Proceedings of a Workshop on
REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS

co-chairmen:

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July 1974

Colorado Water Resources Research Institute

Information Series No. 10

Colorado State University

REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS

Proceedings of a Workshop at Fort Collins

January 31 to February 1, 1974

Co-Chairmen

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Colorado State University

In cooperation with:

Climax Molybdenum Company
Colorado Department of Highways
Soil Conservation Service USDA
University of Colorado
U. S. Forest Service
Vail Associates
Agricultural Research Service USDA

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July 1974

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PREFACE

Nineteenth-century mining left its mark on the landscape of Colorado. These scars and mine wastes are now usually regarded as a historical legacy. Will time treat our present attitudes on land disturbances in the high country with the same nostalgia?

Today we have the potential to create far greater disturbances. We also recognize the unique scenic and watershed values of the subalpine and alpine, and understand better the fragility of these ecosystems. The need for rehabilitation of present-day disturbances is obvious. However, many past and current revegetation efforts are after-thoughts.

Information on rehabilitation potential and procedures must be available for planning and in considering alternatives. Rehabilitation must include use of the best available technology, and long-term commitments for management and maintenance.

To help in meeting these needs a workshop on revegetation of high-altitude disturbed lands was held at Colorado State University on January 31 and February 1, 1974. Cooperators included Climax Molybdenum Company, Colorado Department of Highways, Soil Conservation Service, University of Colorado, U. S. Forest Service, Vail Associates, and Agricultural Research Service.

The large number of participants showed by their presence that there is great interest and concern in disturbance and revegetation of the high country. On behalf of the participants and other readers, the co-chairmen express appreciation to the above agencies and companies and their representatives who presented the papers that follow.

William A. Berg

James A. Brown

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A CONCEPT OF NATURAL VEGETATION BASELINES

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Essential to any kind of repair is a clear concept of the functioning unit. That which works provides fundamental guidance for repair, be it a timepiece, a leg bone or a natural landscape. The maintenance of a high altitude landscape requires an especially thorough understanding of "how it works". The vegetation cover resembles a fragile fabric which once torn is most difficult to repair. Disrupted tundra and high elevation forests remain distressed for decades and even longer.

The understanding of how something works involves a knowledge of where the parts fit. It is this purpose which natural vegetation baselines serve. Identified are what grows with what and where. As the result of centuries of selective screening a harmonious relationship between vegetation and the environment has been achieved. It behooves us to utilize this evidence from long periods of natural process "research and development".

To understand vegetation baselines it is necessary to understand the shape of the environment since the former is intimately tied to the latter. The environment is much too complex to reduce it to some familiar form, but it has patterns which may be better conceived by use of common objects with contrasting features. Other examples might make the point better, but consider for a moment a polyhedron (perhaps the plastic desk type with a calendar month displayed on each face) and then a wrinkled potato. We often approach environmental management as if the environment was shaped like a few-sided polyhedron, but the potato, it turns out, is the better model.

The straightforward simplicity of the polyhedron model is attractive, and this may account for our tendency to put the pieces in place, or revegetate, on that basis. Broad, reasonably uniform areas with sharp boundaries allow fairly simple "either-or" decisions about what should be reestablished. These generalizations are partially valid, especially for the dominant species. Abrupt changes, related to topography, exposure, snow cover, etc., are not uncommon among high-altitude environments, and there are fairly sizeable areas with reasonable homogeneity. In the high country of Colorado it is safe to say that areas below timberline with a northwest-facing slope and heavy snow cover are best suited for a subalpine forest of Englemann spruce and alpine fir. At similar elevations where the slope is southeast-facing and the dry, windy conditions of the atmosphere are accompanied by a highly mineral soil the adapted cover will be lodgepole pine. Tundra areas of moderate snow cover, considerable water inflow, protection from the strong winter winds, and reasonable soil stability provide excellent habitats for alpine tufted hairgrass communities.

If the environment could, in fact, be characterized by a polyhedron there would be few subtleties or grey-area decisions. However, the polyhedron represents none of the gradations which strongly characterize the environment and the vegetation cover. Marked changes in topography or other environmental conditions are suggested by the wrinkles and the eyes of the potato, but the large portion of the potato is represented by areas with gradual changes. The pitch of the slope on the potato represents a gradient, as do the direction of the slope and the coloration. In nature gradual changes in slope direction and steepness of slope result in gradual changes in the net solar input, soil temperatures, soil moisture and other factors. Correspondingly, environmental conditions range from wet to dry, warm to cold, heavy snow cover to virtually no snow cover, stable to unstable ground, etc. The vegetation cover, integrated with the environment, develops similar gradients. Commonly used vegetation "types" actually represent major segments along gradients, and are generalizations which often will not be sufficiently sensitive to represent the variation along the gradient.

Since a gradient represents an infinite set of variable conditions, it may be asked how is it possible to analyze gradients in a way useful to establishing vegetation baselines?

