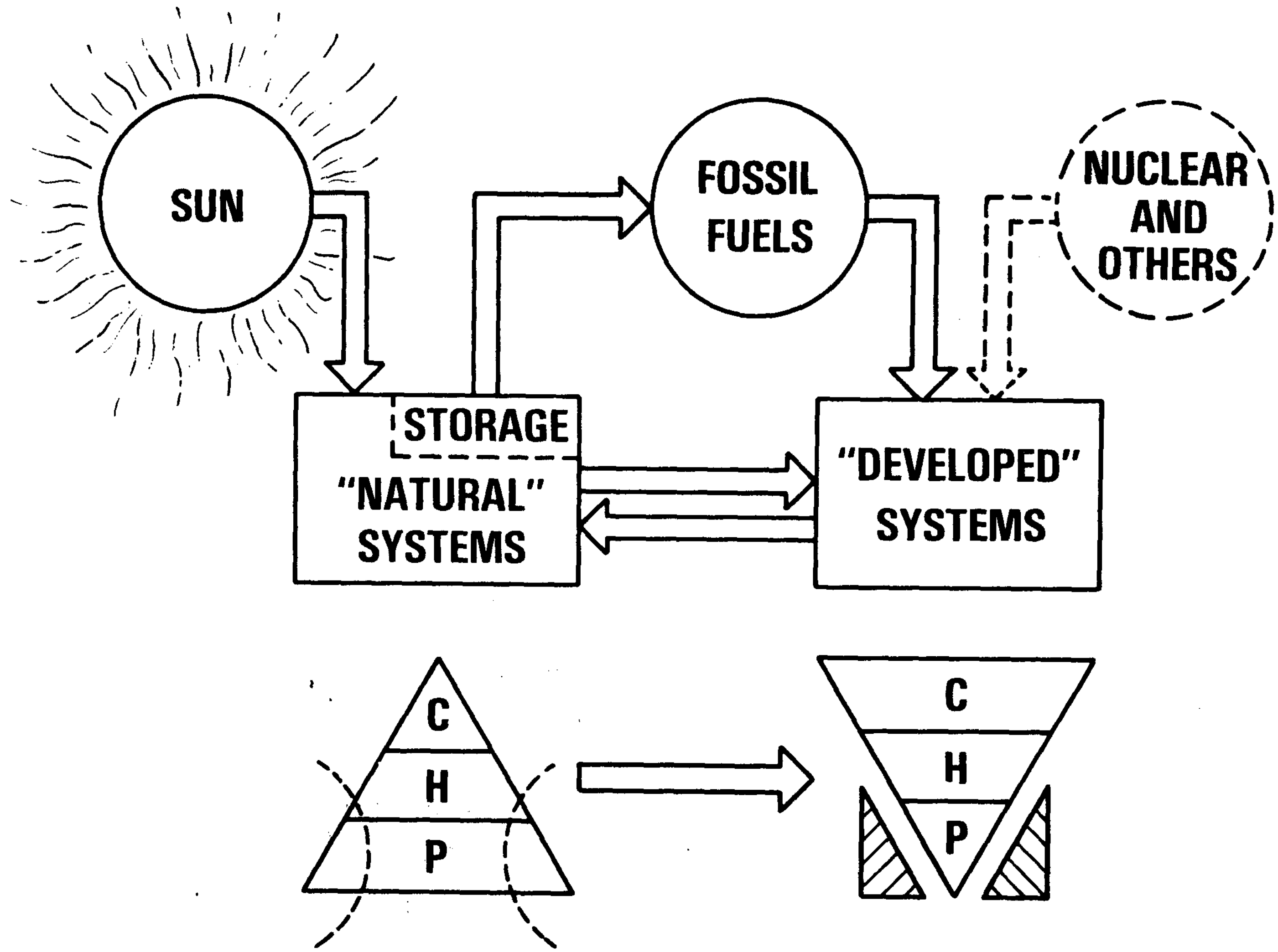

Figure 1. A simplified diagrammatic representation of the major component parts of a generalized natural ecosystem. The flow of energy is used as a means of illustrating the various component parts and their interrelationships. (Redrawn with permission, from Brisbin, 1975).

that a greater emphasis than has been given in the past, might be in order in the future. Such a reordering of priorities to include concern for all ecosystem components in the high altitude environment would provide a more balanced and integrated picture of the way in which these ecosystems were functioning before revegetation and may provide more useful predictions of how they might function after revegetation procedures have been undertaken.

Finally, it is important, at all hierarchical levels of organization, to distinguish between what may be defined as natural systems from those which may be alternatively described as developed systems. As indicated by Odum and Odum (1977), natural systems, including those at the ecosystem level, are those capable of maintaining themselves on sunlight energy alone. Developed systems on the other hand, cannot exist in a steady-state on sunlight energy alone and are dependent upon supplementary energy overhead payments in order to continue to exist in a steady state. The interrelationships between natural and developed systems, as illustrated in Fig. 2, is basic to many forms of environmental impact study. In an earlier presentation (Brisbin, 1975) the basic interaction between natural and developed systems, as illustrated in Fig. 2, was used to address environmental problems associated with the production and utilization of energy. This same scheme however, could equally well be used in addressing problems of the disturbance of high altitude environments by any form of developed system found in these regions. These developed systems may include mining operations, ski resorts, or any of a number of similar types of activities. The important point is

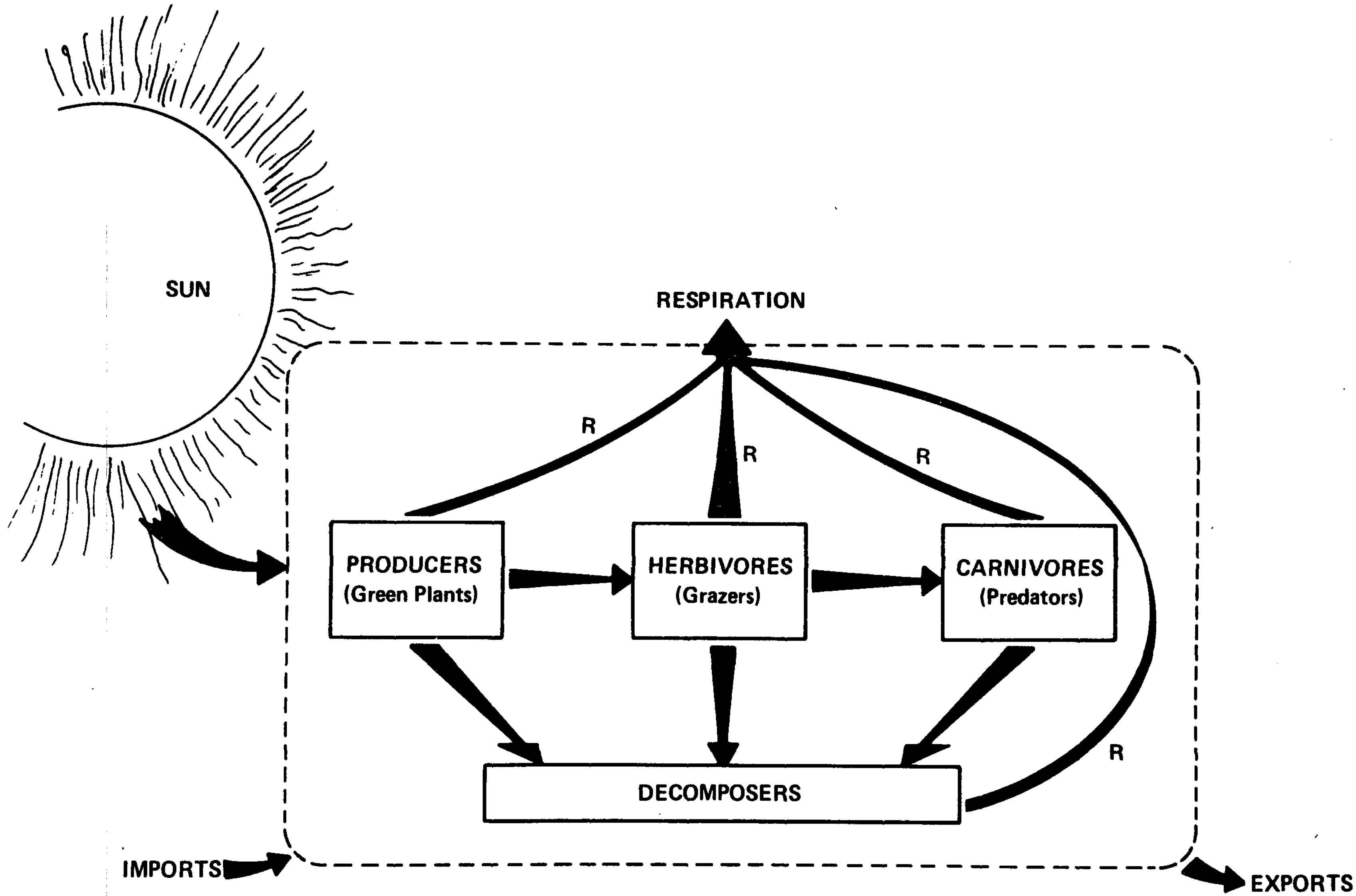

Figure 2. A diagrammatic representation of the relationships between natural and developed ecosystems. Pyramidal figures indicate the relative stability of the trophic or feeding levels of the two types of ecosystems. P = producers, H = herbivores, and C = carnivores. The trophic instability of developed systems is often balanced by borrowing from the productivity of adjacent natural systems, as indicated by these figures. (Redrawn with permission, from Brisbin, 1975).

that the ski resorts or mining operations represent developed systems since they are dependent on fossil fuel or some other form of supplemental energy overhead payment in order to maintain a steady state. Their impacts on nearby natural systems, as indicated by the double arrow in the center of Fig. 2, are the crux of many environmental issues and are therefore important subjects for concern by this symposium and future meetings in this series.

Concerns for the interactions between natural and developed systems, as indicated in Fig. 2, have led to the development of a system of National Environmental Research Parks (NERPS). These areas, as designated by the United States Depatment of Energy, are sites with programs specifically aimed at studying the interactions between natural and developed systems as illustrated by the double arrow in the center of Fig. 2. A number of examples may be cited in which the NERP philosophy of environmental study has been most useful in helping to provide perspective for environmental impact analysis, assessment and public demonstration. Extant NERP sites and their concommitant programs have not only provided information of interest to those concerned with environmental quality but have also provided, on the other hand, equally valuable information to those who are charged with the management of developed systems (such as mining operations or ski resorts) by providing them with the facts and perspectives needed to better undertake their activities while minimizing and/or mitigating unavoidable environmental impacts upon neighboring natural systems.

It is interesting to note that to date, although several of the major biome systems of our nation are currently represented within the

Department of Energy's national NERP network, there is as yet, no specifically-designated NERP program or site within the major high altitude environments of North America. The experiences with NERP programs at such sites as the Department of Energy's Savannah River Plant, Hanford Reservation, Los Alamos National Laboratory, Idaho National Engineering Laboratory and Oak Ridge National Laboratory, have proven the ability of the NERP concept to enhance both the public image and acceptability of potentially environmentally disruptive activities (see for example, Brisbin, 1975). This suggests that the designation of a NERP program within a high altitude environment might be a useful idea to consider in the case of a proposal to develop a mining operation and/or a ski resort in some as yet undisturbed alpine region.

In summary then, it is the basic principles of modern ecology, their extension to both natural and developed systems and the mutual interactions of these two types of systems with one another, which provide a framework for a total ecosystem approach which can combine high altitude revegetation activities with other aspects of concern for environmental quality in such regions. The philosophy of the National Environmental Resarch Park programs, embodying the interaction between natural and developed ecosystems, as well as component sub-systems at all levels of complexity of organization of the natural world, provides just such a framework for study. Such a framework considers revegetation as a component but not the totality of environmental work in such an area and would require the close coordination of those involved in revegetation work with those concerned with other aspects of ecosystem structure and function such as consumer population welfare (e.g. wildlife management) or studies related to the decomposer portions of high altitude food weds. When these approaches are used, it is likely that productive avenues will be found to integrate high altitude revegetation research with complimentary studies of all components of high altitude ecosystems.

ACKNOWLEDGEMENTS - The author is grateful to Dr. W. S. Osburn of the Office of Ecological Research of the United States Department of Energy, for continuing intellectual input to the development of many of the concepts presented in this address and for his pioneering efforts in promoting NERP program developments throughout the nation. Larry F. Brown of Amax, Inc., provided assistance in making arrangements for the presentation of this address, and manuscript preparation was supported in part by a contract (DE-AC09-76SR00819) between the United States Department of Energy and the University of Georgia.

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THE HIGH ALTITUDE REVEGETATION COMMITTEE - WHO WE ARE AND WHAT WE DO

Robin L. Cuany (Chairman)[1/]

THE COMMITTEE

The committee is made up of representatives of industry, federal and state agencies, and universities and colleges (Table 1) who have an interest in revegetation of disturbed lands at high altitudes. This has been nominally defined as anything above 9,000' (2740 m) in the Central Rocky Mountains, or ecologically, the subalpine and alpine zones. The disturbances needing repair are those caused by mining, ski-slope construction, highway building or other types of transportation corridors, condominium landscaping, and presumably also those scars left by nature, such as landslides.

Our role is to bring people together to talk about, study, and see techniques of revegetation applicable to our problems, and in some cases appropriate for lower elevations also. To do this we have held workshops like this one, summer field tours where we visit sites in the mountains, and the Committee has sponsored research programs at Colorado State University in the testing of plant materials and the improvement of plants for subalpine and alpine revegetation use. Committee members representing industry have provided encouragement, and their industries have donated financial aid toward accomplishing the stated goals. We acknowledge this help gratefully.

The Committee supports an appointed secretary through a Graduate Research Assistantship at CSU, for High Altitude research and committee functions. The present secretary is Miss Julie Etra. Her predecessor was Stephen Kenny whose Ph.D. degree was attained in May, 1981.

THE WORKSHOPS

As one of the original triumvirate of 1974 explained in the 4th Workshop (Brown, 1980) we have Jim Ludwig of Climax Molybdenum to thank for encouraging Berg, Brown, and Cuany to call the first Workshop and edit its proceedings. We expected about 50 people and were surprised with a crowd of 110. Since then each workshop (Table 2) has drawn more people and until we "purged" our mailing list last fall we had over 900 names on it. Including duplicating and envelopes, that takes over $200 to send a notice by first class mail. Bulk mail is undependably slow and can't be forwarded. We add names from each workshop and tour as we wish to keep communication open, and we add names of inquirers at any time.

[1/] Department of Agronomy, Colorado State University, Fort Collins, CO 80523.

Table 1. High Altitude Revegetation Committee Members

Affiliation		People
Mining	AMAX, EXXON, Homestake	5
Ski Areas	Aspen, Steamboat, Winter Park	6
Seed	Mile-High	2
Landscape Architects	Gibbs & Hill	2
Ecological Cons.	Stoecker-Keammerer & Associates	1
Federal/State	SCS, RMNP, Wildlife	3
Academia	CSM, CSU, CMC	4
	Total Members (1982)	23

Chairman: Robin L. Cuany (CSU)
Vice Chairman: Larry F. Brown (AMAX)
Secretary: Julie Etra (CSU)

Table 2. High Altitude Revegetation Workshops

Workshop and Location	No. papers†	Attendance
1st Feb, 1974 Fort Collins	13 + 4	110
2nd April, 1976 Fort Collins	13 + 3	184*
3rd March, 1978 Fort Collins	20 + 1	174*
4th Feb, 1980 Golden	19 + 1	263
5th March, 1982 Fort Collins	21 + 2	243**

† second figure indicates panel or small-group discussions

* some additional attendance at some talks

** added in publication

The second and third workshops were, like the first, held here at CSU, and we developed a pattern of having some ecology or other scientific background, some nuts-and-bolts of reclamation on the job, some case histories, some reports of advances in plant materials or mulches or machinery, and some philosophy or argumentation about laws and regulations affecting our attempts to protect or restore the environment. The committee collectively decides on topics and speakers to invite, and individual committee members chair a morning or an afternoon session or a panel, being responsible for liaison with their speakers. Members of the committee have also taken on the task of editing the manuscripts into the published proceedings. Each volume of proceedings is sent to all registrants at that workshop, and can be ordered by others from the Bulletin Room, Aylesworth Hall, Colorado State University, Fort Collins, Colorado, 80523. We try to get them out within six months following the workshop.

The Fourth High Altitude Revegetation Workshop was held by the invitation of committee member Professor Bettie Willard, at the Colorado School of Mines, and the turnout was the largest yet, perhaps helped by its proximity to Denver. This year we discovered some schedule conflicts but we still have a great crowd. We have taken a slight departure from previous practice in having about 40 minutes for general discussion and short 3 - 4 minute voluntary contributions on Tuesday afternoon. We hope everybody will learn a lot from one another in this Fifth Workshop.

THE SUMMER FIELD TOURS

Every year starting in 1974 we have held a meeting at a combination of field sites of revegetation in action and in research, trying to sample the proper mix of mine reclamation, ski-slope reseeding and repair, natural area ecology, including the alpine of Trail Ridge Road in 1978. In that same year on a previous afternoon we co-sponsored an equipment display in Denver (Table 3). In some cases our hosts have provided transportation up their steep mountain roads, partly to cut down on the number of vehicles involved. In the past we have charged nothing for these summer tours (you are on your own for lodging and meals) but think we may need to collect a nominal $5 registration in future. After Tuesday's noon meeting of the Committee we hope to announce some more detail on this year's tour.

In closing this part of my description of Committee - organized educational activities, I cannot do better than quote from Jim Brown's (1980) statement of philosophy "It is imperative that the spirit of cooperation and the free exchange of problems, solutions, and techniques should continue to be the spirit of these workshops and field trips."

Table 3. High Altitude Revegetation Field Tours

Year	Places visited	Attendance
1974	Climax+, Vail*	100
1975	Urad+, Winter Park*, Rollins Pass	120
1976	Idaho Springs, Keystone*	
1977[2]	Snowmass*, Aspen, Ashcroft+, Redstone+	130
1978	Denver (equipment) Trail Ridge Road (alpine)	85
1979[2]	Durango*, Silverton+, Bayfield	110
1980[2]	Vail Pass, Copper Mountain*, Ten Mile Cr. and Climax+	140
1981[2]	Crested Butte+, Gunnison, Homestake+ and Monarch Quarry+	133

[2] Two-day tour   + Mine   *Ski Area

RESEARCH ACTIVITIES

In that spirit, and as a progress report of the work under my care and sponsored by the Committee through donations of funds, sites, and some field help, I want to present the areas of Species and Strain Testing, Grass Breeding, Lupine Domestication Studies, and Alpine Seed Production Research.

SPECIES AND STRAIN TESTS IN THE SUBALPINE

The 1974 plantings

Since many of the disturbances, and therefore the revegetation needs, fall in the subalpine zone, our testing program has mainly been between the elevations of 9,000' and 11,500' (2740 to 3500 m). Although this zone is forested, the immediate needs of stabilization of a reconstructed slope, and in many cases the end-use of the land, will call for a herbaceous cover of grasses and forbs. The testing of available plant materials, especially cultivars of grasses and legumes that are now on the market, seemed an essential first task. Their trial in a variety of locations on mined areas, ski slopes and other disturbances was started in 1974 with Committee assistance and encouragement, advice from Dr. William A. Berg, who provided some initial data at the First Workshop (Berg, 1974), and an initial set of about 35 materials. Progress on these plantings and some more made in 1976 was described by Kenny and Cuany (1978).

Planting was done by hand in furrows about ½ - 1" deep and about 1' apart, about 10 - 15' long, usually made with a corner of a hoe. Prior to making rows, the ground was worked over to incorporate 100 lb. per acre of P_2O_5, and in the season following germination, 50 lb. per acre of N was added as a top dressing. Two replications of all strains were seeded, using 25 seeds per foot of row, at each site listed in Table 4. Observations were made in late summer or fall for the first few years to assess the vigor and survival. Where the original stand was poor, the surviving plants have been watched and rated without regard to the density of the row, because there was only one opportunity for the original stand to be established, seedlings could have failed for several reasons, and persistence of older plants is a useful trait.

The preliminary conclusions of Kenny and Cuany (1978) have been borne out in the 1978 to 1981 observations of these 1974 and 1976 plots. Among "large" grasses the ones with most promise were meadow foxtail, smooth brome, orchardgrass, reed canary grass and timothy (Table 5). The best small grasses are the fine leaved fescues - hard fescue, red fescue and Chewing's fescue, and the bluegrasses - Kentucky and Canada bluegrass. All these grasses have been incorporated in one or another seed mix sold for high altitude use, or made up for the larger industrial users according to specification. Our data confirm that these introduced species are better able to do a job in this reclamation situation than those native grasses tried (not many in 1974 tests).

Table 4. Location of Tests 1974 - 1976

Ski Areas	Summer 1974	Summer/Fall 1976
Snowmass	-	9,500' 10,500'
Steamboat	-	9,700'
Winter Park	10,600'	9,400' 10,600
Mining Areas, etc.		
Climax	11,200'	11,400'
Urad	10,600'	-
Eisenhower West Portal	-	11,200'

Plots seeded at Breckenridge (Peak 8) and Vail in 1974 had to be abandoned by 1979 because of invasion.

Table 5. The Best Performers in 1974 and 1976 Tests.

Good Large Grasses

meadow foxtail	timothy
smooth brome	mountain brome
orchardgrass	slender wheatgrass
reed canary grass	thickspike wheatgrass

Good Small Grasses

red fescue, including Chewings fescue
hard fescue
Canada bluegrass, and some Kentucky blue

Good Legumes

alfalfa
zigzag clover
cicer milkvetch

The only comparable natives in performance were 'Bromar' mountain brome and 'Primar' slender wheatgrass.

Among legumes tested, beginning in 1974, best were alfalfa, zigzag clover (on the coarse wet gravelly Urad site) and cicer milkvetch, 'Lutana' and Size 12 experimental strains. Although the value of cicer milkvetch was not noticed in 1978, there has been an increased survival and growth vigor on all plots of this species in the 1978-81 period. Moreover, some plots planted in 1969 by Berg at Climax have shown plants whose growth is thigh-high, so this non-bloating grazeable legume deserves more use in reclamation. It starts slowly but is good for the long haul. The variety 'Monarch' has been released (Townsend, 1980).

<u>The 1976 plantings</u>

The 1976 plantings were intended to test additional places and materials: two more ski areas were Steamboat and Snowmass (only legumes at two elevations 9,500' and 10,500' at Snowmass), and a plot above the West Portal of the Eisenhower Tunnel was provided by the Colorado Department of Highways. At Climax an attempt was made to compare late spring planting 6-30-76 with fall planting 10-2-76. At Winter Park one plot was planted at a base lot (9,400') in July, and one on the saddle at the top of Mary Jane (10,500') in October. The former did very well, and the latter rather poorly owing to the very dry winter of 1976-77 and the rather windswept site on this saddle. Nevertheless the general impression is of the same successes and failures as from the 1974 plots, with meadow foxtail, several lines of smooth brome, 'Latar' orchardgrass, reed canary grass and 'Climax' timothy leading the 28 large grasses tested. The red and Chewings fescues again excelled among 14 small grasses, with 'C-26' hard fescue, and there was some evidence of value in the natives Canada bluegrass, 'Sodar' streambank wheatgrass and 'Critana' thickspike wheatgrass. Western wheatgrass and green needlegrass, along with Kentucky bluegrass, were very disappointing in their survival and vigor.

Among the legumes, alfalfa was poor except at Snowmass, alsike clover and white clover were fair, and 'Empire' birdsfoot trefoil was the only one with a good rating at the Eisenhower Tunnel plot. Also that plot showed a strong growth of the native variety'Bandera' Rocky Mountain Penstemon. At the lower elevation sites (Snowmass and Mary Jane base) in forest clearings with a more moderate climate, it is possible to get a number of things to grow well, and the rating scale had to be modified from that used higher up.

There was no clear difference between the June and October 1976 plantings at Climax except in the first two years, when it was obvious that one plot had a one growing season head-start. For this reason the 1978 trials were designed to be planted in October and the succeeding June so that both would make use of the 1979 growing season, as their first season.

The 1978-79 plantings

The rationale of planting in fall is that in a "frost-seeding", if one waits till there is a negligible chance of germination that fall, the seed will be ready to come up as the snow melts in spring, two or three weeks before it would be possible (mid-June is usually the earliest) to get in and prepare a plot for (late) spring seeding. One might expect the fall seeding to do a little better than the spring seeding when they have the same first growing season.

We tried to find a range of sites that would be near our previous tests yet (if possible) less subject to future disturbances, and settled on six locations that included three ski areas, two mining areas and one which is the edge of a gravel quarry in Dry Gulch, not far from the East Portal of the Eisenhower Tunnel (and now under jurisdiction of the Arapahoe National Forest). Table 6 shows the elevations and planting dates of the two replications planted in October 1978 and two in June - July, 1979. Unfortunately, the Steamboat plot, on very dry soil with a westerly exposure, produced negligible emergence of seeded rows in a rather thick stand of volunteer smooth brome (washed down from higher slopes?). The other five have given interesting results in their first three seasons of growth.

There were 88 materials in the Fall, 90 in the Spring which were almost entirely the same as in the Fall, but totalling 94 different strains of 22 different grass species and 10 legume species (no non-leguminous forbs this time, Table 7). In 1979 we also tested coated and uncoated seed of smooth brome, tall fescue, Kentucky bluegrass, alfalfa and white clover, but did not find significant differences due to the coating. These 10 entries made the Spring total 100. These 88 or 100 strains included some new strains of previously tested introduced species, and over 20 strains of native grasses, some of which came from Bill Mitchell's program in Alaska, reported in a previous workshop (Mitchell, 1978). The only released cultivars, as far as I know, among the natives were 'Primar' and 'Revenue' slender wheatgrass (Agropyron trachycaulum) and 'Sourdough' bluejoint reedgrass (Calamagrostis canadensis). We did not have any native legumes in these tests, although we will refer to alpine clovers later.

Because we have incomplete results from one of the sites and have not visited another since mid-summer of 1980, we will not attempt an exhaustive final report now. In any case, the characteristics of recent summers and winters have been so "abnormal" that we would rather wait to make a complete survey in late summer of 1982, all in the same week, and publish those results, which will evaluate persistence and vigor after four growing seasons. For now, I will limit comment to mentioning the apparent best items and their early behavior.

Table 6. Location of Tests 1978 - 1979

Location	Alt.(ft)	1978 Fall	1979 Spring
Ski Areas			
Breckenridge (Peak 9)	10,700	10-5	6-22
Steamboat (Five Points)	9,700	10-10	6-22
Winter Park (Dormouse)	10,600	10-9	7-10
Mine Areas			
Climax (Observatory)	11,160	10-7	7-9
Urad (above upper tailings)	10,600	10-8	6-21
Highway			
Eisenhower Tunnel (East Appr) Dry Gulch	11,100	10-6	6-21

Planted by Stephen T. Kenny and Robin L. Cuany, Department of Agronomy, Colorado State University, Fort Collins, CO 80523.

Table 7. Grasses and Legumes Tested in 1978/79

Grass genus	Common Name	Species	Strains
Agropyron	wheatgrass	5	12
Arctagrostis	polargrass	1	1
Bromus	bromegrasses	2	5
Calamagrostis	reedgrass	1	1
Dactylis	orchardgrass	1	3
Deschampsia	hairgrass	2	4
Elymus	wildrye	1	1
Festuca	fescue	3	20
Phleum	timothy	2	5
Poa	bluegrass	2	8
Trisetum	spike trisetum	1	2
		22	66

Legume genus	Common Name	Species	Strains
Astragalus	cicer milkvetch	1	7
Coronilla	crownvetch	1	3
Lathyrus	flatpea	1	1
Lotus	trefoil	2	5
Medicago	alfalfa	1	1
Onobrychis	sainfoin	1	3
Trifolium	clover	3	8
		10	28

The introduced grasses and the cultivars of native slender wheatgrass were the first visible in July 1979 from the Fall 1978 seeding, and they have continued to be successful and prominent in most of the 10 date/site combinations. In 1980, 'fall' grasses were a little better than spring-sown grasses at Eisenhower, but the same at Winter Park. In 1981 they had equalized. On the other hand, legumes at Eisenhower (Dry Gulch) were better in the spring plots, both years. At Climax, alfalfa, white clover and cicer were good from fall planting, not from spring, whereas crownvetch, flatpea, sainfoin and trefoil were good performers only from spring. These cannot be taken as general truths, and no doubt depend on very localized variability of ground moisture and pH.

Among large grasses (Table 8), meadow brome, orchardgrass and timothy have been most generally successful with smooth brome a close runner-up. Intermediate wheatgrass and slender wheatgrass are showing some vigor, but there was concern (Berg, 1974) about their possible lack of persistence - we shall follow that closely.

The smaller grasses in the 1978-79 tests are interesting; the red fescues (including Chewings and creeping red) continue best, especially at Eisenhower, Breckenridge, and Winter Park. Possibly they are a little less outstanding on the mine sites (different substrate) and a similar comment can be made about hard fescue and perennial ryegrass. Sheep fescue and Canada bluegrass did fairly well at Eisenhower, Breckrenridge and Winter Park, but not at the mines. Kentucky bluegrass was poor everywhere, at least in these tests 7 strains were; there are over 50 strains in the trade. Among native grasses we had little success with those from Alaska, but tufted hairgrass and alpine timothy have done fairly well at the ski areas.

GRASS BREEDING

Little will be said here as we have incomplete test information on 77 best-surviving smooth brome parent plants from the 1970 nursery at Climax, which were moved to Fort Collins at various dates for seed production. All available progenies must be tested before we can define the 25 best parents to put into a synthetic variety (Cuany, 1974; Kenny and Cuany, 1978). The other grass we have made progress in selecting is an orchardgrass type found to set seed at the 10,600' altitude of the Urad plots. Seedlings of this source were planted at Fort Collins and allowed to pollinate. We have a pound or two of seed but it has not yet been in any high altitude test plantings.

LUPINE DOMESTICATION

The topic that was chosen for Steve Kenny's Ph.D. thesis was a consideration of the variability found in native Rocky Mountain lupines of Colorado and their potential usefulness from the point of view of revegetation in the 6,000' - 11,500' zone. He collected 22 different

Table 8. The Best Performers in 1978/79 Tests.

Good Large Grasses	
meadow brome	smooth brome
orchardgrass	intermediate wheatgrass
timothy	slender wheatgrass

Good Small Grasses

red fescue (including Chewing's and creeping)

hard fescue

perennial ryegrass	alpine timothy
Canada bluegrass	tufted hairgrass

Good Legumes

red clover

white clover

crownvetch (some sites)

cicer milkvetch

sainfoin (low persistence)

birdsfoot trefoil

populations of Lupinus argenteus and 14 of five other species and worked out methods for self and cross pollination, as well as germinating the seed and growing the plants in nursery conditions. The Fort Collins environment was unfavorable for populations collected above 10,500', while the Environmental Plant Center at Meeker was generally favorable for all populations. Three revegetation test plots, at Climax, near Frisco, and in the Piceance Basin, showed that lupine establishment is often low, but once established these plants persist (Kenny, 1981).

Two reclamation-related characters were studied: dinitrogen fixation and alkaloid concentration. The capacity for the former is important in supplying nitrogen in infertile places to the revegetation mixture, without the need for periodic fertilization. It was proved that soil near lupine plants had more NH_4-N and NO_3-N, and certainly more total N (66 ppm more) than soil further away from plants. This suggests that fixation was going on. Greenhouse screening of the populations as two-month old seedlings, after inoculation with eight different strains of Rhizobium (nodule-bacteria), showed threefold differences among the lupines for plant dry weight, nodule weight and nodule number, and in the acetylene reduction which is a measure of dinitrogen fixation. Some of the Rhizobium strains were as much as 5 or 6 times as effective as others, the best derived from locally gathered nodules sent by Steve Kenny to the Nitragin Company.

The seedling tops were used to screen for the alkaloids in lupines which are poisonous and can cause abnormalities in livestock (wildlife may be smarter and keep away). In the greenhouse, with a good correlation with field samples, the populations were found to differ seven-fold in total alkaloid concentration. When grown with added N, there was a fifteen-fold difference in alkaloids. The relative presence of anagyrine, the alkaloid causing crooked-calf disease, also varied, and some of the collections were below the threshold level for this chemical (Kenny, 1981).

It seems possible to identify strains which are good in nitrogen fixation and low in alkaloids, so as to make lupines available for revegetation use. At present we are working (in another project) on the problem of low seed multiplication, which hampers use of this native plant.

ALPINE SEED PRODUCTION RESEARCH

With the addition of Julie Etra, we have speeded our attack on the problem of getting enough seed from native alpine grasses and forbs to be useable for revegetation in the tundra zone where only a few introduced plants could be used even if this is justifiable or allowable. Red fescue is one of the species which is really a circumpolar native growing in Arctic and Subarctic North America as well as Iceland and Europe, so perhaps it should not be thought of as introduced.

As was stated in the Third Workshop (Kenny and Cuany, 1978) we have cooperated in two directions with industry. One aspect - the establishment method - has been tried out with hand-gathered seed from the alpine zone, planted at three sites at Climax and reported by Mike Guillaume (1980). The other aspect is the testing of seed production potential of several plants outside their alpine environment. We want to see if it is possible to raise seed in a lower-elevation "garden" type plot and reduce the cost and product variability associated with hand-collection from native stands - the commonest present method. We selected three test sites for transplanted young plants (and these three plus a fourth for direct-seeded rows). They are at Fruita (4,700'), above Collbran (7,400'), the top of Grand Mesa near Land's End (10,000') and a site near the Henderson Mill in Williams Fork Valley (about 9,000').

For a choice of materials we have consulted several sources. The best items identified in several years of research in Montana have been reported by Brown and Johnston (1978, 1979). Natural succession in Rocky Mountain National Park is known to take a very long time (Willard and Marr, 1971) and in our 1978 Field Tour we saw species resulting from 42 years of succession on Old Fall River Road, west of Trail Ridge Road. With Bettie Willard's encouragement we have collected there and in the Climax region. Regarding forage use by domestic sheep, their choice in diets for several alpine species was noted by Thilenius (1979). The most important forb species were _Trifolium dasyphyllum_ (14% of total herbage consumed), _Polygonum bistortoides_ (11%), _Geum rossii_ (10%), _Trifolium nanum_ (10%); the two fescue grasses _Festuca rubra_ and _ovina_ were 13% of the diet. Only _Trifolium_ species were utilized heavier than 7% of their available biomass, but nevertheless the _Trifolium_ spp. decreased in the vegetation cover when prevented from being grazed, and appear to be well adapted to such grazing pressure.

There are June 1981 transplanted seedlings of nine species, raised in the CSU greenhouse, in our experimental sites. Six grasses and three alpine clovers (Table 9) are each represented by ten seedlings at each site, in five-plant plots spaced 1.5' apart. In order to compare several accessions of these species we had to wait on August and September 1981 collection of seeds for Kokomo Ridge, Old Fall River Road (by permit!) and elsewhere. We are grateful to David Buckner for some seeds. In October 1981, 10' rows were direct-seeded in two replications at the four sites, for the nine species (6 grasses and 3 clovers) plus the forbs _Geum rossii_, _Oxyria digyna_, _Potentilla diversifolia_, _Dryas_, and _Sibbaldia procumbens_. Many of these were represented by more than one collection. One important species that we do not have in our plots is _Deschampsia caespitosa_, which is being studied by Ray Brown.

Growth in the summer of 1981 was fair to good for the transplants. One or two plants of alpine timothy produced immature heads by October, but we don't expect information on seed production until 1982 fall, or even 1983 for the October 1981 seeded rows. Julie will also compare the feasibility of collecting seed with the garden production method.

Table 9. Selected Alpine Grasses and Forbs in Experimental Plots, Spring Transplant, 1981, and Fall Seeding, 1981.

Scientific names	Common names
Grasses transplanted	
Agropyron latiglume	subalpine wheatgrass
Agropyron scribneri	Scribner wheatgrass
Festuca thurberi	Thurber fescue
Phleum commutatum	alpine timothy
Poa fendleriana	mutton-grass
Trisetum spicatum	spike trisetum
Forbs transplanted	
Trifolium dasyphyllum	whiproot clover
Trifolium nanum	dwarf clover
Trifolium parryi	Parry's clover
Grasses seeded	
Five of above (except *Ag. scribneri*), plus	
Poa alpina	alpine bluegrass
Forbs seeded	
All three alpine clovers, plus	
Dryas octopetala	mountain dryad
Geum rossii	alpine avens
Oxyria digyna	alpine sorrel
Potentilla diversifolia	varileaf cinquefoil
Sibbaldia procumbens	sibbaldia

Seeds from both the native tundra and the garden plots will be harvested, cleaned, weighed, and tested for viability. Experiments have already been done to find the best way of checking viability in these plants, such as the Dryas octopetala that we were unable to rate satisfactorily by standard test.

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MANAGEMENT'S ROLE IN DEVELOPING RECLAMATION PROGRAMS

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It is indeed an honor to be a speaker at this 5th High Altitude Revegetation Workshop. I have had an association with the program since the beginning in 1974, never in an active, but always a supportive sense. Jim Brown, who was the Climax Mine's first environmental engineer, along with Robin Cuany and Bill Berg of C.S.U. perceived the need for such a seminar and organized the Committee which has served us so well.

The subject of high altitude horticulture has always fascinated me, both from a personal and a business standpoint. My early efforts in 1958 to raise a vegetable garden in Buena Vista expanded into flower gardening and then native species horticulture about 1970. Our early efforts to reclaim disturbed land at Climax prompted me to personally purchase land at Buena Vista dedicated to the propagation of native species for reclamation and landscaping. This nursery continues today under the able direction of my son, Gary, and the goal has not changed.

In retrospect, this has been an interesting time during which I have been involved personally in not only "hands on" reclamation, but more importantly, as a mining executive, deeply involved in planning, regulation, political and public policy, administration, analysis of results, and financial aspects of mined land reclamation. I have listened to many experts, proponents and opponents alike on reclamation and revegetation issues. Right or wrong, decisions were made because they had to be made.

Management must make decisions because it is faced with the never-ending task of maintaining an economically viable business. There is no other reason for its existence. Reclamation is a cost of doing business, and must be considered as such.

Prior to the environmental awakening of the late 1960's there was generally little concern for reclamation. At times, reclamation became an issue only if a costly liability was feared or if the obvious residual value of mined land could be enhanced.

Initial regulations begrudgingly were accepted if the public safety was improved, but the general attitude was that a business could not afford to be concerned with esthetics.

The passage of the National Environmental Policy Act, and later various regulatory acts concerning mined land reclamation, brought management to attention. Management had to accept the costs of reclamation. Reclamation became a definite factor in the evaluation of any proposed project and reclamation costs became an important factor at any mining operation.

Company managers had to consider various ways of implementing a reclamation program. Some companies chose to establish a new staff department, others chose to hire a consultant or assigned responsibility to the engineering group. Legal advice had to be arranged.

Whichever method of organization was selected, immediate questions of policy had to be considered. Let me examine a range of possible policy options that might be considered and I will discuss each in some depth later on:

Option 1: The law is so costly and illogical that it must be changed. We will attempt to do so.

Option 2: The law is acceptable; however, the regulations under the law are incorrectly written. We will adopt a minimum program and contest the regulations in court.

Option 3: Neither the law nor the regulations will be changed; therefore, we must conduct an extensive public relations program which will change the will of the public and changes of the law or the regulation will follow.

Option 4: The law, the regulations and the public will are set. We will cooperate, innovate and lead the industry in compliance and beyond.

Option 5: We will accept the law and its regulations with reservation. We will attempt to minimize costs through research and experimentation on methods and materials.

The executive policy makers must fashion a combination of the above options that is most cost-effective and contains the least risk.

A typical large mining company has a diversified management group. The Chief Executive officer may be an engineer, lawyer, salesman, metallurgist or M.B.A. His assistants may be any of the above or other. Mine managers come from a variety of backgrounds. Seldom will any of them be horticulturists, agronomists, foresters, or have education in the biological sciences. However, management does understand the importance of policy in an important area and it understands the need to rely on the company's experts on the subject.

A basic corporate policy will be formed. It may specifically address the issue or be very general. Responsibility for reclamation is fragmented because it is site specific. Implementation of policy will be imperfect and continued administration of policy even less perfect. The executive understands these problems.

A statement of reclamation policy means little to a mine manager who knows his mine will be shut down if operating costs exceed income over a period of time. A least cost program may be mandatory - not withstanding company policy, regulatory requirements and the desires of his reclamation staff. A manager will assess the costs and the risks and chose the most cost effective approach containing the lowest risk. The law will not allow him to ignore the question.

Keep in mind that the reclamation question is only one of many a manager must consider. His decision will be affected by the reports of his various staff groups, each of which will express its own particular concerns. Each will be biased in its own direction and a manager expects this. A reclamation program could be a minor matter compared to production problems, financing or labor relations. A manager must remember the results of past reclamation related programs. He must be acutely aware of costs, of successfully managed risks and the competence of his staff.

It is important that a manager be aware of trends in public policy that will determine the legal and regulatory framework under which he will be required to operate in the future. It is possible his past actions have helped establish these very trends which he is now trying to understand.

Let me restate the five policy options I mentioned previously and examine how they fit into the manager's decision-making process:

Option 1: The law is costly and illogical and must be changed. We will attempt to do so.

This statement appears to be adverse to the public, the politicians and the regulators. A small company cannot afford to take this position on an individual basis. It may express its opinion through membership in a trade organization where the overall costs are minimal and so are the results.

A large, strong company may be very active in the political arena and the cost may be substantial. The intent of this expenditure is to change the politicians' view of reclamation and thereby change the law under which a company must operate.

This approach takes a long-term concerted effort and results are not easily discernable or predictable. I would venture, however, that some changes that have recently occurred in apparent public policy, law and regulation are a result of such effort.

Option 2: The law is acceptable; however, the regulations under the law are incorrectly written. We will adopt a minimal reclamation program and contest the regulations written under the law in court.