While it is not practicable to study every spot of ground it is possible to obtain data from a large number of sites, and then by techniques of comparing and ordering the data determine the patterns of species importance along gradients. Species importance curves based upon reasonable extrapolation for the spaces between points may be drawn and may be related to a second axis representing gradients of selected environmental parameters. Once established it is possible to key into such a system with a set of environmental gradient points and retrieve information about the best adapted combination of species. Or one can utilize a set of associated species to estimate the environment. Such a system does not fully exist for Colorado as yet, but it can be constructed. Much progress for the subalpine forests has been made by Dr. R. Dix and his students at Colorado State University.

The necessity of establishing detailed gradient baselines for vegetation before the landscape is drastically changed should be self-evident. There will be less tendency to "put things back" in a simple, polyhedron fashion, revegetation failures will be less numerous, and the blend with existing, unimpacted landscapes will be much more acceptable.

There is a second point about vegetation baselines which needs to be emphasized along with the point about gradients. It is that vegetation is not a species list, it is not a map of types, nor is it a monoculture. Vegetation has form and spatial relationships. It has tall plants and dwarf plants, closely growing and widely spaced individuals.

It has times for doing certain things--putting on new growth, flowering, fruiting, and going dormant. These characteristics may be measured and incorporated into the gradient system for subsequent retrieval. This information should be available for registration of the success (or lack of it) of revegetation efforts. Other components of the vegetation baseline may include natural repair tendencies for different portions of the vegetation gradients, identification of easily disrupted areas, communities and plant species especially endangered, and the relationships of wildlife to the gradients.

Natural vegetation baselines cannot be obtained by casual or survey-type observations, but will require intensive ecological studies. Although not inexpensive, the investment needed is apt to be negligible compared to investments made to develop and mine the landscape. Baselines which reflect natural gradients will be more accurate and ultimately more useful and efficient.

SOILS AND SOIL PROBLEMS AT HIGH ALTITUDES

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Success in rehabilitation of high-altitude disturbances depends, in a large part, upon the physical characteristics and fertility of the soil, subsoil, or geological material to be revegetated. Soils at the high elevations vary greatly in depth, rockiness, water-holding capacity, susceptibility to erosion and fertility. The rehabilitation potential of soils must be evaluated before disturbance so treatment intensity and cost can be anticipated, or in the case of certain soils the area avoided. Thus a soil survey or at least soil information should be available for use in rehabilitation of disturbed areas (U. S. Forest Service, 1973).

Inadequate seedbed preparation has been the most obvious problem in vegetation establishment on soils in the subalpine. Other soil problems observed include lack of soil fines, very high clay content, deficiency of nitrogen, deficiency of phosphorus, low organic matter content, over-steepened slopes, very acid reaction, and inadequate soil moisture.

Three soils are described below to illustrate the diversity in soil characteristics and capabilities:

Well drained soils developed over igneous or metamorphic rocks. The textures throughout the profile are sandy loams or loams without marked clay increase in the subsoil. Coarse fragments compose 30 to 80 per cent of the volume of the surface horizon and increase with depth. These soils derived from igneous and metamorphic rock represents the most extensive soil found at the higher elevations in Colorado and Wyoming. These soils are often shallow and rocky. Site potential is relatively low for grass. Exposed subsurface material derived from igneous and metamorphic rock will be very difficult to revegetate. The C horizon is usually very coarse in texture and may consist of weathered rock or coarse, angular gravel. Potential for plant growth is reduced because of less water and nutrients available. These soils are also extremely acid to slightly acid, with the average pH about 5.0. Below pH 4.5-5.0 plant toxic ions, such as aluminum, come into solution; essential nutrients, such as phosphorus, become less available. Cation-exchange properties of these soils are low and will require a fertility maintenance program.

Poorly drained soils. These soils lie along drainageways. They are developed over alluvial and colluvial and/or glacial drift materials derived from non-calcareous metamorphic rocks. The profile consists of a peaty organic layer, over a dark colored surface horizon. The subsoil has rust-colored mottles of iron compounds over a gleyed horizon. Textures in the profile are loams, except for the clay loam gleyed horizon. These soils are highly productive for herbage. A high watertable and unstable soil conditions will be the most limiting soil characteristics if disturbed.

Well drained soils developed in fine textured materials. These soils are slightly acid to alkaline developed in fine textured materials derived from weathered limestone and shale. Loam or silt loam textures predominate in the soil profile. These soils are deep and dark, with usually 12 inches or more of good friable topsoil. The soils have a high potential for herbage production and are easy to revegetate, except when the soil is compacted or if most of the topsoil is removed.

Before the disturbed areas can be revegetated, the following problems must be resolved:

STEEP SLOPES IN SPRUCE-FIR ZONE

Only a minimum amount of disturbance should be allowed on slopes steeper than the angle of repose. Hand clearing and other special practices are necessary to maintain or build the protective ground cover on these critical slopes. The maximum slope ratio on which to grow grass on small areas is commonly agreed to be 1.5 horizontal to 1 vertical. Sometimes variations can be used because of soil types or when very special management practices are used on small areas. A ratio of 2 horizontal to 1 vertical is considered better for successful turf establishment on larger projects. If reasonable slope-grade and suitable soil exist, it is usually easier to establish turf on a fill than on a cut slope.