This is also an adverse position, specifically against the regulators. A minimal program, staying within the company's interpretation of the law may be less costly in the near term. Some major companies and many smaller, less financially secure companies have adopted this position.

Unfortunately, some weak companies have no other choice because they are fighting to exist. Money simply is not available. If found in violation, they may be unable to contest the regulatory agency so they adjust their program in a least costly manner and comply as best they can, or they go out of business.

A financially secure company electing this position may find near term costs low, but time lost may be valuable and lengthy. A legal contest can be costly.

The long range effect is questionable. There are instances where the legal contest clarified the intent of the law to the benefit of both the regulatory and business interests. One negative result is that the company and the agency establish a determined adversary position.

The risks of this approach are reasonable.

Option 3: Neither the law nor the regulations will be changed; therefore, we must conduct an extensive public relations program which will eventually change the will of the public, and changes of the law and the regulations will follow.

This need not be an adversary position. It is costly, not easily accomplished and has rather high risk. A small company will do little in this area.

Most large companies wage a continuous campaign to influence the public's perception of the company. Many natural resource companies do not retail directly to the public, so direct advertising is unnecessary. However, anyone who watches television will see prime time ads extolling the virtues of various major natural resource companies. Many of the ads directly address the company's performance in the environmental area, including revegetation and reclamation. Believe me, this is a costly program, but is usually funded by corporate rather than local operations.

It is hard to judge the cost effectiveness of such a P. R. effort. If current political power is an indication, the public has been influenced to elect more moderate environmentalists.

Option 4: The law, the regulations and the public will are set. Therefore, we will cooperate, innovate and lead the industry in compliance and beyond.

This is definitely a cooperative or supportive position. It will be costly in both the short term and long term and is not without risk. A small company may not be able to support this position. It calls for a large, well paid staff that will find many places to spend money.

A large company supporting this position may intend to use the results for public relations effort, supporting the political status quo or it may be sincerely interested in doing the job as well as it can be done.

The risks are that the cost may make an operation uneconomic, that you may alienate fellow companies who cannot afford this position, and that political fortunes may change, and your effort was unnecessary. It is also probable that the first set of regulations for a particular law really are illogical and that specified programs are a waste of money.

Option 5: Accept the law and its regulations with reservation and attempt to minimize costs through research and experimentation.

This is a cooperative position that attempts to remain neutral to the political situation. Costs can be substantial and results can be sporadic and inconclusive. Small companies can, at best, only hope that they are informed of latest developments. They must rely on public institutions, consultants, and those companies strong enough to lend individual support.

The results of research are accumulative and are not lost by a change in regulation, law or public opinion. Agricultural research has accumulated to the point that our nation is bread basket to the world. Revegetation for revegetation's sake is a relatively new field, particularly when it concerns locations not normally used for agriculture.

In 1974 this conference decided that the first requirement was to assemble a bibliography of publications helpful to high altitude revegetation. I also recall this conference a few years later deciding to continue as a methods and materials seminar and not to become a political pressure group. These directions are compatible with the cooperative spirit of Option 5.

The risks of this option are only financial, the returns can be good over the long term.

What is management to do?

The chances are that a large company will adopt from each of these options in preparing policy recommendations. Top executives will set a general policy. Operations management will greatly influence the specific implementation of that policy.

The specific economic and political climate of the time will have great influence. Certainly, business will always test unreasonable regulation and attempt to have a favorable political climate. Business will always put is best face forward to the public.

One problem I have observed is that not all management realizes the long term benefits of research and experimentation on revegetation methods and materials. Many managers in the mineral industry will quickly fund metallurgic or geologic research and ignore revegetation research.

Most of you here today are professionals concerned with reclamation and revegetation. Many of you work for a business that must be involved in reclamation and revegetation by law and has a management which accepts those activities as an unwelcome cost.

Another observation stemming from my continuous contact with management is that you are not keeping them informed about your efforts in these areas. It is my advice to you that you improve your communications with decision-making management. Management needs to know the effects of its decisions on your programs. You must be realistic in the analysis of your situation. Do not put yourself in the position of being an adversary or hiding behind the excuse that "it's the law". A request for $10,000 to study "The effects of high altitude cosmic radiation on sagebrush growth" is foolish when the business is barely breaking even and will convince the manager you have no concern for his financial problems.

By the same token, a well-conceived plan to delay the cost of topsoil removal will be welcomed. An awareness of economic conditions will strengthen your influence in the future.

Reconsider, then, a manager's viewpoint. Reclamation and revegetation are a cost of doing business. Management must minimize cost through various options. The results of some options are short range and well understood. Other options have longer range effects and are less well understood. Management must assess the costs and the risks and make decisions. The ability to make correct decisions is based on the timeliness and reliability of information that only you, as reclamation/revegetation professionals can give to management.

DRASTICALLY DISTURBED LANDS

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Conservation Needs, Technology, and Policy Alternatives

Drastic land disturbances by mining, mineral-waste disposal, and earth construction greatly alter soil, water, land use, and aesthetics. These alterations, in turn, affect a much larger off-site area. Adverse effects of drastic disturbances on the environment and land use can be reduced, and in some cases, nullified by timely, **well-planned reclamation based on experience and** research. In certain situations, reclamation can even enhance the environment and land use

About 200,000 acres in the United States are disturbed each year by surface mining. Waste disposal from mineral processing, along with earth movement involved in roads, subdivisions, dams, canals, dredging, pipelines, mineral exploration, and well sites, disturbs several times as much area as does mining.

Earth disturbances are often so spectacular that the off site effects, both positive and negative, are overshadowed. Then, disturbance and reclamation become the center of controversy rather than the more basic issues such as product need, economics, and social impacts. Assurance is needed that drastically disturbed land can be reclaimed or at least rehabilitated to avoid long-term pollution or aesthetic problems. We must also be able to predict which sites cannot be satisfactorily reclaimed and forecast the impact if they are disturbed.

Agriculture and mining supply basic resources to our economic system. As we as a nation strive for energy independence, it is apparent that we must rely on coal to supply more of our energy. Coal production will be increased through surface mining. In fact surface mining now accounts for about 60% of the coal produced. Also, more phosphate, more iron, and more sand and gravel are being mined by surface methods. To meet these needs we must strike a balance between protection of the environment and the nation's need for coal and other minerals

Disturbed-land research must find ways to reduce reclamation costs, optimize productivity of reclaimed areas, and validate performance requirements. To accomplish these objectives we must:

1. Integrate Reclamation with Mining and Earth Construction

We need to devise methods to integrate reclamation practices with earth construction and mining in ways that minimize aquifer damage during mining and protect water supplies from adverse effects of drastic land disturbances. Technology is needed to achieve the following goals:

a. Restore the recharge capacity of affected aquifers.

b. Identify critical environmental factors and develop standardized monitoring procedures.

c. Evaluate processing techniques to make mineral waste more suitable for alternative uses or disposal. Problem materials are acid-producing substances, uranium tailings, coal ash, spent oil shales, and others.

2. Balance Land Disturbances and Environmental Quality

We need to devise reclamation practices that optimize productivity and aesthetics and enhance or intensify land use throuh development of more productive soils, reservoirs, recreation and building sites, wildlife habitat, or landscapes shaped for water harvesting. To meet these objectives we must:

a. Predict and achieve visual acceptability, site productivity, and stability based on resource inventory and reclamation planning.

3. Plan Reclamation for Long-Term Site Stability

We need to devise practices for use in planning and reclamation that optimize site stability and minimize problems of subsidence, slumping, piping, and wind and water erosion tha may become apparent during and long after reclamation, as follows:

a. Develop improved techniques to minimize erosion and stream sedimentation.

b. Reduce costs and fuel requirements of contouring and topsoiling disturbed sites.

An overview of the basic research needs which are primarily related to drastically disturbed soils sites and the surface reclamation of the vegetative cover should involve the following points from a practical sense.

I. Preliminary, multidiscipline integration of reclamation planning into the total mining/construction plan and the phasing of the reclamation work into the construction sequence is critical. The design of the features within the project require consideration to enhance the capabilities of plant materials instead of stretching their capabilities in favor of false economics by using vegetation alone as a cure-all.

Slope repose, soil texture, slope aspect, soil color, drainage and equipment access or safety capabilities require preliminary consideration in lieu of laminated after the fact planning which postpones the revegetation sequence until the end of the project due to its phasing and not necessarily its importance.

How do we develop this process into reality? From the same standpoint, how do we develop research data/findings into a usable format for field personnel-technology transfer?

II. Materials Development

Mulching materials:

Hay/straw with changes in agricultural practices (i.e., minimum tillage or stubble return, fluctuations in weather which cause shortages result in fluctuations in cost and supply. A need is a cost effective material other than hydromulches which provide the results comparable to hay or straw.

Hydromulch fibers that provide equal results to hay or straw in more xeric sites should also be investigated for steeper slopes in lieu of labor intensive nettings.

Plant Materials:

Drought tolerant, sterile, annuals which have varied soil toxicity tolerance and extremely active seedling vigor through which to build biomass and retard soil movement. This could be used as interim covers or develop as an in-place mulch for interseeding of perennial species in a sequence of revegetation development.

Specific ecotypes which may be palatable within a normally non - palatable species or a non-palatable individual within a normally palatable species should be looked at. This could be used as a management tool in increasing productivity while maintaining the preservation or integrity of a plant community. Tissue culture may be a very viable alternative in specific selection of ecotypes.

Equipment:

Minimum tillage seed planter which will handle fluffy seed, dispense fertilizer below seed and hold together upon harsh sites.

Equipment that is developed should be low in maintenance requirements and rugged, with varied applications in ability to maneuver rough terrain.

Cost Benefit from Watering

What duration and frequency is most effective in establishing warm season species upon large sites considering root development for drought tolerance, population density and their crowding when the irrigation is removed and the plants are stressed? What are the cost advantages of bonding time versus no irrigation and utilizing time, climate, biomass development and interseeding? It is realized that laws mandate times or sequence of treatment but results and economics should be considered.

III. Testing or Proofing of Regulations As To Their Validity

Determination of best land use is essential when the law mandates the return of the surface vegetation to equal diversity, density and vigor while equaling productivity. Many areas due to past management are not very productive. With the expense of the land conversion process a higher level of production is possible but that possibility is over - shadowed by the theme of returning the site to its pre - mining condition. Why should the private land manager be mandated by the law to establish sage and other low production species when within the same area the tax supported land manager is practicing eradication of the same species? The same is true in the original contour theory; why duplicate an eroding gulley when engineered terraces could more effectively utilize run-off for forage production and reduce sedimentation and improve aquifer recharge.

The use of irrigation in areas of low water resource is not relative to water management when time and mother nature could be equally as productive and save the water resource for a higher level of agricultural use.

Many points need validation in proofing of regulations as to the application of management for the future land use.

These are some points that industry has asked daily in relation to costs and returns which researches or simple initiative upon active people need additional thought.

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SIX EQUIPMENT ITEMS FOR REVEGETATING SURFACE-MINED LANDS

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ABSTRACT

Surface mining for coal in the Western United States is expected to increase dramatically before the end of the century. Land managers find themselves caught between the demands of the new mining laws, which require complete restoration of vegetation, and the difficulty of establishing plant growth in the arid and semiarid West where the mining is occurring. To help the land manager, the Bureau of Land Management has funded the Forest Service Missoula Equipment Development Center to develop new equipment and techniques for revegetating mined lands. Six equipment systems accomplishing six specific revegetation tasks have been developed at the Center and are currently being evaluated. This paper describes these systems.

When surface mining for coal in the West began in earnest, about 10 years ago, it became apparent that many techniques developed over the years for improving range habitat were unsuited to revegetating mined land. Surface mining mixes soil profiles, alters surface and ground hydrology, and removes all vegetation. Clearly, new equipment and techniques were needed to restore this land.

The Bureau of Land Management (BLM) of the Department of the Interior (USDI) was the logical Government agency to tackle the problem. About 80 percent of strippable coal in the West is Federally owned, and the BLM manages most of the land where the coal is found. The BLM, along with the Office of Surface Mining, another USDI agency, is responsible for determining the revegetation potential of these lands.

Federal and State mining laws require that restored vegetation equal what existed before mining. Fortunately, coal seams in the West often are thick; seams of 20 feet and more are not unusual. So revenue from mining deposits of that magnitude make it economically feasible for operators to do the revegetation job that is required.

As part of its effort to develop new revegetation techniques, the BLM turned to the USDA Forest Service Missoula Equipment Development Center (MEDC). MEDC and its sister Center at San Dimas, Calif., were the only equipment development organizations involved in rangeland improvement activities.

In 1975 MEDC personnel began working with the BLM to develop equipment and techniques to revegetate lands under arid and semiarid conditions where establishing vegetation is difficult and expensive. Six pieces of equipment were eventually built to accomplish six specific revegetation tasks. Each piece of equipment is described in the following pages. The six equipment systems currently are being evaluated in various locations in the West to perfect the techniques and to establish cost data. For additional information, write USDA Forest Service, Missoula Equipment Development Center, Fort Missoula, Missoula, MT 59801.

DRYLAND PLUG PLANTER

Function

The dryland plug planter is designed to automatically plant containerized trees and shrub stock on surface-mined reclamation sites. To insure survival on semiarid sites, the root systems must stay in contact with soil moisture. To help accomplish this, the planter is able to plant containerized stock seedlings that are up to 61 cm long.

Description

The dryland planter is designed to be mounted on the rear of a tractor. It features hydraulic leveling devices, hydraulic auger with a scarifier, rotating carousel mounted on a movable carriage and two packing spades. The machine plants containerized shrubs or trees quickly and effectively. The leveling devices and high clearance enable operation on rough ground or moderate slopes, while insuring adequate placement. The containerized root system and auger holes allow sufficient moisture uptake and unrestricted root growth for better survival.

The planting is automatic and controlled from the tractor. When the planter is positioned, the platform is leveled with hydraulic cylinders. The auger digs a hole; the scarifier auger then removes any competing vegetation from around the hole. The carousel containing the seedlings rotates and the carriage moves forward on the platform, dropping a seedling into the hole. The packing spades firm the soil around the seedling. Planting rate is estimated at more than one per minute.

Dryland plug planter.

Specifications

Carousel capacity: 24 seedlings
Auger diameter: 7.6 to 12.7 cm
46 cm scarifier
Depth: 61 to 76 cm
Power requirements (drawbar): 52 to 75 kW

TREE TRANSPLANTER

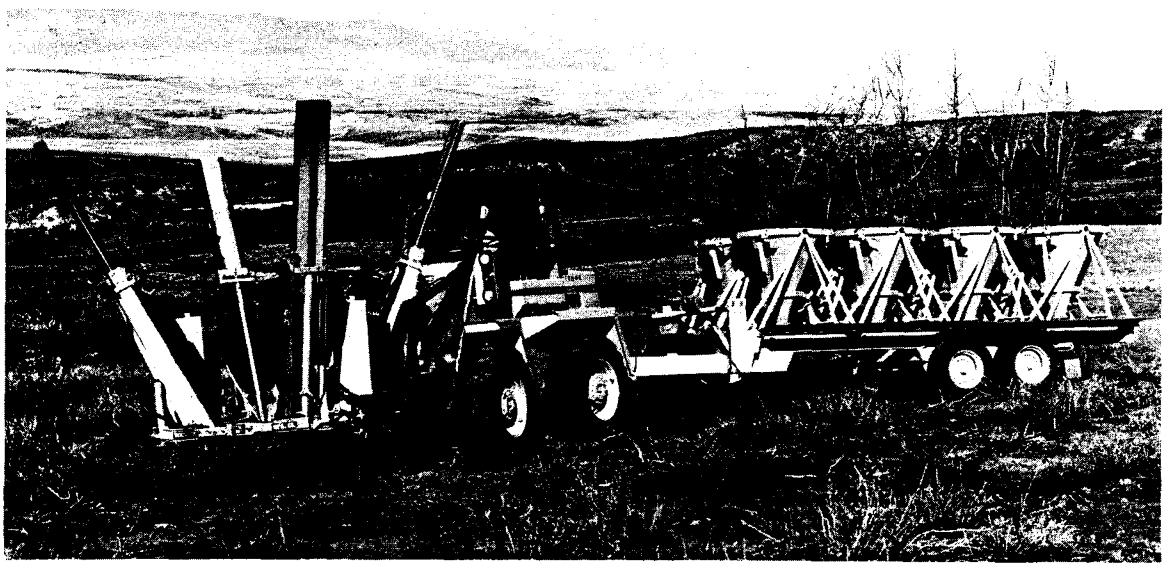
Function

The tree transplanter system was designed to transplant small trees and large shrubs that grow naturally around the mining site to the revegetation area. The trailer is an important part of the system because it greatly reduces overall transplanting costs by reducing the transport time required for each tree. Up to 24 trees per day can be transplanted with the tree transport trailer system. The front-end loader-mounted tree spade is very maneuverable and can negotiate slopes up to 20 percent.

Description

The system consists of a Vermeer Model TS-44A Tree Spade mounted on an Owatonna 880 articulated front-end loader and a specially built trailer consisting of two rows of four cone-shaped pods. The pods are 112 cm in diameter and 108 cm deep.

Eight soil plugs are removed from the transplant site, loaded into the trailer, and transported to the transplant supply area. They are then replaced in the trailer with selected trees and shrubs that are transported back to the transplant site and planted. The front-end loader-mounted tree spade digs the trees or plugs, places them in the trailer pods, and tows the trailer between the transplant site and transplant supply area.



Tree transplanter.

Specifications--Trailer

Overall width: 2.4 m with walkway removed
Height: 2.1 m
Weight: 2,722 kg
Capacity: 8 trees or plugs or 3,922 kg
Cone size: 112 cm diameter, 109 cm deep
Power requirements: 60 kW recommended

Specifications--Tree Spade

Ball (cone) diameter: 51 to 198 cm
Ball (cone) depth: 46 to 152 cm
Tree size:* to 25 cm diameter
Mounting: tractors, trailers, truck, or front-end loaders

*Maximum tree size may vary with the type of root structure.

DRYLAND SODDER

Function

The dryland sodder transfers native topsoil from the mine area to the reclamation area with its structure, profile, and vegetation intact. Reclamation is greatly enhanced because the soil horizons are not mixed, so soil development does not have to be repeated.

The dryland sodder strips the top layer of soil and vegetation (sod, forbs, shrubs, and small trees) from areas to be surface mined and places it intact over reshaped areas. The soil layer is scooped into the sodder and transported to the reclamation area. It is removed by tilting and shaking the bucket while slowly moving the loader backward. The conveyor system will feature hydraulic control of the conveyor rollers, allowing the sod to be removed without tilting the bucket.

Description

The dryland sodder is a modified frontend loader bucket. The side walls and back wall are vertical to minimize damage to shrubs and tree seedlings that are stripped along with the soil and sod. The wide, flat bottom of this bucket is sprayed with plastic to reduce friction. A conveyor system is being developed for the bottom of the dryland sodder to aid loading and unloading of the sod strips and to prevent excess soil separation during the transfer.

Dryland sodder.

Specifications

Width: 4.3 m
Length: 2.4 m
Depth: to 30 cm
Power requirements (flywheel) 80 to 391 kW

SPRIGGER

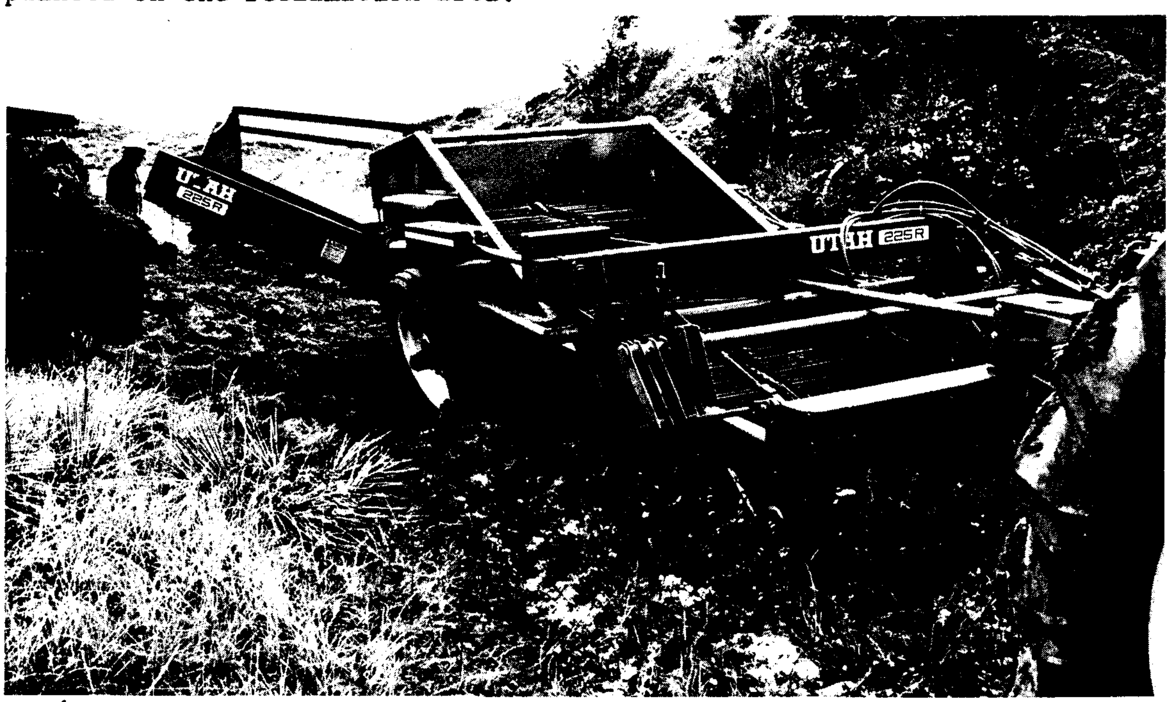
Function

The sprigger undercuts and gathers sprigs, or portions of rhizomatous stems, that can produce roots and shoots. The harvested sprigs are then spread out on the area to be revegetated and covered with soil.

Description

The sprigger is a modified potato harvester. It consists of an undercutting blade and a pair of wide, inclined conveyors. The conveyors are long rods attached between two chains and spaced 3.8 cm apart. A third conveyor across the top of the machine moves the harvested material to the side where it is dumped into a truck or piled in windrows. The sprigger is towed and powered by a tractor.

After the shrubs are mowed, the sprigger is pulled through the stand, cutting the roots well below the ground surface. The cutting action lifts the soil and shrubs onto the conveyors. The soil is shaken loose and falls through the spaces in the conveyors to the ground. The bareroot rhizomatous shrubs, or sprigs, are gathered and carefully planted on the reclamation area.



Sprigger.

Specifications

Width: 1.5 m
Depth: 30 cm
Power requirements (drawbar): 60 to 75 kW

BASIN BLADE

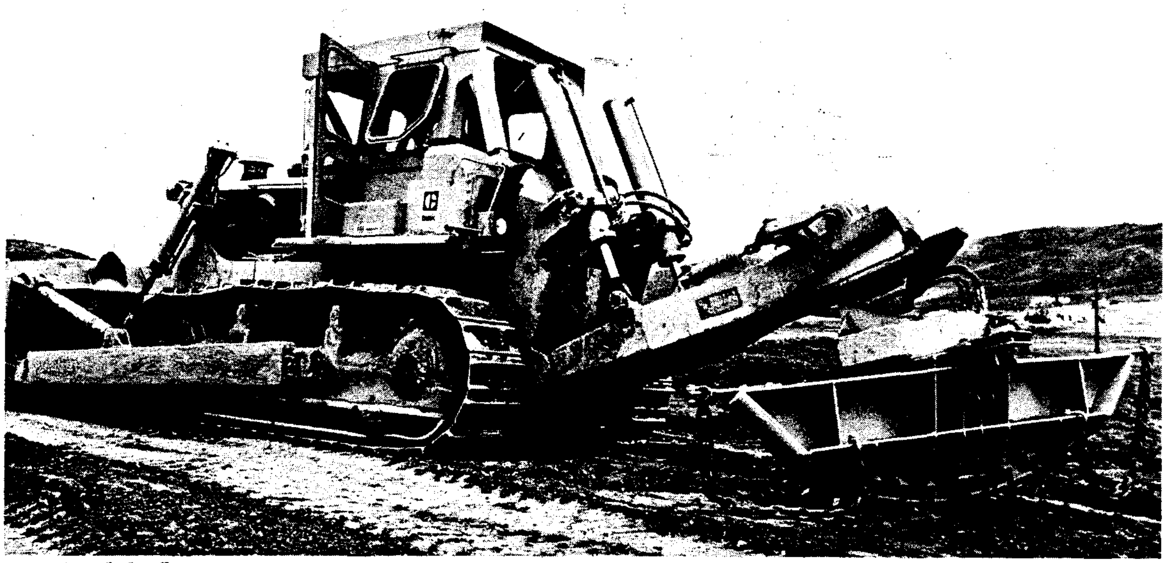
Function

The basin blade scoops out large basins or depressions along slopes. Moisture accumulates in these basins to provide a favorable microsite for plant growth. The large basins reduce wind erosion. They also provide the advantages of terracing with fewer hazards and less expense. They collect runoff and trap snow and blowing topsoil. The furrows formed by the scarifying teeth help retain broadcast seed and fertilizer and promote increased infiltration.

Description

The basin blade is a large, crescent-shaped, heavy steel blade mounted on the rear of a crawler tractor. The blade is mounted on a parallelogram multiple-ripper shank. It is raised, lowered, and tilted hydraulically. Several replaceable scarifying teeth are located along the bottom edge of the blade.

The tractor is driven along the contour of a slope and the blade is periodically raised and lowered to form large depressions. Seed is then broadcast along the slope.



Basin blade.

Specifications

Width: 3 m
Depth: to 91 cm
Power requirements (flywheel) 216 to 276 kW

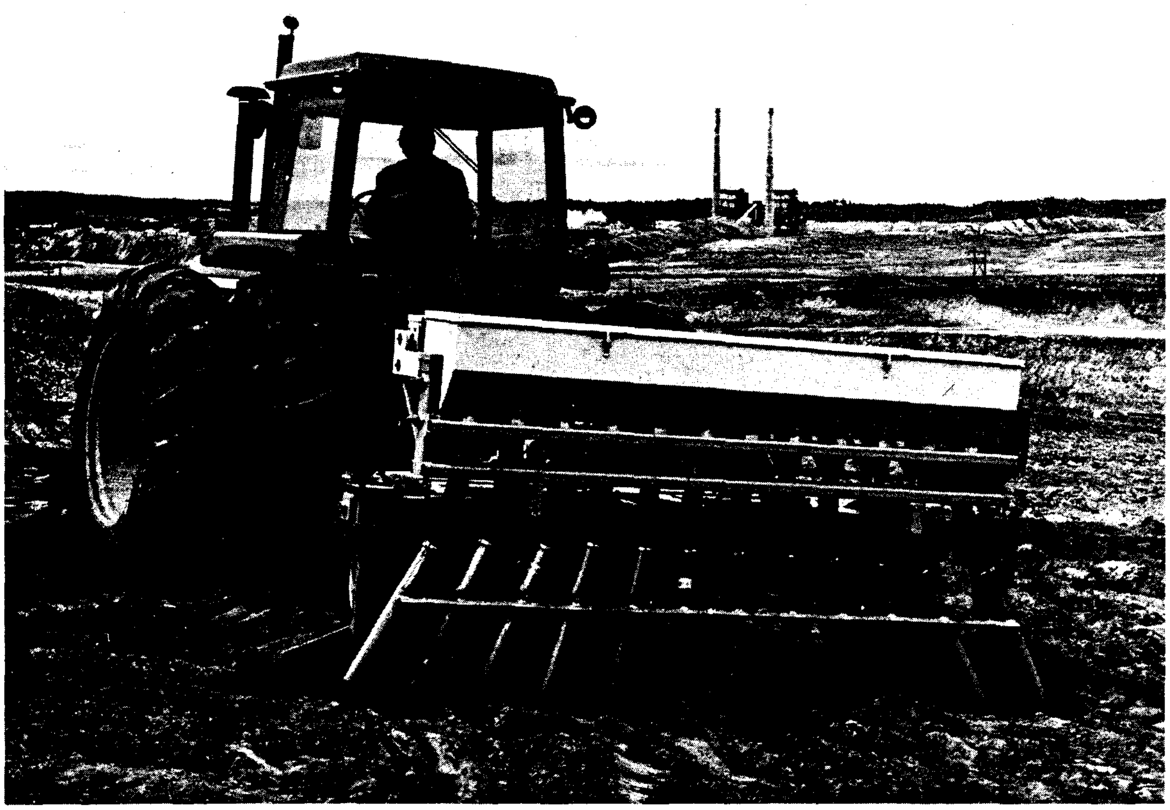
HODDER GOUGER

Function

The gouger creates numerous depressions in the soil surface. These depressions provide a suitable microclimate for plant establishment by increasing moisture availability, preventing wind and water erosion, and providing shade.

Description

The gouger consists of three to five semicircular heavy steel blades attached to solid arms. Each blade has three scarifying teeth along the bottom edge. The arms are attached to a heavy-duty frame with spring-loading mechanisms. They may be mounted in either one- or two-row configurations. The frame is supported with side wheels that are periodically raised and lowered to allow the blades to scoop out depressions. The unit is operated hydraulically and features positive depth control and automatic up and down cycling. A seedbox spreader is mounted on the rear of the machine to broadcast seed into the depressions.



Hodder gouger.

The gouger is towed behind a tractor. The hydraulically powered automatic cycling system moves the frame up and down in relation to the wheels to create depressions. The depth of the depressions, cycle rate, and blade configuration can be varied to suit the site conditions. Average production rates have varied from 1 to 1.1 ha per hour.

The gouger creates more and larger depressions than similar equipment. The automatic cycling and hydraulic depth control make it easier to operate and the adjustable cycle rate and variable blade configurations contribute to its versatility. The spring-loaded blade arms enable it to operate in fairly rocky ground.

Specifications

Implement width: 3.4 m
Depression width: 38 to 56 cm
Depression length: 0.9 to 1.2 m
Depth: 15 to 25 cm recommended
Power requirements (drawbar): 37 kW minimum

NEW EQUIPMENT DEVELOPMENTS FOR STEEP SLOPE/HIGH ALTITUDE REVEGETATION

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INTRODUCTION

The increasing cost of hand labor, difficult working conditions, and the unavailability of commercially manufactured machines, designed specifically for revegetation on steep slopes, have resulted in the assignment of several projects to develop such machines at the USDA-Forest Service Equipment Development Center, San Dimas, California.

These projects are:

1. A steep slope containerized tree/shrub planter,
2. A steep slope seeder,
3. A liquid fertilizer spray system, and
4. The testing, evaluation, and development of attachments for the commercially manufactured hill-climbing machines.

EQUIPMENT DEVELOPMENT

Steep Slope Containerized Tree/Shrub Planter

A project to develop and test a planter for containerized trees and schrubs was undertaken to reduce the costs and improve the efficiency of stabilizing soil on slopes newly created during road construction in mountainous terrain, and on disturbed lands resulting from strip mining operations. Other goals were to maximize the esthetic impact of hillside revegetation, increase the effectiveness of replanting on roadside slopes, protect hillside watersheds, and reduce lake and stream siltation.

Planter Operation

The planter can be carried and positioned by a hydraulic crane or a cable crane if a second cable drum is available to keep the planter properly oriented. Some of the cranes can reach over 100 feet (30.5 m) from the road with the planter attached. After the tree or shrub seedlings are removed from their containers and are loaded into the carousel tubes, the crane operator places the planter on the slope. The planting cycle, once initiated by the operator is fully automatic (electric over hydraulic). First, debris is scalped or scraped off the ground where the seedling is to be inserted. Next, a hole is augered and the carousel rotates; a rachet mechanism lines up a carousel tube with the augered hole. As alignment occurs, a high-velocity blast of water propels a seedling down the carousel tube, through a drop tube into the hole in the ground. Finally, a packing foot compacts the soil around the root system, while forming a small depression for water.

Field Test

A test site on the Willamette National Forest, Oreg., was divided into five areas to cover a wide range of conditions and plant varieties. Area 1 was in a campground, nearly flat, shaded and well stocked with grasses. The soil was gravelly sandy loam, river alluvium that was moist and contained a good amount of plant nutritive material. A total of 400 mixed noble and Douglas-fir seedlings were machine planted.

Area 2 was a long cutbank of predominately southern aspects. The cutbank had raveled so that the lower half had a shallower slope, near 1½:1, while the upper half was steeper, about 1:1. The soil was gravelly loam less than 3-feet (9.1-m) deep over massive red breccia. A total of 600 mixed noble and Douglas-fir seedlings was machine planted. At the time of planting, the surface soil was loose and dry (10 percent moisture or less) with very little plant nutritive material; while 2 inches (5.08 cm) or so below the surface, the soil was moist and much firmer.

Areas 3 and 4 were south aspects with cutbanks and slopes just steeper than 1:1. The soil was shallow gravelly loam with bedrock of anthracite, basalt, and breccia outcroppings. Very little soil moisture could be detected (less than 5 percent). Each area was divided into two planting sites--one for machine planting, the other by hand for comparison. Three species of native shrubs were planted -Mahonia repecus (oregon grape), Prunus virginiana (choke cherry), and Rosa woodsii (woods rose).

Area 5 was divided into two sections. Half was identical to areas 3 and 4. The other half was north facing aspect with a slope just steeper than 1:1, but with more moist soils and an established groundcover of grass. Again, the three species of native shrubs were planted both by machine and by hand.

Production Rates

The only production data obtained were that the planter planted 24 tree seedlings (full carousel) in 21 minutes. This equates to 53.5 seconds to plant 1 tree seedling, which includes time for setting the planter in place, initiating the planting cycle, and moving to the next planting spot. The planter is designed to insert a seedling into the ground in 15 seconds. If this time were actual, then the time for setting in place, initiating the planting cycle, and moving took 38.5 seconds. Assuming 30 minutes for loading/reloading the carousel, moving the prime mover, and planting the full carousel, then the production rate would be 48 tree seedlings per hour. The production rate for shrubs was much lower and not very realistic because of their poor condition and the problems with the roots and broken root balls.

Planting Costs

Planting costs from 25 to 33 cents per plant were calculated using the planter. Cost of hand planting data was obtained from several agencies and one contractor. These costs range from 17.6 to plus 50 cents per plant depending somewhat randomly on location and contract specifications and more linearly on the size of containerized stock being transplanted. The size/cost relationship is not known, but is assumed to normally be a function of the number of plants one person can carry. Stock grown in 4-in^3 containers cost 18 to 21 cents per plant when planting 200 to 500 plants per acre on slopes less than 60 percent. Stock grown in 7-in^3 containers cost 18 to 24 cents per plant when planting 400 to 800 plants per acre on slopes less than 60 percent. There are very little data available for planting on slopes from 60 to 100 percent. Large potted plants have been planted for over 50 cents per plant on 100 percent slopes where at times the planters used ropes for safety and stability. So the best that can be concluded is that the cost of using the planter (25 to 33 cents per plant for planting 24-in^3 containers on 60 to 100 percent slopes) is within the range of data for planting container-grown nursery stock by hand.

Plant Survival

The time between planting and plant examination was approximately 14 weeks. During the interim, an unusually long drought for the area occurred with no rain for more than 30 days.

A random survey of area 1 indicated a survival of more than 95 percent of the 400 machine planted noble and Douglas-fir seedlings. In area 2, of the 600 machine planted seedlings, there was no survival of the approximately 300 planted on the upper bank; however, on the lower bank, approximately 95 percent of the remaining 300 survived where sluff had accumulated.

In areas 3, 4, and 5, only 3 of the 1,000 machine planted shrubs survived, and only 67 of the 1,500 hand planted shrubs survived.

The unsuccessful survival rate in areas 2 through 5 can be attributed to several factors. At the time of planting, thunderstorms had been predicted for the area to occur within the next few days; therefore, the drought that did occur was not expected. The soil moisture content was not measured, but was estimated to be 10 percent or less. Soil scientists state that ideal moisture content is at field capacity (20 to 30 percent) and the minimum for plant survival is near the wilting point (10 to 15 percent).

The upper cutbanks and slopes were nearly barren with no top soil and very little moisture, vegetation, or plant nutritive material. The lower half was mostly sluff with some moisture and plant nutritive material.

The most contributing factor to the survival failure was probably the poor condition of the plants when received. Therefore, the results indicate that survival is neither a function of machine nor human, but that of the condition of the plant and soil where planted.

Results

The planter successfully planted 24-in^3 containerized tree and shrub seedlings on 60 to 100 percent cutbanks and slopes.

The failure of the shrubs to survive was due to the poor condition in which received and to soil conditions that were nearly void of moisture and plant nutritive material and not because of machine or hand planting methods.

More data are needed to realistically rate the planter's production and planting costs against that of hand planting. The data that are available indicate that the planter compares favorably with the cost of hand planting.

The planter's compactor foot angle needs to be changed and the stroke length made adjustable because in loose dry soil, the compactor forced dirt under the seedling causing the seedling to be pushed out of the ground. Root ball breakup may have been a contributing factor because of the lack of weight to hold the seedling in place.

Steep-Slope Seeder

The steep-slope seeder is an implement that can simultaneously scarify, seed, and fertilize steep slopes. The SDEDC seeder is designed to be attached to the telescoping boom of a hydraulic crane for operation on steep slopes. It has also been adapted to being towed by a small tractor on moderate slopes such as ski runs.

Effectiveness Tests

The first prototype seeder was tested in 1976 on the Boise National Forest, Idaho (Intermountain Region). Germination, survival, and growth rates for the seed planted by the seeder were very high. The table compares, after 1-year's growth, effectiveness data for seed planted, using four different approaches, on slopes in the Idaho City, Idaho area.

Seeding Method	Plant germination and survival rate: No. of plants per 10.8 sq ft ($1m^2$) plot	Plant growth: Percent ground cover attained
Hydroseed with Silva fiber mulch	30	20
Broadcast (hand scattered)	42	37
Broadcast with straw mulch and jute netting	60	31
SDEDC steep-slope seeder	80	43

Operational Tests and Results

In 1978, the seeder was evaluated for mechanical reliability on the Willamette National Forst, Oreg. Just under 25 acres (10 hectares) of roadside slopes were seeded in 5 days; additional time was spent seeding a recreation site.

The seeder was operated on both cutbanks (some as steep as 3/4:1) and fill slopes (most were mild). Both cuts and fills were littered with rocks, stumps, limbs, etc. The seeder adapted well to the terrain and its operation was not seriously affected by the litter. The seeder/crane combination was capable of seeding 2 acres/hour (0.8 hectare/hr). This production rate does not consider long travel times between sites, performance of preventative equipment maintenance, etc. The seeder showed that it can function well in coarse-textured granitic sand; clay; and highly organic, decomposed granite soil types, both wet and dry.

Cost Comparisons

The table presents cost data from the Willamette National Forest tests plus average costs reported to SDEDC by the Pacific Northwest Region for other currently used seeding methods.

The $100 per acre ($250 per hectare) for the seeder includes 40 lb (18.1 kg) of seed, 160 lb (72.6 kg) of fertilizer, and expenses incurred for a Gradall boom crane, a pickup truck, two equipment operators, and a swamper. The estimated cost of the SDEDC seeder is approximately $9,000.

Cost Data

Seeding method	Approximate cost per acre ($)	Approximate cost per acre ($)
Hydro-seed with Silva fiber mulch	400 to 600	1,000 to 1,500
Broadcast	40	100
Broadcast with straw mulch and jute netting	3,200	7,900
SDEDC steep-slope seeder	100 (180 when large amounts of slash)	250 (450 when large amounts of slash)

Seeder Fabrication

A set of drawings (RM 33-01 through 33-18) for fabricating the seeder can be obtained from the San Dimas Equipment Development Center, 444 East Bonita Avenue, San Dimas, CA 91773; commercial telephone numbers 213/332-6231 or 714/599-1267; FTS 793-8000.

Liquid Fertilizer Spray System

The liquid fertilizer spray system is designed to fit on a pickup truck and provide a low-cost means of applying fertilizer along roadside cuts and fills to promote plant growth and revegetation.

The system consists of a fiberglass slip-on tank, such as is used for fire trucks of 100- to 200-gallon capacity, a Briggs and Straton-Eco pump, and an adjustable spray boom with three nozzles. The nozzle angle and spray pattern are adjustable also. Shutoff valves for each nozzle and an engine throttle control are located on a panel on the left side of the vehicle above the door and within reach of the driver.

This system allows one person to drive the pickup truck and operate the spray system and still maintain control of the spray so that it does not pollute streams or waste the fertilizer.

The system was developed by SDEDC for the Willamette National Forest. No formal tests have been conducted on the system, however, the equipment is used on the Lowell Ranger District of the Willamette. The liquid fertilizer system has evolved from the 100-gallon tank system to a 200-gallon system because of excellent results. The system now consists of a 200-gallon tank on a 1-ton stakeside truck with a 300-gallon trailer to resupple the truck system.

A volume type centrifugal pump capable of 60 psi and larger nozzles are used to increase the distance covered.

Last year, 15,000 gallons of fertilizer were applied along approximately 300 miles of roadsides. Bare areas are broadcast seeded and then sprayed with the spray system.

Native plants are sometime burned by the liquid fertilizer but come back readily with more lush foliage

Hill-Climbing Machine

The hill-climbing machine is a unique new answer to the problem of using mechanical equipment effectively and efficiently on rugged, steep, rocky, and inaccessible work sites. The key to the machine's ability is a unique design that allows individual control of each leg and wheel. Each leg or wheel may be raised or lowered, extended or retracted, or moved in and spread out to adjust the working base of the machine to incredible changes in the angles of the terrain and surface.

SDEDC has conducted limited tests on the machine over the past 2 years to determine its adaptability for Forest Service work. The Center has tested the machines in the following kinds of work:

1. Mountain road maintenance where landslides have destroyed the road--working on 100 percent slopes

2. Test pit digging to determine subsurface materials in inaccessible areas prior to road, binwall, and bridge design

3. Fish habitat improvement, accelerators, pools in environmentally fragile inaccessible canyon bottoms

4. Timber slash piling and windrowing on steep slopes

5. Water bars on fire and fuelbreaks

6. Harvesting with the feller buncher attachment

7. Pipeline installation on 100 percent slopes

8. Water tank installations for wildlife drinkers in remote areas

9. Site preparation for planting on steep slopes.

The Center purchased a machine and is evaluating the machine and its various attachments (various shaped buckets, grapples, grading blades, feller buncher) on several National Forests. Next year, the Center will develop new attachments as a result of the evaluation and modify existing attachments for use in Forest Service work.

At this time there are two manufacturers of hill-climbing machines. They are the Menzi Muck climbing hoe, which is manufactured in Switzerland, and the Kaiser Walking Excavator, which is manufactured in Liechtenstein.

TRANSPLANTING TECHNIQUES USED IN THE ESTABLISHMENT OF NATIVE VEGETATION

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INTRODUCTION

A great deal of political and ecological emphasis is being placed on the reestablishment of native vegetation on disturbed sites. The purpose of this paper is not to address the desirability of reestablishing native vegetation but to compare various techniques that have been proposed in terms of their economic and operational feasibility. Our experience has been that many widely advocated reclamation concepts and equipment ideas have been accepted by reclamation specialists, not because of field data supporting their use, but due to extensive advertising the product has received. One of our major reasons for presenting this paper is to compare the long term survival data with the arguments originally used to advance that technique. Our objective is to bridge some of the gaps between the political and ecological ideas advanced by regulators and researchers, and put them into a form that the reclamation specialist who has responsibility for the revegetation effort can understand and hopefully apply. We recognize that no new ideas are contained herein, but ask the reader to consider the discussions relative to different transplanting techniques and see if perhaps this information can be utilized.

SEEDLING TRANSPLANTS

For the sake of simplicity, we have segregated transplanting into two general categories: seedling transplants and mature transplants. The most common transplanting technique involves the planting of seedlings obtained from a nursery or from a natural source wherein native seedlings or wildings are collected on or adjacent to the disturbed sites. Almost all wildlings are planted as bareroot stock and artifically propagated seedlings are planted either as bareroot or containerized nursery stock.

There is currently a great deal of confusion as to whether bareroot stock is superior to container grown stock and vice versa. The user is usually confronted with a commercial supplier who specializes either in bareroot or else containerized material, and it is not often that a choice is available as to what kind of material he can supply.

The merits of bareroot and containerized planting stock have been summarized by several authors, USDA Forest Service (1979), McKell et al. (1979), Stevens (1981) and McKell and Van Epps (1981). The relative advantages and disadvantages of these types of planting stock as taken from these references are summarized below:

CONTAINERIZED STOCK

Advantages	Disadvantages
Can be grown quicker, has better protected root system, usually has higher survival, available any time, has gained wide popularity, can be planted with intact soil core, can be planted over longer period, more suitable for planting on harsh sites.	Some species are difficult to grow, heavier weight, increased shipping and handling cost, higher acquisition cost, more difficult to maintain in field, hardening off is a problem, forced growth produces weak plants, more costly to plant, potting medium must be covered by soil, interface problems between growth medium and spoil.

BAREROOT STOCK

Advantages	Disadvantages
Acquisition cost is lower, plants are usually more hardened off, easier to ship and handle, usually has proper mycorrhizal fungi, higher survival, establishes quicker, better developed root system, easier and cheaper to plant, no interface problems.	Takes longer to cultivate, must be lifted and planted when dormant, roots more susceptible to drying.

Due to the various and often conflicting claims made to support the advantages of these two types of planting stock, we have adapted survival percentages for bareroot and containerized transplants as they have been reported in the scientific literature. In the 17 studies presented in Table 1, bareroot and containerized seedlings have been compared, and there is no direct evidence in terms of survival or growth that either method is superior to the other. Averaging all plantings, there is a consistent trend for bareroot survival to be higher than containerized survival. This phenomenon has been noted previously and has been explained by the fact that most of these studies do not actually involve a comparison of transplanting methods because comparisons were being made between different sources of genetic stock. These data however, do contain 7 plantings made with identical genetic stock, which also confirm the trend for higher survival to be expected with bareroot nursery stock.

Another argument commonly heard in the defense of the reported superiority of containerized planted plants deals with the question of container size and that poor performance of container material in the past can be attributed to improper container size and shape. To ameliorate this problem, a machine capable of planting 24 inch deep containers has been developed (Warren and Karsky 1982). A plant possessing a deeper root system should have more available moisture and hence, will have greater survival. Available field survival data however, do not support this logic. Jensen and Hodder (1979), at their Pompey's Pillar Study II site compared survival and growth between 12 and 24 inch containers. Average third year survival and height were greater for the 12 inch container. On the Federal Oil Shale Tracts in eastern Utah, McKell et al. (1979) found that first year survival and growth in the field were directly correlated with container volume and not container depth. In this study, root system length, spread and biomass could not be correlated with depth of the container. There are no current standards for container size (USDA Forest Service, 1979) and until additional research is conducted in this area, the reclamation specialist will be confronted with an assortment of containers ranging in volume from as small as 120 cm^3, to as large as 37,850 cm^3. It is our recommendation, based upon our own experience and the data of McKell et al. (1979) and Jensen and Hodder (1979) that if containers are used, the optimum container size should be about the size of a quart milk carton (1176 cm^3). Nowhere have we seen sufficient documentation for planting containers smaller than this size, nor any larger than the 12" X 2.5" (3763 cm^3) container tested by Jensen. Under most conditions, we would recommend caution in using container volumes outside this range.

PLANTING METHODS FOR SEEDLING TRANSPLANTS

Most seedlings transplanted in the reclamation process are planted by using hand planting methods. These methods include using a shovel or specialized reforestation tools. Recently there has been a trend toward the usage of hand operated gasoline powered augers. It must be emphasized that planting rates are dependent upon the terrain, soil conditions, type of planting tool used, degree of site preparation and experience of the planting crew (Shaw, 1981 and Penrose and Hansen, 1981). Working on disturbed sites in the Intermountain Region, Shaw reported that bareroot stock can be hand planted at rates of between 400 to 600 plants per person per day. Our experience indicates that planting rates of between 1,000 and 1,200 bareroot seedlings per person per day is common for experienced planters. Hand planting of containerized plants is considerably slower and usually averages approximately 480 plants per person per day. Gasoline powered auger planters usually require a crew of three to four people. A three man auger crew can plant approximately 480 plants per person per day and a four man auger crew can plant approximately 800 plants per person per day.

To the industry reclamation specialist who has a bonded liability to return a specific shrub density to his reclaimed site, or to an agency person responsible for living within his budget, percent survival, growth rates, aquisition costs, shipping costs and planting costs are not the primary concern. The real issue involved here is how much is it going to cost him to achieve his required reclamation standard? It is within this context that any ecological argument advanced in favor of

TABLE 1

Shrub Survival as Affected by Method of Transplanting

Reference		Method	Percent Survival by Year 1	2	3	4	5	10
Dietz et. al. (1980)		BR	64	47	-	-	36	26
		CO	49	23	-	-	11	9
Van Epps and McKell (1980)		BR	71	56	49	44	-	-
		CO	79	65	61	55	-	-
Draves and Berg (1979)		BR	54	12	5	-	-	-
1976 Planting		CO	66	6	2	-	-	-
1977 Planting		BR	33	28	27	-	-	-
		CO	27	25	25	-	-	-
1978 Planting		BR	3	14	-	-	-	-
		CO	38	42	-	-	-	-
Howard et. al. (1979)		BR	-	77	-	-	-	-
Topsoiled Oak Creek Site		CO	-	69	-	-	-	-
Butterfield & Tueller (1980)		BR	72	-	-	62	-	-
		CO	79	-	-	49	-	-
Bjugstad (1979)		BR*	-	36	-	-	-	-
Planting Stock Trial		CO*	-	29	-	-	-	-
Stevens et. al. (1981)		BR	33	-	-	-	-	-
Forestland Planter		CO	10	-	-	-	-	-
Modified Whitfield		BR	95	-	-	-	-	-
		CO	37	-	-	-	-	-
Jensen and Hodder (1979)		BR*	61	58	54	54	53	-
Pinehills	24"	CO*	70	62	60	57	56	-
Colstrip		BR*	87	74	60	59	-	-
	24"	CO*	64	45	43	43	-	-
Pompey III		BR*	65	55	52	-	-	-
	24"	CO*	73	60	55	-	-	-
Pompey IV		BR*	78	62	59	-	-	-
	24"	CO*	80	54	51	-	-	-
Orr (1977)		BR*	88	-	-	-	-	-
Fall Planting		CO*	86	-	-	-	-	-
Spring Planting		BR*	60	-	-	-	-	-
		CO*	52	-	-	-	-	-
Bjugstad et. al. (1981)		BR	-	-	-	46	-	-
Irrigation Study		CO	-	-	-	46	-	-

*Plantings made using identical genetic stock.

AVERAGE ALL PLANTINGS	BR	62	48	43	53	45	26
	CO	58	44	42	50	34	9
AVERAGE PLANTINGS	BR	73	57	56	57	53	-
With Same Genetic Stock	CO	71	50	52	50	56	-

any specific reclamation technique must be considered. The issue at stake then becomes one of selecting the reclamation methodology that will allow him to achieve the best results for the least amount of money. Let's ignore the differences in weight, handling ease, and survival assuming for the sake of simplicity that the shipping and planting costs of bareroot and containerized nursery stock are equal and assume also that the only difference between them is the acquisition cost. Using current prices, an average bareroot seedling costs approximately 20 cents each, and the average cost of a popular size containerized plant is approximatley 80 cents per plant. The assumptions used in this example are that a particular species is purchased in quantities of 1,000, that the reclamation shrub density standard is 1,000 stems per acre, and that a survival percentage of 50 percent is expected. Translating this standard into dollars, it would cost $400 to achieve this standard using bareroot stock and $1,600 using containerized stock. Within the context of this example, bareroot stock is 400 percent more cost effective than is containerized stock. Upon applying only the acquisition costs involved to the field data in Table 1, and using as examples the data sets of Van Epps and McKell (1980) and Draves and Berg (1979), where containerized survival was statistically higher, the cost per established seedling is in every instance lower for bareroot: $.45 versus $1.45 using the figures of Van Epps and McKell (1980) and $1.43 versus $1.90 per established seedling, using the data of Draves and Berg (1979). In other words based upon the 17 studies cited in Table 1, no instance can be found which would justify the planting of containerized stock in lieu of bareroot stock.

The differences to be expected under field conditions where competition is uncontrolled and grazing may be greater are even more alarming. The results presented in Table 1 probably present an overly optimistic picture and if containerized stock is not more cost effective under tightly controlled research conditions, how can it be more cost effective under the real world conditions of drought and constant herbivory? Our experience in northwest Colorado has been that it isn't. For example, in the Fall of 1976, the Bureau of Land Management - Energy Mineral Rehabilitation Inventory and Analysis staff transplanted 1761 containerized plants on the Energy Mine. After 18 months of monitoring the 2 percent survival was deemed so poor that monitoring of these plots was terminated. Between 1977 and 1979 we planted under favorable conditions 16,560 containerized seedlings at the Energy Mine without being able to locate one surviving seedling. Recognizing that the plants were planted under favorable conditions we suspected that the forced growth of the seedlings resulting in a low root/shoot ratio and plant dormancy problems could have been responsible for their poor performance. To avoid this problem, we took the containerized seedlings ordered in the Spring of 1980 and kept them for harding-off until they were planted in the Spring of 1981. After approximately one year of harding-off the plants have done about as well as our bareroot planted stock, but the time and effort required to harden the plants increased costs considerably. In summary, we believe based upon examination of the literature and our own experience that the recommendation to plant containerized stock is over recommended and not economically justifiable.

MECHANIZED SEEDLING TRANSPLANTERS

Mechanized seedling transplanters have been used extensively for reforestation work and only recently has their utility been tested for mining reclamation purposes. To date several systems have been used but only three appear to have any value for this application. They are the Modified Whitfield*, the Forestland Transplanter and the newly developed Dryland Plug Planter.

Modified Whitfield Transplanter

Since the Modified Whitfield Transplanter machine was initially tested in 1977, the Utah Division of Wildlife Resources has planted approximately one million seedlings with this machine. When tested against three other commercial tree planters this machine was found to be superior (Stevens et al. 1981 and McKenzie et al. 1980). Transplanting rate is dependent upon the species planted, the size, type, surface condition and degree of site preparation. Actual transplanting rates using this machine range between 4,800 and 8,640 per day (Stevens, 1981). If costs are calculated using the 1982 Rental Rate Blue Book and production averages 6,720 plants per day, the cost of transplanting one plant with this system is 7 cents per plant (Table 3). Using the survival data reported by Stevens et al. (1981), the cost per surviving seedling using this technique is calculated to be approximately 28 cents per plant (Table 3).

Forestland Transplanter

The Forestland Transplanter is similar to the Modified Whitfield Transplanter in that it is pulled by a prime mover and is operated by two operators. This machine has been recommended by Shaw (1981) for usage on mine sites and she reported that under favorable conditions approximately 8,000 seedlings per day could be planted. Using this planting rate and the assumptions used for the Modified Whitfield Transplanter, the average transplanting cost was 8 cents per plant (Table 3). Although tested by Stevens et al. (1981) and McKenzie et al. (1980) they could not recommend this machine for use on the harsher sites they worked. They felt that when compared to the Modified Whitfield Transplanter, the Forestland Transplanter was too small and light, was not adapted to rocky or heavy textured soils, and that the depth of the cutter bar at 6 to 8 inches was too shallow for their planting conditions. They did conclude, however, that this machine was well suited for sandy soils and this could partially explain why Shaw (1981) working

*Use of a trade name in this paper is solely for the convenience of the reader and does not consitute an endorsement for that product by the authors or by Colorado Yampa Coal Company.

in southern Idaho had such good success with this machine. Using the survival data reported by Stevens et al. (1981), the cost per surviving seedling using this technique is calculated to be approximately 47 cents per plant (Table 3).

TABLE 3

A Comparison of Cost Per Established Transplant by Transplanting Method

	Equipment/ Labor Cost	Seedling Cost	Reported Percent Survival	Survival Year	Cost Per Surviving Plant
Hand Planted	$ .32	$ .20*	26	10	$ 2.00
Backpack Auger	$ 1.02	$ .20*	26	10	$ 4.69
Modified Whitfield	$ .07	$ .20*	95	1	$ .28
Forestland Planter	$ .08	$ .20*	59	1	$ .47
Dryland Plug Planter	$ 1.30	$ 1.98	69	1	$ 5.10
Tree Spade	$ 36.83	$ -	26	5	$ 141.65
Modifed Tree Spade	$ 40.94	$ -	35	2	$ 116.97
Backhoe	$ 11.20	$ -	56	5	$ 19.77
Front End Loader	$ 6.84	$ -	79	5	$ 8.66

*Bareroot Seedling Cost

Dryland Plug Planter

The Dryland Plug Planter is a relatively new transplanting system developed with a carousel assembly that can be mounted on the three point hook up assembly of an agricultural type farm tractor in the 100 horsepower class. This machine is designed to handle specially built 24 inch containers and was developed on the premise that increased survival can be expected by placing the roots of the transplant into the subsoil where moisture and nutrients should be more available (USDA Forest Service 1980a). This system requires two operators for optimum production and under favorable conditions can plant between 300 and 400 plants per day. Equipment and labor planting costs for this system were $1.30 per planted seedling (Table 3).

Several serious problems exist before this system will gain acceptance by the reclamation specialists. Aside from the low production rates, the high planting costs, this system utilizes a specialized container that costs $1.98 in addition to the equipment cost when ordered in quantities over 10,000 plants (Warren and Karsky 1982). First year survival data collected from the Western Energy Mine yielded a survival percentage of 69 percent, which when compared to first year survival percentages for containerized plants summarized in Table 1, is not superior to those of the more commonly used containers or to bareroot stock. Since documentation by Jensen and Hodder (1979) and McKell et al. (1979) have shown field survival of containerized plants to be unrelated to container depth, we must await additional testing to determine whether or not this system will prove to be practical. Using the survival data reported by Warren and Karsky (1982), the cost per surviving seedling using this technique is calculated to be approximately $5.10 per plant (Table 3).

MATURE TRANSPLANTING

The concept of mature transplanting was initiated to take advantage of indigenous plant material at a site prior to disturbance. Methods and equipment had to be developed which could efficiently remove and plant this vegetation and still maintain a high survival. This equipment included equipment commonly found on most mines such as backhoes and front loaders as well as the tree spade, a common piece of equipment used in commercial nurseries.

Placement of clumps of mature vegetation on disturbed sites provide excellent food and cover for wildlife, and seed islands for dispersal of seed either by wind or wildlife. The clumps can also be utilized as a means of instant reclamation for severe site stabilization and can provide a certain degree of aesthetic modification to the site.

Vermeer Tree Spade

The Vermeer Tree Spade is a transplanting system that has been widely used for landscaping purposes and has been recently widely tested for its utility in the reclamation of highway and mining sites. During the fall of 1975 Dressler and Knudson (1976) tested a trailer mounted Vermeer Model TS-44A tree spade at the Western Energy Mine in Montana and the Edna Mine in Colorado. In 16 days of transplanting they were able to plant 137 trees and shrubs with an average daily rate of 8.6 plants per day. Assuming this system can plant an average of 8 plants per day, the labor and equipment costs involved in transplanting one seedling averages approximately $36.82 per plant (Table 3). They concluded that this machine was a versatile, reliable, sturdy machine that was very well suited for used in the revegetation of disturbed lands. Jensen and Hodder (1979) tested this same machine in eastern Montana and concluded that this system was a successful and practical means of transplanting large trees. Williamson and Wangerud (1980) tested this system on the Glen Harold Mine in North Dakota and had mixed results as compared to bareroot and potted greenhouse stock. A front end loader mounted version of this system was tested by Larsen and Knudson (1978) at the Trapper Mine in Colorado during the fall of 1977 to see if the previously identified problems of mobility could be overcome using this system. The popularity of this machine is based upon its success achieved for landscaping and little longterm data have been collected for sites revegetated using this system. The purpose of this discussion is to present long term survival data.

Edna Mine Tree Spade Plantings

First year survival data collected from this planting were presented by Dressler and Knudson (1976). Seven species totalling 72 plants were transplanted in this 9 day planting study set out on mine spoil. Approximately half received 25 gallons of supplemental water when transplanted and all were subjected to three levels of pruning: control, lightly pruned to remove half of the previous year's growth and moderately pruned which left only the main stems. The planting was in September 1975 and the pruning operation was conducted the following February. Third year survival figures from this planting are found in Table 4.

Irrigation at the time of transplanting appeared to lower overall plant survival. Third year non-irrigated survival averaged 76 percent while

TABLE 4

Third Year Edna Mine Tree Spade Survival Data as Influenced by Irrigation and Pruning[1]

	Non-Irrigated			Irrigated		
	Moderate Pruning	Light Pruning	Unpruned	Moderate Pruning	Light Pruning	Unpruned
Aspen	100	67	50	100	50	40
Chokecherry	0	33	25	-	0	0
Wildrose	50	100	100	100	100	100
Serviceberry	100	100	100	-	-	-
Gambel Oak	50	100	0	-	-	-
Snowberry	100	100	100	-	-	-
Sagebrush	-	100	50	-	-	-
Average	80	86	61	100	50	47

[1] Unpublished data BLM-EMRIA staff in Craig
-Species was not planted

irrigated survival averaged only 66 percent. Survival of aspen and chokecherry seemed to be depressed by supplemental irrigation, but survival of rose was slightly enhanced by irrigation. Pruning seemed to improve survival, and when averaged across treatments, unpruned plants yielded 54 percent survival, lightly pruned plants yielded 68 percent survival and moderately pruned plants yielded 90 percent survival.

Energy Mine Tree Spade Plantings

In the Spring of 1976, the BLM-EMRIA from Craig and Energy Fuels personnel planted 48 plants of 7 different species using the trailer mounted Vermeer Model TS-44A tree spade. Treatments involved in this planting involved spring versus summer transplanting and irrigated versus non-irrigated treatments for the spring transplants. All the transplants were planted on respread topsoil and lightly pruned. All initially received 10 gallons of supplemental water and approximately half were watered on 6 additional occasions through the summer and into the fall.

Third year survival as shown in Table 5 indicate that the addition of supplemental water did not increase overall survival. Overall sixth year survival was about the same as in the third year survival, but root sprouting of chokecherry and serviceberry increased overall survival of these species. Season of transplanting did not affect survival. Overall third year survival of spring transplants was 28 percent while survival of summer transplants was 25 percent.

TABLE 5

Survival of Energy Mine Tree Spade Plantings

Species	1978 Survival % [1] Irrigated	Non-Irrigated	1981 Survival Percent
Aspen	25	14	18
Chokecherry	0	20	33
Serviceberry	25	40	44
Snowberry	100	80	33
Gambel Oak	0	0	0
Average	30	31	26

[1] Unpublished data BLM-EMRIA staff in Craig

Modified Tree Spade

In 1977 engineers at the Missoula Equipment Development Center redesigned the trailer mounted Vermeer Model TS-44A Tree Spade by mounting it on a one yard Owatonna 880 articulating front-end loader and designing a trailer mounted transport system capable of hauling 8 transplants (Larsen and Knudson 1978). This system increased daily production rates from 8 plants per day with the trailer mounted tree spade to 24 plants per day for a front-end loader mounted tree spade. Based upon this average daily production rate, the labor and equipment costs involved in transplanting one mature trasplant averaged $40.98 per plant (Table 3). Although no survival data were presented, these authors were of the opinion that this system would prove to be an effective way to establish woody vegetation on surface mined lands because it is the only practical way to move trees without seriously damaging their roots.

Trapper Mine Modified Tree Spade Plantings

This system was field tested in October 1977 at the Trapper Mine near Craig. Treatments employed in this study consisted of transplanting three species onto topsoiled spoil and bare spoil and treating half of the holes with an absorbent polymer called SGP which is reported to have the ability to absorb water at between 500 to 1000 times its own volume then release this water during the growing season. Each transplant received approximately 100 gallons of water at the time of transplanting.

Survival data collected in the fall of 1979 (Table 6) indicate that transplants made into raw mine spoil had a slightly higher survival than those planted into 20 inches of topsoil. Under control conditions topsoil survival was 26 percent and spoil survival was 42 percent. Averaging all treatments, spoil survival was 40 percent as compared to 35 percent for topsoil. The addition of the water holding polymer almost doubled overall second year survival. Control plantings had a survival rate of 34 percent while the survival rate of the polymer treatment averaged 63 percent. Given this result it appears that additional testing of water holding polymers is warranted.

TABLE 6

Second Year Survival of Trapper Mine Site Modified Tree Spade Plantings as Affected by Planting Medium and Usage of an Absorbent Polymer[1]

Species	% Survival Topsoil Control	% Survival Topsoil Polymer	% Survival Spoil Control	% Survival Spoil Polymer
Gambel Oak	0	50	0	25
Serviceberry	77	100	100	100
Chokecherry	0	0	25	0
Average	26	50	42	42

[1] Unpublished data BLM-EMRIA staff in Craig

Comparison Of Survival Data Obtained Using The Standard and Modified Tree Spades

It has been suggested by the designers of the modified tree spade (Larsen and Knudson 1978) that due to the increased mobility of the front-end loader, increased plant survival can be expected. In order to test this assumption, we compared second year survival from the Edna, Energy and Trapper mines to see if any differences in survival could be detected between the trailer mounted tree spade and the front-end loader mounted tree spade. We recognize that this is only a relative comparison but we believe it is meaningful due to the common species used and general similarity of these sites.

As can be seen in Table 7, overall second year survival of species transplanted onto mine spoil did not differ between the trailer and front-end loader mounted tree spades. The same relationship holds true for topsoiled sites. These comparisons seem to indicate that the increased mobility of the front-end loader mounted tree spade does not increase transplant survival.

TABLE 7

Second Year Transplant Survival Comparing the Front End Loader and Trailer Mounted Tree Spades[1]

	Spoil Sites		Topsoiled Sites	
Species	Edna Mine (Trailer)	Trapper Mine (Loader)	Trapper Mine (Loader)	Energy Mine (Trailer)
Gambel Oak	33	0	0	0
Serviceberry	86	100	77	40
Chokecherry	0	25	0	20
Average	40	42	26	20

[1] Unpublished data BLM-EMRIA staff in Craig

Backhoe Transplants

Mature transplanting utilizing a backhoe having a 30 inch bucket was initiated at the ColoWyo Mine near Meeker, Colorado. Transplants of oak, serviceberry, chokecherry, and snowberry were made in October, 1975. Each of these shrubs were lifted with a root ball approximately 24 inches in diameter and 20 inches deep. Additional transplants of serviceberry were completed in May, 1976 and a final transplanting of serviceberry and oak was made in November, 1976; a total of 134 plants were moved (Draves and Berg, 1979).

The initial transplanting consisted of eight shrubs of each species planted dry and seven shrubs of each species planted and then watered with 15 gallons of water. Fifteen additional serviceberry were transplanted and fertilized with MgAmp slow release fertilizer at a rate of one pound per shrub. Eight serviceberry were transplanted dry and seven were watered. All of the 1975 transplants were severely pruned to six inches prior to transplanting.

Survival data for oak, serviceberry, chokecherry, and snowberry were collected in August 1981 and resulted in 0%, 79.7%, 6.7% and 100% respectively (Table 8). Percent survival by species transplanted without cultural modification in the Fall of 1975 compared to transplants with the addition of water and/or fertilizer indicated that water and fertilizer did not increase survival. Serviceberry survival was higher, 100% versus 71.4%, without the addition of water. Dry planted serviceberry with fertilizer had higher survival, 71.4% versus 25.0%, than wet-planted serviceberry with fertilizer. Chokecherry survival was slightly higher, 14.3% versus 0%, without the addition of water. Oak and snowberry were not affected by cultural modification.

The backhoe was able to move 30 plants per 8 hour day with the distance from the source area being less than 100 yards. Ninety-five square feet of soil and vegetation could be moved each day under optimum conditions. Based upon this average daily production rate, the labor and equipment costs involved in transplanting one mature transplant averaged $3.54 per square foot and $11.20 per plant (Table 3). Utilizing an overall fifth year survival value of 56%, a cost per surviving plant of $19.77 is calculated. This figure would be much higher if the distance traveled was more representative of the usual field situation.

TABLE 8

Fifth Year ColoWyo Mine Backhoe Transplant Survival

	Species			
	Serviceberry	Chokecherry	Oak	Snowberry
Number of plants	74	15	30	15
Number alive	59	1	0	15
% Survival	79.7	6.7	0	100.0

The primary disadvantage with the backhoe method of mature transplanting is the small number of plants that can be moved in a day under normal mining conditions. A distance of a mile between the source area and the transplant site is common and a piece of equipment that can only move one plant at a time is not time efficient or cost effective.

Front Loader Transplants

The use of large front loaders for mature transplanting enables large areas of soil material containing many plants to be moved at one time. A Hough-Pay-Loader H-120C was used at Montana's Rosebud Mine in 1972 to transplant pads of shrubs and ponderosa pines. (Sindelar et al. 1973). In December of 1975, Energy Fuels Mine near Steamboat Springs, Colorado initiated transplants with a Terex 72-71A front loader equipped with normal 12 yard coal bucket. (Crofts and Parkin, 1979). The buckets mounted on these loaders were designed for volume and not for large surface area capacity. Two attachments were subsequently designed to accomodate larger surface areas enabling more plants to be moved at one time. The USDA Forest Service Equipment Development Center in Missoula fabricated a bucket 14 feet wide by 8 feet deep which we field tested in June of 1979 (USDA Forest Service, 1981).

In July 1980, Energy Fuels mounted an attachment on the Terex 72-71A loader that was designed at Colorado State University. The attachment was 15 feet wide and 5 feet deep with an area of 75 square feet. (Workman et al, 1980; Carlson and Crofts, 1982). The five foot depth on the CSU bucket alleviated the observed problem of loader stability and excessive pad breakage which were associated with the Forest Service bucket (USDA Forest Service 1980b).

In 1980, a study was initiated at Energy Fuels to evaluate the transplant attachment and to collect survival data relative to clump placement, season of transplanting and pad thickness on the transplants placed since 1975. The trees and shrubs studied were aspen, oak, serviceberry and chokecherry with 1975-1980 transplant survival of 23.1%, 37.4%, 84.8% and 87.7% respectively. (Carlson, 1982). (Table 9).

TABLE 9

Percent Survival by Species Utilizing Front Loader, 1976-1980, Colorado Yampa Coal.

Species	Number of Individuals	Number Alive	% Survival
Aspen	8,438	1,948	23.1
Oak	821	307	37.4
Serviceberry	1,259	1,068	84.8
Chokecherry	1,929	1,692	87.7

The clumps were placed to approximately their natural distribution when possible. The aspen were placed at the bottoms of swales in large clumps of 10 or more pads. By locating a clump in a swale, soil moisture by volume increased from 22% at spring recharge at a flat site to 40% in the swale site. The other shrubs were placed in clumps consisting of three to five pads in swales and areas that were dryer such as slopes and flatter, non-water-collection sites.

Survival and sprouting of aspen, oak, serviceberry, and chokecherry were compared to the season of transplanting: December-March, April-June, July-August and September-November. The results indicate significantly higher survival and sprouting of aspen transplanted during July and August. Oak survival and sprouting were significantly higher during the September-November transplants. Serviceberry and chokecherry survival were lower during July and August, and sprouting was lower during the September-November, (Figures 1 and 2), (Carlson, 1982). Based upon

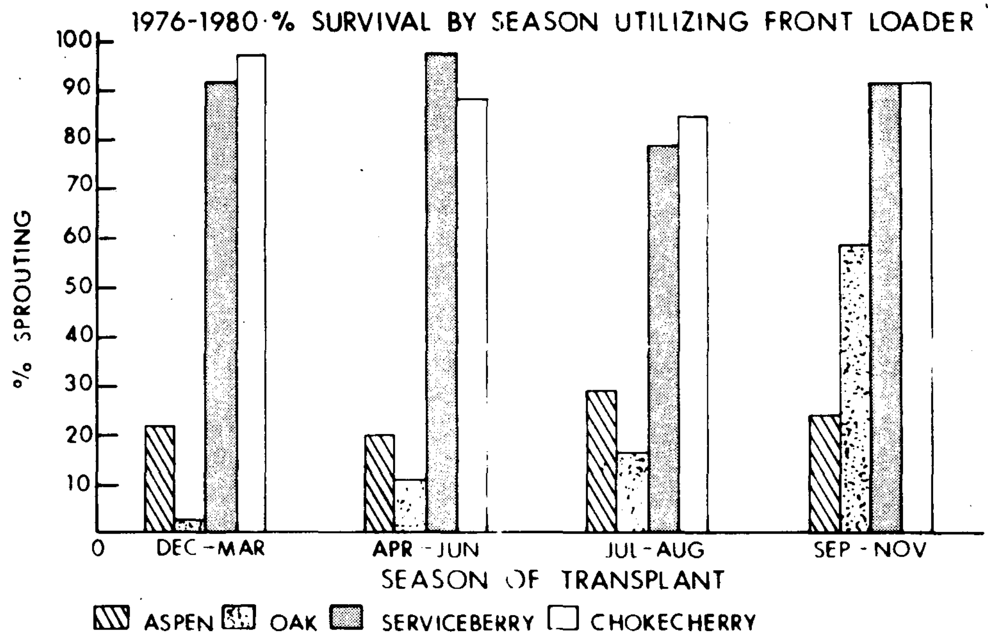

FIGURE 1 PERCENT SURVIVAL BY SPECIES BY SEASON FROM 1976-1980 UTILIZING FRONT LOADER

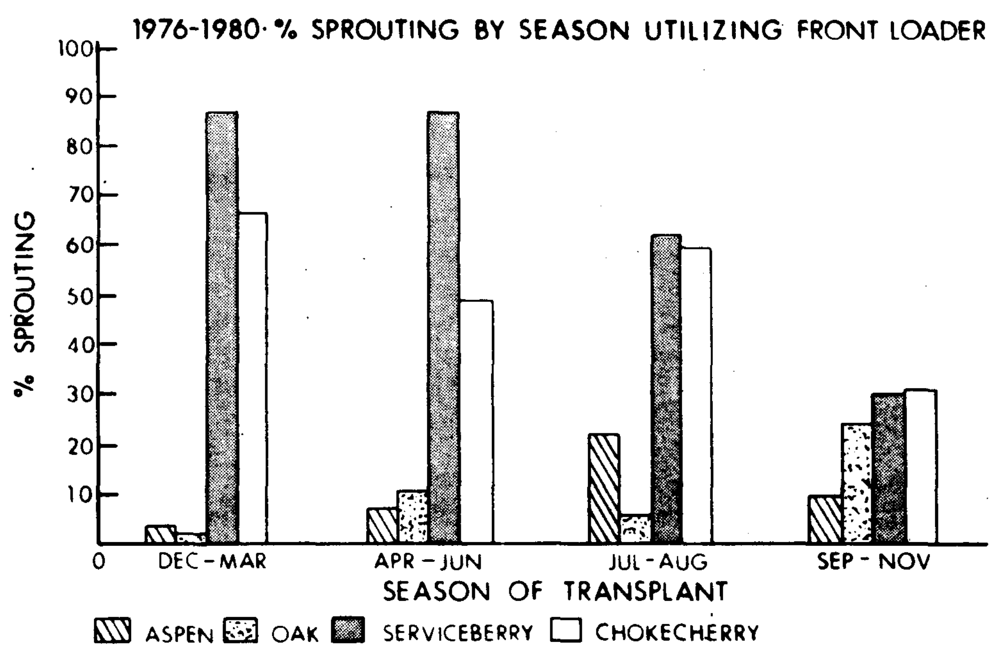

FIGURE 2. PERCENT SPROUTING BY SPECIES BY SEASON FROM 1976-1980 UTILIZING FRONT LOADER.

these data, it would appear that movement of mature transplants during the summer increases the likelihood of establishment for some taller species.

Survival of chokecherry and serviceberry are tied directly to the depth of the soil and roots retrieved in the transplanting process. Survival of serviceberry was lowest, (40%), with a 30-35 cm thick pad and highest, (82.4%) at a pad thickness of 60-65 cm. Chokecherry survival was lowest, (54.6%), with a 30-35 cm thick pad and highest, (89.5%), at a pad thickness of 40-45 cm (Figures 3 & 4), (Carlson, 1982). The potential to increase survival with increased pad thickness is believed to be related to the amount of root biomass, carbohydrate levels and moisture inherently associated with these thicker pads.

The productivity of the front loader is dependent on the disturbance and the type of terrain over which the pads must be moved. Moving 160 pads approximately 1 mile, travel time averages 82 percent of the total round trip transplanting time of 18.2 minutes. The total area of soil and vegetation moved in 1980 was 57,000 square feet with 1981 area estimated at 100,000 square feet. Twenty-six pads with an average of 9 trees and shrubs on each 75 square foot pad, could be moved during a normal eight hour day. This resulted in 234 trees and shrubs being moved per day. Using the above information, the cost of transplanting on a square foot basis is $.82 and for each tree or shrub, $6.84. Utilizing the overall survival rate of 79%, a cost of $8.66 per surviving plant is calculated (Table 3).

A few very important advantages to mature transplanting with a front loader are the large amount of material moved on a daily basis and the resulting high percentage of survival. The clumps established in the transplant process can be used to stabilize critical areas in addition to providing immediate wildlife cover. This method can never replace other revegeation practices due to cost, the small area covered, and the distance from the source area to the transplant site, but can be an effective addition to accepted reclamation practices.

CONCLUSIONS

The various methods of establishing native vegetation on disturbed sites are most often site specific. The decision as to which method or methods used should be made at the site by a person familiar with the area.

Each method of establishment listed has its advantages and disadvantages. The principal disadvantages with containerized material are that often root development is sacrificed for lush top growth, the poor interface formed between the rooting medium and the receiving site, and high cost. With bareroot stock the primary disadvantages are the short period of time during which planting is ideal, and the sometimes limited material available.

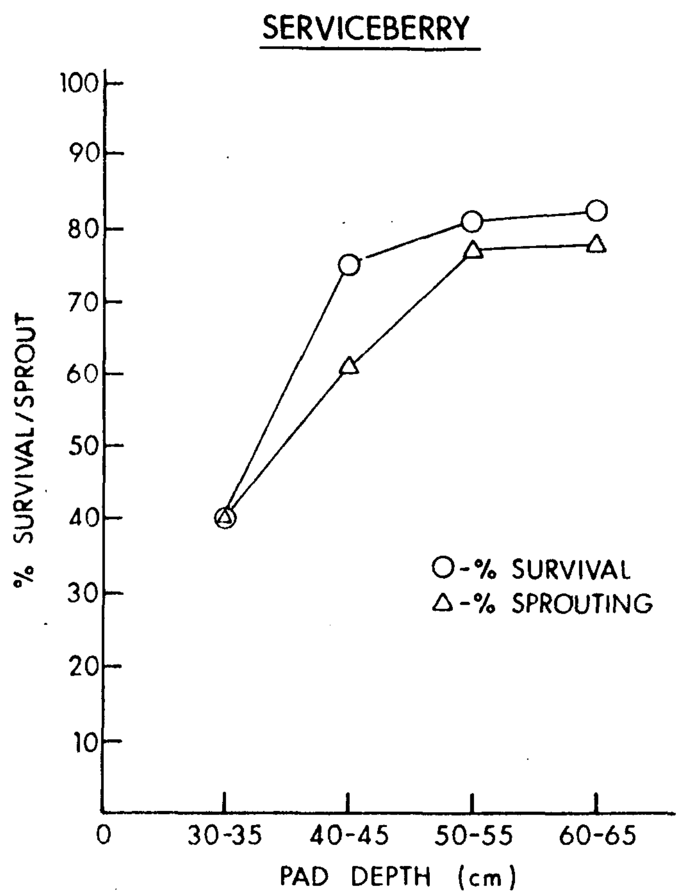

FIGURE 3. PERCENT SURVIVAL AND SPROUTING OF SERVICEBERRY COMPARED TO PAD DEPTH.

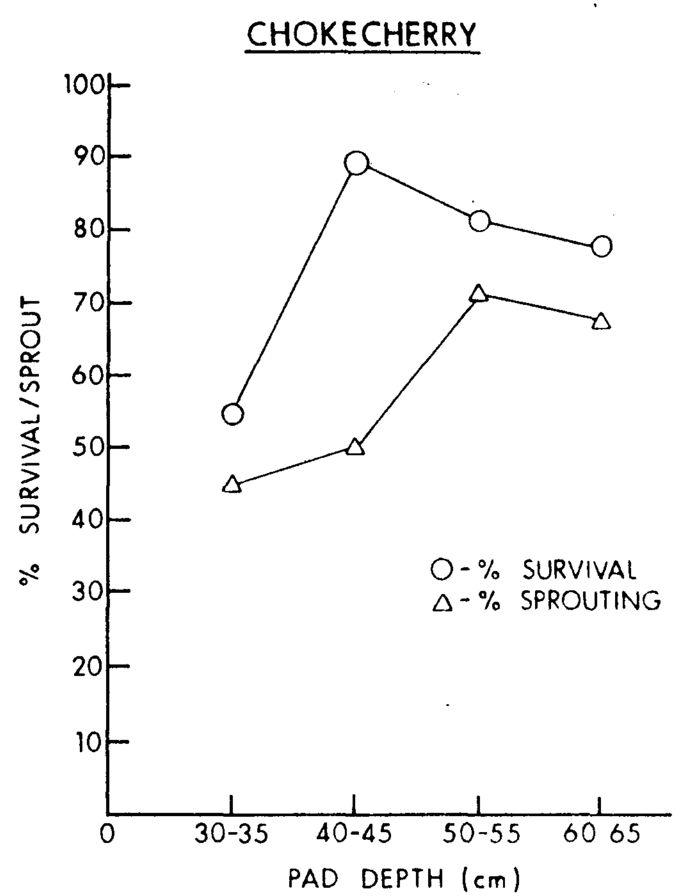

FIGURE 4. PERCENT SURVIVAL AND SPROUTING OF CHOKECHERRY COMPARED TO PAD DEPTH.

Equipment developed for reclamation use in the past has generally been poorly tested in actual field situations. Much of this equipment was designed without adequate input by the people who eventually will be required by the regulations to use it. Some new equipment, such as the modified Whitfield Transplanter, has proven to be quite acceptable. Equipment like the Dryland Plug Planter appear to be of questionable adaptability under our field conditions due to its low production rate and high cost per surviving plant.

Both aspen transplanted during July and August show increased sprouting when compared to material moved from September through November. The addition of cultural inputs in the form of irrigation and fertilization appear to negatively affect field survival and growth of transplants. Pruning appears to increase the likelihood of survival, but is not economically justifiable.

Transplanting of mature vegetation onto a disturbed site will never replace other methods of shrub and tree establishment but can be an important addition. Often the methods of shrub and tree establishment used are very site specific and any reclamation decision must encompass such concerns as the importance of an area for wildlife habitat and the amount of time available to mitigate the loss of that habitat. Mature transplants do provide areas of immediate reclamation and warrant the increased costs of this method in areas of critical wildlife habitat. Establishment of seedlings is less costly, but the time frame involved for that seedling to withstand drought, grazing and eventually provide wildlife cover, may be prohibitive in these critical areas.

Mature transplanting must be done with a piece of equipment which can move large amounts of material efficiently and with high survival. The limited testing of the modified tree spade system indicates that production is too low and survival is inadequate. The front loader survival and production values taken over a period of 5 years show high overall survival and production. The backhoe method of transplanting, like the tree spade, appears to be of limited effectiveness for use in an actual mining operation due to its low productivity.

During the design of new reclamation equipment, input from the reclamation specialist is a must. Any new equipment should be thoroughly tested at actual reclamation sites before it can be placed on the market.

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AN UPDATE OF URAD MINE RECLAMATION

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Mining has been the mainstay of the Woods Creek valley for more than a century. The head of the valley is at the Continental Divide about 50 miles west of Denver, Colorado. (Figure 1). First, it was the quest for gold and silver that drew people to the valley. Then, when molybdenum became a high-priority item with the U.S. government during World War I, it was the valley's moly-rich orebody that attracted the most attention.

The moly orebody was first developed and mined by the Primos Exploration Company from 1914 to 1919. Later, the Urad Mine - as it has always been known - was worked intermittently by the Molybdenum Corporation of America during World War II. In 1963, AMAX Inc. purchased the property for $2 million. After spending nearly $30 million for exploration and development, AMAX put the mine into production again in 1967.

A modified block-caving system of underground mining was used to remove the ore from the deposit located inside Red Mountain. The Urad orebody contained approximately 14 million tons of ore at an average grade of about 0.33 percent MoS_2. The mining and milling rate was about 5,000 tons of ore per day, which represented about five percent of the free-world production of molybdenum during the years AMAX operated the mine. At the time of shutdown in 1974, the mine had produced about 48.5 million pounds of pure moly.

Conventional crushing and flotation milling circuits were utilized to process the ore: less than four pounds of molybdenum were produced from each ton of ore mined. The remaining approximately 99.7 percent of the 14 million tons of ore was predominately composed of silica and was transported by water slurry to two tailing deposition areas. The water then decanted from the surface of the tailing areas and recycled back through an industrial mill water circuit.

CLIMATE

Climatological data for the past 16 years (1965-1981) shows the mean annual temperature to be 33° F with maximum and minimum temperatures of 80° F (August 1979) -35° (January 1979) respectively. Approximately 45 to 60 consecutive frost-free days occur each summer. Total annual precipitation has varied from 17.5 to 36.6 inches, averaging 24.3 inches, most of it occurring in the form of snow. No wind velocity data is available; however, it is estimated that maximum gusts might reach as high as 70 to 80 miles per hour.

Figure 1. Aerial photograph of Urad Valley in 1973.

VEGETATION (1)*

The bottom of the valley, which is that portion most affected by mining activities, falls in the subalpine zone of vegetation. The uppermost portions of Red Mountain fall in the alpine zone of vegetation.

The naturally occurring climatic vegetation of the valley is the Engelmann spruce (Picea engelmannii) - subalpine fir (Abies lasiocarpa) forest common to the subalpine zone of the Rocky Mountains. This stand type presently dominates most of the valley in spite of past disturbances such as logging and fire.

Other vegetation associated with the dominate stand type are listed below:

- Trees. aspen (Populus tremuloides), lodgepole pine (Pinus contorta), bristlecone pine (Pinus aristata)
- Shrubs. dwarf blueberry (Vaccinium caespitosum), dwarf juniper (Juniperus communis), shrubby cinquefoil (Potentilla fruiticosa), leafy cinquefoil (Potentilla fissa), creeping holly-grape (Berberis repens), currant (Ribes spp.), willow (Salix spp.)
- Grasses and Sedges. smooth brome (Bromus inermis), alpine timothy (Phleum alpinum), Idaho fescue (Festuca idahoensis), tufted hairgrass (Deschampsia caespitosa), ebony sedge (Carex ebenea)

DISTURBANCE OF THE LANDSCAPE

The upper end of the valley was extensively strip-cut logged as recently as 1960 through 1962. Most of the valley shows signs of logging at some time in the past. Mining generally went hand-in-hand with logging in the 1800's. In addition, much of the logging in the valley was done during the 1920's.

The south side of the lower portion of the valley suffered a severe forest fire during the 1880's. Some of the damage was reforested, but regrowth has been extremely slow demonstrating the extreme harshness of the habitat. The lower end of the valley also shows signs of fire, but lodgepole has produced new forest growth relatively quickly in that area.

Avalanches were a major problem in the valley during mining and are a continuing source of natural disturbance. There are 17 avalanche runs, 12 of which are classified as major, in the approximately three miles of the valley.

Each previous mining operation left its mark on the valley. The road systems up from the bottom of the valley were present, along with the old mill and tailing area. There were other, less-significant mining disturbances up and down the valley.

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* numbers in parenthesis refer to Literature Cited

Each of the companies that obtained molybdenum from the Urad Mine operated in a manner somewhat similar to AMAX, however, the scope of their operations was not as large as the AMAX operation. Tailing and mine-waste-deposition areas became progressively larger as the years passed. Prior to AMAX ownership, tailing disposal resulted in a significant amount of water pollution as there was no seep-water or settling pond to contain pollution and erosion into the watershed.

In the summer of 1980, 60,000 to 75,000 cubic yards of a rocky soil were borrowed to fill an old road cut. The cut slope of part of the access road was reduced from near vertical to 1-1/2 to 1 (horizontal to vertical) to facilitate the revegetation effort. Unnecessary roads have been and are being ripped/scarified, revegetated, and blocked.

The following is a breakdown of the types of acreages of disturbances at Urad at the initiation of reclamation:

Disturbance	Acreage
Upper Reservoir	36
Lower Reservoir	20
Upper Tailing Area	78
Lower Tailing Area	43
Mine Yardand Refuse Area	17
Borrow Areas	22
Mine Waste on Red Mountain	5
Glory Hole	13
TOTAL	234

Plus 15 miles of road

TEST PLOT (1)

Research in establishing vegetation directly on tailing at the Climax Mine indicated various problems such as blowing and drifting, excessive evaporative moisture loss, and physical instability in the root zone for trees during high winds. For these reasons, a test plot was designed to utilize various waste products (rock, sewage sludge, wood waste) to amend the tailing to provide a more suitable growth medium.

Development Rock

Since the origin of the rock is 2,000 to 3,000 feet below ground, it is very poor growth medium for plants. The major problem to be overcome is the lack of organic matter and nitrogen.

As poor as it is, the test plots indicate that the fragmented rock is actually a much better growth medium than tailing. Besides stabilizing the tailing, the rock eliminates the problems of blowing and drifting encountered when revegetating tailing. Rock is also an ideal mulch. Very little moisture is lost by evaporation from the surfaces of rocks, thereby conserving water in the root zone which encourages vegetative growth between rocks. The rock also provides a stable (solid) root zone for trees. Trees grown in tailing might be uprooted by high winds after growing to a height of five or six feet. Another advantage over tailing is the slightly darker color of the rock. The darker color absorbs more energy from the sun, which increases the temperature of the "soil" surface. Higher soil temperatures at this elevation increase both the growing-day length and the growing season. With the very short growing seasons and cold summer nights, every growing day is important.

Sewage and Wood Waste

Soil tests were performed and vegetation test plots established to compare the rock and tailing as growth media. A 4 X 4 factorial experimental design using various application rates of sawmill wastes and sewage sludge (with two replications) was implemented in the spring of 1974 (Figure 2). The design crossed three application rates of sewage (5, 10, and 20 tons per acre) and one rate of nitrogen (60 pounds per acre) with two rates of sawdust (4 and 8 tons per acre), one rate of wood chips (20 tons per acre), and a control. All plots were uniformly treated with 300 pounds of P_2O_5 per acre and received light daily irrigation the first season only.

5t/aSS 20t/aWC	20t/aSS 20t/aWC	10t/aSS 20t/aWC	60#/aN 20t/aWC
5t/aSS	20t/aSS	10t/aSS	60#/aN (Control)
5t/aSS 8t/aSD	20t/aSS 8t/aSD	10t/aSS 8t/aSD	60#/aN 8t/aSD
5t/aSS 4t/aSD	20t/aSS 4t/aSD	10t/aSS 4t/aSD	60#/aN 4t/aSD

Figure 2. Revegetation test plots for testing the feasibility of utilizing wood waste and sewage sludge to aid revegetation of fragmented rock and tailing growth media. SS = sewage sludge, SD = sawdust, WC = wood chips, N = nitrogen, t/a = tons per acre, #/a = pounds per acre. All plots received 300 pounds of P_2O_5 and light daily irrigation for germination and establishment during the first season. All values are dry weights (one replication shown).

TAILING RECLAMATION SEQUENCE (1)

Results from the test plots indicated that the elements considered for tailing reclamation would be appropriate for a more widespread application. Various items or steps in the process are described in more detail after this section but the sequence of revegetating the tailing areas was:

1. Cover with development rock.
2. Landscape with rock (small hills to break the flat contour).
3. Spread P_2O_5 and wood chips.
4. Rip wood chips and P_2O_5 into the surface (by dozer).
5. Spread sewage sludge (manure spreader).
6. Seed with grass.
7. Scatter dead timber onto the surface.
8. Irrigate (1st growing season only).
9. Plant trees and shrubs (transplants and seedlings) during second growing season.
10. Maintenance fertilize with inorganic fertilizers.

Early in the project trees and shrubs were planted in an area at the same time as grass was planted. Beginning in 1977, trees and shrubs were planted during the second growing season. It was felt that trees required protection from the sun and wind to increase the survival rate.

Another deviation from the reclamation sequence occurred in 1979 when the last 18 acres of unvegetated tailing surface were to be treated. This patch was at the upper (slimes) end of the upper tailing pond and was still not adequately dewatered to support heavy equipment in the summer. Rock was placed on these "slimes" areas in the winter when they were frozen and could support the weight. Because heavy equipment could not be supported, it was necessary to distribute the wood chips and sludge manually. Consequently, the coverage of organics was lighter, and they were not ripped into the rocks. The grass cover on the 18-acre patch is doing well despite the lack of ripping.

ROCK COVER (1)

Hauling of the fragmented rock from the Henderson Mine began in July 1974. The purchase of seven trucks and a D-8 dozer was necessary to initiate the program. Approximately 1.5 million tons of rock were hauled and spread on the tailing dam faces and surfaces to ensure permanent stability.

Drainage of water in the tailing was assured by the placement of coarse-rock drain courses on the faces of the dams as shown in Figure 3. Coarse-rock (greater than 2-inch) benches 10 feet deep were built across the faces of the dams about one-half of the way up each face. In addition, coarse-rock benches were constructed at the bottom of each dam (Figure 3). Coarse-rock water drain courses were constructed down the face of each dam and connect the lateral benches. Any subsurface water reaching the face of the tail dams is removed by these rock drains.

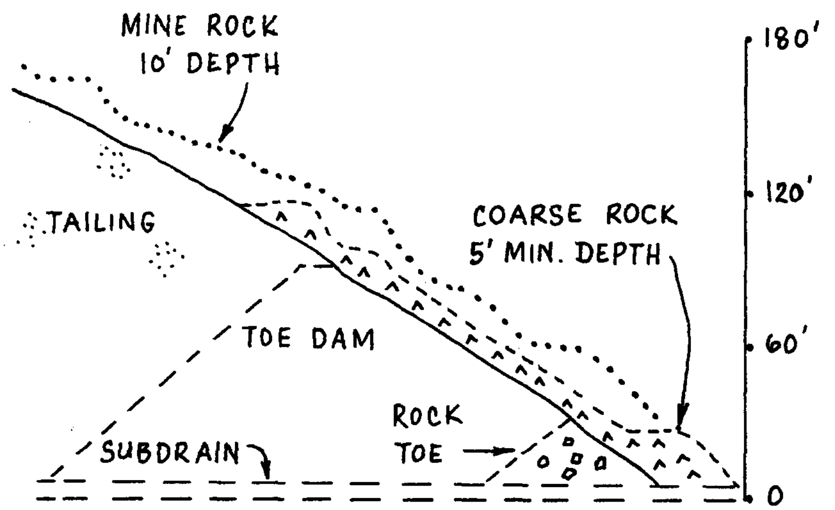

Figure 3. The placement of the coarse (segregated) and unsegregated mine rock was engineered to insure stabilization of the tailing dam faces.

To complete the stabilization of the dams, ungraded fragmented rock was benched up the faces of the dams at a minimum depth of 10 feet (Figure 3). The surfaces of the tailing areas were covered with three feet of rock.

Piezometer wells have been drilled in the crests and faces of the tailing dams to monitor the water level which is stable (Figure 4).

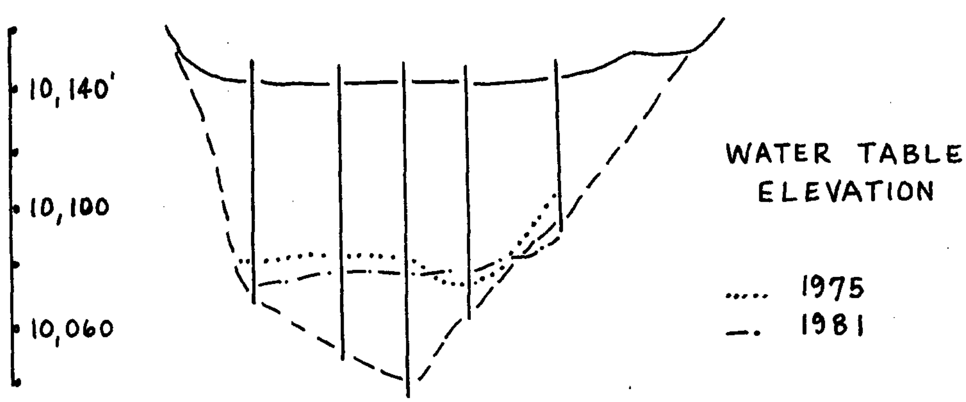

Figure 4. Water table elevation measured from piezometer holes for 1975 and 1981 for the lower tailing dam show that the level is stable.

Attempts were made to utilize the rock covering to break the flat contour of the tailing areas. Hillocks and ridges were constructed with the rock while keeping in mind the importance of cold-air drainage to plant growth. The amount of this type of landscaping possible was dependent on the stability of the tailing. Hillocks and ridges 10 to 12 feet high were expected and that is approximately what was attained given the stability of the underlying tailing.

SOIL AMENDMENTS (1)

An evaluation of the research test plots, consultant advice, literature review, and experience led to the conclusion that the most practical and beneficial combination of amendments to be used on the fragmented rock was an application of 20 tons per acre soil of wood chips and 30 tons per acre of sewage sludge. Metropolitan Denver Sewage Disposal District No. 1 and the Forest Products Division of the Koppers Company, Inc. cooperated in providing respectively 4,200 dry weight tons of anaerobically digested sludge and 24,000 cubic yards of wood chips for use on the tailing areas.

Applying 50 tons of organics to the rock is a giant step toward building a mature soil which is prerequisite to achieving self-sustaining vegetation. It was initially hypothesized that the application of organics, along with good vegetative growth maintained through the years with inorganic fertilizers, should provide a soil of sufficient maturity to sustain vegetation within 15 to 20 years.

The process has occurred more rapidly than anticipated. The vegetation has been maintenance fertilized only once, in 1979. The vegetation now appears to be permanent and self-sustaining only 6 years since the initial planting. Even so, the vegetation may receive one or more additional applications of maintenance fertilizer to maintain its vigor.

The reason for inorganic fertilization can be illustrated with a half life analogy. In the harsh climate at this elevation, the half-life of nitrogen in sewage sludge might be from two to five years. Twenty tons of sewage contains roughly 1,200 to 1,600 pounds of nitrogen. If half of that were to become available for plant use within two years, the result would be similar to applying 300 to 400 pounds of nitrogen per acre per year of vegetation requiring only about 60 pounds of nitrogen per acre per year. This would be a gross overapplication of nitrogen except for the presence of wood chips. Wood chips have a high carbon-to-nitrogen ratio (about 90 to 1). Soil organic matter, the desired product, has a carbon-to-nitrogen ratio of about 10 to 1. Microbial decomposition of the wood, therefore, requires relatively large quantities of nitrogen and uses the excess nitrogen from the sewage to form humus. Thus, much of the excess nitrogen is immobilized and retained in the soil for future plant use. The sewage and wood chips complement each other. The process allowed a significant quantity of nutrients and organic matter to be applied at one time. The potential for severe nitrogen immobilization was monitored, but never materialized. It is expected that severe nitrogen immobilization has not occurred because of the low rate of microbial decomposition controlled by the cold climate.

REVEGETATION

Grasses are the backbone of the revegetation program, but 44,000 tree and shrub seedlings have also been planted at Urad. Table 1 lists the reclamation species used at Urad.

Grasses

Research on the revegetation of the tailing material has been an ongoing program since 1965 at the Climax Mine near Leadville, Colorado. In 1967, research at Climax was begun in cooperation with Dr. William Berg of Colorado State University and his graduate student, Henry Barrau.

Initially, a grass-seed mixture was chosen for use as a result of the high-altitude species adaptation research done at the Climax Mine in conjunction with Dr. Berg. There were eight herbaceous species in the initial seed mixture. Additions of species and changes in the proportions have occurred as a result of research and seed availability in appropriate quantity from suppliers (Table 2).

Additional research was initiated in 1974 to expand the effort of finding which of the commercially available seed species and varieties are best adapted to high altitudes. The objectives of the project are to eventually select varieties of species for their adaptability, possibly cross them, and produce seed sources for high-altitude vegetation programs. Native species have been included when possible. Approximately 80 different species and varieties have been planted in each of five different high-altitude sites in the central mountains of Colorado. The Climax and Urad mines are two of the sites.

The principal investigator is Dr. Robin Cuany of the Colorado State University Agronomy Department. The project is being funded by AMAX and a few other institutions such as ski areas, seed companies, and government agencies. Dr. Cuany has been conducting similar research on smooth brome since 1970 in an effort to produce a seed source of an improved high-altitude synthetic of the species.

Table 1. URAD RECLAMATION SPECIES LIST

TREES

Engelmann spruce (Picea engelmanni)

Lodgepole pine (Pinus contorta)

Limber pine (Pinus flexilis)

Bristlecone pine (Pinus aristata)

Subalpine fir (Abies lasiocarpa) - transplants

Aspen (Populus tremuloides)

SHRUBS

Dwarf juniper (Juniperus communis)

Clematis (Clematis ligusticifolia)

Red elderberry (Sambucus racemosa)

Creeping holly grape (Mahonia repens)

Wild rose (Rosa woodsii)

Mountain mahogany (Cercocarpus montanus)

Shrubby cinquefoil (Potentilla fruticosa)

Leafy cinquefoil (Potentilla fissa)

Wild strawberry (Fragaria ovalis)

Wild raspberry (Rubus strigosus)

Willow (Salix spp.)

Rocky Mountain gooseberry (Ribes inerme)

Colorado currant (Ribes coloradense)

Squaw currant (Ribes cereum)

Golden currant (Ribes aureum)

Table 1. (continued)

Snowberry (*Symphoricarpos oreophilus*)

Kinnikinnic (*Arctostaphylos uva-ursi*)

Blueberry/huckleberry (*Vaccinum scoparium*)

FORBS

Firewood (*Epilobium angustifolium*)

Purple fringe (*Phacelia sericea*)

Yarrow (*Achillea lanulosa*)

Miner candle (*Cryptantha virgata*)

Monument plant (*Frasera speciosa*)

Little red elephant (*Pedicularis groenlandica*)

Indian paintbrush (*Castilleja* spp.)

Tall chiming bells (*Mertensia ciliata*)

Columbine (*Aquilegia caerulea*)

Collected and purchased wildflower mixes

AQUATIC VEGETATION

Cattail roots (*Typha latifolia*)

Sago pondweed tubers (*Potamogeton pectinatus*)

Wild celery tubers (*Vallisneria spiralis*)

Wild rice seed (*Zizania aquatica*)

GRASSES (See Table 2)

Table 2. CLIMAX SEED MIX

Scientific Name	Common Name - Variety	Percent by Weight in Mixture 1975	1976-1981	1981[2]
Agrostis alba	Redtop	15	3	3
Alopecurus arundinaceus	Creeping foxtail		5	5
Alopecurus pratensis	Meadow foxtail	10	5	5
Astragalus cicer	Cicer Milkvetch - Cicer		8	4
Bromus inermis	Smooth brome - Manchar	20	17	15
Dactylis glomerata	Orchard grass	10	5	5
Festuca arizonica	Arizona Fescue			4
Festuca ovina	Hard fescue - Durar	10	8	8
Festuca rubra	Red fescue - Pennlawn	10	8	8
Phleum pratense	Timothy - Climax	15	5	5
Poa ampla	Big bluegrass - Sherman			3
Poa compressa	Canada bluegras - Reubens			2
Poa pratensis	Kentucky bluegrass - Troy		3	3
Secale cereale	Rye - Balbo [3]		23	20
Trifolium repens	White Dutch clover [1]	10	10	10
TOTAL		100	100	100

Notes: 1. Legumes are innoculated using the Rhizo-cote method.

2. New mix composed as a result of the Mt. Emmons reclamation plan was used at Urad in 1981.

3. This mixture was seeded at the rate of 30 to 40 pounds per acre, depending upon the severity of the habitat. An additional five to 10 pounds per acre of 'balbo' rye (*Secale cereale*) is applied to provide fast cover and serve as a nurse crop for the establishment of the eight perennials.

Trees and Shrubs

Potted evergreens, shrubs, and aspen seedlings purchased from various nurseries are used in the tree/shrub revegetation. These materials are native to the area. Evergreen seedling survival rates have been estimated to range from 50 to 60 percent. Survival plots of 100 seedlings have been installed in recent years (1980, 1981) to provide a long-range measurement, and they substantiate earlier estimates.

The holes for trees and shrubs are dug by pick and shovel, the tree and shingle are implaced, the hole is backfilled, the ground is compacted by foot, and a gallon of water is poured on the ground around the tree to further compact the soil and eliminate air spaces. The shingle slats serve to protect the evergreen seedlings from the sun and wind. Aspen are not provided with this protection. No further maintenance is provided to materials except for fertilizer which is applied jointly to plant materials and grass in subsequent years.

The most unique biological phenomenon observed to date. was the emergence in 1979, of aspen seedlings on the waste rock growth media. This observation prompted the broadcasting of aspen seed. In the spring of 1980, small aspen trees and branches from larger aspen with apparently ripe seed were cut and the seed scattered by sharing the branches on the ponds on a windy day. The procedure was repeated over a two-week period to increase the chances that the seeds were ripe. It may be years before the results of this trial are evident.

Fertilizer tablets (21 grams each, 20-10-5, NPK) were planted with 150 lodgepole pine on the lower pond and 150 Engelmann spruce on the upper pond in 1981. Control evergreen seedlings were planted adjacent for points of reference.

For scenic purposes fifty three-foot-tall blue spruce (Picea pungens) in 20-gallon tubs were planted in piles of topsoil on the upper and lower tailing surfaces in 1981. Two to three cubic yards of topsoil were placed on the leeward side of the small hills on the tailing surfaces for wind protection. Trees were planted in groups of four with four-foot spacing among them. They were planted close to guarantee that at least one tree of the four will survive the harsh conditions and provide scenic variety. Water (1-2 gallons) was poured on the ground surrounding each tree after planting to pack the loose backfill. A one-foot-deep cover of wood chips was spread over all the two to three cubic yards of topsoil and around the trees to reduce evaporative losses. Two trees in each of the 12 groups of four trees were sprayed with an antitranspirant latex-base spray to reduce moisture losses. Moistness of the soil under the wood chips was checked periodically throughout the summer. No mortalities were apparent by the end of the first summer season. Survival after the first winter will, however, be a better indication of success/failure.

Several pounds of lodgepole pine seeds (at 90,000 seeds per pound) have been distributed at Urad during the past three years. A handful of pine seeds are mixed with grass seed or fertilizer when maintenance is performed on unresponsive or established areas respectively. Results of these efforts are thus far inconclusive.

It may take two to three years for the seed to break dormancy and then the seedlings are barely discernible for a season or so.

Willows have been planted in suitable wet spots at Urad. Besides the purchase of potted materials, willow transplants are utilized. Willow cuttings are also potted by summer temporary personnel in spring and/or fall, held over a growing season in a protected area, watered occasionally, and outplanted when adequately rooted.

Forbs

Various wildflower seeds separately and in mixtures have been broadcast along with the grass seed mixture or with the maintenance fertilizer applications. The bulk of the seeds have been obtained from seed supply firms, but summer revegetation personnel also gather seeds at the end of the summer. Collected seed is either hand-scattered on a windy day or mixed with a load of hydromulch. Forbs supply an element of vegetative diversity to the overall landscape. Showy, colorful wildflowers are used as focal points in the foreground at highly visible locations in the reclamation area.

Water-filled, shallow (less than three feet deep) depressions on the tailing surfaces were planted with various aquatic vegetation types in addition to willows which have been previously planted. Aquatic types tried in 1981 were cattail roots, sago pondweed tubers, wild celery tubers, and some wild-rice seed. The degree of success achieved by these species is presently unknown.

FLOOD CONTROL

Flood protection was a major aspect of the reclamation program. In 1978 and 1979, the company constructed a 12-foot by 12-foot box-culvert bypass of the lower tailing pond and two water retention dams. This flood bypass system - in addition to an original water bypass system built in the mid-1960's - was constructed to provide maintenance-free protection for the tailing areas against a "probable maximum flood."

MYCORRHIZAL FUNGI RESEARCH (4)

AMAX funded a research project through Colorado State University to inoculate evergreen seedlings planted on the mine wastes at Urad with mycorrhizal fungi. The fungi were cultivated separately and then added to the potting medium. Mycorrhizal fungi, when effective, serve to increase the surface areas of roots to allow a tree greater intake of nutrients and water. Early research (1976-1978) could not conclusively support a statement that seedling growth or survival was increased as a direct result of mycorrhizal-fungi inoculation. Further field investigation in 1980-81 is being analyzed now. Preliminarily, the research indicates that fungal inoculation alone is not the panacea for increased seedling growth and survival. There are environmental extremes of temperature and moisture stress that may be so limiting as to effectively nullify any possible positive effects from the fungal inoculation.

VEGETATION AND SOIL MONITORING

Vegetation and soil monitoring was first conducted in 1979 and will be repeated in 1983. A private consultant has been retained to investigate plant species cover, diversity, and production on the Urad tailing surfaces, the nutrient regime of the waste rock plus amendments that were placed on the Urad tailing, and materials uptake by vegetation growing on the tailing.

Plant Species Cover, Diversity, and Production (5)

Comparisons were made between the vegetation on the tailing surfaces, a borrow pit area, a road cut, and a very diverse spruce/fir complex that was burned circa 1879. Table 3 lists native species which are invading reclamation areas at Urad. Tailing seeded areas in 1976 had a greater total cover than the burn. Forbs were more prevalent on the burn (13 percent) than on the tailing-pond surface (one percent). Seeded areas were dominated by smooth brome, hard fescue, and timothy. If water and ample-to-excessive nitrogen were to be available on a continuous basis, these species could be expected to continue to dominate.

Vegetative cover on the tailing ponds equals or exceeds that of the native community. Stands are well established, productive, and effectively controlling wind and water erosion.

Reclaimed areas are not as diverse as the native communities, but diversity is increasing with time. A few species of grass dominate the reclaimed areas and forbs occur infrequently.

Seeded grasses have become well established and are producing more herbage than is produced by a nearby burned-over spruce-fir community.

It was recommended that inorganic fertilizers be sparingly applied even though this may result in a reduction in cover and production. The benefit would be that native invasion and thus diversity would increase.

Nutrient Regime of Waste Rock Plus Amendments (6)

An attempt is being made to monitor the soil building process. Measurements were made of the nutrient regime to determine if chemical constituents of the waste rock have increased or decreased.

Samples were taken from tailing areas covered with waste rock and amendments and seeded from 1975 to 1979 and compared to a native soil from a spruce/fir community above Urad lake (Table 4). Seven elements were concentrated two times more in the soil than in waste rock, but of these molybdenum (Mo) and boron (B) are essential for plant growth and

Table 3. Species invading seeded areas on upper and lower tailing ponds, a borrow pit, and a roadcut.

Scientific name (common name)	Comments
1975 Seeding - Urad Tailing	
Grasses	
1. Agropyron trachycaulum (slender wheatgrass)	Probably included in seed mixtures.
2. Bromus marginatus (mountain brome)	Brought in with aspen transplant.
3. Bromus tectorum (cheatgrass)	
4. Hordeum jubatum (foxtail)	
Forbs and Shrubs	
1. Achillea lanulosa (western yarrow)	
2. Arctostaphylos uva-ursi (bearberry manzanita	Probably brought in with a transplant.
3. Aster bigelovii (Biglow tansy aster)	
4. Campanula parryi (Parry bellflower)	
5. Chaenactis alpina (alpine dusty maiden)	
6. Descurainia richardsonii (Richardson tansy mustard)	
7. Epilobium angustifolium (fireweed willowherb)	
8. Geranium viscosissimum (sticky geranium)	
9. Penstemon whippeleanus (Whipple penstemon)	
10. Rumex acetosella (sheep sorrel)	
11. Rumex crispus (curly dock)	
12. Senecio ambrosioides (ragweed groundsel)	
13. Senecio soldanella (soldanella groundsel)	
14. Taraxacum officinale (common dandelion)	
15. Trifolium pratense (red clover)	

Table 3 (continued)

1976 Seeding - Urad Tailing

Forbs and Shrubs

1. *Achillea lanulosa* (western yarrow)
2. *Arctostaphylos uva-ursi* (bearberry manzanita) — Possibly brought in with a transplant.
3. *Populus tremuloides* (aspen)
4. *Aster bigelovii* (Biglow tansy aster)
5. *Epilobium angustifolium* (fireweed willowherb)
6. *Fragaria americana* (strawberry) — Possibly brought in with a transplant.
7. *Potentilla glandulosa* (gland cinquefoil)
8. *Rumex crispus* (curly dock)

1977 Seeding - Urad Tailing

No evidence of outside invasions

1974 Seeding - Borrowpit Area

Grasses and Sedges

1. *Carex geyeri* (elk sedge)
2. *Carex* sp. (sedge)
3. *Hordeum jubatum* (foxtail)
4. *Juncus drummondii* (Drummond rush)
5. *Muhlenbergia* sp. (muhly)

Forbs and Shrubs

1. *Achillea lanulosa* (western yarrow)
2. *Antennaria rosea* (rose pussytoes)
3. *Arctostaphylos uva-ursi* (bearberry manzanita)
4. *Aster bigelovii* (Bigelow tansy aster)
5. *Chrysopsis villosa* (hairy goldenaster)
6. *Epilobium angustifolium* (fireweed willowherb)

Table 3. (continued)

7. *Fragaria americana* (strawberry)
8. *Penstemon* sp. (penstemon)
9. *Potentilla glandulosa* (gland cinquefoil)
10. *Rumex acetosella* (sheep sorrel)
11. *Rumex crispus* (curly dock)
12. *Senecio* sp. (groundsel)
13. *Taraxacum officinale* (common dandelion)
14. *Trifolium pratense* (red clover) — Possibly included in seed mixture.

1972 Seeding - Roadcut

Grasses and Sedges

1. *Bromus* sp. (brome grass)
2. *Carex nebraskensis* (Nebraska sedge)
3. *Deschampsia caespitosa* (tufted hairgrass)
4. *Equisetum* sp. (horsetail)
5. *Festuca parviflora* (millet woodrush)
6. *Luzula parviflora* (millet woodrush)

Forbs and Shrubs

1. *Aster* sp. (aster)
2. *Epilobium angustifolium* (fireweed willowherb)
3. *Melilotus officinalis* (yellow sweetclover)
4. *Taraxacum officinale* (common dandelion)

Control - Spruce - Fir Burn Area

Grasses and Sedges

1. *Agrostis humilus* (snow bent)
2. *Carex* sp. (sedge)
3. *Festuca ovina* (sheep fescue)

Table 3. (continued)

4. *Hesperochloa Kingii* (King spikefescue)
5. *Poa interior* (inland bluegrass)

Forbs and Shrubs

1. *Achillea lanulosa* (western yarrow)
2. *Antennaria rosea* (rose pussytoes)
3. *Arctostaphylos uva-ursi* (bearberry manzanita)
4. *Arnica cordifolia* (heartleaf arnica)
5. *Aster* sp. (aster)
6. *Cerastium* sp. (chickweed)
7. *Clementsia rhodantha* (rose crown)
8. *Epilobium angustifolium* (fireweed willowherb)
9. *Fragaria americana* (strawberry)
10. *Castilleja miniata* (scarlet paintbrush)
11. *Castilleja sulphurea* (yellow paintbrush)
12. *Juniperus communis* (common juniper)
13. *Potentilla fruticosa* (shrubby cinquefoil)
14. *Potentilla glandulosa* (gland cinquefoil)
15. *Populus tremuloides* (quaking aspen)
16. *Pseudocymopterus montanus* (false spring parsley)
17. *Rosa woodsi* (woods rose)
18. *Sambucus* sp. (elderberry)
19. *Saxifraga bronchialis* (spotted Saxifraga)
20. *Shepherdia canadensis* (buffaloberry)
21. *Vaccinium myrtillus* (Myrtle blueberry)

Source: Trlica (5).

Table 4. Elemental concentrations (ppm wt.) of native soil and waste rock as determined by spark source mass spectrometry.

Element	Native Soil	Waste Rock
Aluminum (Al)	> 1%	> 1%
Antimony (Sb)	0.58	0.69
Arsenic (As)	1.4	4.7*
Barium (Ba)	≃ 4200	≃ 4600
Beryllium (Be)	< 0.33	7.0**
Bismuth (Bi)	0.35	8.2**
Boron (B)	29+	6.7
Bromine (Br)	1.2	6.0*
Cadmium (Cd)	0.68	1.4*
Calcium (Ca)	≃ 4700	1%
Cerium (Ce)	340	190
Cesium (Cs)	4.9	8.6
Chlorine (Cl)	15	15
Chromium (Cr)	130	280*
Cobalt (Co)	2.2	5.1*
Copper (Cu)	24	24
Dysprosium (Dy)	4.0	2.7
Erbium (Er)	2.3	1.9
Europium (Eu)	0.66	0.66
Fluorine (F)	450	≃ 1900*
Gadolinium (Gd)	1.7	4.0*
Gallium (Ga)	8.4	15
Germanium (Ge)	0.70	1.4*
Hafnium (Hf)	18+	7.9
Holmium (Ho)	1.1	0.65
Iodine (I)	0.29+	0.10
Iron (Fe)	> 1%	> 1%
Lanthanum (La)	100	68
Lead (Pb)	35	120*
Lithium (Li)	43	43
Lutetium (Lu)	0.44+	0.22
Magnesium (Mg)	> 0.5%	> 1%*
Manganese (Mn)	18	66*
Molybdenum (Mo)	1.5	69**
Neodymium (Nd)	51	51
Nickel (Ni)	10	56*
Niobium (Nb)	43	43
Phosphorus (P)	≃ 1600	≃ 2400
Potassium (K)	1%	> 1%
Praseodymium (Pr)	4.9	9.9*
Rubidium (Rb)	560	420

Table 4. (continued)

Element	Native Soil	Waste Rock
Samarium (Sm)	6.2	12
Scandium (Sc)	5.4+	2.7
Selenium (Se)	0.16	0.94*
Silicon (Si)	< 1%	< 1%
Silver (Ag)	0.2	0.43*
Sodium (Na)	< 0.5%	≃ 3200
Strontium (Sr)	230	240
Sulfur (S)	51	≃ 2400**
Tantalum (Ta)	3.6+	1.5
Terbium (Tb)	0.41	0.81
Thallium (Tl)	0.60	4.0*
Thorium (Th)	24	24
Thulium (Tm)	0.26	0.43
Tin (Sn)	3.1	13*
Titanium (Ti)	≃ 4200	≃ 4200
Tungsten (W)	0.46	4.6**
Uranium (U)	2.7	5.4*
Vanadium (V)	50	50
Ytterbium (Yb)	1.8	0.92
Yttrium (Y)	29	43
Zinc (Zn)	38	160*
Zirconium (Zr)	600+	230

+ indicates concentration of element in soil exceeds that in waste rock by at least 2 x.

* indicates concentration of element in waste rock exceeds that in soil by at least 2 x.

** indicates concentration of element in waste rock exceeds that in soil by at least 10 x.

Source: Trlica (6).

their availability to plants is unknown. Beryllium (Be), bismuth (Bi), molybdenum (Mo), sulfur (S), and tungsten (W) were at least 10 times more concentrated in the waste rock than in soil. Be as an ion is very toxic to plants. Mo and W as ions are moderately toxic to plants. The form of these five elements in the waste rock is unknown as well as the availability and rate of uptake by plants. Twenty other elements were two times more concentrated in the waste rock as in the control soil but again the unknown of availability and rate of uptake prevail.

Two to three years after addition of amendments, there has been some decline in conductivity, nitrate nitrogen, potassium, and zinc due to plant uptake (Table 5). Nitrogen is limiting as would be expected. There is a need for 150 to 200 pounds per acre per year if grass is to flourish or 100 pounds per acre per year if native invasion is to be encouraged. Phosphorous levels are moderately high. Iron, copper, and manganese are all high. Calcium and magnesium are marginally low in the growth medium but in the waste rock, so it is expected that these will become available to plants (Table 6). Beryllium, cobalt, lead, nickel, and tin are more concentrated in waste rock than in the native soil (Table 4). They are very toxic and could become a problem if the pH becomes more acidic. Microorganisms may be adversely affected in the future which affect decomposition of dead materials, nutrient cycling, and humus production.

Materials Uptake by Vegetation (7)

Vegetation was sampled to determine if potentially toxic compounds, elements, and heavy metals are being concentrated in established vegetation on waste rock on the Urad tailing. A secondary question asked was whether older, deeper-rooted plants are concentrating more toxic materials than younger, shallower-rooted plants.

Compared with soil, as reported in the literature, arsenic, copper, fluoride, and manganese concentrations in the waste-rock growth medium are lower while lead and molybdenum are higher (Table 6). Lead and molybdenum are primary constituents in the ore so this higher concentration would be expected. The 1975 stands of vegetation contain lower concentrations of arsenic and molybdenum than the 1977 stands sampled (Table 7).

Although there is a higher concentration of some elements in the growth medium compared to concentrations reported for soil, no plant toxicity has been observed. It is not expected that occasional grazing by wild ruminants on the revegetated ponds will present a toxic uptake problem.

The investigator surmised that older plants may uptake less of the elements or that maybe the element is less available as the growth medium ages. For whatever reason, the hypothesis that older plants with a developed root system would uptake more elements is not supported by the finds.

Table 5. Some average physical and chemical characteristics of crushed rock waste compared to crushed rock with addition of sewage sludge and wood chips in 1976. These data are compared with similar data for the amended growth medium that was collected in 1978 and 1979 on the 1978 and 1979 parcels.

Growth medium	Year of collection	Number of samples	ph	Conductivity (mmhos/cm)	Lime	% Organic matter	in ug/g NO_3-N	P	K	Zn	Fe	Mn	Cu	Mo
Crushed rock without amendments	1975	2	8.3a[1]	4.8a	High	0.7b	54ax	3ay	200a	14b	52a	—	—	—
Crushed rock plus amendments	1976	2	7.2a	3.6a	High	2.4a	137a	179a	173ab	100a	75a	—	—	—
Crushed rock plus amendments	1978 & 1979	12	7.7a	1.0b	High	2.4a	8ay	66ax	107b	30b	85a	20.0	15	1.6

[1]Means in a column followed by a similar letter are not significantly different at $p < 0.05$.

Source: Trlica (6).

Table 6. Mean concentration (ug/g) of elements in soil as compared with the plant growth medium of the Urad tailing reclamation area.

	Urad plant growth medium		Soil			
	Mean	Range	Mean	Range		Reference
Arsenic (As)	< 0.03	< 0.03		10	0.3–38	Williams & Wheatstone (1940)
Calcium (Ca)		12–46			50–350	Bowen (1966)
Copper (Cu)	14	2–37		45	10–200	Reuther & Labanauskas (1966)
Fluoride (F)	0.6	0.4–0.7		190	20–500	NAS (1971)
Lead (Pb)	27	11–44	16		2–200	Swain (1955)
Magnesium (Mg)		0.5–1.6			20–60	Bowen (1966)
Manganese (Mn)	20	5–52	600		200–3000	Swain (1955)
Molybdenum (Mo)	1.6	0.1–10	2.5		0.6–3.5	Robinson & Alexander (1953)
Zinc (Zn)	30	5–64	175		10–300	Swain (1955)

Source: Trlica (7).

Table 7. Average elemental concentration in forage samples of *Bromus inermis* and *Trifolium repens* collected from Urad tailings seeded in 1975, 1976 and 1977. All sample collections were taken in August, 1979.

Year of seeding	Species	Chemical constituent (ug/g)										
		As	Al	Zn	Fe	Pb	Mn	Cu	Mo	Cu/Mo	CN	F
1975	Both	.07b[1]	81a	47a	128a	< 5	224a	10a	104b	.21a	2.45a	22.2a
1976	Both	.15a	152a	39a	186a	< 5	181a	11a	155ab	.16a	7.87a	30.0a
1977	Both	.20a	97a	62a	134a	< 5	203a	12a	258a	.14a	5.37a	38.9a
1975-77	*Bromus inermis*	.11a[1]	48b	38b	89b	< 5	195a	11a	42b	.29a	2.04b	18.0b
1975-77	*Trifolium repens*	.18a	171a	60a	209a	< 5	210a	11a	303a	.04b	8.41a	42.8a

[1] Means in the same column followed by a similar letter are not significantly different ($p < 0.05$).

Source: Trlica (7).

White Dutch clover had significantly higher concentrations of aluminum, zinc, iron, molybdenum, arsenic, and fluoride than smooth brome.

COSTS

The total cost to reclaim the Woods Creek valley areas disturbed by molybdenum mining was approximately $7 million, more than three times the $2 million AMAX paid for the property in 1963.

One way to calculate the cost per acre for reclamation would be to divide the $7,000,000 by the 234 acres with a resultant cost of about $30,000/acre. However, as is indicated by the cost breakdown presented below, Urad was a unique situation to reclaim. For example, the expenditures of approximately $3 million on flood control and $2 million to put waste rock from an adjacent mine to beneficial use at Urad are unusual. Actual costs for revegetation were only about $2,500/acre.

Approximate costs to AMAX for the Urad reclamation project are as follows:

Rock covering	$2,200,000
Flood control	2,900,000
Revegetation	600,000
Management, protection, research, taxes, insurance, etc.	800,000
Long-term potential maintenance	500,000
TOTAL ESTIMATED COST	$7,000,000

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METHODS USED TO REVEGETATE THE COEUR d'ALENE MINE DISTRICT OF IDAHO

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A major revegetation program was begun in 1974 by The Bunker Hill Company in the mine-affected area of the Coeur d'Alene Mining District in Northern Idaho. Research work was initiated in 1972 by the College of Forestry at the University of Idaho. The grant which initiated the research work was awarded to the University by the mining companies located within the Coeur d'Alene District. The initial grant created a great deal of interest, since little research had been done on heavy metal mine and smelter disturbances in the West. This research was expanded by grants from the U.S. Bureau of Mines and U.S. Forest Service's Surface Environment and Mining (S.E.A.M.) Organization.

For background, the Coeur d'Alene Mining District has been producing ore since 1885. Numerous mines have operated throughout the District's history, producing values estimated at approximately three billion dollars, based on metal prices in the year of production.

The ore produced is generally concentrated on site, and then transported to a smelter for processing. It often takes 10 - 20 mines to support one smelter.

The Bunker Hill Smelter has been in operation since 1918. From 1918 until 1954, SO_2 emissions from the Smelter prevented natural revegetation of mountain slopes which had been previously denuded by forest fires. Beginning in 1954 with the construction of the first of three sulfuric acid plants, Bunker Hill began to reduce SO_2 emmissions. Today, in addition to virtually eliminating SO_2 emissions that inhibit natural reforestation, The Bunker Hill Company has embarked on an aggressive campaign to re-establish vegetation on disturbed areas.

The major disturbance around Kellogg is the mountainous slopes. Vegetation is completely lacking on the slopes adjacent to the lead smelter and electrolytic zinc plant. As distance is increased from the processing activities, vegetative cover is increased in different degrees. Shrubs are the first to appear, followed by conifer trees. When The Bunker Hill Company's revegetation program was developed, careful planning had to be carried out in order to take into account different environmental conditions. Major considerations were: degree of slope, aspect, depth of soil, temperature, vegetative cover present and pH of the soil.

Aspect is one of the more important considerations in any reforestation plan in the Northern Rockies because of the different species of trees and shrubs found on a north slope, compared to a south-facing slope. Another consideration is elevation differences on the same slope (2200 - 6000 ft.).

Shrub cover observations were utilized together with soil pH to determine the harshness of the site. Little or no native vegetation was present where the pH was lowest on the slopes adjacent to the lead smelter and zinc plant. Initial plantings showed that the traditional bare root type trees had no chance of survival on the completely barren slopes. Mortality on these areas was 80 - 100%.

After the initial failures with bare root plantings, a more thorough soil sampling was taken. The results indicated that the soils had a very low pH in the upper levels of the stratum. Below fourteen inches, the pH rose to 6.0 - 6.5 from 3.7 in the upper levels. With the low pH concentrated in the upper 14 inches, bare root type trees had little chance of surviving since their root systems would be planted within the upper 14 inches of soil. Trees which had been grown in containers where the roots could be planted with the same soil in which they had been grown showed promise. The container soil was located in the upper stratum, and root growth occurred in the lower and better soils. The major problem with container-grown tree stock is availability since this technique is relatively new, and only a small number of nurseries can supply these trees.

Initial containerized trees were obtained from the University of Idaho greenhouse and at the U.S.F.S. greenhouse in Coeur d'Alene, Idaho. The trees were planted on all sites within the District. Survival of the conifer trees was very encouraging, ranging from 80% to 100% in the plots compared with 50% survival of bare root trees on the favorable sites and no survival on the harsh sites. The better survival of containerized trees on the more favorable sites permitted the planting of fewer trees per acre.

Since containerized trees are grown under greenhouse conditions, their initial growth involves high operating and capital costs. Hence, containerized trees are expensive and difficult to obtain.

The Bunker Hill Company's revegetation plan called for an accelerated program. Taking into consideration the superiority of the containerized trees and the lack of their availability, it was apparent that a greenhouse capable of growing 200,000 trees annually should be put into operation if the Company's objectives were to be achieved. Since the Coeur d'Alene Mining District is located in steep, mountainous terrain, several problems for operating a greenhouse in the narrow valleys were naturally present.

At the time the greenhouse program was found to be necessary, a newspaper story was released on miners growing plants underground. The idea of raising trees in an underground greenhouse was considered and investigated. This underground investigation located a ventilation drift where the temperature was a constant 74°F, and the CO_2 content in the air was 0.3% which is ideal for plant growth.

The major problem encountered was raising large numbers of trees in the complete absence of sunlight. A search was made for a lighting system which would emit a large amount of light with wavelengths of 429-453 and 630-660 nanometers.

This effort was successful, and a pilot project was initiated in July, 1975. Eight high intensity, 1000 watt, mercury-vapor discharge lamps were purchased. The lights were initially installed in the ventilated drift in such a way as to utilize the greatest amount of available light as possible. A roof was built in order to support the lamps and shield the trees from dripping acid mine water.

Ponderosa pine seeds were planted in 4,000 containers and taken underground on September 1, 1975. Simultaneously with the pine tree planting, 250 containers of crown vetch were planted. The initial concern was that with the acid mine water present in the drift, air entrainment of the dripping water would cause damage to the young seedlings. Crown vetch, which is susceptible to sulfuric acid mist, acted as an indicator, in that spots on the leaves or death of the plants would occur. After four months of growth with the plants growing out of their 30-cubic-inch containers, no spots or death had occurred.

The pine seeds began to germinate within 10 days. Elongation of the stem began within 7 days after germination. At this point, it was realized that one important factor had been overlooked. Fungus and insect problems usually kill several plants in each tray of 200 in a normal greenhouse; however, there are no insects or fungus typical of plant life that exist underground. All that seemed necessary was care in not introducing any of the undesirable species distinctively harmful to the delicate young plants. Fungicide treatments were continued, however, to prevent an outbreak from spores being carried in on the clothes of workers and visitors. Insecticide treatment was eliminated because of the complete lack of insects.

After 12 weeks of growing, 3-needled fascicles typical of Ponderosa pine species started to replace the juvenile needles. At 18 weeks, the young trees had filled the 30-cubic-inch container with roots and averaged 7 inches in height.

The medium used to grow the seedlings was a 60-40 mixture of peat moss and vermiculite. Fertilizer is a major factor in that young seedlings are very susceptible to too much fertilizer. We have tried several methods ranging from slow-release capsules to very dilute solutions applied at each watering. The method we use now is fertilizing weekly with a Peters mix, at a rate of 8 ounces to 15 gallons of water.

With the underground greenhouse, The Bunker Hill Company can now grow seeds not only of conifers, but also native shrubs. Native shrubs are difficult to obtain from a nursery, and when they can be purchased, the seed will most likely not have been collected from a like ecotype where they will be planted. This ecotype factor has been found to be very important in conifers and seems to be carried over in any native type transplanting. A major advantage for a greenhouse operation is that trees can be grown and transplanted at the proper time of outplanting rather than when commercial nurseries are able to make seedlings available.

Cost-wise we have not found the expense of containers that has been reported. We can grow our own for 8-10 cents per tree. Planting costs vary with the terrain, but range from 8 cents to 14 cents. We essentially plant an acre of 400 trees for 80-100 dollars. With our survival and growth rates, we are very pleased. Over 5,000 acres have been replanted with 80-95% success rates and now have trees 8-10 feet tall on slopes originally planted in 1976 from our first crop of seedlings.

The surface disturbance present today in Coeur d'Alene District is a remnant of past practices and technology. This disturbance within the Silver Valley is especially noticeable due to its proximity to a major interstate highway. But the acreage disturbed along I-90 can now be included in an even-age forest management program due to Bunker Hill's reforestation campaign. This even-age management is similar to management of clear-cut areas used by the Forest Service in our National Forests.

Although this is an expensive program, The Bunker Hill Company has taken a responsible and encouraging position. Credit must also be given to the University of Idaho College of Forestry and Agriculture, and the U.S. Forest Service.

SOIL DISTURBANCE & STABILIZATION ON HIGH ALTITUDE SKI SLOPES

Duke Hall
Beaver Creek Associates, Inc.

The Beaver Creek Development is located in Eagle County, 10 miles west of Vail and approximately 100 miles west of Denver. The ski mountain includes 2,775 acres under a U.S. Forest Service Special Use Permit. Future plans on the mountain will include numerous activities from summer hiking and horseback riding to winter cross country skiing. The primary activity now to which construction activity on the mountain has been directed for the last four years is alpine skiing. At total build-out the mountain will include fourteen chairlifts and designed to ski 9,000 to 10,000 people daily. As of now the mountain has seven chairlifts and the peak skier day of 4,700 skiers on an area of approximately 500 acres of cleared ski trails.

Construction activities on the mountain occur from elevations of 7,500 feet to 11,400 feet. There are seven basic ecosystem classifications which are: aspen, alpine, meadow, mixed evergreen, mountain shrub, riparian and spruce fir. There are seven major soil types which range generally from sandy to gravelly clays and very clayey sand and gravels. Slope percentages associated with soil disturbance vary from 5% to 10% to as high as 65%. Normal annual precipitation is 32.5 inches, 21.1 inches of which occur from October through April. Snow depths are above normal this year with present depth of 70 inches to 80 inches at the top of the mountain to 30 inches in the base area. Soil disturbances on the mountain are primarily associated with construction of roads, buildings, chairlifts and ski trails. The majority of soil disturbances on the mountain, however, are related to ski trail construction and is the subject of this case study.

Prior to any trail construction, an in-depth Master Plan must be submitted to the U.S. Forest Service for their approval. Once this is accomplished the designated trails to be constructed during any given summer must be laid out on the ground and flagged. This includes designating trail edges, islands, drainages, areas to be dozed, etc. After walk-throughs by U.S. Forest Service and mountain company personnel, in which any potential problems are addressed and the final layout approved by all parties, construction begins.

Historically, the majority of the personnel involved with trail construction at Beaver Creek came down from Vail Mountain and use the knowledge gained there, with certain modifications applicable to unique situations regarding soils, slopes, trail design, etc. Initially the sawyers clear cut all the trees within the approved trail limits, leaving the designated islands. After all the merchantable trees are skidded and decked the slash is piled and burned. Once this is accomplished, heavy equipment such as TD-25's or D-8's destump and doze designated areas. Even though it is in general agreement among mountain company personnel that destumping and dozing the ski runs provides a much better surface for skiing, there are critical areas that the U.S. Forest Service will not allow any major earthwork. All of this is subject to prior approval, including areas to be destumped, burial areas for the stumps and areas to have major dozing. During this sequence any drainage problems are dealt with, whether it be culvert, french drain or water bar.

Upon completion of clearing, destumping and dozing, the Slopes and Trails Department initiates its revegetation activities. There are two relative documents that qualify all work regarding trail construction on the mountain. One is the Environmental Analysis Report (E.A.R.) which was approved and signed prior to the issuance of the Beaver Creek Special Use Permit. The second is an annual Summer Operating Plan which is submitted to the U.S. Forest Service for their approval prior to each summer's activity. This Summer Operating Plan addresses all aspects of summer activity including specifications of summer trail construction, from destumping, brush raking, slash removal, water control, blasting, revegetation, to vehicle policy. According to the Summer Operating Plan all revegetation of any soil disturbance must occur within ten days of disturbance and no soil disturbance is allowed after August 20th, except on a case-by-case approval basis by the U.S. Forest Service. Revegetation efforts are accomplished by a summer trail crew which varies in size depending on the workload. The trail crew not only handles revegetation, but also culvert installation, drainage control and various other utility projects as designated.

Revegetation techniques include seed bed preparation, seeding, fertilizing, mulching and subsequent follow-up seeding and fertilizing as needed. All areas of soil disturbance are left in a rough surface condition as in a disced field. Any compacted areas are scarified by a disc or harrow. Seeding is done by hand broadcasters at a rate of 50 pounds/acre, then the seed is lightly raked into the soil. There are two sets of seed mixtures, developed for Beaver Creek by Colorado State University, in use on the mountain. One mixture is for land above 9,500 feet and is referred to as High Altitude Mix. The other is for land below 9,500 feet and is referred to as Low Altitude Mix. These two mixes are listed below.

High Altitude Mix - Above elevation 9,500 feet

Type	Variety	Percent by Weight	Rate (pounds/acre)
Smooth Brome	Manchar	27	13.5
Timothy	Common	13	6.5
Clover	White Dutch	7	3.5
Fescue	Red Creeping	13	6.5
Meadow Foxtail	Garrison	13	6.5
Winter Wheat		27	13.5
		100	50.0

Low Altitude Mix - Below elevation 9,500 feet

Type	Variety	Percent by Weight	Rate (pounds/acre)
Orchard	Potomac	13	6.5
Perennial Rye		20	10.0
Winter Wheat		20	10.0
Smooth Brome	Manchar	27	13.5
Timothy	Common	13	6.5
Clover	White Dutch	7	3.5
		100	50.0

Fertilization requirements, as indicated by soil tests, are also accomplished by the trail crew and are met in two applications. The first application of 320 pounds/acre of commercial 25-25-0 fertilizer is spread by hand and raked into the soil with the seed. The second fertilizer application of urea (152 pounds/acre) or ammonia nitrate (205 pounds/acre) will be done the following spring as soon as the snow melts.

Mulching, also accomplished by the trail crew, is conducted by applying straw to the seeded and fertilized soil at a rate of two to three tons per acre, taking care to avoid a greater thickness than three inches. Even though straw is by far our most common mulch on everything from ski trails to road cutbanks, there are a few occasions when jute, excelsior, etc. is used in problem areas.

Also incorporated into the annual Summer Operating Plan is a maintenance fertilizer using ammonia nitrate (34-0-0) at a rate of 205 pounds/acre. This application is for all areas revegetated the preceding construction season and other areas where vigorous growth has not occurred. This plan is submitted each year to the U.S. Forest

Service for approval and is completed early in the summer after the snow melts.

As indicated in this case study, all revegetation practices are carried out by hand. This same procedure has been in application on Vail Ski Mountain for several years. Various other techniques to minimize the time and cost per acre have been tried, but the end result of quality and amount of revegetation has been impacted. In addition, there are many areas of extreme slope percentage and inaccessibility that make it impractical to use any methods other than by hand. Particular slopes revegetated last summer (1981) fall into this category. These areas were found to be excessively steep and almost inaccessible by any equipment. To expedite revegetation efforts, the Slopes and Trails Department incorporated the operation of a helicopter to sling load approximately 1,200 bales of straw to the faces of these slopes. This helicopter support practice was found to be very cost effective and will be used again in revegetation of inaccessible areas.

The Slopes and Trails Department feels that the revegetation techniques incorporated at Beaver Creek result in a high success ratein regard to soil stabilization on ski trails. There have been unique problems in the past to overcome and will be more to face in the future as the mountain expands. The mountain company works closely with other ski areas and technical people such as the High Altitude Revegetation Committee here at Colorado State University and the U.S. Forest Service in addressing these potential problems. This close working relationship within the industry is regarded highly by the Slopes and Trails Department of the Beaver Creek Mountain Company.

OIL SHALE RECLAMATION: REVIEW AND OBSERVATIONS

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ABSTRACT

Vegetative establishment studies on processed oil shale from 1965 to the present indicate methods using both native and introduced plant species are available to establish and maintain adequate cover. Results of early research (1965-1970) in laboratories and greenhouses provided chemical analysis, recommendations, and substantiated theories with small scale demonstration studies. In the early 1970's, field demonstration plots were initiated utilizing information obtained in earlier climate controlled studies. Early 1970 demonstration studies further defined species adaptability, fertilizer rates, mulching techniques, and results of leaching. The final phase from the mid 1970's to the present concentrated on soil depths, species mixtures, and fertility-toxicity studies. Although continued studies will improve and refine the methodology, present knowledge is adequate to restore processed shale embankments to similar appearance, use, and soil stability as present native rangelands.

BACKGROUND

In the mid 1960's private industry initiated detailed studies of the feasibility of establishing a useful vegetative cover on processed shale disposal embankments which would result from large scale production of shale oil in northwestern Colorado, eastern Utah, and southwestern Wyoming. During 16 years of tests it has been demonstrated that processed shale not only is capable of supporting growth, but capable of supporting a plant cover that is varied, productive, and self-sustaining. This paper summarizes data gathered from 1965 to 1981 on several aspects of private industry's studies. Cost/benefit methods of implementing a reclamation program for processed shale embankments resulting from commercial-size operations have been projected. The goal of the program is the establishment of a natural functioning ecosystem that does not eliminate future use.

There are as many varieties of processed shale (also called retorted shale, cooked shale or spent shale) as there are types of oil shale retorting processes. The characteristics of the retorted shales vary with the type of retorting process, the temperature of the retorting process, the degree of crushing of the raw shale prior to retorting, and the richness of the raw shale.

In-situ methods retort and leave oil shale in place underground. Above ground retorts such as Paraho Indirect and Union B processes, produce a gravelly silt loam material, which is black in color. The TOSCO II and Lurgi material differs appreciably from the other processed shales in its particle size. The charcoal colored processed shale has a uniform silt loam texture. An entirely different processed shale is produced by Union's Steam Gas Recirculation (SAR) process. This material is light tan in color, similar to natural soils, due to removal of organic carbon. Texture is gravelly similar to native talus soil, however, alkalinity is quite high. Chemical characteristics include high p.H. - 8.5-12.3, high electrical conductivity - 6.3-17.7 MMHOS/CM on saturated extract, high sodium adsorption ratio 7.8-29.0, and low nitrogen and phosphorus.

Oil shale development is concentrated in the Piceance Basin of N.W. Colorado and the Uinta Basin of N.E. Utah. Climatic conditions differ substantially between these two basins. In the Piceance Basin, mean annual precipitation at the lower elevations (5700') is approximately 12 inches and at the higher elevations (8200') is 16-20 inches. In the Uinta Basin average precipitation ranges from 6 inches at the lower elevation to 12 inches at the higher elevations. The evapotranspiration rate usually exceeds precipitation even at higher elevations. The seasonal nature of the precipitation results in leaching problems at the higher elevations.

Native vegetation ranges from a sagebrush/pinyon/juniper type adapted to the semi-arid conditions of the Piceance Creek and part of the Uinta Basins to salt-desert species in the drier parts of the Uinta Basin. Almost as much variation may be found at a given locale due to different aspect and slope of that area.

The aspect of slopes has a significant effect on type and density of vegetation. For example, in the canyon country of the south portion of the Piceance Creek Basin, south and west-facing slopes are very sparsely vegetated with sagebrush and grasses, whereas the east-facing slopes are more completely covered and the north-facing slopes may even have small areas of Douglas fir and aspen forests.

SUMMARY OF REVEGETATION STUDIES

A large number of revegetation studies are being carried out in the Piceance and Uinta Basins. The following projects have continuing revegetation research:

Rio Blanco Oil Shale Project (Federal Lease Tract C-a)

Oil Shale Tract C-b (Occidental and Tenneco)

Colony Development Operation (Parachute Creek area)

TOSCO Corporation (Uinta Basin)

Vegetative Stabilization of Spent Oil Shales by Colorado State University/Colorado Department of Natural Resources/ EPA (Anvil Points and Black Sulfur Creek plateau area)

Intensive Study Site by Colorado State University/DOE (ERDA), near Tract C-a

Anvil Points Lysimeters by Colorado State University/EPA

Upper Colorado Environmental Plant Center (Meeker, Colorado)

Union Oil Company (Parachute Creek, CO and Brea, California)

STATUS

Generally, all inclusive conclusions must be carefully qualified because of different sources of processed shale, and site or climate variables.

The fact that vegetation is difficult to establish on processed shale without "input amendments" is well known. The following research projects noted that fact over ten years ago: In the early 1970's W.R. Schmehl concluded that "chemical analysis of spent shale from the processing of oil shale revealed the material was highly saline, highly alkaline, and low in available P (phosphorus) and N (nitrogen)." But, he also found, "....when one of the spent shale materials was reclaimed by leaching with low-salt water to remove excess salts, good growth of tall wheatgrass was obtained if both N and P fertilizers were applied." In 1968 through 1970 Dr. Lawrence Schaal found, "....germination will take place in processed shale, but subsequent growth is markedly reduced and plants eventually die before reaching maturity."

But, concluded with, "....complete fertilizer, when added weekly and in sufficient amounts, promotes excellent growth. Growth is equal to that of plants in normal soil." In 1973 Daniel L. Merkel, Soil Conservation Service, concluded, "It does not appear practical to plant seed directly into fresh processed shale without special treatment, such as leaching, irrigation, or covering with topsoil."

Studies from 1965 to 1971 have shown conclusively that with careful management of fertilization, mulching and irrigation, a satisfactory vegetative cover can be grown on processed shale (Bloch and Kilburn, 1973).

Lack of fertility is essentially a management problem which can be corrected with fertilizer. Nutrient deficiencies of processed shale in both nitrogen and phosphorus are so marked that satisfactory plant growth cannot be obtained without the application of a nitrogen-phosphorus fertilizer combination. The addition of potassium or micro-nutrients yield little, if any, additional response (Schmehl and McCaslin, 1973).

Recently, researchers have noted the potential for accumulation of molybdenum to levels that could cause molybdenosis in herbivores grazing on plnats. This potential may indicate the benefits of pH reduction (which reduces Mo solubility) and proper copper levels (the ratio of Cu:Mo influences toxicity). Therefore, molybdenum is also a management problem.

Placing a mulch cover atop processed shale has been found to be very important for seedling survival and for erosion control. Schmehl and McCaslin (1973) reported surface temperatures of 140° - 150°F from processed shale exposed to solar heating. Since temperatures of this magnitude would inhibit germination and seeding establishment, it is necessary initially to use a light-colored material as a mulch for protection from the sun. Excelsior matting, chemical binder, jute netting, hydro-fiber and manure/sawdust combinations have been tested in revegetation studies with varying degrees of success. To date, straw has proven to be the most satisfactory material and has been used extensively because of its availability and low cost. The feasibility of using sewage sludge and coarsely ground garbage as mulches or substrate additives is under investigation.

Other studies indicate that a minimal six-inch cover of native soil or talus provides additional benefits not found with the mulching treatments. In addition to reducing the problems of high surface temperatures, and high run-off rates, a soil cover serves to hold moisture at the processed shale/soil interface. This increases the availability of water for infiltration and percolation, and thus, helps both the downward movement of soluble salts and the lowering of pH. Berg (1973) indicated leaching reduced levels of boron and sodium adsorption ratio of processed shale. A soil cover also aids in blending the disposal embankment visually into the surrounding areas.

Irrigation is a tool which may influence species mixture, depth of soil cover, and ultimate success. Klein (1981) found that irrigation during plant community establishment appears to exert a major effect on subsequent plant growth and related microbial activity. The increases in ATP levels, dehydrogenase, phosphatase, nitrogen fixation processes and on the percent organic matter which has been observed, support this concept. Water applications also had long-term effects, as irrigation-related changes were noted in the plots which had been irrigated from the previous year. This was believed to largely be a result of increased organic matter in the upper soil profile.

RESEARCH RESULTS

In C.S.U. Experimental Station Technical Bulletin 135, revegetation success on Union Oil Process B retorted shale was reported. The study consisted of the following four treatments:

1) Process B shale to the surface (leached).
2) 15 cm, or approximately 6 inches, soil cover over Process B shale (leached).
3) 30 cm, or approximately 12 inches, soil cover over Process B shale (unleached).
4) Soil control (leached).

The leached plots were sprinkled with 36 cm of water from June 19th to 23rd, 1975. After leaching, the plots were fertilized with N and P. Following leaching and fertilization, the plots were broadcast seeded with a mixture of native grasses, forbs, and shrubs. "Within years, vegetative ground cover was similar for all treatments, over the 1976-1978 observation period."

At the Colony project in 1973, Baker and Duffield (1973) reported, "The various studies undertaken in the revegetation program have shown that the detrimental effects of the dark color of processed shale can be compensated for by the use of a light colored mulch or soil cover. The problem of the high pH and high soluble salt content can be handled through leaching, and the nutrient deficiencies can be readily corrected through the addition of specially formulated fertilizers."

Redente (1981), indicated cover and production was highest on spent shale treatments with capillary barrier and 91 cm or nearly three feet of topsoil; however, no differences were observed between the other two topsoil treatments (30 cm or one foot, and 61 cm or two feet) and the control (no spent shale). Diversity, in fact, declined as soil depth increased. Dr. Redente concluded that "Paraho retorted shale cannot be directly revegetated after three years of natural weathering without great inputs of water, fertilizer, and mulch."

Early 1965-1975 research confirms the need for inputs of water, fertilizer, and mulch. Future research must carefully weigh the benefits of inputs, i.e. water, fertilizer, mulch and soil cover, for site specific requirements and cost effective reclamation plans. For example, a six inch soil cover with 18 inches of irrigation may be as successful and more cost effective than three foot of soil cover and no irrigation.

SUMMARY AND CONCLUSIONS

The ability to grow plants on processed shale and have them prosper has been successfully demonstrated. But, where does industry go from here? First, a careful evaluation of extensive, existing data must be reviewed. Second, methodology must be evaluated. This site specific evaluation must review input parameters such as fertilizer, water, mulch and soil cover. Heley (1973) reported cost of soil cover per acre to be:

Depth of Cover	Cost Per Acre*
2"	$327
6"	980
12"	1960
24"	3920

* Based on $1/ton hauling cost and 90 lbs. per cu.ft. density.

At that rate, 36" of soil cover would cost $5880 per acre if available on the site. Haulage from off-site areas would greatly increase this cost and would indeed be folly to reclaim one area at the expense of another. Therefore, at C-b with use of 12" of soil cover and intensive use of inputs (including sufficient irrigation to insure germination and establishment), reclamation costs are estimated to cost $4000-$5000 per acre. A cost evaluation with 3 foot of soil cover, if it was available, and no irrigation (approximately $7000 per acre) vs. C-b plan would indicate less soil cover plus intensive inputs is the best method. This cost evaluation is based on equal reclamation success of the two alternatives.

A similar cost/benefit evaluation should be analyzed for each oil shale site. Although this paper has not dealt with engineering questions concerning the size, slope, and final configuration of the processed shale disposal embankment, these should be considered in detail by private industry. Engineering aspects such as the design of the final surface, location and design of a system of benching contours and micro-terraces, placement and construction of catchment dams, etc., must be planned to maximize the embankment's overall stability, and to minimize the erosion potential of the exposed surfaces while a vegetative cover is being established.

Post reclamation management is very important for all types of reclamation, but especially for oil shale reclamation. High numbers of livestock and wildlife seasonally inhabit oil shale areas. They must be temporarily excluded from the areas being reclaimed during the initial plant establishment phase in order to reduce damage to the new vegetation. Following vegetation establishment, proper stocking numbers are important, just as for all rangelands.

Reclamation programs must be kept flexible so that specific plans or methods can be revised in order to incorporate new and better ideas which are inevitable for this relatively new industry. For example, above ground disposal is the most feasible, proven, and economical method available to handle large quantities of processed shale. However, methods of disposing of the processed shale (by placement in areas where work has been completed), have been evaluated and may in the future be practical for at least a portion of the processed shale.

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REVEGETATION PROGRESS IN ALASKA

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Areas of Development

First, I'd like to talk a little bit about developments in Alaska that require or will require revegetation. Of course the one that has probably received the most national attention is the proposed natural gas pipeline that will originate in the Prudhoe Bay oilfield in the Arctic coast and is scheduled to parallel the oil pipeline from the Arctic down past the river by Fairbanks to Delta Junction. From there the oil pipeline heads south to its coastal rendezvous at Valdez where the natural gas pipeline will continue to follow the Alaska highway, the Alcan, through Canada and finally into the United States. That project is on hold, the current problem involves financing. I don't know what they perceive there, but they do have their plans underway for revegetation efforts. We have some people here in the pipeline office in Alaska that know more about that than I do but they've based their plans pretty much on the assessment of the results Alyeska obtained in their revegetation efforts along the oil pipeline on native plants that are successful.

Other developments that are taking place there of course are oil; that is receiving national attention and they're having extensions of the Prudhoe Bay oil field, and a new field has been opened up that is on the Western edge of the Prudhoe Bay oilfield. In the future there will be most definitely increased activity in the Naval Petroleum Reserve which is even further away. In the past, all of the activity in the Naval Petroleum Reserve has been under government auspices but in the future, private companies will hold leases there. They are conducting their first lease sale so expect increased activity in that area.

Actually, the way the oil companies operate in the Arctic or at least the way they are here (with sufficient sources of gravel), it turns out there is very little disturbance. They can't travel across the tundra except in the winter when it is frozen or snow-covered and there is very little destruction to the tundra at that time. Where they are going to require summer travel, they build roads and these are gravel roads and they also build gravel paths. Most of the disturbance involves gravel recovery. Actually they have learned to operate so they disturb as little as possible.

[1/] Transcript of a talk given on March 8 by Dr. Mitchell. His postal address is Box AE, Palmer AK 99645.

Actually some of the developments for which we have received a lot of requests are road activities and small construction projects. There is talk of extending the railroad; we do have a railroad in Alaska and the railroad is federally owned. It is likely to be turned over to the state shortly. There is some hard-rock mining and one of the recent finds in southeastern Alaska is molybdenum. It is thought to be the world's biggest deposit and there are developmental activities taking place with regard to that.

A development that is receiving increasing attention involves Alaska's coal deposits. We don't hear too much about Alaskan coal because Alaska isn't supplying coal to anybody else but itself but it is supplying oil; but Alaska's coal reserves are tremendous, with a fuel value equivalent to many Prudhoe Bays.

Currently, we only have one active mine of any commercial significance and this mine is in the interior portion of Alaska located on the railroad. It recently signed a contract with a corporation of South Korea; I think, although I could be wrong, it will deliver one million tons per year. The port facilities are being developed at Seward where the coal will be delivered by rail from the Usibelli coal mine and then be shipped to South Korea. Our oriental neighbors have apparently made a decision to become less dependent on oil from the Middle East and to rely more upon coal for their energy needs. Of course they're looking to any source to obtain coal at an economic advantage. They're importing coal already from the United States and from Australia. The oriental people are interested in Alaska in a lot of ways because of the resources there and because of the proximity of Alaska to their nation.

In particular, there is high interest in the Beluga coal field which is an undeveloped field at this time with exploration taking place there. This field is near tidewater, which makes it attractive because they don't have far to go before they can put it aboard ship, and located in south central Alaska. In fact, it is a very interesting situation because the coal fields extend all the way from tidewater up into the alpine region for many miles. Alaskan coal, most of it, is of low grade sub- sub-bituminous quality, but a lot of it has shallow overburden; this is true of the Beluga coal field and it is low in S content, so it does have that attraction. Our one active mine in Alaska is located at about 1500 feet elevation and at this latitude that places it at just below, right at, or a little above timberline. We have an interesting situation there given that we're operating both below and above timberline. The Usibelli mine voluntarily started a reclamation program about ten years ago. We do have this natural field laboratory to look at as a result of their reclamation efforts.

Plants

Dr. Cuany this morning mentioned some species that showed promise at Colorado high altitudes and common among them were smooth bromegrass and red fescue. These have been the most successful species in the coal mine reclamation efforts. Actually, I imagine some of the very same varieties are being used at the high altitudes in Colorado that have been used in this mine effort at a much higher latitude. The variety Boreal red fescue out of Canada and the variety Manchar bromegrass, which must be an introduction from Manchuria, have been used up there to a considerable extent. They were also important components in the oil pipeline revegetation mixes. However, the bromegrass was dropped out of the Arctic revegetation mix because bromegrass is unsuccessful in the Arctic. The Manchar smooth bromegrass is an introduction, and a variety that was released in Alaska (Polar) does include some native germplasm. Actually it is a complex species because it is a hybrid of native germplasm and smooth brome introduction. Neither one of them has succeeded in the Arctic in Alaska.

A real concern of the mining folk engaged in this revegetation effort is the need to establish a cover that will be self-sustaining after 5 years or so. That is, it will not require periodic rejuvenation through fertilization. This represents an expenditure of energy and also an economic expense that they want to get away from. Also there is the legal requirement of bonding, and in order for them to obtain their bond back there is a requirement for these communities to be self-sustaining. Now we just got into the research on mine site reclamation about 2 years ago on a project funded by DOE and this is one of my chief interests, to determine what species can provide an enduring cover without much management input.

I work a lot with native grasses but I'm concerned with what works. Whenever I put out tests I put them out to include native grasses and legumes and introduced species and if an introduction works I'll recommend it. I have released 4 varieties of native grasses so far that are (at least three of them) being used to some extent in Alaska today.

Our coal spoil work is situated in 3 different coal fields. One of the sites is in the Beluga coal field and is as yet undeveloped and in the exploration stage. The site that we're operating at is an alpine site. At that latitude, in this south central coastal region, the alpine is at 2000 feet. You can see this is quite different than timberline in Colorado. We are working on this site at a pit opened up by Placer Amax in order to extract some coal samples for test purposes in Japan. This site is tucked in right next to a glacier that comes off the Alaska range, which is the main mountain range that extends all the way to the Aleutian islands and around to the interior and is part of the Rocky Mountain system. This is the site that has the characteristics of a high altitude site - a short growing season, snow often doesn't disappear till late June or early July. We start getting increasing weather in late September. It does get relatively warm there at times, though when it clouds up and rains it can get quite cool and remain cool for several days. There are warm periods interrupted by quite cool periods.

Dr. Cuany mentioned some grasses from Alaska that he tried in some of his trials and some didn't do very well. One of them was polar grass, Arctagrostis latifolia and the other was Calamagrostis canadensis (bluejoint). It didn't surprise me that these grasses didn't do well in his trials. Polargrass is one that is restricted to the northern latitude. It doesn't occur any farther south than the northern boreal regions so its whole district has been in these north latitudes. Moving it this far south and dealing with the changes in daylength is something to contend with. Also, even though it is high altitude, you in Colorado get some very warm days, certainly much warmer than we do on these slopes, particularly south facing slopes where it gets quite dry. The evaporative stress is quite high relative to that generally found in Alaska. This is of great significance to these grasses. Bluejoint (Calamagrostis) does have a distribution that extends south into the Rocky Mountains and all the way into Iowa, but its major distribution is in the boreal and northern latitudes.

Hairgrass (Deschampsia) is one we've tried from Alaska and did have some success with. It is, of course, a species that occurs all along the Rocky Mountain chain and is more important as a species in the Rocky Mountain chain than is bluejoint. There are a lot of affinities of the Rocky Mountain flora, the high altitude flora, here in Colorado, Wyoming, and Montana with the north latitude flora. There has been some chance in the past for gene exchange in the movement of these things along the Cordillaran chain.

Grasses that I am working with and have a lot of interest in besides the polargrass, bluejoint, and the hairgrass, are in the red fescue, a species native to Alaska and all along the Rocky Mountain chain, and bluegrass. These are species that I think are more plastic and more widely adapted. They have the ability of being moved around more and have a better chance of adapting to a greater variety of sites than some of the others. We have difficulty in Alaska in moving some of our collections up there from one place to another. Even in our work near Palmer, we have alpine and mountain regions. Bringing materials in from these local alpine regions to our lower elevations doesn't amount to more than 3000-4500' change. A number of these simply don't do well and won't even succeed at our lower altitudes. Often they'll winterkill. Often you think you'll take plants from a severe alpine site and they'll really do well down here at this milder climate site, but some of them will winterkill at this lower elevation site and probably for various reasons. One reason is that at our particular location we get high and frequent winds in the winter that wipe out the snow cover. This is a situation that some of these alpine species don't encounter. They only occur in situations where they have a lot of snow cover. Another is your changing their fall regime going into the winter.

I had some interesting experiences working with hairgrass. Some of my first efforts with it involved tests with it at Amchitka Island. The species hairgrass is native to this Amchitka Island. The Aleutians extend way out into the Pacific. In fact, a flight from Anchorage to Amchitka is just as far as a flight from Anchorage to Seattle. Our hairgrass, which is a native to the Palmer area, was quite successful out in Amchitka.

We have been dealing with some research work in Iceland and I thought this hairgrass would do well in Iceland (hairgrass is a native to Iceland as well). It has indeed done quite well there. If you think about reclamation and the seriousness of reclamation and its significance, you ought to go to Iceland. Iceland is a nation which to begin with was estimated to be about 50% vegetated. The other half of the island was unvegetated, partly because of the higher altitudes and winds that are too strong, partly because of glaciation, partly because of volcanic action. Half of that vegetated area has been lost to erosion as a result of overgrazing by sheep, and then the wind action, as it is in Amchitka. So they are very seriously engaged in testing and research attempting to reclaim some of this denuded land. The Soil Conservation Service of Iceland is actively working with the farmers in this respect. I saw some of their data and some of their trials and this hairgrass is the most successful one they have had. We have sent a few tons of hairgrass seed from our SCS plant materials center at Palmer, and they are very interested in obtaining more seed.

Iceland occurs at about 64-66^{o} north latitude which is probably more comparable to Fairbanks. Amchitka occurs at about 52^{o} north latitude. Actually Amchitka is the southernmost point in Alaska of any significant size. Iceland is not only working with the hairgrass seed from Alaska but they also have looked at lupine (L. nootkatensis) and Sitka spruce. They import a lot of Sitka spruce and grow it in the nurseries and the people are using it for landscaping purposes. Sitka spruce, from Alaska, on Iceland grows to 40 feet tall or more.

During World War II, when Amchitka was occupied by our troops and the Air Force, they also introduced Sitka spruce on Amchitka Island. After 30 years or more of growth, the Sitka spruce introduced in the Amchitka Island's sheltered areas is still only about 3 feet tall. This tells me that Amchitka is really a more severe environment than Iceland even though it occurs in a more southern latitude. Part of the reason for this is that the Gulf Stream passes near Iceland.

Red fescue is one of the species I am working with. I think it is one that has wide adaptability and I am working with some collections that may merit testing under these conditions down here.

One of the varieties developed in Alaska that has been quite successful is Nugget bluegrass. It was developed as a turfgrass. It's really a fine turfgrass, the best we have for Alaska, and it is also used in northern states. This grass was collected at an old mining camp. I'm convinced that it was an introduction into this mining camp. It persisted there for a number of years and probably underwent natural selection, and of course became better adapted - it probably was adapted to begin with - through natural selection.

I think a good source of germplasm for testing purposes is in some of these old settlements or mining camps where plants possibly were introduced and have persisted and undergone natural selection. This could be a good source of germplasm for research; don't just look at the native things occurring in native communities but look at those things that have been introduced and have persisted. There's been some good work at our experiment station on a physiological basis showing how adaptive modifications have taken place over relatively short periods of time.

OVERVIEW OF SOILS CONSIDERATIONS IN HIGH ALTITUDE REVEGETATION

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Soil reclamation can be viewed as the alteration of the chemical and physical properties of the matrix to provide a more desirable medium for plant growth. The theory and techniques employed in reclaiming disturbed lands have originated mainly in the context of agricultural production and management. In some instances this approach has not been totally successful. One reason is that the spoil material being reclaimed may not, pedologically speaking, be a soil but instead be unweathered geologic material. This means that established concepts of soil science may require modification prior to their use. The intent of this presentation is to discuss certain aspects of soil chemistry which will have a direct bearing on the reclamation of disturbed soil and/or spoil material.

For our purpose, soil is defined as a 3-phase, non-rigid, anisotropic natural body formed from the weathering of native rock.

Weathering is divided into (1) physical weathering, associated with mechanical disintegration, and (2) chemical weathering, which alters the chemical composition of the mineral constituents of rock. Chemical weathering ultimately determines the soil properties which affect reclamation strategy. Simplified examples of chemical weathering (incongruent dissolution) involving K-feldspar (orthoclase) in the presence of CO_2 and water are

[1] $$\underbrace{2KAlSi_3O_8}_{\text{orthoclase}} + H_2CO_3 + 4H_2O = \underbrace{K^+ + 2HCO_3^- + 2H_4SiO_4}_{\text{soluble}} + \underbrace{KAl_2Si_4O_{10}(OH)_2}_{\text{illite clay}}$$

[2] $$\underbrace{2KAlSi_3O_8}_{\text{orthoclase}} + 7H_2O = \underbrace{4H_4SiO_4 + 2K^+ + 2OH^-}_{\text{soluble}} + \underbrace{Al_2Si_2O_5(OH)_4}_{\text{kaolinite clay}}$$

It is noted that the weathering process results in soluble products plus an insoluble secondary phase. In reaction 1, the product formed is the secondary aluminosilicate clay called illite, whereas in reaction 2, the product formed is the clay, kaolinite. If reaction 2 is allowed to proceed further, i.e.,

[3] $$\underbrace{Al_2Si_2O_5(OH)_4}_{\text{kaolinite}} + 5H_2O = H_4SiO_4 + \underbrace{2Al(OH)_3}_{\text{gibbsite}}$$

Then the relatively stable kaolinite clay is altered to form the mineral gibbsite, which can also be represented as $Al_2O_3 \cdot 3H_2O$. Illite and kaolinite are representative of the silicate mineral clay group, whereas gibbsite belongs to the oxide clay group. Silicate clays include minerals as illite, montmorillonite, vermiculite, kaolinite, etc., whereas oxide clays are primarily aluminum and iron oxides. Silicate clays are formed by the chemical weathering of minerals that include: mica, feldspars, and ferromagnesian minerals. Which clay is formed is a function of the weathering environment and its intensity. Illite, a non-swelling clay, forms where weathering is not intense. Montmorillonite, a swelling clay, requires the presence of magnesium and a neutral or slightly acid pH. Illite can be weathered to form montmorillonite. Under acid conditions, montmorillonite can be altered to form kaolinite, a non-swelling clay. However, kaolinite can be formed directly from primary minerals by weathering as given above in reaction 2. Weathering of non-crystalline, amorphous minerals can also lead to silicate and oxide clay formation as shown in Figure 1 where mineral weathering is summarized. Clay minerals can also form from the reaction of soluble constituents present in the soil solution. This process called diagenesis occurs primarily in concentrated solutions.

It is a matter of record (Grim, 1962) that each clay mineral has properties with a wide range of values which reflect the conditions that existed during its formation. Soils represent a complex mixture of primary and secondary minerals in various stages of weathering together with the presence of organic matter (humus). The organic component in soils is essential for profile development and has a profound effect on the physical and chemical properties of the soil system. A major objective of reclamation should be the establishment and maintenance of the organic matter content of the reclaimed matrix.

For reclamation purposes, our interest in clays and humus is based on the fact that they constitute the colloidal fraction of the soil which acts as the center of chemical activity. Table 1 gives the general formulations, the range of specific surface areas and cation exchange capacities (CEC) of representative major clay types and humus.

Clay minerals are negatively charged and the magnitude of this charge is determined by the measurement of CEC. The CEC is obtained by standard laboratory procedures but the value obtained is a function of the method used. This complicating factor is due, in part, to the fact that 2 types of charges exist at the clay surface. They are (1) permanent charge, and (2) pH dependent charge. The permanent charge results from the isomorphous substitution of Al^{3+} for Si^{4+} and Mg^{2+} for Al^{3+} in the tetrahedral and octahedral positions, respectively, of the crystal lattice (see Table 1) of silicate clays during formation. The pH dependent charge results from the dissociation of protons from the surface hydroxyl groups associated with Si or Al ions existing on edges of clay particles. Schematically this is represented as

[4] $\underline{M\text{-}OH} + OH^- = \underline{M\text{-}O^-} + H_2O$ (negative charge)

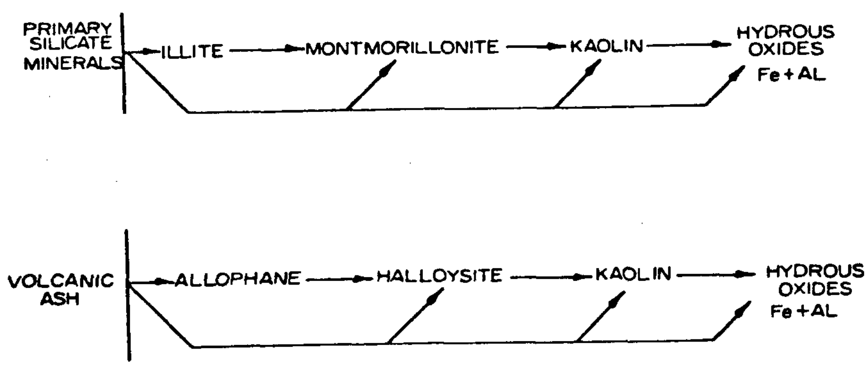

Figure 1. Schematic summary of the weathering sequence resulting in silicate and oxide clay mineral formation.

Table 1. Characteristics of major clay types and humus

Mineral	Surface area m^2/g	CEC meq/100 g
Illite $K_2(Si_6Al_2)Al_4O_{20}(OH)_4$	70–120	15–40
Montmorillonite $Si_8(Al_{3.33}Mg_{0.7})O_{20}(OH)_4$	600–800	80–100
Kaolin $Si_4Al_4O_{10}OH_8$	5–20	2–15
Humus	600–850	150–300

[5] $\underline{M\text{-}OH} + H^{+} = \underline{M\text{-}OH_2^{+}}$ (positive charge)

where M represents constituent Al or Si ions of the clay. Note both - and + sites can be formed on the clay surface depending on whether a proton is desorbed (reaction 4) or adsorbed (reaction 5). All charge (+ and -) on oxide clays is pH dependent. All charge on humus is negative and pH dependent which results from the dissociation of functional groups, e.g., carboxylic and phenolic groups. Figure 2 shows the relation between the pH and CEC for montmorillonite and humus. Note that any reclamation treatment which alters significantly the matrix pH can affect the CEC.

The CEC of spoil material has a great impact on the response to reclamation treatment because it serves to buffer the matrix against any sudden drastic change in its chemical properties. For example, a nonsaline silty clay loam from central Utah has a CEC of 15 meq/100 g, a bulk density, ρ_b, of 1.4 g cm^{-3}, a "field capacity" (FC) of about 22% (weight basis) and at this moisture content the soil solution concentration is 30 meq/L. Assuming a calcium saturated system, calculation shows that at "field capacity" the soil water contains 248 lbs of Ca^{2+}/acre-6" (277 kg/ha-15 cm) while the exchange complex contains 6000 lbs of Ca^{2+}/acre-6" (6,700 kg/ha-15 cm) or about 24 times more ions exist on the exchange complex than are present in the soil solution. These data show the capacity of the colloidal fraction to retain cations against leaching in addition to its role as the buffering agent in soils.

Soil pH

The pH of the soil is one of the more informative measurements that can be made on soil material to be reclaimed. The soil reaction has a marked effect on the availability of plant nutrients (Brady, 1974) and microorganism activity, e.g., nitrifying organisms are inhibited below pH 5.5. Soils with pH $\leq$ 4.0 contain free acid which can arise from the oxidation of sulfide which is often associated with mine land reclamation. For example, the chemical oxidation of iron pyrite is a complex process but for our purpose it can be represented by

[6] $2FeS_2 + 7\ 1/2\ O_2 + 4H_2O = Fe_2O_3 + 4SO_4^{2-} + 8H^{+}$

where the oxidation of 1 mole of iron pyrite ultimately yields four equivalents of acidity: 2 eq from the oxidation of Fe(II) and 2 eq from the oxidation of S_2(-II) (Stumm and Morgan, 1981). Equation 6 can also be mediated by autotrophic bacteria such as Thiobacillus and Ferrobacillus which act as catalyst to the oxidation process but do not change the ultimate end products. The low pH generated by pyrite oxidation can result in the dissolution of both aluminum and heavy metal compounds producing soluble metal ion concentrations that can reach phytotoxic levels. This is shown in Table 2 where selected acid soluble heavy metal data of pyritic spoil material from the Blackbird mine (copper-cobalt) near Salmon, Idaho, indicates the potential magnitude

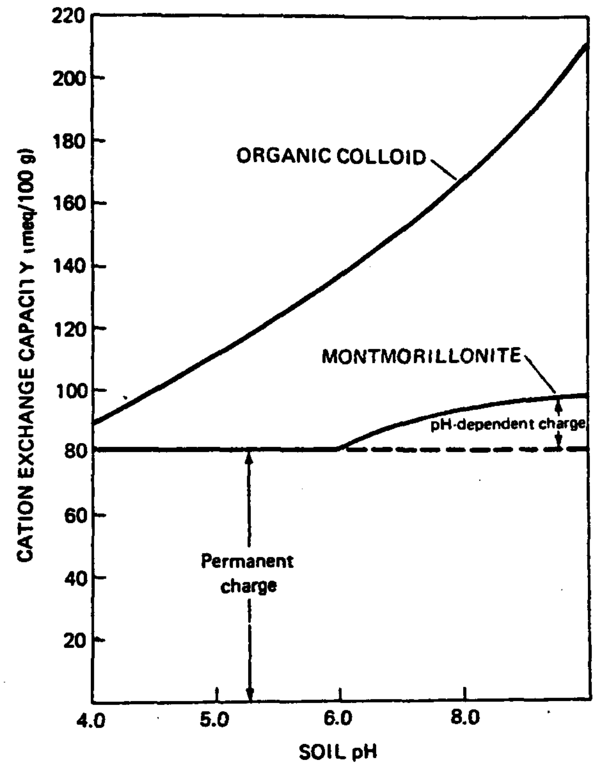

Figure 2. The permanent and pH dependent charge contribution to the CEC as a function of pH for humus and montmorillonite (Brady, 1974).

Table 2. Selected pyritic spoil analyses*-Blackbird Mine

Sample No.	3	4	5	6
pH	3.8	3.9	4.0	4.5
EC (mmhos/cm)	20.0	10.5	3.25	7.26
Al (ppm)	18,690	24,500	29,980	29,060
Cr	50	20	30	30
Co	70	500	520	1,110
Cu	37,400	16,590	7,890	25,510
Fe	68,110	71,590	69,000	94,270
Pb	20	30	40	30
Mn	250	250	140	210
Hg	--	10	25	50
SO_4	64,970	41,900	1,650	31,500

*pH and EC determination on saturated paste and saturation extract, respectively.
Cation analysis (acid soluble) in ppm (from Farmer et al., 1976).

of the problem (Farmer et al., 1976). Table 2 also shows that the salinity level (EC) can also present a problem to establishing vegetation.

The total amount of acidity due to pyrite oxidation and the amount of lime ($CaCO_3$) required to neutralize it can be readily calculated from equation [6]. Assuming the spoil material has a ρ_b of 1.75 g cm^{-3}, then the calculated mass of the material is 2.36 x 10^6 lbs/acre-6" (2.62 x 10^6 kg/ha-15 cm). Calculations show that for each percent of FeS_2 oxidized it will require 39.4 tons of pure $CaCO_3$/acre-ft (87 m tons/ha-30 cm) to neutralize the acidity produced. This is based on the total oxidation and dissolution of FeS_2. It must be noted that sulfides of other heavy metals, e.g., ZnS, will also produce protons upon oxidation. The acidity produced will depend on the stoichimetry of the reaction formulated and whether both the sulfide and metal ion are oxidized. The total amount of lime needed depends on the purity of material available, thus the calculated values represent minimum tonnage per unit percentage of oxidized iron pyrite. Any lime material naturally present in the spoil material will serve to reduce the amount of amendment needed. Also to be considered is the fact that kinetics of pyrite oxidation may preclude the need to consider the total potential acidity produced. In the oxidation example given, no account was taken of the acidity associated with the protons and aluminum adsorbed by the exchange complex which became of major importance in the absence of pyrite oxidation.

Considerable data have shown that commonly aluminum (and manganese) toxicity appears when the pH of a soil is lower than about 5.5. Figure 3 shows the fraction of the CEC satisfied by Al^{3+}, $Al(OH)^{2+}$ and $Al(OH)_2^+$ ions between pH 4.0 to 5.5 for a large number of soils from Virginia (Thomas, 1967). Above pH 5.5 only a small amount of exchangeable Al exists because the precipitation of insoluble ($Al(OH)_3$ (gibbsite) is almost complete at this pH. In agronomic management, the primary purpose of adding lime to an acid soil is not to neutralize the "proton acidity" of the soil solution per se but to precipitate toxic aluminum ions which are associated with soil pH by the hydrolytic reactions represented as

[7]
$$Al^{3+} + H_2O = Al(OH)^{2+} + H^+$$
$$Al(OH)^{2+} H_2O = Al(OH)_2^+ + H^+$$
$$Al(OH)_2^+ + H_2O = Al(OH)_3 + H^+$$

As shown by equation [7], an acid spoil material or soil in reality is an Al-H system. To emphasize the importance of the buffering capacity of the exchange complex to the acid-base chemistry of the matrix, an example is given. Our previously discussed soil (CEC = 15 meq/100 g, ρ_b = 1.4 g cm^{-3}, FC = 22%) now has a pH of 4.0. The calculated amount of lime ($CaCO_3$) required to neutralize the solution acidity at field capacity is only 4.1 lbs/acre-ft (4.6 kg/ha-30 cm). This minute amount

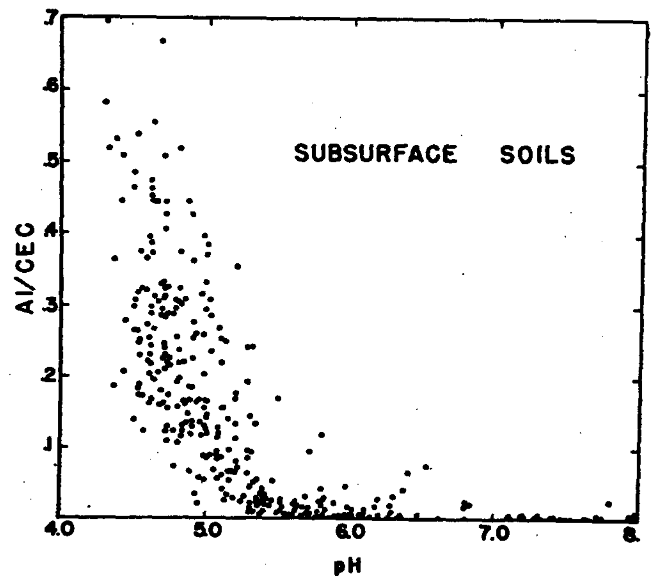

Figure 3. Relation between exchangeable Al and soil pH (Thomas, 1967).

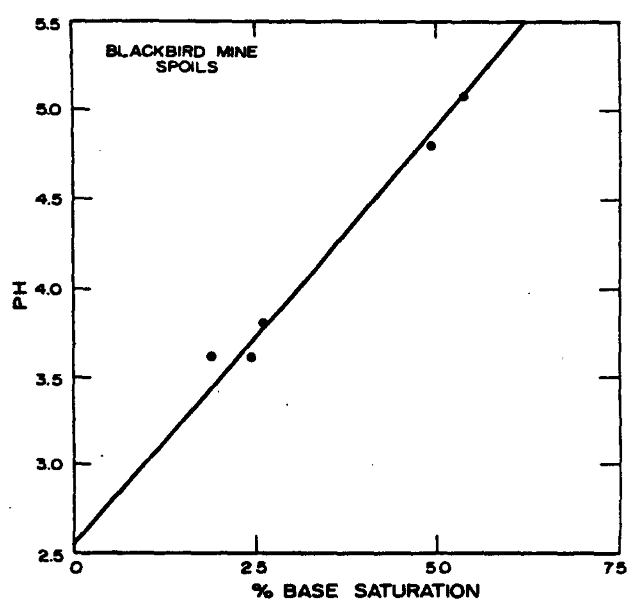

Figure 4. The relationship between percent base saturation and pH for Blackbird minespoils.

of lime needed indicates the "exchange" acidity (adsorbed Al + H) of the matrix is of maximum importance when determinining the lime requirement. This is shown by the fact that to completely neutralize the "exchange capacity" of our example soil would require 12 tons of $CaCO_3$/acre-ft (26 m tons of $CaCO_3$/ha-30 cm) to account for the Al-H on the exchange complex, assuming 20 percent base saturation.

To determine how much lime is needed to change the pH of spoil material requires that the relationship between the percent base saturation and the pH is known. The percent base saturation = (exchangeable [Ca + Mg + Na + K]) 100/CEC. The percent base saturation-pH relation varies with soil texture, nature of clay minerals and organic matter content and must be determined for each material. Using limited data from the Blackbird mine study (Farmer et al., 1976), the relation between pH and percent base saturation is plotted in Figure 4. The CEC of the spoil material varied from 2.1 to 5.8 meq/100 g and had a textural grade of gravely silt loam. The linear regression equation is:

$$pH = 0.0455 \text{ percent base saturation} + 2.6$$

$$r^2 = 0.967$$

Assuming linearity over the pH range of interest, the amount of lime needed to alter the base saturation to produce a given pH can be calculated. If a final pH of 6.0 is desired, percent base solution = (6.0 - 2.6)/0.0455 = 74.7. If the average CEC is taken as 4.0 meq/100 g and $\rho_b = 1.75$ g cm^{-3}, the calculated minimum amount of pure $CaCO_3$ needed to raise the pH to 6.0 is about 3.5 tons/acre-ft (7.8 m tons/ha- 30 cm). This relatively small amount of lime to raise the pH is a reflection of the coarse texture of the spoil material (low CEC) and does not include any consideration of pyrite present which becomes the dominant acid source as oxidation commences.

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EROSION CONTROL ON LOGGING ROADS

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INTRODUCTION

Forests have small erosion and sediment problems compared to other land uses. This fact must not deter us from finding the sources of erosion and reducing this loss. In addition, any associated water pollution that occurs within these lands must also be reduced. It remains for us to pinpoint the problems and react intelligently to lower the pollution risk associated with forest activity.

Roadways have been and still are a major source of erosion within our forested lands. Where a road is located has much to do with its potential to cause a problem. The amount of raw earth exposed over time also is important. These items we will consider in more detail later.

Let's first define erosion and sediment on forest roads. Basically, erosion is the wearing away of a surface. For us and our concern with roads, this is most often the displacement of soil, rock, and organic particles caused by the external force of rain and flowing water, gravity or both.

Sediment is material which has been in transit and has settled out of suspension. For roadways, it is the main pollutant of water and the risk we are committed to lower.

The basic sequence of events leading to water-polluting sediment begins with the displacement of mineral and organic particles by the force of water or gravity. These disturbed particles travel from the point of displacement in the air or water or both until the energy necessary for the materials' transport drops. At this point, the particles settle out which cannot be supported, and come to rest as sediment.

Water pollution resulting from erosion and sediment activity on roadways is part of a continuous process. Whenever erosion exists, sedimentation also is present. If pollution occurs, it results from one or both of the former two processes.

Water pollution for our discussion is reserved for the particles disturbed on roadways which find their way into water and violate set legal requirements for this water's quality.

For successful forest road erosion and pollution control, the sequence of events just described must be interrupted. The level of success depends upon understanding, concern, commitment, execution of plans, and follow through.

A word about the bounds for this logging road discussion. Only the accelerated erosion and sediment caused directly or indirectly by the actions of people is being considered. Natural levels of activity are not affected by man's actions and are not within our realm of concern today.

The goal of this endeavor is to encourage those who build and maintain forest roads to limit erosion and sediment along with any resulting pollution to tolerable social and practically acceptable levels.

In the next few moments, we will delve into some of the main points in the development of a forest road and how erosion and sediment control fit into the process. We will discuss, in brief, the causes of pollution, the philosophy, and principles of control associated with the basic phases of road development. Some examples will be given of various erosion control measures.

ROAD BUILDING

When you think about erosion and sediment production from roads in conjunction with pollution, most often the attention is focused on the physical process of particles moving due to raw earth exposed to rain, slides, and mass earth movement associated directly with the road right-of-way. This is obviously important, but I would like you to think about the road's planning and location. If the road is built in the wrong place--erosion, sediment, and pollution problems can be greatly magnified. Along with this--construction and maintenance costs can explode.

The process of erosion, sedimentation, and possible pollution starts with the planning of the road then progresses through location, construction, and maintenance. Since the road building process is integrated, each step depends on the other. A poor move in planning will show up later. To control erosion, sediment, and any associated pollution, start at the beginning of the road process—the planning phase--and follow through each step along the way.

All this sounds very complicated and confusing. In reality, many planning steps are not complicated. Some planning does require data and analysis before a choice is made. In all cases, you are not wasting your time doing planning.

The seat on a dozer is one place to make decisions, but it is not the best place to plan. A few hours of thinking can save money and many hours of agony.

Some items to consider in your planning are:

1. Your management goals and objectives.

2. Any legal requirements such as boundary lines, right-of-way easements, permits to connect to a public road, and insurance to cover the workers if you hire the job out.

3. Collect existing information including weather, topographic maps, soil, geology, streamflow, snowpack melt, storm intensity, who will use the road and for what purpose, when will the road be used and how long, or any other factors that seem useful.

4. Decide the type of road needed based on the management goals, the type of use expected, along with any constraints involved.

5. Set road standards for grade, width, curves, and travel speeds.

Take the time to write out the elements considered. Review the topographic, geologic, and soil information. Ask questions of professionals available to you including the State Forester, the Soil Conservationist, the County Extension Agent, among others.

How does planning affect pollution control, erosion, and sediment abatement? By reducing the length and width of a road to the minimum, exposure to the forces of erosion are reduced. Avoiding rock, soil, and topographic formations that are unstable reduce the risk of road failure. Knowledge of weather conditions and stream flows helps you to insure that road drainage systems and stream crossings will provide reasonable service. Areas that may fall, slip, or are subject to flooding also are valuable to know and avoid where possible. None of us would violate a boundary line or bring a road into a public highway at a dangerous point. A moment to comply with existing laws can save you problems and enhance the safety and property of others.

Each road should be searched out on the ground. Mark the route that meets the specifications set in your plan. This may take more than one try at running grade. In some cases, time can be saved by running several paper projections of grade on your topographic maps. The best of these are checked on the ground.

Rough road locations must avoid the areas that will cause problems from a pollution standpoint. If the job is done correctly, the road location should have avoided steep side slopes, slides, slumps, swamps, floodplains, poor soils, and rock types, or structure. In this regard, a short summary of causes, symptoms, and recommendaations to avoid problems with slides, slumps, creep, and rockfall is enclosed with this paper. Above all, the properly located road will have crossed water courses safely and quickly. Proper buffer zones which can trap eroded particles will have been provided.

Impossible, you say? No, but it does require real work and knowledge. The alternative is a poor road location with little chance of improvement.

Field design of simple roads is possible on the ground by most practitioners. To accomplish this, some knowledge of road construction and standards is a necessity. A few basic points concerning erosion, sediment, and pollution need to be made here.

1. Roll the grade for drainage.

2. Make cut and fill banks as small as possible.

3. Change grade in safe locations away from stream crossings.

4. Provide buffers of undisturbed forest soils and litter cover below a roadway fill slope of at least 50+ (4 X % slope) in feet.

In general, your road should be physically capable of achieving the objectives you set at the least cost economically and environmentally. Placing the road "lightly" on the land will often accomplish most of these goals.

The "light" road will have many modest shifts in grade, be rather narrow, and have an efficient yet inexpensive drainage system which is not a pollution source.

Surfacing will exist only where necessary to assure safe passage and the integrity of the road.

The payoff is lower exposure to erosion and sediment problems, less maintenance, and initial cost. When this effort is coupled with good pollution control practices in construction and maintenance, the water quality is maintained or improved.

Drainage is a key part of your road. Without proper stream crossings and surface drainage, the road can become useless in wet weather and a possible problem to water quality. It is here that much of the pollution control can be inserted into the roadway.

Consider stream crossings. First, one needs to insure that the culverts are large enough to handle the average storm or snowmelt flows. In most cases, this can be done with relatively simple observations and calculations. Suitable aids are available to assist with these estimates.

The goal for culverts at stream crossings is to transport water safely under the road without endangering the road or water quality. To avoid water quality problems:

1. Have a large enough culvert diameter to handle the water.

2. Make sure the culvert is long enough to follow the natural streambed and extend beyond the fill banks.

3. Plan to control erosion by protecting the culvert intake and outfall fill bank faces.

Other stream crossings are available besides culverts. Fords and bridges can also be used to cross live streams.

Bridges follow much the same logic as culverts, but consult an engineer for structural detail. Fords need special design to prevent ditch water from flowing directly into a stream. Gentle grade in and out of a ford helps reduce the problem.

From a water quality standpoint, avoid changing a road's grade at a stream crossing. By planning ahead, this problem can be solved before it starts.

Cross drains of any type need to be placed frequently enough to avoid an erosion problem. In addition, the water flowing from these facilities must not cause the down grade of water quality. To accomplish this requires some special considerations other than the practical need to remove water from the road surface.

A few points to remember about cross drains and pollution control are:

1. Water discharged from cross drains must be filtered before it reaches a stream channel.

2. Water energy below the outlet of a cross drain must be reduced to tolerable levels.

3. Drains must be placed in a manner to reduce clogging and maintenance.

4. Service ditches and adjacent cut banks need to be treated to reduce the erosion potential.

5. Ditch water must not be placed where it can aggravate slides, slumps, rock falls, or creep.

Road drainage requires careful planning to avoid these pitfalls. The locations for cross drains should be marked on the ground before construction. This assures there will be suitable buffer, that grade changes in the proper place, and that the outflow will not aggravate a natural weakness already present.

One point needs stressing above all others. Road surface drainage must never become a portion of a natural stream system. Any time cross drain ditch water flows openly to a creek, eroded particles from all the drainage area associated are dumped into the stream directly. You can see that obvious pollution potential exists. If you can become sensitive to this situation, the problem can be avoided.

Oh yes--before you think about construction, mark your road with tags or flagging on the ground. Set slope stakes at critical points along the route with reference stakes in safe locations.

These efforts take some time, but they make it possible to check on the construction later. It does little good to mark a road and take reasonable care in its design only to bury your effort under a "dozer's pass". The finished product should look like you had it planned--not an accident.

Construction needs your whole concentration and effort for it is here earth is exposed and pollution can result. Take the time to plan your work. Felling and bucking can be done during weather conditions unsuitable for earth moving. Clearing and grubbing require good weather to prevent erosion problems. Pioneer paths and the construction of the finished road both require suitable weather. By limiting the amount of earth exposed at any one time, risks are lowered.

It might be useful to consider where the dollar goes in road construction. Moving equipment absorbs about 10 percent of the dollars; nearly 1/4 is spent in clearing, grubbing, and slash disposal; another 1/4 is expended for excavation; 10 percent for drainage, and about 30 percent is allocated to rock. Where rock is not needed, road cost can be reduced.

Erosion and sediment controls during construction work can be enhanced by following several simple rules:

1. Keep equipment out of the creeks.

2. Remove slash from the streams promptly.

3. Stay out of the buffer zones as much as possible.

4. Make sure skid trail and other construction erosion is trapped before it enters a stream.

5. Disturb only what is necessary.

6. Work in suitable weather.
7. Service machines at safe locations.

8. Be careful about personal sanitation.

The particulars of construction are beyond our discussion today. Good methods and procedures are recommended.

Do make frequent checks to be sure your road is developing as you planned. Always check the pollution controls. By becoming observant, one can check for erosion while doing other tasks.

Finally, mulch and seed the cutbanks, fill slopes or other exposed surfaces to reduce the exposure to erosion. When the roadway will not be completed during one season "put it to bed." Use water bars, seeding, mulch, and out sloping to accomplish the objectives.

Maintenance can be a cause of erosion and, ultimately, sediment. Two basic conditions exist. The first is the maintenance associated with the vehicular traffic and the second is associated with other causes.

Like all other aspects of forest roadways, maintenance needs some thought. Make a simple maintenance plan for your roadways that fits the use, weather, and investments. Close roads that are not used and do maintenance on the others at a level to keep their usefulness and the facility. A side effect of this work is good water quality. Poor maintenance is a sure way to lose your road and investment. Poor water quality will often result as well.

Basic principles involved are:

1. Keep water away from the road with bypass ditches.

2. Remove the water from the roadway. Extra culverts, dips,

or outsloping could accomplish this.

3. The water removed from the road and the immediate vicinity must not cause a problem with water quality down slope. In other words, only clean water should reach a stream.

4. Keep the traffic way usable and not a pollution problem.

After a road is constructed, wet spots from springs in or above the facility may develop. When possible, divert this water through ditches away from the road. Often, extra culverts, outsloping, or dips will do the job.

Always remember that water removed from the roadway must not become a problem downslope. Keep the stream clean. Use energy dissipators along with forest buffers as filters to absorb the flow--strip it of eroded particles--and render high quality water under ground to your stream.

Remember, the objective is to maintain your road. Shape the travel surface to make it usable and prevent vehicle tracks from causing erosion problems. Do only the work needed to clear your ditches and culverts for uninhibited flow. Place rock to reinforce soft spots in the travelway or to protect ditches from erosion.

One last thought. Maintenance is not a process of reconstruction. It is a process dedicated to preservation.

CONCLUSIONS AND RECOMMENDATIONS

To conclude my remarks, I would like to highlight a few points. First, forest roads are often a source of erosion and sometimes pollution from forested lands.

Second, that most of the erosion and sediment problems associated with these roads can be eliminated through careful planning, proper design, good construction procedure, and maintenance.

Third, this improvement is possible through a better understanding of forest road erosion, sediment and pollution causes, and cures.

My recommendation is that you seek the knowledge to reduce the erosion, sediment and pollution caused by forest roads. This is not an impossible job and I encourage you to undertake it.

These comments are a brief of a small book about to be released entitled "Building Water Pollution Control Into Small Private Forests and Ranchland Roads." Copies are limited because of cost, but you should be able to order a copy through your State Forester.

I thank you for your attention and courtesy. I hope my words this day will spark some thought and ultimately result in better roads and cleaner water.

Mass Movement on Forest Lands -- Abbreviated Discussion and Management Recommendations

Types of Disturbance	Comment	Characteristics	Recommendations
DEBRIS SLIDES(Fast*) Avalanches, Flows	Often spontaneous turns into flows; velocity 5-15 ft. per sec. Process often continuous; from avalanches to torrents. Activity can initiate naturally or be encouraged by man's activity.	Slides usually occur in shallow low clay soils on impermeable bedrock or glacial till. Water content is least in slides increasing through avalances and flows. Slides frequently start on slopes above 75%, in upslope depressions, and in ephemeral channels on steep V-shaped water courses. Slopes over 65% overloaded with road fill or side cast are a problem. Surface and anchor roots help hold the soil mantle. These shallow landslides are frequently initiated by excess water from storm or other sources.	On roads, do not overload slopes with fill on shallow non-cohesive soil. Direct road cross drains onto stable soil. In steep country, minimize miles of road. Utilize ridge tops, avoid excess excavation on steep ground, full bench the road and haul excess material to safe place, keep maintenance going through big storms, direct water off roadfills and unstable slopes; leave headwall area in trees, remove slash without burning, outslope roads and use retaining walls for support (get eng. help). Use air photos to locate unstable ground, oversteep slopes, old slides, and poor drainage.
Torrents (fast)	Relatively fast moving; deposits vast amount of debris; a massive extension of debris avalanche and flows. Pathways often visible on mountain sides.	Usually cuts to bedrock; wet slurry-like flow; activity mostly in 1st, 2nd, 3rd, order streams. Weak bedrock or bedding planes parallel to slope typical of unstable hillside.	Prevent avalanches; avoid discharging excessive water into steep stream drainages; clear debris from swales in harvested areas; do not overload upland swales with water - increase cross drains; outslope roads where possible; add structural support such as walls (bins, gabions, cantilever, tie-back) with eng. help; stay out of active movement areas and wet zones; leave trees in the active zone; use logging systems that cause the least impact on the surface such as cable.

Type of Disturbance	Comment	Characteristics	Recommendations
CREEP (Slow)	About 1/4"/yr. downhill movement; where deep clay rich soils exist, slumps and earth flows can form. Problem increases with increased moisture. Accelerated where road drainage concentrates water or cuts remove suport	Where expanding clays predominate, creep can accelerate. Creep exists where stonelines, springs, and slumps are present. Creep is found in highly faulted metamorphic and sedimentary rock (weathered serpentine, mudstone, pyroclastic) ignious rocks (tuffs, breccias, ash). Area is often hummocky or rolling topography with poor drainage. Trees sometimes tilted and are pistol butted. Root loss in deep soil usually not important.	Keep road cuts shallow. Be sure fill is compacted and trash free. Drain the road to stable ground. Remove heavy debris from draws. Keep area in road to a minimum. Avoid construction is unstable areas.
SLUMPS AND EARTH FLOWS(slow to modest)	Disturbances are technically different, but often occur together. Slumps are rotational failures which can change into an earth flow, or continue as a block-glide. Velocity ranges from a creep rate to several feet per min. Failure is dependent on soil strength and water content.	Slumps occur in deep fine textured silt or clay rich soil with poor drainage; slopes are usually less than 40%; scarps, a slump bench, tension cracks and sag ponds may be present; vegetation often tipped or jackstrawed; water-loving vegetation may be present. Large slumps often have "hummocky" terrain.	Plan development using air photos to locate active and old slumps. Roads should avoid slump areas. Where crossing must occur, keep the road cuts shallow. Compact fills keep fill material clean, drain water to stable ground. Maintain existing drainage systems and consider horizontal drains in wet low clay cut slopes. Use the weight of rock buttresses to replace excavated road materials (consult engineer). In a potential slump zone, load the toe and/or unload the head of the area.

Type of Disturbance	Comment	Characteristics	Recommendations
SINGLE PARTICLE (single particle movement, Dry Ravel)	Gravity caused, activity in a thin sheet; common in drysites where mechanical weathering dominates; often follows defoliation, litter disturbance; help fill shallow uphill basins, a source of avalanches. In Idaho Batholith it can be half the fill slope erosion.	Steep dry slopes denuded or sparsely vegetated with coarse non-cohesive soil are subject to dry ravel; wetting and freezing increase the potential; ravel accumulates on uphill side of trees.	Mulch and plant fill slopes; avoid sliver fills; clean ditches before fall and winter rains; protect litter on forest floor. Consider alternatives to burning.
ROCKFALL AND ROCKSLIDES (extremely rapid)	A rockfall is free-falling rock (or nearly so) from a cliff or steep slope; road cuts excavated into unstable rock are subject to rock-falls. Rock stability is maintained through competence of the rock and friction along the bedding planes. Undercutting by erosion on a road is a common cause of rockslides or falls.	Occurs in highly fractured rock and soft interbedded siltstone and sandstones, silts and pyroclastics; most susceptible when bedding planes slope downhill toward road; activity can be indicated by a lack of vegetation on scarp, and damage done by falling rock; long lived trees may be absent on active face; benches or ditches often full of rock from above.	Avoid large cuts in unstable rock such as basalt over fractured rock, interbedded sandstone, clay, or mudstone; avoid downslope dipping bedding planes by going to other side of the hill. Check geology in road planning phase, construct benches to trap falling rock in hard-soft rock inter-bedding sequences; construct drainage ditches around top of cut slopes to dewater area. In some places rock bolting will work; in a few places retaining walls will work. Avoid the site by relocating.

Consolidated from: Slope Stability on Forest Land, by Roy C. Sidle, 1980; Creep and Failure of Slopes in Clay, by F. Tavenas and S. Leroveil, 1980; Soil Disturbance Caused by Clearcutting and Helicopter Yarding in the Idaho Batholith, by James Clayton, 1981; Soil Slumps and Debris Flow: Prediction and Protection, by Robert Hollingsworth and G. S. Kovacs, 1981; Slope Stability in Road Construction, by Edward R. Burroughs, Jr. et al., 1976; An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook), EPA, 1980, Chapter V.

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* Relative movement

NEW DEVELOPMENTS IN SOIL AMENDMENTS -- A BIOLOGISTS POINT OF VIEW

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I. INTRODUCTION

Soil reclamation is generally seen as a problem apart from revegetation activities even though success depends on a combination of the best practices in both plant and soil technologies. Drastic disturbance not only destroys the structure and sequential nature of soil layers but also the unique processes of soils so vital to plant establishment and growth. Soil reclamation practices must be responsive to remedying the main effects of disturbance including restoration of biological activities diminished by topsoil removal, storage, and replacement.

To overcome the loss of a stable plant community, plant species may be chosen for their vigor, productivity, and relatively desirable place in the sequence of succession. Seeding or planting recommended species according to best available methods may generally solve the revegetation problem. In contrast, achievement of stable soil conditions and processes is long term and techniques for accelerating soil genesis and stability appear to be less amenable to the relatively simple solutions involved in choosing the appropriate species and using appropriate methods for their establishment.

Soil amendments may be a means of restarting soil developmental sequences at some point further along the time scale than at the beginning. Some of the more serious soil problems that might be ameliorated by amendments might include: soil surface instability; reduced biological activity, reduced fertility status, reduced soil wetability, reduction in ion exchange capacity, toxic ions present in low levels, and low water holding capacity. Methods and materials are available for use in moderating the aforementioned problems even though not all solutions are sure to work or would be economically feasible.

The purpose of this paper is to review some of the options available for amending unfavorable soils characteristics. However, this cannot be considered an exhaustive review but only a thoughtful overview. A detailed discussion on soil conditioners may be found in symposium proceedings edited by Moldenhauer et al., (1975). Some of the suggestions in this paper are presently under investigation with only limited information available. Some suggestions may even appear unorthodox but are mentioned to stimulate discussion.

II. SOIL RECLAMATION PROBLEMS THAT CAN BE MODERATED BY AMENDMENTS

Some effects of drastic soil disturbance are highly visible and are thus the target of regulatory review while others are of concern mainly to the reclamation specialist because they are involved in the achievement of ecosystem stability. For each of the following problems a brief discussion of the causes, possible amendments and expected benefits from their solution will be given.

A. Surface Instability

One of the most critical soil problems from an environmental perspective is surface instability. This problem occurs because of the destruction of soil structure and aggregation when soils are removed and respread. Loose surface particles on drastically disturbed sites are subject to both wind (Chepil and Woodruff, 1963) and water erosion (Lusby and Toy, 1976) and are given prime attention in federal and state regulations (U.S. Congress, 1977; Bowling, 1978). Dust and off-site erosion must be controlled "to prevent, to the extent possible, additional contributions of sediment to stream flow or to runoff outside the permit area" (Federal Register, 1979).

Two main types of amendments are available to increase surface stability: soil particle stabilizing agents and mulches and mats (Table 1). If these amendments are to be used in conjunction with a revegetation strategy they must allow water penetration and seedling emergence. At the same time, they must bind soil particles together or cover them so that they will not be picked up by wind and water. Solution of this seeming contradiction can

Table 1. Soil surface stabilizing materials.

Chemical or Generic Name	Some Commercial and/or Common Names	References
Polyvinyl acetate	Aerospray 70 Crust 500 Curasol AE Soil Seal Terra Krete Soil Bond	Dean et al., 1974 Malek, 1979 Kay, 1978
Styrene butadiene latex	SBR Petroset SB	Kay, 1978 Malek, 1979
Asphalt emulsion	Coherex	Kay, 1978
Algae extractines	Terra Tack I, II, and III Kelgum Ecology Control M-Binder	Kay, 1978
Organic mulches	Hay Straw Jute mat Excelsior mats Plastic/fiber mat/netting Wood fibers Agricultural waste fibers	Kay, 1978

often be achieved by adjustment of rates, dilutions and/or thickness of application. Mulches and surface covers can provide a stabilizing advantage but at the same time, they may result in nitrogen immobilization, contribute unwanted weed seeds or fail to maintain contact with the soil surface depending on the type of mulch and application techniques (Kay, 1978).

Obvious benefits are reduced soil particle movement as dust or soil erosion. Results from surface stabilizing amendments are generally short term, lasting until the materials degrade or decompose. Longer-term benefits are those that accrue as a result of retaining fine soil particles in place thus gaining their values for improved ion exchange, soil moisture relations, and soil texture.

B. Reduced Biological Activity

The most common cause of reduced biological activity is the anaerobic condition created in the deeper portions of a topsoil stockpile. Propagules of all kinds including seeds, spores, single cells, hyphae, and vegetative parts may be adversely affected by prolonged storage in an oxygen-deficient environment. Dilution is another cause of reduced activity that occurs as a result of mixing a shallow biologically-active surface soil layer with a larger amount of biologically deficient sub-surface soil.

Application of sewage sludge is an inexpensive but non-specific means of restoring some degree of biological activity to topsoil. Another means of restoring biological activity is the transfer of topsoil slices or pads containing roots and associated organisms using a front-end loader bucket (Crofts, 1981). Obviously only a small area can be moved because of the cost of handling.

Other possible amendments involve experimentally valid but commercially-untested materials such as mycorrhizae (Aldon, 1975; Reeves et al., 1979; Call, 1981) and nitrogen-fixing algae (Parkinson, 1978). Native Plants, Inc., is currently developing a methodology for inoculating container-grown plants with appropriate strains of mycorrhizae. Using rhizobium bacteria for inoculation of legumes has been an accepted practice for many years and procedures are generally well known.

Expected benefits from these biological amendments must be considered in relation to the size and site conditions of the areas treated. In the case of soil pad transfers only a small area is affected and time will be required for extension of roots and biological activity to adjacent areas. Benefits from sewage sludge have been described more in terms of organic matter addition than biological activity. Expected benefits from mycorrhizal inoculation of transplants include greater plant survival, increased phosphorus and water uptake, and a reduction in the accumulation of heavy metal ions (Reeves et al., 1979; Menge, 1981). For all of the practices, the general benefits would include improved nutrient cycling, increased soil fertility, and improved plant growth.

C. Reduced Soil Fertility

This problem is caused by mixing infertile soil layers with a shallow layer of topsoil or by substituting an infertile subsoil layer for a physically or chemically unstable topsoil (Federal Register, 1979). Unusual plant growth media such as processed oil shale may present unique problems of low fertility and plant growth suitability. Using nitrogen, phosphorus potassium, or sulfur fertilizers as amendments to correct nutrient deficiencies is a commonly known practice in agriculture but the problems involved in reclamation require different approaches (Bauer et al., 1978). One of the most difficult problems is the lack of information on nutritional needs of native shrubs, grasses, and forbs for survival and growth under stress field condition (Van Epps and McKell, 1980). Second is the inadequacy of data on disturbed soils on which to base sound interpretations. Generally, the two main elements that need to be applied are nitrogen and phosphorus, but the actual amounts required will depend on moisture available for plant growth, a demonstrated soil nutrient deficiency and plant nutritional requirements.

Benefits from applying fertilizers as amendments may not always be clearly understood. Fertilization may aid in establishment and survival, but amounts in excess of the basic requirements may cause extensive foliar growth and subsequent depletion of soil moisture resulting in drought stress to the plants even to the point of death.

D. Reduced Wetability

This soil characteristic may be a problem when a surface soil is replaced or layered over with a subsurface layer having hydrophobic properties. According to Savage (1975) water repellency may occur as a result of organic residues in soils or after exposure to high temperature such as in wild fires (DeBano, 1975) or retorting of oil shale. Decreased percolation and surface runoff may occur because of reduced wetability. Conversely, practices that increase wetability may be used to increase surface runoff for water harvesting.

Some possible amendments to increase wetability are commercial grade surface active materials that reduce surface tension on soil particles. Some examples are common detergents and surfactants. Letey (1975) described results with two commercial non-ionic surfactants, Aqua Gro and Soil

Penetrant that increased soil wetability. Wetting agents have been shown to have negative effects on plant growth in solution culture studies but toxic effects occur only under high application rates when applied to soil systems.

Benefits that may be expected from applying surfactants include reduced runoff, increased percolation, and a subsequent increase in plant growth due to improved soil moisture conditions.

E. Reduced Ion Exchange Capacity

A reduction in ion exchange capacity may occur in a reclamation project when light textured soils are placed on the surface over spoils in place of heavier textured soils that may have been buried in the spoils because of their unsuitability for one or more reasons. Thus, the low ion exchange capacity soils may have a low production potential as a result. Mixing of montmorillonite or bentonite clays into the topsoil may help to increase ion exchange capacity but the volume required may be uneconomic.

A suggested alternative is to apply a naturally occurring zeolite. According to Mumpton (1981) zeolites are crystalline hydrated aluminosilicates of alkaline earth metals that possess infinite three-dimensional crystal structures. Their ion exchange capacities are in the range of three to four milliequivalents per gram (meq/g) as compared with 0.8 to 1.0 meq/g for bentonite clay and 0.05 meq/g for a sandy soil. Other amendments to increase ion exchange capacity include sewage sludge and organic mulches.

Benefits from adding zeolites to a reclamation soil would primarily be an increase in ion exchange capacity but greater retention of ammonia and 'trapping' of heavy metals may also be expected.

F. Toxic Ions Present in Low Concentration

The possibility that ions of heavy metals and other categories may be present in non-toxic concentrations but could be selectively concentrated by certain plants or chemical cycling pathways is a potential problem in reclamation. Normally, any spoil or soil material containing potentially toxic levels of ions would be buried. However, where a change in pH, irrigation, or abundant growth of a plant species known to selectively accumulate certain ions could occur, a soil amendment may be appropriate.

Recommended practices to solve this complicated problem would be to: (1) add lime to buffer the soil to reverse or prevent a pH change; (2) trap the potentially toxic ions in an exchange material such as zeolite (Mumpton, 1981); or (3) allow plants to accumulate the ions in their tissues and then bury the plants.

Benefits would be a reduced potential for ions to be accumulated at toxic concentrations. The need for using amendments would have to be sufficiently compelling to justify the costs involved. Obviously the costs of the amendments would have to be considered in light of the value of the resources being developed by the mining operations which might otherwise be unavailable if toxic conditions were not managed.

G. Low Water Holding Capacity

Ordinarily low water holding capacity is difficult to increase because it is a property resulting from the particle size complement of the soil.

Organic matter and naturally occurring polymers also contribute to soil water holding capacity and can be increased by management in some situations (Donahue et al., 1971). Thus, if a sandy material was to be used as a topsoil, it may be desirable to increase its water holding capacity. At the same time, treatments used should improve the surface stability and reduce erosion.

Some of the possible means for increasing water holding capacity include: (1) mixing clay soils with sandy soil; (2) adding organic matter; and (3) applying commercial polymers to temporarily absorb soil water. Mixing of clay soils with sandy soils would require that clay soils be locally available as part of the topsoil inventory. Adding organic matter in the form of mulch or sewage sludge may also be limited by the availability of a low cost source within the local area. Commercial polymers have recently entered the market for limited use as a transplant additive or field amendment where costs can be justified by the magnitude of benefits obtained. Two examples of the commercial polymers are 'Gel-Guard' marketed by Dow Chemical Company, and 'Terra Sorb' marketed by Industrial Services International, Inc. These materials are essentially starch combined with a synthetic polymer. They are temporarily effective for three to six months and may be rewetted with successive periods of precipitation.

III. A PERSPECTIVE OF SOIL AMENDMENTS

Over the years, numerous additives have been considered that can modify soil physical, chemical, and biological properties. Usually the big deterrents are cost and longevity of response. Because of the large volume of soil to be affected by an amendment (the top six inches of an acre of soil weighs approximately 2.5 million lbs.), either a large quantity must be applied or the material must be very effective in small quantity. Thus, amendments usually must fit a unique requirement that solves a high value problem. Some of the best examples are plant establishment and temporary control of erosion until a plant cover is established and natural soil and vegetation processes are underway.

Soil amendments that can be applied and become part of the natural soil processes appear to be the best long-term investment. They are soil mixing organic matter additions and fertilization. Appropriate management of the soil and vegetation are essential to retain the advantages of amendments.

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SOIL SURVEY—ACCOMMODATING USER NEEDS

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This paper is written primarily for natural resource managers with limited training in soils, and is also intended to benefit the soils professional engaged in survey work. For the former, its purpose is to help evaluate available soil survey information, and to suggest possible solutions when available information is less than adequate. For the soils professional, this paper provides a rationale for assessing and responding to the needs of the soil survey user. In either case, it is essential to recognize that the study of soils is an interpretive art as well as a science.

New Challenges

The soil is a basic natural resource. It is a resource which is being wasted in alarming proportions all over the world, including the United States, a land richly endowed with productive soils. However advanced our civilzation, our survival and comfort are still based on the productivity of our soil. As the bumper sticker says, "When you're out of soil, you're out of food."

Knowledge of soils is essential in land use planning, land development, and disturbed land rehabilitation. One of the main challenges facing the modern soils professional is how to provide information about soils in a way that is meaningful and useful to resource managers and decision makers--people who frequently have no real background in soils.

A soil survey is the foundation for making sound land use decisions. From very broad surveys used in regional planning to the very detailed surveys used to characterize local sites, the ability to predict constraints to selected land uses is of prime importance. By determining soil characteristics, many limitations or hazards to land use can be defined and mitigated. Traditionally, agriculture has been the primary beneficiary of soil survey information. This is a rather significant distinction since survey methods developed over many years to provide useful information for the farmer may not be as useful in other applications.

Today, concern for environmental quality affects every industry which uses the land and the government agencies which regulate them. Helping to meet these concerns is a new challenge to the soil surveyor.

This paper is divided in two main sections. A major portion of the first section is devoted to the Soil Conservation Service and the standards of the National Cooperative Soil Survey. Also included is a discussion of land system inventory, a mapping system currently used by parts of the U.S. Forest Service. Suggestions are also offered for users when the available soils information is not adequate. The second major section focuses on two specific users of soil survey information and discusses the problems with current survey methods or applications and the possible solutions.

NATIONAL COOPERATIVE SOIL SURVEY

Background

The Department of Agriculture, under the aegis of the Bureau of Soils, started soil survey work in 1899. Soil surveys were conducted on a local basis with very little national correlation. In 1934, with the establishment of the National Cooperative Soil Survey, a national system of soil classification was initiated and more detailed mapping techniques were utilized. The Soil Conservation Service was placed as the lead agency for soil survey work, in cooperation with state land-grant colleges and other federal, state and local agencies. The Soil Conservation Service was originally called the Soil Erosion Service; the name change is analogous to making the Defense Department out of the War Department.

The initial thrust of the SCS survey efforts were mapping agricultural land and providing technical assistance to farmers. Mapping was generally done on a farm-by-farm basis. In the early 1950's, efforts to map areas in a systematic manner evolved and soon, soil surveys were conducted on a county-by-county basis. These types of surveys are known as progressive soil surveys and are the current emphasis of the SCS. In 1951, the Soil Survey Manual was published and provided a definitive standard for the conduct of soil surveys (Soil Survey Staff, 1951). The Manual is currently being revised and published as part of the National Soils Handbook. Soil survey and classification efforts were greatly aided by the publication of the 7th approximation of Soil Taxonomy in 1975. It provided a national system for the classification of soils used in making and interpreting soil surveys (Soil Survey Staff, 1975).

SCS Survey Methods

The soil survey methods used by the Soil Conversation Service are fairly standardized nationwide. Since their methods are the most frequently taught, used, and called for in environmental regulations, a brief discussion of them may be useful for soil survey users.

The criteria for identifying the different kinds of soil surveys are presented in the National Soils Handbook (Soil Survey Staff, 1978). Kinds of surveys are divided in a hierarchical fashion of five levels, called orders, with each order being less detailed and broader in scope than the one above. Kinds of map units, field procedures, and appropriate mapping scales for each order are also well defined. Orders are differentiated by map scale, kinds and components of map units, accuracy of map unit boundary delineation, and intended use. Orders 1 through 3 are the most detailed and frequently used soil surveys and will be briefly discussed.

An Order 1 survey is the most detailed; a map scale of 1" = 1,000' or larger is usually used. Each map unit is narrowly defined and usually contains only one soil type, for example, Fort Collins loam, 1 to 3 percent slope. The boundaries between map units are observed throughout their length. An Order 1 survey is used for very intensive planning purposes, such as in surface mine planning or for site-selection of homes, where appraisal of the soils of small areas is needed.

An Order 2 survey is less detailed and generally maps at a scale of between 1" = 1,000' and 1" = 2,500' are used. Map units generally have just one soil type, but may contain two or three. Map unit boundaries are plotted by observation and aerial photo interpretation and are verified at closely spaced intervals. Order 2 surveys are used for operational planning where interpretations of specific soils on discrete tracts of land are needed. Order 2 surveys are commonly used for mapping agricultural land and planning surface mine operations.

Order 3 soil surveys are broad based surveys most frequently used in the Western United States. The scale of maps is generally smaller than 1" = 2,000' and most map units contain two or three soil types. Map unit boundaries are plotted by observation and interpretation of aerial photos. They are verified with some field checking. Order 3 surveys are suitable for general planning at the county level or of extensive rangelands.

SCS Soil Survey Reports

The most tangible aspect of the SCS work and the one survey users are most likely to encounter is a published soil survey report. In the past, most soil survey areas were delineated by county lines and soil survey reports were published on that basis. Some survey areas now cross county lines. In order to fully appreciate the value and limitations of an SCS soil survey report, a brief dissection may be helpful.

There are five main sections of a modern soil survey report. Generally, there is an introduction describing the general nature of the survey area and how the survey was conducted. A second major section is the map unit descriptions. They are just that; they describe the map unit. A description generally tells the location on the landscape of the map unit, a brief description of the soil(s) or landtype(s) in the map unit, and possible inclusions. A short narrative describes the soil's physical properties, such a permeability and surface runoff. Finally, most map unit descriptions include some interpretations about land uses relevant to the survey area.

A third section of a modern soil survey report is a description of the soil series that occurred within the survey area. The particular soil profile description included in a report was chosen as most representative of that particular soil. Following the profile description is usually a range of characteristics for that particular soil in that particular survey area. In other survey areas, the range of characteristics for a particular soil series may be different.

Another section of a survey report is a summation of soil properties and interpretations for use and management. This information is generally obtained from the SCS Form 5, the Soil Interpretation Record. The Form 5 for a particular soil series summarizes soil properties and provides limitations for selected land uses. The SCS has increased the number of selected land uses for which limitations are given in response to increased demand for new soils information. In a soil survey report, the Form 5 information is presented in tables by soil property or land use for all the soils identified within the survey area.

Finally, most survey reports have the soil maps and a map legend located at the end of the report. The soil maps are generally reproduced aerial photographs which show the map unit delineations and symbols. Local cultural and water features are also located on the maps.

Limitations

A detailed critical evaluation of the soil survey program of the SCS is beyond the scope of this paper. There are, however, two limitations that affect many survey users and they will be briefly discussed.

The first limitation concerns the detail that the SCS soil surveys provide. Most soil surveys in the West are an Order 3 level at a scale around 1" = 2,000'. For their intended use of regional planning, the SCS surveys provide reliable and accurate information. Order 3 surveys cannot, however, be used when site-specific information or a high degree of accuracy is needed. This point cannot be overly emphasized. If more detail is needed, a larger scale photo as a base map and closer observation of map unit boundaries (e.g., Order 1 or 2) are required.

A second limitation of the SCS information is the method used to present interpretations. For the past several decades, soil interpretations have been presented by rating of the soil by limitation to a particular land use (Soil Survey Staff, 1978). A three class system, with the terms "slight", "moderate", or "severe" indicating increasing severity is used to describe the limitation. For example, the limitation of a soil for dwellings may be severe due to its shrink-swell property. Soil limitation ratings, however, do not indicate suitability or the corrective measures needed to overcome restrictive soil properties (Guthrie and Latshow, 1980; Rogoff, et al., 1980). This point will be discussed in greater detail under soil survey use by land use planners.

The SCS has been in the business of making soil surveys for over 80 years. They have been responsible for a great deal of research, in both the theoretical and applied areas of soil science. As a service organization, they serve an invaluable function as source of soils information. The SCS should be one of the first contacts when the need for soils information arises.

INTEGRATED INVENTORIES

The SCS mapping system is not the only one used to provide soils information for management purposes. Integrated inventories are surveys which characterize units of land, for mapping purposes, in terms of any combination of several defined land characteristics required by the survey's objectives (Society of American Foresters). One of the first of these types of inventories was made in the 1920's. Parts of the U.S. Forest Service use a similar mapping concept called land systems inventory. The Northern Region of the U.S. Forest Service assisted in development and extensively use land systems inventories because the map unit design and the resulting interpretations were the most useful for their management objectives.

Survey Methods

As with the SCS system, the land systems inventory has several levels of intensity or detail; the level most frequently employed is the landtype. Landtypes are typically mapped at scales between 1" = 2,000' and 1" = 5,000' or roughly equivalent to an SCS Order 3 soil survey. The primary difference between the two mapping systems is the approach to map unit design (Cline, 1981). The map unit design of landtypes allows for several important land characteristics that were not incorporated into SCS map units. The components of landtype map units are generally landform, lithology and geologic structure, naturally occurring vegetation, and soils. Each of these features of the map unit has interpretive value on its own merit. Their combination in the design of a single map unit provides interpretations that can be used by a wide range of disciplines. For example, vegetation habitat types and landforms, both components of the landtype map unit, are very influential in determining hydrologic response characteristics (Society of American Foresters).

Limitations

As with any system that attempts to categorize a natural system, the land system inventory has its limitations. It has been difficult to quantify the reliability of occurrence of map unit characteristics. As a consequence, the reliability of the interpretations, based on map unit characteristics, is not well defined (Cline, 1981). This limitation will be at least partially mitigated with increased use of landtype mapping and increased data collection. Another limitation of land systems inventory is that, in the absence of one of the defining components of the landtype map unit, such as pronounced land forms or natural vegetation, map unit definition is difficult. For example, in gently rolling cultivated land, the use of landtype mapping is difficult. Under these conditions, other survey techniques may be more appropriate (Society of American Foresters).

CONTRACTED SOIL SURVEYS

After investigating the available soil survey information, a person may find that the information is inadequate or not existent. He may find, for instance, that the

SCS has not mapped the particular area in question or, if they have, that the information is not sufficiently specific to his needs. In such situations, a person must contract for the completion of the desired work.

Contractors

As a result of environmental regulations promulgated in the 1970's, many people found that existing soils information did not meet the regulatory guidelines. Consequently, a large market for providing soil survey information developed and was filled by private consultants. Consultants offering soil survey services range from one-man enterprises to large multi-disciplinary firms.

The Soil Conservation Service also provides technical assistance in a wide range of soil-related problems in cooperation with local Conservation Districts. The SCS can provide contracted soil surveys for individuals as well as other federal agencies. In fact, much of rangelands which are managed by the Bureau of Land Management are being surveyed under contract to the SCS. The Forest Service also contracts with the SCS for soil surveys. The emphasis of the SCS, however, is the progressive soil surveys of counties at an Order 3 level and frequently does not have the manpower to conduct surveys on smaller areas.

Suggestion for Users

Many times the person seeking soil survey information is not trained in soils or agronomy and has only a vague notion about soil survey. There are many facets of a soil survey that can be shaped to suit the needs of the user. The most basic component of a soil survey is the map unit and its design. Although the nature of the landscape and the complexity of the soils dictate to some extent the design of a map unit, significant latitude exists to accommodate particular user groups. For example, a person may want to know where all the soils shallower than 40 inches exist within a survey area. The person conducting the survey can structure map units that divide those soils from soils deeper than 40 inches.

A very similar type of flexibility exists in the definition of the component(s) of a map unit. In the larger-scale surveys of the SCS (Orders 1 and 2), phases of soil series are exclusively used. For example, Fort Collins loam and Fort Collins fine sandy loam are textural phases of the Fort Collins soil series. The particular phase used is dependent upon the information desired by the survey user. Some commonly used phases of soil series are based on surface texture, percent slope, or degree of erosion.

Another area in which a user can influence the end product of a soil survey is in the map unit description and soil interpretations. Those interpretations that are most crucial to the user should be included in the map unit description. Other interpretations may be better presented in a tabular form.

When contracting a soil survey, one should work closely with the contractor throughout all phases of the project. From initial design of map units and their components to the final report, a soil survey can be structured to reflect the needs of the client.

SELECTED SOIL SURVEY USERS

The diversity of users of soil survey information is very broad, ranging from homeowners and farmers to mine planners and tax assessors. Some users, such as farmers, have the beneficiaries of soil survey information since the inception of soil surveys. Others, like mining companies, have a relatively recent need for soils information. This section will present two user groups, the coal mining companies and land use planners, and will discuss their needs and how these needs are being met.

Coal Mining Industry

The soil survey needs of the coal mining industry are the identification of soil materials suitable for plant growth and their location on the landscape. Regulatory agencies, charged with reviewing mine permit applications, also need sufficient soils information to evaluate the adequacy of a post-mining reclamation plan. Many state regulatory agencies have issued guidelines defining criteria to establish suitability of topsoil (Berg, 1981). Because of the need for greater accuracy in delineating map unit boundaries and in locating individual soil types, a soil survey more detailed than an SCS Order 3 is required for surface mine planning. Order 1 and 2 surveys are of sufficient detail to provide characterization of and interpretations for the soils of a particular mine site. Soils sampling for laboratory analyses is also required by mining regulations.

A soils survey and sampling at any intensity, however, does not insure that adequate soil materials will be salvaged or that post-mining reclamation will be successful. Although the soils at a particular site may have properties that limit vegetation re-establishment, reclamation success potential is very often dependent upon close cooperation between those involved in reclamation planning and those responsible for the plan's execution. One of the difficulties for mining companies has been to translate the soils information provided in a permit application to an operational stripping plan. The salvage operator needs to know where to get how much soil material. Two methods can be used to communicate strippable areas to an operator. The first is by staking and flagging an area; the person responsible for the staking must have a thorough understanding of the soils of the mining area. Another way to tell the operator where and what to strip is with descriptive terms. For example, "strip the valley bottom soils down to 7 feet and avoid the ridge sideslopes" will generally be clear to the operator where and what to strip. The soil surveyor can greatly facilitate this process by correlating soils with landscape position to the greatest extent possible.

Because soils are naturally occurring bodies formed under the influence of numerous environmental factors, it is often difficult to keep solutions to soils-related problems within the confines of regulatory guidelines. Site-specific conditions, such as sporadically occurring saline subsoils, demand innovative solutions that frequently are not within the regulatory specifications. Consequently, a conflict between the needs of the soil survey user and the regulatory standards enforced by federal and state agencies arises. The conflict could be minimized by increasing the flexibility afforded to regulatory enforcement personnel and by, as a coal mining environmental coordinator put it, a shift from methods-oriented to results-oriented regulations.

LAND-USE PLANNERS

As the population in the United States continues to grow and there is increasing conflict in use of finite land resources, the need for sound land use planning increases. Land use planners are often employed by governmental agencies to assist in the development of local and regional master plans. Land use planners are not, for the most part, interested in the soil survey per se, but in the interpretation of soil characteristics for selected land uses. The suitability of soils for a particular land use is one of the factors determining the patterns of development.

Use of Soil Survey Information

The use of soil surveys in land use planning is not new. One of the first soil surveys made specifically for this purpose was in Virginia in the early 1950's. The SCS provided the manpower to conduct a soil survey and to develop the necessary interpretations. Since that time, there has been increasing sophistication in the use of soil survey interpretations. Soil scientists, as a result, have been asked to provide more quantitative predictions of soil behavior.

As mentioned earlier, interpretations of soil survey information are presented using a three class rating system based on limitation. These ratings, however, are not necessarily indicative of suitability. Furthermore, the ratings use the most restrictive feature, such as depth to rock, and consequently do not indicate degrees of limitation within a rating class nor the effects of combined factors on suitability. There have been several attempts in recent years to develop guidelines rating a soil, in comparison to other soils in the area, on its potential after measures to overcome limitations have been applied (Guthrie and Latshaw, 1980; McCormack, 1974; Rogoff, et al., 1980). The result has been the development of soil potential ratings.

To prepare soil potential ratings, four kinds of information are needed. First, a precise definition of the intended land use and basic assumptions must be formulated. Second, the limitation(s) of the soil for the selected land use must be determined. The SCS interpretation sheet (Form 5) can provide this information. Next, in consultation with a multidisciplinary team of planners, engineers, contractors and soil scientists, the cost of corrective measures is calculated. The cost of installing a septic tank absorption field in a soil with a severe limitation is an example. Finally, the kinds of continuing limitations is determined. The above information is then quantified and a soil potential index derived (Guthrie and Latshaw, 1980; Rogoff, et al., 1980).

The use of soil potential ratings for making local land use decisions has proved very beneficial. They provide information on the degree to which corrective measures are feasible and effective in overcoming soil limitations. They are also localized and responsive to local costs and constraints (Guthrie and Latshaw, 1980). The use of soil potential ratings offers the planner, engineer, soil scientist and other resource development professionals with a quantitative method for selecting the most suitable soils for a particular land use. Their use will undoubtedly continue.

SUMMARY

Soil surveys can provide a great deal of information about the land and the soils upon which we live. A great variety of people require soil surveys, with even a wider diversity of informational needs. There are two sources of information about soil surveys. The Soil Conservation Service is the federal agency charged with the primary responsibility for the nation's soil survey program. Much of the nation's soil resources have been mapped and classified by the SCS and reports published of these surveys. The SCS is also the source of much valuable technical information about a wide range of soils-related matters. There are also other inventory systems that can provide information concerning soils. Parts of the U.S. Forest Service use a system called land systems inventory. Although it is not based strictly on soil taxonomy, it does incorporate soils in the map unit design. It has proven very useful for making the required resource management decisions.

A person seeking soil survey information, especially site-specific, will sometimes find that the available information is not adequate. Technical assistance is available from the Soil Conservation Service or private soil consultants. A close working relationship between the person seeking the information and the person providing it is necessary to achieve maximum results and satisfaction.

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EROSION CONTROL REVEGETATION ON LAND DAMAGED BY THE 1980 MT. ST. HELENS ERUPTION

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INTRODUCTION

The Mt. St. Helens eruptions in 1980 severely damaged soil, water, plant, and animal resources of the surrounding area. Much land was buried by deep, sterile ash of varying textures. More than 150,000 acres were damaged by the initial blast itself. Mudflows and flooding damaged 7,440 acres of Toutle River floodplain and about 1,800 acres of farmland along the Cowlitz River. The Toutle and Cowlitz rivers were choked by ash sediment and debris and tributary outlets were blocked. About 80 percent of the channel capacity of the lower (0-23 miles) Cowlitz River was lost due to sedimentation. Severe flooding of areas near Kelso and Longview was likely without rehabilitative measures as the fall rainy season approached. In addition, approximately 55 million cubic yards of the finer sediment choked the Columbia River, below river mile 68, causing navigation problems. Extensive accumulation of fine sediment occurred all the way down the Columbia River to its estuary. About 15 feet of sediment was deposited at the Green River Salmon Fish Hatchery. The river invert was about three feet above the top of the rearing pond walls and fall and winter flooding was imminent.

As one of several requests for emergency assistance, Cowlitz County, through the local Cowlitz Conservation District, contacted the USDA-Soil Conservation Service (SCS) which administers Section 403 of the Emergency Watershed Protection Act. A resource assessment team was formed to inventory non-federal lands and identify areas needing treatment and propose specific conservation practices to control erosion, reduce runoff, and alleviate flooding. The assessment report was completed in July 1980 (USDA, 1980) about one month after the initial request for assistance. The report recommended, among other measures, large-scale revegetation of the upper watershed.

REVEGETATION PLANNING

Conservation treatment of any large watershed to reduce the threat of flooding is a very complex process. Although no one disputes the need for sediment reduction and associated flood protection, various land management objectives of the land owners or operators in the watershed often impede agreement on means and extent of treatment. The Mt. St. Helens disaster was no exception.

Overall, the watershed treatment program evolved to consist of (1) the dredging and clearing of the Toutle, Cowlitz and Columbia River channels and revegetation of the dredge spoils by the U.S. Army Corps of Engineers (COE)

(2) construction of two sediment dams on the Toutle River by COE, (3) large-scale grass-legume seeding administered by SCS, (4) clearing blocked tributaries by SCS, and (5) breaching large ash and debris dams by COE. Considerable effort was spent to coordinate activities where needed because of very short time frames and heavy workloads in the months after the initial blast.

Planning the large-scale grass-legume seeding was accomplished during July-August 1980, overlapping the initial inventory and assessment and even continuing after contracting began in late August. There were three major planning forces that shaped the eventual revegetation package. First was the stated need for sediment reduction to achieve flood protection for the downstream residents of Cowlitz County and fish habitat restoration. Secondly, preservation of unique areas within the blast zone became an increasingly important idea during this period. Third, private land owners were engaged in salvage logging and reforestation to re-establish the economic base within the affected area.

About two-thirds of the blast area actually lay in the Gifford Pinchot National Forest. Concurrent with rehabilitation planning on private land, the U.S. Forest Service (USFS) thoroughly assessed their watershed treatment needs, one of which was to seed the upper Clearwater and Bean Creek drainages of the Lewis River and the headwaters of the Green River. The criteria for selecting areas to be seeded was (1) the area must have been clearcut recently, (2) slopes were less than 30 percent, and (3) areas lay below 4,000 foot elevation. Ash depths ranged 10-28 inches. Emphasis was placed on initial stabilization and the need to accelerate nutrient retention and recycling in the sterile ash. The USFS Emergency Watershed Rehabilitation Team decided on the following seed mix, which will be called Mixture 1.

Mixture 1 Components

1. Annual (*Lolium multiflorum*) and perennial ryegrass (*L. perenne*) - Seeded at 10 and 15 pounds per acre, respectively. They were designed to provide quick, high volume short-lived cover. Both grasses have high nutrient requirements.

2. Hairy vetch (*Vicia villosa*) - Annual, high volume, sporadically reseeding legume; moderate seedling vigor at best; good nitrogen-fixer; seeded at 4 pounds per acre.

3. Subterranean clover (*Trifolium subterranean*) - Rapidly developing, low-growing, self-reseeding legume; has high potential for seeding new clearcuts because of high nitrogen-fixing ability and low competitiveness with trees; cold hardy only to 10-15^{o}F and particularly susceptible in seedling stage; seeded at 4 pounds per acre.

The combined seeding rate for the mix was 33 pounds per acre, or 141 seeds per square foot. Only 7 of 141 seeds (5 percent) were legumes.

Three seed mixes were selected for use on private land and were based primarily on recommendations in the Oregon Interagency Seeding Guide. Species recommendations in this guide for seeding logging roads, landings, skid trails, and clearcuts largely are the result of tests by the SCS Corvallis Plant Materials Center and research by the USFS Pacific Northwest Forest and Range Experiment Station and Oregon State University. Potential seed supply also had a major influence on species selected for each mixture. The magnitude of the project largely precluded variety preference. In addition, composition of the three mixtures was determined by the ability to provide rapid ground cover, long-term non-competitiveness with trees, symbiotic nitrogen fixation by legumes, and value as a food source for wildlife returning to the devasted area.

Mixture 2 was selected for upland areas above 2,800 foot elevation on state and private timberland where ash depths were 6-8 inches.

Mixture 2 Components

1. Annual and perennial ryegrass - Seeded at 15 and 5 pounds per acre, respectively; fast cover.

2. Creeping red fescue (*Festuca rubra*) - Seeded at 10 pounds per acre; considered to be native by some botanists; low-growing sod-forming grass; slow developing.

3. Timothy (*Phleum pratense*) - Seeded at 2 pounds per acre; a minor component adapted to wet areas; valuable forage; considered non-competitive; a bunchgrass; more cold hardy than orchardgrass.

4. White clover (*Trifolium repens*) - Seeded at 2 pounds per acre; rapidly developing perennial legume; high nitrogen fixer; tends to dominate sterile sites but goes out when its nitrogen production stimulates other plants.

5. Birdsfoot trefoil (*Lotus corniculatus*) - Seeded at 2 pounds per acre; slow starting but persistent low growing legume; non-competitive with trees.

The combined seeding rate was 36 pounds per acre, or 358 seeds per square foot. Of 358, 58 seeds (16 percent) were legumes.

Mixture 3 was designed for upland areas below 2,800 foot elevation where ash depths ranged 3-8 inches. Components were the same as for Mixture 2 except orchardgrass (*Dactylis glomerata*) was substituted for timothy. Orchardgrass was seeded at 4 pounds per acre and essentially filled the same niche except it is more drought tolerant. This seed mix rate was 38 pounds per acre, or 345 seeds per square foot.

Mixture 4 was developed for seeding the mudflow areas on the lower Toutle River. Mudflow depths ranged from a few inches to several feet. Components were adjusted to emphasize forage values since some of the area eventually may revert to pasture.

Mixture 4 Components

1. Perennial ryegrass - 6 pounds per acre.
2. Creeping red fescue - 7 pounds per acre.
3. Orchardgrass - 6 pounds per acre.
4. Tall fescue (Festuca arundinacea) - 5 pounds per acre; highly competitive; widely adapted to various sites.
5. White clover - 3 pounds per acre.
6. Birdsfoot trefoil - 3 pounds per acre.

The combined seeding rate for this mixture was 30 pounds per acre, or 311 seeds per square foot. Of these, 87 seeds (28 percent) were legumes.

Analysis of several volcanic ash samples throughout the affected area indicated high bulk densities, low water holding capacity, and very low nutrient levels, especially nitrogen. Therefore, the Cooperative Extension Service recommended an initial fall application of 300 pounds per acre of 10-20-20 NPK to be followed by a spring application of 50 pounds per acre actual nitrogen. The rate was adjusted for Mixture 4 to 375 pounds per acre 16-21-21. USFS Mixture 1 fertilizer rate was the same as for Mixture 2 and 3.

Recommended seeding dates varied by site. Mixtures 1 and 2 should have been seeded between August 1-30 to permit optimum germination and growth into the winter months. Recommended periods for Mixtures 3 and 4 were August 15-September 15. These are standard seeding dates for erosion control seedings in the Pacific Northwest, designed to take advantage of late summer and early fall rains and warm temperatures. This advantage was somewhat offset by higher surface temperatures encountered on volcanic ash than on typical weathered forest soil.

To obtain the maximum erosion control and sediment reduction, the SCS recommended 66,448 acres of blast area and mudflow on state and private lands be seeded. Several meetings of the land owners, sponsors, and SCS and USFS representatives were held to determine which areas were to be seeded and to agree on seed mixtures, fertilizer, method and timing of application, and other technical aspects of the proposed project. Most of the discussion centered on which areas were to be seeded. Much of the pyroclastic flow and mudflow east of Camp Baker was considered to have high potential for preservation as a unique site for plant and animal successional studies and as a special geological area. This consideration was strongly supported by environmental groups and provided the greatest controversy during the planning stages, particularly in late August. Significant other areas of state and private land were scheduled for salvage logging. Due to continued disturbance during salvage, these areas also were considered unsuitable for seeding. Finally, there were small portions of the blast zone along the fringe that were sufficiently stable to preclude seeding. Accounting for all factors, seedable acreage was reduced to 13,165 acres, or less than one-fifth of the non-federal land within the blast zone. Most of the land to be seeded lay between the Green River south to the ridge above the North Toutle River, primarily in the Schultz and Hoffstadt Creek drainages. Drainage was mostly into the Green River which emptied into the Toutle River below the large sediment dam at Camp Baker (see Figures 1 and 2).

Figure 1. Areas Seeded to Reclaim and Control Erosion and Sedimentation on Land Damaged by the 1980 Mt. St. Helens Eruptions.

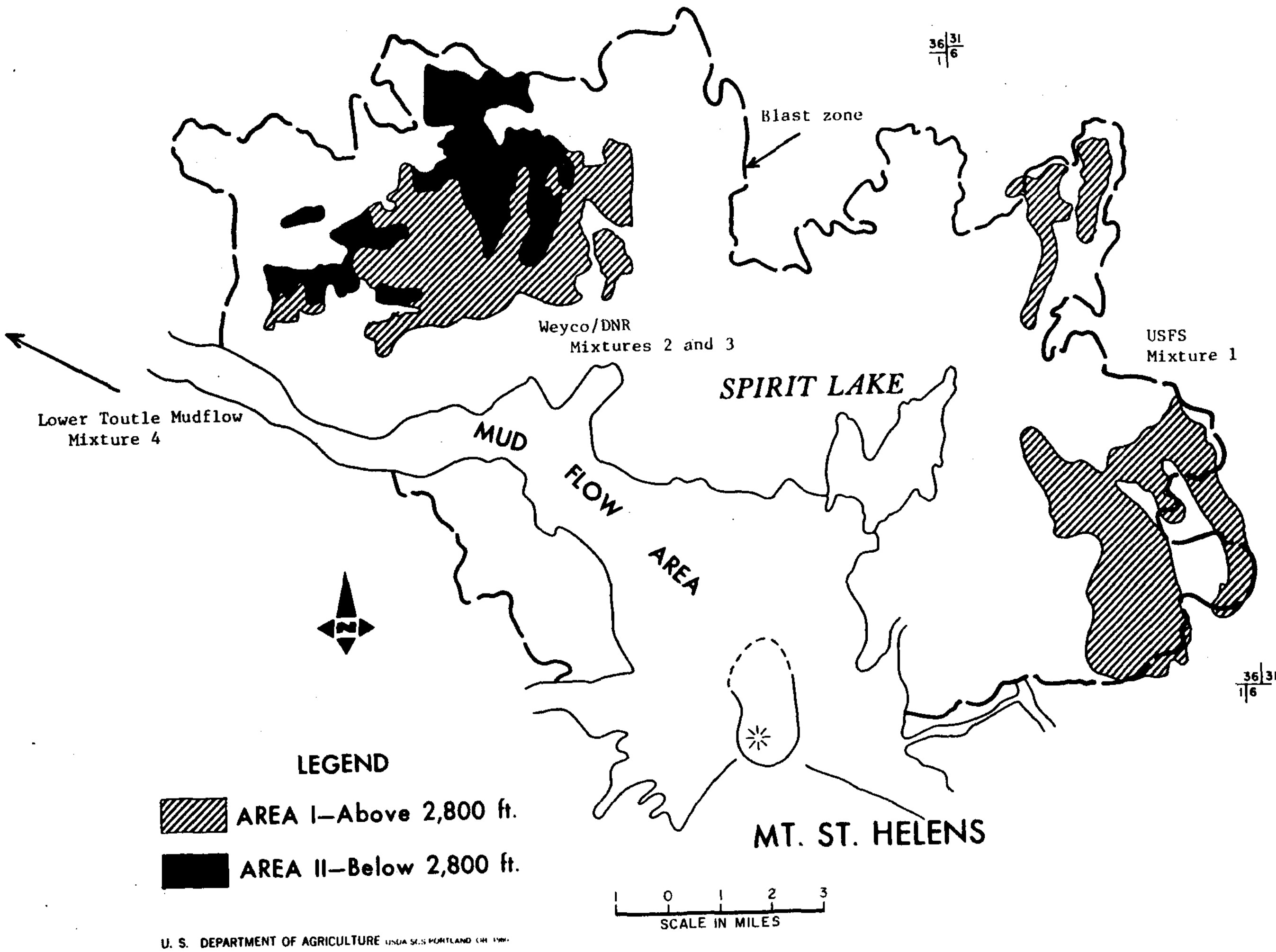
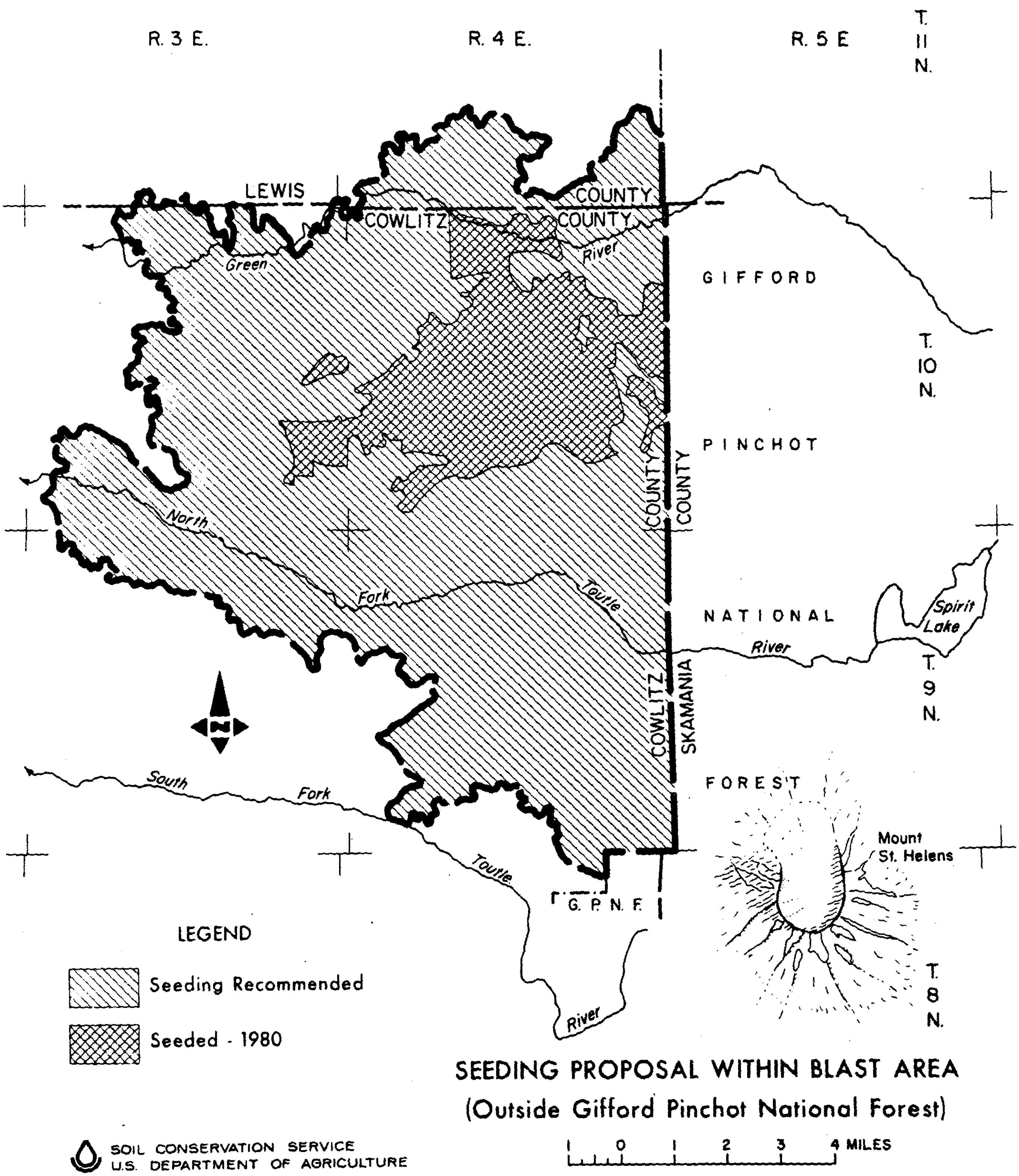


Figure 2.



SEEDING PROPOSAL WITHIN BLAST AREA
(Outside Gifford Pinchot National Forest)

On national forest land, 8,225 acres were scheduled for seeding, primarily in the Clearwater and Bean Creek drainages. This represented a small portion of the blast zone on federal land, but included two of the three major watersheds within the blast zone that fed Swift and Cougar Reservoirs south of the mountain.

The only feasible way to apply seed and fertilizer was broadcasting by helicopter, the standard method used for large burn seedings in the western states. There was also the potential hazard of additional eruptions, so application had to be with a minimum of personnel on the ground.

In summary, planning the emergency revegetation program on Mt. St. Helens was completed over a two month period. Seed mixtures, rates, fertilizer, dates, and methods of application were developed and agreed upon by all parties in a relatively short period. However, determining which areas to be seeded was much more difficult to resolve and added almost 2-3 weeks to the planning process. As a result, contracting was delayed and seeding actually began on September 4, 1980.

CONTRACTING AND APPLICATION

The Mt. St. Helens seeding and fertilizing project was divided into three contracts. Two solicitations for bids were issued August 18, 1980. One covered seeding of 12,153 acres of blast zone uplands on state and private lands (seed Mixtures 2 and 3). The other covered seeding 8,255 acres of Forest Service land (seed Mixture 1). Bids were opened on August 22. They ranged from $76.99 to $90.00 per acre. The lowest bidder, the same company in each case, was awarded both jobs.

The third contract covered 994 acres of mudflow (Mixture 4) on the lower Toutle River. Bid solicitations were issued September 16, 1980, and the contract awarded on September 23 for $110.90 per acre. A followup contract was awarded in spring 1981 for refertilizing 460 acres and seeding and fertilizing 270 new acres on the lower Toutle.

Higher elevations were seeded first. Mixture 1 was applied between September 5-15, 1980, one-two weeks after the latest recommended seeding date. Mixture 2 was broadcast between September 15-25, two-four weeks later than recommended. Mixture 3 was applied from September 25-October 1. Mixture 4 was seeded October 3-9. For Mixtures 1-3, areas were seeded one section (640 acres) at a time to permit adequate inspection by SCS representatives. For all mixtures, the broadcasting equipment was calibrated to the proper seeding rate. No seed diluent was used. Distribution was rated good to excellent with a few minor problem areas.

Seeding equipment consisted of one Alouette and five Bell 205 helicopters equipped with aerial broadcasters, normally used for large burn seedings. Several mobilization sites were used and three SCS representatives inspected progress on the project.

Fertilizer was applied September 15-October 20 on federal land, and September 28-October 15 on state and private land. Application was less systematic than the seeding operation, but used the same calibration and inspection procedures.

The seeding project strained available supplies of many of the plants specified in the contract. Nearly 760,000 pounds of seed were applied. Preferred varieties were indicated in specifications but generally were unavailable in the amounts needed. Most, if not all, seed came from U.S. sources.

PLANT PERFORMANCE DURING THE FIRST GROWING SEASON

Fall temperatures were somewhat higher than normal following seeding and continued mild through the winter with only occasional snow cover over the seeded area. Rainfall, normally 50-100 inches in the seeded areas, was below normal in the fall with extended dry periods throughout January 1981 and in late February-early March. For the recording period October 1, 1980, to September 30, 1981, approximately 15 percent of total precipitation fell between October 1-December 15; 45 percent between December 15-March 1, most of it from two storms in late December and mid-February; and 30 percent between March 1-June 1. Total precipitation was below normal to normal in the seeded areas.

Heavy rain in mid-December 1980 caused severe erosion and sedimentation to fill the large sediment dam near Camp Baker on the North Fork of the Toutle River, which breached on December 25, 1980. The failure of the North Fork Toutle River debris retaining structure south spillway resulted in the loss of 10-15 percent of the 2 million cubic yards of sediment that had accumulated.

On October 1, 1980, Mixture 1 showed poor to good emergence for grasses and poor to fair for legumes. In late October grass emergence increased while few legumes could be found. Some areas provided four inch grass growth entering the winter. However, total plant cover was insignificant.

On November 4, Mixtures 2 and 3 showed fair grass emergence and no legumes. October apparently was too cold for legume emergence. Grass vigor and color was rated good, with most plants in the 1-3 leaf stage. Total plant cover was less than one percent.

Mixture 4 germinated readily and grew slowly throughout the winter. Some ponding on flat mudflow suffocated small areas of this seeding. Plant cover was not measured but was significantly higher during the winter than the other mixtures at higher elevations.

In late January 1981, grass stand counts maintained or increased for areas seeded to Mixtures 1-3. However, nutrient stress was evident at all sites. Growth was minimal since the fall. Annual and perennial ryegrass comprised nearly all of the plants found. Very few legumes were found. Mixture 4 had excellent stands of both grasses and legumes. However, nutrient stress also was evident entering the spring.

In late February, ash samples from the Shultz Creek drainage (Mixtures 2 and 3) showed that virtually none of the fall applied nitrogen and phosphorous remained for use by the grass seedlings. Samples of the lower Toutle mudflow indicated no nitrogen and 25 percent of the phosphorous remained (see

Tables 1 and 2). These findings supported followup fertilization recommended in the initial revegetation package. Plant cover, except perhaps on the lower Toutle, was insufficient to control erosion and needed fertilization for further growth.

All four seed mixtures were evaluated for ground cover and vigor May 4-6 (Stroh and Oyler, 1981). In five transects (10 samples each) at two sites in the Clearwater drainage, Mixture 1 ground cover averaged 3.5 percent (see Table 3). Plant composition primarily was ryegrass. There was no invasion of unseeded indigenous vegetation. Wood debris accounted for 2 percent cover and 94.6 percent was bare ground. Depth of ash was 14-20 inches and elevation 2,400 feet at the two sample sites. Stand counts ranged from 0-88, averaged 28 plants per square foot. Plants were 1-2.5 inches high and severely stressed for nutrients. Leaves were purple-orange in color. Elk droppings found in the area produced lush 4-6 inch growth in adjacent seedlings. Growth also was noted to be greater near logs where nutrients had been washed off and leached into the ash.

Ground cover was rated along eight transects at two sites in the Green River-Shultz Creek drainage where Mixtures 2 and 3 were seeded. Slope, aspects, elevation, and ash depth varied by sample. Seeded ground cover averaged 11.2 percent, again primarily ryegrass. Very few legumes were seen anywhere. Natural invasion, primarily from established plants exposed by erosion or emerging through shallow ash layers, comprised 16.2 percent cover. Indigenous species included fireweed (Epilobium angustifolium), pearly everlasting (Anaphalis margaritacea), horsetail (Equisetum sp.), Canada thistle (Cirsium arvensis), and trailing blackberry (Rubus ursinus). Wood debris covered 9.5 percent, bare ground 63.5 percent. North slopes, facing away from the crater, were recovering more rapidly. Nutrient stress in seeded species was evident where roots had not penetrated into the mineral soil beneath the ash. Those plants that did generally displayed adequate vigor.

Ground cover and grass/legume composition also was rated along six transects at three sites on the lower Toutle River mudflow, where Mixture 4 was seeded. Elevation was about 300 feet and sites were flat. Seeded ground cover was 56.4 percent. Weeds provided 0.1 percent and wood debris 5.4 percent. Plant composition was 61 percent grass, 39 percent legume. Grass was primarily ryegrass, except on one transect where orchardgrass dominated an apparently lower fertility site. Growth had attained 12 inches and plants generally were vigorous. Much of the seeding had been refertilized on April 25, 1981, with 375 pounds per acre of 16-21-21.

The May evaluation concluded that additional fertilization was needed to improve ground cover in areas seeded to Mixtures 1-3. Subsequent discussions among the agencies and groups involved produced no consensus on refertilization, so none was attempted. Fertilizer at a 40-80-50 pound N-P-K per acre rate was applied to small plots throughout these areas on June 8-9. Observation during July showed dramatic differences in color and ground cover. Refertilized plots were bright green and contained more biomass than adjacent areas with reddish-yellow, poor vigor plants. By November 1981, these differences were less dramatic though still evident on the poorest sites. No ground cover readings were taken to accurately reflect differences. General observation implied that slower release fertilizers than those used might be more effective in promoting plant growth on sterile ash.

TABLE 1. Amounts of Available Nitrogen, Phosphorous, and Potassium in Pounds/Acre on Fertilized Areas of Schultz Creek in the Blast Zone. February 24, 1981.[1/]

Site Description	NO_3	P_2O_5	K_2O
Ridge top	2.0	10.0	96.0
Alluvial fan, slope bottom	2.0	2.8	56.0
Level bench	1.0	4.4	106.0
Upper terrace	1.0	12.8	132.0

1/ From Stroh and Oyler (1981)

TABLE 2. Amounts of Available Nitrogen, Phosphorous, and Potassium in Pounds/Acre on Fertilized Areas of the Toutle River Mudflow.[1/]

Date		NO_3	P_2O_5	K_2O
Before seeding		0.0	3.8	114
12/22/80	0-1 inch	0.61	24.6	165
	12 inches	1.05	2.5	101
	24 inches	0.16	3.0	107
1/26/81	0-1 inch	1.38	26.7	127
	12 inches	3.68	3.9	96
	24 inches	0.24	2.7	98

1/ From Stroh and Oyler (1981)

TABLE 3. Percent Ground Cover of Seeded Grasses and Legumes, Indigenous Species, Wood Debris, and Percent Bare Ground at Representative Sites within the Four Areas Seeded Near Mt. St. Helens. Evaluations Taken May 5-6, 1981.1/

Site	Seeded Species	Indigenous Species	Wood	Bare Ground
	%	%	%	%
Mixture 1				
Clearwater Creek (5 transects)	3.5	0.0	2.0	94.6
Mixture 2				
Schultz Creek >2,800 ft. elev. (3 transects)	10.0	5.7	14.4	69.0
Mixture 3				
Green River-Schultz Ck. <2,800 ft. elev. (5 transects)	11.9	22.5	6.6	59.0
Mixture 4				
Lower Toutle Mudflow (6 transects)	56.4	0.1	5.4	38.1

1/ From Stroh and Oyler (1981)

An independent study contracted by SCS (Klock 1981) evaluated plant performance on areas seeded to Mixtures 1-3 between June 10-July 22, 1981, after most plant growth of the seeded species was completed for the year. Seventeen transects were established for Mixture 1, 116 for Mixture 2, and 25 for Mixture 3. Included were unseeded checks. Sampling density was one transect per 117 acres on the areas seeded to Mixtures 2 and 3.

Ground cover for Mixture 1 averaged 10.7 percent. Seeded species, overwhelmingly ryegrass, occurred in 88.3 percent of the observation plots. Indigenous plants were found in only 1.6 percent of the plots (see Table 4). Ryegrass showed moisture, temperature, and nutrient stress symptoms.

The area seeded to Mixture 2 averaged 27 percent total cover, which was twice as great on north slopes than the remaining aspects. Both indigenous and seeded species were found in 50 percent of the observation plots.

Ground cover was observed to be greater on steeper slopes where ash had eroded, exposing mineral soil. In many areas, grass developed in rills and subsequently trapped ash sediment. Even where total plant cover was poor, grass plants trapped fine ash sediment moving downslope in rills. In contrast, fireweed (Epilobium augustifolium), also commonly found in these rills, did not trap ash nearly as well. Relatively flat slopes, where much early sedimentation occurred, had the poorest ground cover. Poor cover was due primarily to poor vigor rather than poor stands. Seedlings on flat slopes generally did not penetrate to mineral soil and were severely stressed for nutrients.

Much of the indigenous plant cover was stimulated by fertilization. Only 0.6 percent ground cover was measured on the 12 unseeded transects. Apparently fertilizer leached through the ash layer and became available to the sprouting vegetation beneath.

Total ground cover in Mixture 3 area was 73.4 percent, compared to 12.6 percent unseeded. This area, below 2,800 foot elevation and ash layers less than 4 inches deep, also was significantly eroded aiding initial plant establishment. Fertilizer also greatly stimulated indigenous growth. The study suggested that the grasses had become too successfully established and may be too competitive with future tree regeneration. Seeded species were observed in 87 percent of all plots, natives in 58 percent.

Overall, seeding improved plant cover on ash but was hindered significantly by lack of nutrients. Where mineral soil was exposed by erosion, plant establishment was excellent and often trapped ensuing ash deposits, filling up rills. Fertilizer stimulated native recovery where ash depths were shallow enough to permit sprouting. The study was unable to establish the relationship between ash erosion and present vegetative cover because of inadequate base data prior to seeding.

Observed frequency of seeded species showed ryegrass dominating all other species. Ryegrass frequency ranged from 49.8-89.1 percent among Mixtures 1-3. Creeping red fescue ranged 0.2-12.8 percent, white clover 2.4-21.2 percent, All other species frequencies were less than 2 percent (see Table 5).

TABLE 4. Total Ground Cover and Frequency of Plant Species at Representative Sites within Three Areas Seeded near Mt. St. Helens. Evaluations taken June 22-July 10, 1981.[1/]

Site	Total Cover	Frequency[2/] Seeded Species	Indigenous Species
	%	%	%
Mixture 1			
Clearwater Creek (17 transects)	10.7	88.3	1.6
Mixture 2			
>2,800 ft. elev. Schultz Creek (104 transects)	27.0	50.2	50.3
Unseeded areas (12 transects)	0.6	0.4	3.0
Mixture 3			
<2,800 ft. elev. Green River-Schultz Ck. (12 transects)	73.4	87.1	58.1
Unseeded Areas (12 transects)	12.6	3.3	44.0

1/ Developed from Klock (1981)
2/ Average frequency that indicated category of plants occurs within sample points along transect.

TABLE 5. Species Frequency at Representative Sites within Three Areas Seeded near Mt. St. Helens. Evaluations taken June 22-July 10, 1981.[1/]

Species	Mixture 1	Mixture 2		Mixture 3	
		No Seed	Seeded	No Seed	Seeded
	%	%	%	%	%
Introduced					
Ryegrass	89.1	T	49.8	0.5	85.9
Creeping red fescue	0.2	0	12.8	0	3.9
Orchardgrass/timothy	-	0	1.4	0.2	0.8
White clover	-	0	2.4	0	21.2
Birdsfoot trefoil	-	0	T	0	0.5
Hairy vetch	T	-	-	-	-
Subterranean clover	0	-	-	-	-
Planted conifer	-	-	-	1.9	1.3
Indigenous					
Fireweed	T	1.7	35.7	2.3	18.9
Pearly everlasting	0	0.2	7.4	0.2	9.6
Willow	0	0	0.4	0.2	T
Trillium	0	0	1.4	0.1	T
Canadian thistle	0	0	8.5	4.7	32.4
Blackberry	0.3	0	2.9	6.6	13.3
Thimbleberry	0	0	0.3	0.1	4.5
Sword fern	0	0	0.2	3.2	6.3
Bracken fern	0.6	0	0.8	0	4.2
Tansy	0	0	1.2	11.7	5.0
Elderberry	0	0	0.2	0	1.8
Wood sorrel	0	0	2.2	0	0.6
Oregon grape	T	0.8	5.6	8.0	2.4
Dandelion	0	0	1.8	1.8	1.9
Other	0	0	6.6	5.2	4.0

1/ From Klock (1981). Frequency expressed as average percent occurrence within sample points along transect.

Informal observations into early November 1981 indicated little apparent change from the summer evaluation. Fall rains produced new seedlings from shattered ryegrass seed in all four seeded areas. Even severely stressed plants in the Mixture 1 area produced a few viable seed. Ryegrass normally is not a prolific reseeder since second year seedlings usually encounter trouble establishing roots through first year residues. Seedling survival will be monitored in spring 1982.

Time of seeding had a negative effect on legume establishment, particularly for Mixtures 1 and 2. The two evaluations during 1981 support the widely accepted notion that August seedings promote legume establishment at higher elevations in the Northwest. Had seed Mixtures 1-3 been seeded when recommended, plant cover likely would have been greater despite the lack of nutrients, since legumes are able to fix their own nitrogen for plant growth.

FUTURE REVEGETATION

Resource inventories since the major eruption have shown generally poor recovery of riparian vegetation, which is crucial for channel stability without protective structural measures. Adequate riparian vegetation is important in the area for anadromous fish habitat. Some land owners already have planted cottonwood (*Populus trichocarpa*) along streams to accelerate revegetation. SCS, in clearing blocked tributaries to the Toutle River, plans to reestablish riparian plants during 1982-83. Species include sitka willow (*Salix sitchensis*), Pacific willow (*S. lasiandra*), redosier dogwood (*Cornus stolonifera*), Douglas hawthorn (*Crataegus douglasii*), nootka rose (*Rosa nutkana*), serviceberry (*Amelanchier alnifolia* v. *florida*), and others.

Many of the upper watershed streams currently have unstable banks, formed by cutting through debris avalanche, mudflows and ash deposition in small valleys and bottoms. Planting riparian plants offers little short-term potential for stabilizing these banks. However, plantings on sites near streams, which can be protected or are not likely to wash away, could provide a seed source that would accelerate recovery of riparian vegetation in this area. Willows, cottonwood, or alder are rapid growers and prolific seeders and would be well suited for this approach.

No further grass/legume seedings are planned in the next few years, except to revegetate areas disturbed by clearing tributary outlets into the Toutle River. The Mixture 1 seeding probably will decline rapidly since little biomass was produced to provide a base for significant nutrient recycling. Reforestation of this area will have to depend on artificial nutrient sources for adequate tree growth. One alternative could be a late summer legume seeding. However, disturbed sites usually "settle" creating a surface unsuited for germination and root penetration by seeds broadcast on the surface. This phenomenon should be tested in small plots before any large scale effort is tried.

Mixture 2 and 3 seedings should be evaluated to determine their effect on future erosion. Total plant cover is expected to increase but with seeded species, mostly ryegrass, declining over the next few years. A late summer legume seeding could provide additional fertility to ash layers, particularly where they have accumulated along bottoms or swales.

Mixture 4 seedings established as well as many pasture seedings do in Cowlitz County. Untended, the ryegrass will decline and its residue will prevent any significant filling in by the other grasses or legumes. Total live plant cover probably will decline after 1982 until plant residues break down and recycle nutrients. White clover will continue to provide nitrogen. However, limiting nutrients probably will be phosphorous and others captured during plant growth and recycled. Seeded areas likely will be invaded by forbs, brush, and tree species which are more tolerant of low fertility and more likely to exploit nutrients deeper in the mudflow profile.

The primary objective of the grass-legume seeding was to reduce ash erosion on sloping land, filter ash sediment before reaching streams, and reduce sedimentation downstream. In the Northwest, a general rule-of-thumb is that ground cover should exceed 40 percent to be effective in controlling erosion and trapping sediment. Only Mixtures 3 and 4 achieved this level. Furthermore, most erosion during the winter 1980-81 in areas seeded to Mixtures 2 and 3 occurred before seedlings became well established. In fact, the most vigorous plants were those that germinated and grew in mineral soil exposed by erosion. However, seeded grasses and indigenous vegetation that was able to sprout through the ash layer and was stimulated by the fertilizer began to be effective in controlling erosion during the spring 1981. Many rills filled back up with sediment and ground cover readings exceeded 40 percent in many areas. Mixtures 2 and 3 likely will become increasingly effective in retaining remaining ash on the slope and will reduce deposition of fine ash off site, particularly in the Columbia River. On the other hand, plant cover is expected to decline on seeded bottoms and valleys where ash depths are much greater. Unseeded (unfertilized) areas with much lower total ground cover will continue to erode severely. Mixture 1, which was seeded on slopes less than 30 percent) will continue to offer little protection or ability to trap sediment.

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Turfgrass Revegetation Projects

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Revegetation in the Rocky Mountain Region with cultivated turfgrasses is very extensive. Industrial and recreational development has resulted in substantial migration to the mountain area. This has caused thousands of acres a year to be disturbed. The revegetation of such areas often requires high quality ground covers, primarily turfgrass.

There is a strong trend to disturb no more land than necessary; also to plant only areas which will be heavily used to cultivated turfgrasses. This is not to say that certain cultivated turfgrasses, especially Kentucky bluegrass and fine fescues, will not tolerate the climatic and adaptic conditions of the mountains without supplemental maintenance. In the mountains, intensely maintained turf areas include condominiums, parks and athletic fields. Large acreage golf course construction calls for the use of high and low maintenance turfgrasses. Golf courses may have a few acres of extremely high maintenance turf, especially for greens. Tees and fairways are less intensely maintained. The cost for land and its development through high quality turf maintenance is great. Consequently, very close attention is needed to select the best grasses possible for the situation. To many, at least at first appearance, high quality turf seems a waste, but many towns and cities in the Rocky Mountains derive a major part of their income from recreational endeavors. Many summer recreational enterprises are centered around turf developments. Many ski resorts have installed, or are in the process of building, golf courses so that employees can be kept year around; also, housing and other amenities can be utilized more intensely if there is an attraction for vacationers.

Soil Considerations

For many turfgrass revegetation projects, existing soil conditions are non-uniform and quite poor. Although these soils might function quite well for most revegetation projects they present some serious problems for high maintenance turf. For instance, rocks, tree stumps and other debris on the site make it difficult to keep turf at 3/4" on fairways. Therefore, one of the usual first efforts on a new site is to assess the existing soil conditions and to plan for proper on site handling of the soil. On many, or perhaps most of the sites, soil is stockpiled for reuse after final landforming. Capping areas with good top soil provides an acceptable growing media as well as covering exposed rock. In some cases, organic amendments are added to existing soils to improve their physical quality. Specific use areas such as golf course greens and tees, soccer and rugby fields, grass tennis courts, etc. are often subjected to extensive soil amending. In the mountains, getting a suitable sand and peat to amend soils or make an artificial turf media can be difficult and very expensive. Most sand specifications call for a rather uniform sand. Particle size normally called for will be in the 0.1 - 1.0 range. In the mountains transportation costs, crushing river stones to make sand, competition by other construction projects, and screening to get the desired material can cause sand to be very expensive. To build an 18-hole golf course, using a high quality sand for greens, it can take 5-6000 cu. yds. and cost around $200,000. Use of poor sand, including those of a calcareous nature, can cause a green to drain too poorly or too rapidly, hold a ball poorly, and be slow to establish.

Native or imported peat is often added to the sand to construct a green. Some serious problems have developed from the use of poor quality peat. In some areas, peat performs quite well as a soil amendment. In other instances, especially those of low organic content, they can cause internal drainage problems. Before using peat its quality should be determined. Normally the peat will be ashed to determine the organic matter content. Also, moisture holding ability, pH, soluble salts, etc. can be valuable in choosing the right peat. Various mixtures of sand and peat are normally tested to assure that the media will drain properly. Percolation tubes can be used for testing. After the mix is decided on, the sand and peat (possibly soil, calcined clay, bark, etc.) may be mixed on or off site. This very brief review gives some idea of what goes into constructing golf greens and perhaps even tees.

Where native soils are to be used it is suggested that the soils be properly sampled and tested to determine fertility needs, and frequently what kind and varieties of grasses to plant. Money can be saved and probably a better job done if the soil is tested to determine starter fertilizer use. Some sites may be too salty for the use of straight Kentucky bluegrass. In this case the test would indicate that a mixture of salt tolerant grasses be used. A common fertility practice is to apply approximately 1 lb. of nitrogen per 1,000 sq. ft. plus 3 or more lbs. of P_2O_5 per 1,000 sq. ft. Although potassium is not routinely recommended a soil test may show it to be quite deficient. This is normally incorporated into the surface of the soil just ahead of seeding.

Turfgrasses

In selecting turfgrasses for revegetating several factors need to be considered. Factors that need to be considered; will the site be irrigated, if so will it be available throughout the year and in times of very short supply? Also, is the area north facing or shaded by trees or mountains? Such areas can be quite prone to serious snow mold problems as well as late greenup by certain grasses. Regardless of all the variables in choice the grasses adaptable for high quality turf use include only a few species. These are primarily Kentucky bluegrass, fine leaved fescues and Perennial ryegrass. For speciality uses, such as golf course greens and tennis courts, bentgrasses are used. In Colorado there is one golf course, and another under construction which has bentgrass fairways as well as tees and greens. Regardless, the basic turfgrass for the mountain area is Kentucky bluegrass.

The tendency has been to get away from seeding of only one cultivar of Kentucky bluegrass. Blends of several cultivars are now used. Also, the sod growers, who supply a great deal of material for revegetation at high elevation, mostly grow blends of Kentucky bluegrass. Colorado sod growers are beginning to look at growing mixtures of both fine and coarse textured grasses for revegetation.

Kentucky bluegrass blends are mostly formulated on a weight basis, usually in equal proportions. Although Kentucky bluegrass blends are often used there is a strong move, supported by the coming of some excellent improved turf-type perennial ryegrasses and fine fescues, to shift to mixtures of two or more species of these grasses.

Several factors determine whether or not to use a blend of Kentucky bluegrass or a mixture of other fine textured cool season grasses. The time of year the planting will be made is an important consideration. If the grass can be planted from approximately mid-May until mid- to late August and irrigation is provided, there should be little problem in getting a blend sufficiently established before cold weather. Failure to establish an adequate fall cover can result in severe erosion during spring runoff. Also, the decision on whether or not to plant a blend or mixture will be, in part, determined by the management of the area. Where high maintenance and exceptionally fine quality turf are desired, Kentucky bluegrass should be used. However, if some or most of the area is to be maintained with less water, fertilizer, or mowing then a shift from Kentucky bluegrass blends to a mixture would be appropriate.

Kentucky bluegrass

There are about 50 commercial cultivars of Kentucky bluegrass available, and the character and maintenance requirements for these can vary a great deal. A major concern will be the availability of cultivars that produce a dense stand that is resistant to snow mold. Use of blends should help to offset a high level of snow mold susceptibility by certain cultivars.

Fine fescues

There are about half as many fine fescue cultivars available on the market compared to Kentucky bluegrass. There are many new cultivars of fine fescues. These include cultivars of hard, creeping red, and chewings fescue. Generally the fine fescues are mixed with Kentucky bluegrass. The creeping fescues can be quite dominate in mixtures in the mountains and this may not be desired. The bunch type fine fescues, that is chewings and hard fescues, tend to be good mixers with Kentucky bluegrass.

Perennial ryegrasses

These grasses are known for their seedling vigor. In the mountains they can establish a good cover in a short period of time, provided they are planted and irrigated during the warmer part of the year. Their quick establishment can provide needed erosion control on disturbed soils. The perennial ryegrasses are very aggressive and should not constitute more than 20% of a seed mixture. A major concern with the perennial ryegrasses remains that of cold hardiness. Cold hardiness was a major concern during the winter of 1980-81 because of a lack of snow cover, and perennial ryegrass stands were thinned or taken out that winter. In areas where the snow cover comes early and goes off late, the perennial ryegrasses, unless they are damaged by snow mold, persist and provide an acceptable turf. There are about the same number of commercial perennial ryegrass cultivars available as there are fine fescues.

Fine grass mixtures appear to be the most prevalent type of grass planted for revegetation in the mountains. But, with the large numbers of cultivars available how does one go about choosing the components of a mixture? Too much perennial ryegrass and it will dominate, or too little fine fescue and it can become a weed problem. The mixing of the grasses will usually cause some reduction in overall quality. However, the benefits of having a broad base mix to better tolerate various environmental stresses seems to be worth the slight loss in quality.

Bentgrasses

As indicated above these are speciality grasses. There are currently four seeded creeping bentgrasses available. These are Penncross, Penneagle, Emerald, and Seaside. Penncross remains the most used of the creeping bentgrasses. In some instances, Penncross and Emerald are blended for golf greens. Penneagle is a new variety which has had limited use, especially in the mountains. Seaside is a fairly salt tolerant grass, but has some characteristics which make it generally less desirable for greens than Penncross. When large areas or fairways are planted, often times a colonial bentgrass is mixed with creeping bentgrass.

Tall fescues

There has been a great deal of interest in recent times in this grass for turf sites. These grasses have seen limited use at higher elevations, and they need more extensive testing. The finer turf-types such as Rebel, Falcon, Clemfine, etc., produce higher quality turf than the old types such as Alta, Fawn and Kentucky 31. In our Region the question of what they offer that we cannot get from Kentucky bluegrass, fine fescue and perennial ryegrass needs more attention.

Warm Season grasses

Buffalograss and blue grama are being used more and more for turfgrass revegetation purposes in the High Plains and along the Front Range. However, with the short growing season in the mountains, these grasses do not seem to have much place, especially at elevations over 6 or 7000 ft.

It should be re-emphasized that great care should be taken to have as good soil conditions as possible for turfgrass production. Also, choosing the best turfgrasses, or combination of grasses at the proper amount, for high elevation sites needs close attention. Otherwise, these turfgrasses will fall short of their potential as a successful mountain revegetation tool.

ALPINE REVEGETATION

RESEARCH AND TECHNIQUES AT THE LAKE LOUISE SKI AREA[1]

David G. Walker[2]

INTRODUCTION

The Lake Louise Ski Area is located on Whitehorn Mountain overlooking the village of Lake Louise, 175 km west of Calgary, Alberta in Banff National Park. Lift construction and ski run clearing methods employed in recent years have had a minimal impact on the vegetation and erosion potential of the area. Earlier methods, however, involved extensive road construction, damage from off-road vehicles, heavy equipment grooming, and large-scale run recontouring. Very little natural revegetation has occurred on the severely disturbed sites and early reseeding attempts were largely unsuccessful.

The Lake Louise Ski area is on federal government land administered by a national park system dedicated to preserving unique areas of Canada as living museums. As such, in Banff National Park, commercial development is limited and the responsibility of the concessionaires is significant. In most instances, ski area interests are in concurrence with park management interests. Both wish to minimize environmental impact by controlling erosion, establishing maintenance-free native vegetation on damaged areas and preserving an attractive wilderness environment.

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[1] This work was supported initially by Parks Canada and later by Village Lake Louise Limited and Walker & Associates Limited.
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Elevational range of the ski area is from 1670 to 2840 meters. A lodgepole pine forest dominates the base, changing to a Englemann spruce/subalpine fir forest by 2100 meters which ends at the tree-line, approximately 2300 meters. A normal ski season begins in early December and lasts until late April. Summers are cool, average temperature 6°C, and short, growing season averages 55 days. The frost-free period is generally 7 days.

Revegetation research began at the Lake Louise Ski Area in 1976 with a Parks Canada grant to the University of Alberta for the development of native grass varieties. Operational rehabilitation of the area began in 1979.

METHODS AND MATERIALS

Native grass species were collected in the Rocky Mountain region of Alberta and multiplied at the University of Alberta Genetics Field Laboratory near Edmonton. Agronomic species were certified varieties obtained from local commercial distributors. Fertilizer was applied as ammonium nitrate (26-13-0) at 100 kg-N/ha (High-N) or 25 kg-N/ha (Low-N) annually at the time of initiation of growth each season. The mulch treatment consisted of peat moss applied to a depth of 1.3 cm. Transplant studies utilized single vigorous plants which had been grown for 3 months in 41 cm^3 Spencer-Lemaire tree seedling root-trainers.

Experimental layout of the species trial was a block design of three replications for each of the High-N, Low-N, and 0-N rate of fertilizer. Species were planted in 1 m^2 plots at 1000 seeds/plot in a randomized sequence in each block. Seedling establishment was measured by counting the number of seedlings/plot after one year. Ground cover of these plots was estimated visually using of a 1 m^2 frame with a 10 cm grid. Estimates were made at the end of the second and third growing seasons and are the average of the readings taken by two observers.

Transplant trials consisted of 16 transplants/m^2 for each species in three replications. Mulch trials were planted as paired plots in three replications. Species competition trials were established by planting seed of an agronomic variety with a native species in a 1:1 by weight ratio in 1 m^2 plots which were maintained annually at the High-N, Low-N, and 0-N fertilizer rate.

The trials site is located at tree-line on a 25° (average) east-facing slope. A ski run recontoured approximately 15 years ago provided a well-drained, sandy-clay, slightly alkaline substate that was barren of any vegetation. Soil nutrients, nitrogen and phosphorous, were extremely low.

RESULTS AND DISCUSSION

TRANSPLANT TRIALS

Survival of native species and agronomic check species established as transplants are contained in Table 1. Additional agronomic check species were established in 1979.

Table 1 Per cent survival of transplanted species after 36 months.

Name			Average 3 Reps
Deschampsia caespitosa		tufted hairgrass	100.0
Poa alpina		alpine bluegrass	93.7
Poa interior		interior bluegrass	89.6
Festuca ovina saximontana		alpine fescue	84.2
Agropyron latiglume		alpine wheatgrass	83.3
Festuca rubra rubra	Boreal	creeping red fescue	79.1
Agrostis scabra		rough ticklegrass	78.1
Poa cusickii		Cusick's bluegrass	78.1
Calamagrostis purpurescens		Purple reed grass	75.0
Agropyron trachycaulum	Revenue	slender wheatgrass	75.0
Agropyron trachycaulum		slender wheatgrass	66.7
Koeleria cristata		June grass	66.7
Agropyron subsecundum		bearded wheatgrass	59.0
Agropyron dasystachyum		northern wheatgrass	58.3
Phleum alpinum		alpine timothy	56.2
Trisetum spicatum		spike trisetum	53.1
Stipa columbiana		Columbia needlegrass	0.0
Agropyron spicatum		bluebunch wheatgrass	0.0
Agropyron cristatum	Parkway	crested wheatgrass	0.0
<u>additional check varieties after 16 months</u>			
Poa pratensis	Banff	Kentucky bluegrass	97.0
Festuca rubra rubra	Boreal	creeping red fescue	92.0
Festuca ovina duriuscula	Durar	hard sheep fescue	89.0
Medicago sativa/falcata	Anik	alfalfa	89.0
Poa compressa	Reubens	Canada bluegrass	81.1
Poa pratensis	Nugget	Kentucky bluegrass	81.0
Festuca rubra rubra	Reptans	creeping red fescue	71.0
Alopecurus pratensis		meadow foxtail	63.0
Phleum bertolonii	Evergreen	diploid timothy	56.0
Poa ampla	Sherman	big bluegrass	50.0

The per cent survival of the top 11 species has remained fairly static during 3 years of observations. The others, with the one exception, have recorded a slow but definite decline in survival. The exception is *Trisetum spicatum* at 53% which was recorded during the first year of observations and has not changed since. The initial die-off could have resulted from animal disturbance or rough handling during transplanting.

Results indicate that species commonly found in alpine areas show better survival than those from lower elevations. *Festuca rubra rubra* var. Boreal is exceptional in equalling the performance of many natives. *Agropyron trachycaulum* var. Revenue also shows good winter hardiness though neither variety has set seed. Native species which have not only set seed but have reseeded and are invading other plots include *Poa interior*, *Poa cusickii*, *Deschampsia caespitosa*, and *Festuca ovina saximontana*.

Results from the 16 month old transplant trial suggest that *Phleum bertolonii* var. Evergreen and *Poa ampla* var. Sherman are not good candidates for high elevation revegetation. Banff Kentucky bluegrass is a newly available variety developed by Canada Agriculture from a collection made in the Banff townsite. The good performance of this variety suggests that it may be substituted for Nugget, an Alaskan variety long noted for winter hardiness. *Medicago sativa/falcata* var. Anik is a new variety developed in northern Alberta and is the first legume to succeed at this elevation.

SPECIES AND FERTILIZER TRIALS

Results of seedling establishment after one growing season in all nine replications and ground cover of the three high-N fertilized replications after three growing seasons are presented in Table 2.

Rate of fertilizer had no significant effect on per cent seedling establishment. Per cent ground cover for all live species at the high-N rate of fertilizer was 37%. This amount was significantly ($P<0.01$) different from the total average for the low-N (<4%) and the 0-N (<1%).

Species with large seeds (*Agropyron* spp.) generally demonstrated better per cent establishment than small seeded species (*Poa*, *Trisetum*, *Phleum*, *Agrostis*). Seedling establishment, however, did not accurately predict subsequent ground cover. The seeding rate was too high (1,000 seeds/m^2) for establishment rates in the range of 50% because plant densities of 500/m^2 are not possible in alpine environments. The 1,000

Table 2 Average per cent establishment and per cent ground cover of species.

Name		% Est.	% Cov.
Deschampsia caespitosa		26	80
Poa alpina		17	45
Poa interior		7	50
Festuca ovina saximontana		59	47
Agropyron latiglume		55	27
Festuca rubra rubra	Boreal	12	23
Agrostis scabra		13	13
Poa cusickii		20	20
Calamagrostis purpurescens		12	47
Agropyron trachycaulum	Revenue	65	40
Agropyron trachycaulum		42	1
Agropyron subsecundum		48	1
Agropyron dasystachyum		33	30
Phleum alpinum		9	60
Trisetum spicatum		9	18
Stipa columbiana		40	0
Agropyron cristatum	Parkway	26	0
Poa compressa	Reubens	7	40

seeds/m^2 rate corresponds to 38 kg/ha for the species with the largest seeds, (*Agropyron subsecundum*) and 10 kg/ha for the species with the smallest seeds, (*Poa compressa* var. Reubens).

Another factor which must also be considered in the selection of native species for alpine revegetation is cost of seed production. *Agropyron latiglume* has a decumbent growth habit which makes harvesting very difficult. *Phleum alpinum* suffers from uneven ripening and *Poa alpina* has shown poor seed yields. Both *Trisetum spicatum* and *Calamagrostis purpurescens* possess small awns which make harvesting difficult and cleaning and processing expensive.

EFFECT OF MULCHING

The presence of a peat moss mulch had no effect on per cent seedling establishment after one growing season although there was some indication that emergence was somewhat delayed on mulched plots. In subsequent years, mulched plots were very poor in comparison to unmulched plots. Only seven species remained in mulched plots after 36 months. These were the alpine species *Deschampsia caespitosa*, *Poa interior*, *Festuca ovina saximontana*, *Poa alpina*, *Agrostis scabra*, and *Trisetum spicatum*. *Festuca rubra rubra* var. Boreal was the only agronomic species which "survived" the mulching treatment.

The most probable explanation for the poor results from mulching is that the ground was insulated by the layer of organic mulch and soil temperatures remained low. This is supported by the fact that alpine species, tolerant of low soil temperatures, were the only survivors.

COMPETITION TRIALS

Results of competition trials in which an agronomic species, *Festuca rubra rubra* var. Boreal was seeded individually with each of five native species in plots maintained at three fertility levels is contained in Table 3. The dominant species now present after 36 months is noted as either agronomic (A) or native (N) or a ratio (A:N).

Table 3 Final composition of plots seeded with an agronomic species (A) and a native species (N) at three fertility levels after 36 months.

Native species	High-N	Low-N	0-N
Agropyron trachycaulum Revenue	A	A	A
Festuca ovina saximontana	A	N	N
Phleum alpinum	A	1:1	1:1
Poa interior	A	N	N
Trisetum spicatum	A	1:1	N

In some applications, it may desireable to use a seed mixture which contains both agronomic species for a fast and efficient ground cover and native species which will eventually provide a self-sustaining ground cover. Results from this study indicate that under high fertility soil conditions, *Festuca rubra rubra* var. Boreal will dominate the native species listed above. At lower levels of applied fertilizer or no fertilizer, it appears that native species have a good chance of taking over.

CONCLUSIONS

A number of agronomic and native species which could make good candidates for revegetation at tree-line elevations have been identified. High per cent establishment for most adapted species indicates that heavy seeding rates are not needed to achieve a good stand. Fertilizer was required to establish an adequate ground cover at this site. The low rate of nitrogen (25 kg-N/ha) had little effect on cover while 100 kg-N/ha may be detrimental to the native species in a seed mixture also containing agronomic species. Organic mulches were found to be unnecessary for plant establishment at this location and may be detrimental possibly due to lower soil temperatures.

NEW AND AVAILABLE VARIETIES OF PLANTS

John Ericson
Mile High Seed Company
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KIND: VARIETY	LATIN NAME	AVAILABILITY
Small Burnet: DELAR	*Sanguisorba minor*	Spring 1984 or Spring 1983
Lewis Flax: APAR	*Linum lewisii*	Fall 1982 or Spring 1983
Bluebunch Wheatgrass: SECAR	*Agropyron spicatum*	Fall 1982 or Fall 1983
Great Basin Wildrye: MAGNAR	*Elymus cinerius*	Limited now
Beardless Wildrye: SHOSHONE FALL PLANT ONLY!	*Elymus triticoides*	Fall 1983 or Fall 1984
Canby Bluegrass: CANBAR	*Poa canbyi*	Limited now
Upland Bluegrass: DRAYLAR	*Poa glaucantha*	Limited now
Indian Ricegrass: NEZPAR Use at high elevations	*Oryzopsis hymenoides*	Available
Mountain Brome: BROMAR	*Bromus marginatus*	Available

PLANT TISSUE CULTURE: An overview of applications and procedures

Sarah K. Upham, Native Plants, Incorporated[1/]

Native Plants, Incorporated is composed of seven divisions. All are interrelated and play an important role in the advancement of the plant sciences today. The seven divisions are:

1. Ecology-Reclamation/Revegetation
2. Botanochemicals
3. Soil Science
4. Microbiology-Mycorrhizae/Genetic Engineering
5. Tissue Culture
6. Seed
7. Nursery

The interaction of tissue culture with these divisions is varied and very much in the forefront in applying technologies developed through research efforts. The functions of plant tissue culture at Native Plants, Incorporated are as follows:

1. Preservation and rapid multiplication of threatened and endangered cacti.

2. Production of clonal material for the botanochemical division. A uniform population will permit the evaluation of stresses and other environmental parameters on secondary product formation without the complications of variance inherent in a seed population.

3. Development of *in vitro* screening systems to eliminate time and space factors; to determine if a correlation exists between *in vitro* phenomena and observations and performance in the field.

4. Rapid multiplication of special selections, both horticultural and agronomical.

5. Rapid multiplication of disease-indexed stock.

6. Development of *in vitro* systems for plants that have been difficult to propagate through traditional propagation systems.

Other applications of plant tissue culture include the production of pharmaceuticals and other plant products, germplasm storage, creation of disease-indexed plants, plant breeding and genetics which involve *in vitro* pollination, *in vitro* germination, anther/microspore culture, ovary/ovule culture, protoplasts, and somatic hybridization.

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A general procedure for plant tissue culture is outlined below.

1. Establishment of aseptic culture
    a. Initiation of callus
    b. Initiation of adventitious buds/shoots
    c. Initiation of somatic embryogenesis
    d. Enlargement of shoot-tip explants

2. Rapid increase of propagule IN VITRO
    a. Callus and/or somatic embryogenesis
    b. Callus and/or adventitious shoots
    c. Axillary branching

3. Preparation IN VITRO for transfer to soil
    a. General hardening
    b. Root/shoot cuttings
    c. Re-establish autotrophism
    d. Impart resistance to moisture stress and disease
    e. Satisfy dormancy requirements (especially bulbs that have lost their leaves in culture)

4. Acclimatization in soil

The first three steps are performed IN VITRO

Parameters needing evaluation

1. The Explant
    a. Organ source within plant
    b. Developmental phase--juvenility vs. adult
    c. Age of explant source
    d. Preculture treatment of explant source
        1. Enhance disinfestation and pathogen-free explants
        2. Satisfy dormancy needs i.e. chilling, photoperiod
        3. Adult-juvenile reversal
    e. Explant size
        1. Survival frequency
        2. Quickness of growth initiation
        3. Infection probability
        4. Probability of variance

2. Nutrient formulations
    a. Chemical compositions
    b. Physical qualities
        1. Gel vs. liquid
        2. Gels
            a. purity of agar
            b. concentration of agar
        3. Liquids
            a. stationary, without supportives
            b. stationary, with supportives
                1. filter paper
                2. glass wool

c. Amount of medium
d. Key nutrient constituents
   1. Inorganic salts
   2. Carbon source
   3. Vitamins--Thiamine-HCl
   4. Water
e. Additional constituents
   1. Adenine sulfate
   2. Additional phosphate
   3. Auxins
   4. Cytokinins
   5. Charcoal

3. Culture Environment
   a. Light
      1. Lamp quality
      2. Photoperiod
      3. Intensity
   b. Temperature
      1. Diurnal needs
      2. Seasonal variations
   c. Atmospheric components
      Toxic substances i.e. ethylene, CO_2 and ethanol in the gas phase

4. Finished product
   a. Reproduction of phenotype
      1. Genetic variation - frequency of variation is directly proportional to the number of subcultures
      2. Disease-free plants

It is the author's belief that the most feasible application of plant tissue culture to high alpine revegetation is the rapid multiplication of selected site-specific plants. The native plants are just beginning to be selected for desirable characteristics. Breeding and traditional propagation has not yet been systematically performed on native plants. Therefore, to revegetate an area with the most adapted plant, plant tissue culture is the answer.

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