SEEDBED PREPARATION

A well prepared seedbed is advantageous in establishing slope seedings. Ideally, the soil should be tilled 6-8 inches deep and the top 4 inches pulverized into small aggregates. On the mountains, the steep topography will probably limit the seedbed to be broken to only 4-6 inches.

A good seedbed usually is prepared best from the topsoil. A rich dark surface horizon is friable (easily crumbled), fertile, and has more organic matter than the subsoil. Topsoil should be stockpiled and spread 4 to 6 inches thick over subsoil areas and coarse textured materials exposed by construction. It is not practical to spread topsoil less than 2 inches deep unless the area is relatively level and the underlying material has enough fines to aid turf establishment. Except for very special reasons, placing topsoil more than 6 inches deep on a fill or steep cut slope is unwise because of soil slumping. Smoothly bladed slopes with a thick layer of topsoil may slide when the soil becomes saturated. When cut slopes are constructed they should, therefore, be left rough. If they are smooth, the topsoil should be bonded to the subsoil by loosening the subsoil before the topsoil is applied. Slopes near the angle of repose should then be mechanically packed to make them firm and stable.

A quality topsoil should have a minimum plant available moisture capacity of 7 per cent (by wt.). This value is determined by calculating the difference in per cent moisture (by wt.) between field capacity (1/3 bar tension) and the permanent wilting point (15 bar tension). In addition, organic matter in the range of 1 to 20 per cent should be a constituent of a good topsoil. A clay content of 30 to 35 per cent should be the maximum.

An exposed subsoil to be revegetated should contain at least 10 per cent clay. This will run about the same gradation and proportion requirements described above for topsoil. A clay content of 30 to 35 per cent should be the maximum.

FERTILIZATION

Subsoil materials used as seedbeds are usually inherently low in plant nutrients and must be fertilized to support erosion-resistant sods. Rates of fertilizer recommended for application will vary with such soil factors as texture, organic matter, ion-exchange capacity, depth and existing supply of nutrients.

In general, expect all subsoils to be Nitrogen deficient. The initial N application should not exceed 60 pounds of available N per acre. Nitrogen fertility may be a problem for years on subsoils that are seeded to grass. Thirty to 50 pounds of N/acre per year may be needed to maintain sufficient vegetative cover to prevent erosion. A light green foliage color and thinning vegetative ground cover are signs of N deficiency. Applying small test strips of N will give an idea of the response that can be expected.

A relatively high rate of phosphorus fertilization of exposed subsoils is recommended (we need more information on rates); 100 pounds P_2O_5/ acre may be adequate on coarse textured subsoils, and 200 pounds P_2O_5/ acre on medium textured subsoils. Phosphorus is not subject to leaching and should be mixed into the soil for maximum effectiveness.

Soils with a pH below 5.5 may be too acid for good grass growth, and a soil with a pH of 4.5 or below is too acid for growth of any of the grass species recommended. Application of agricultural ground limestone, at least 50 per cent of which passes a 100 mesh sieve, is recommended on soils with a pH below 5.5. The lime rate should be determined by a soil test, but a rate of one ton per acre may be adequate on coarse textured soils. Lime is essentially insoluble and must be mixed into a soil to be effective.

SEEDING IN THE ALPINE

Seeding in the alpine is very, very difficult and in most cases has not proven practical. Needle ice action, frost thrusting and solifluction are some of the dangers in establishing alpine plants. Seedling growth is very slow under natural conditions and at the end of the first season the seedling of most species is still very tiny. Coarse-textured soils and shallow soils on exposed ridges are difficult to revegetate because they become droughty during the latter part of summer. If seeds are to be sown in the alpine, they should be planted during September and October. A seedbed should be prepared by raking or harrowing. The seeds should then be protected with a very light cover of soil, rolled and mulched. Native species that show some promise for revegetating bare soils are: *Achilea lanulosa* Nutt., *Artemisia norvegica* ssp. *saxatilis*, *Deschampsia caespitosa* (L.) Beauv., *Phacelia sericea* (Graham) A. Gray, *Phleum alpinum* L., *Poa alpina* L., and *Rubus strigosus* Michx.

FERTILIZING IN THE ALPINE

Nitrogen can be limiting in the cold soils probably due to the low rates of bacterial activity and also the relative lack of availability of certain other nutrients. Nitrogen build-up can be aided by bacterial nodules on legumes and particularly on plants of *Dryas*. Dry matter production can be increased by adding nitrogen fertilizer. Cold soils also appear to inhibit growth by suppressing the absorption of phosphorus by plants. Often the exposed alpine subsoils are very acid.

SODDING IN THE ALPINE

All topsoil and turf that is removed should be preserved and carefully replaced at the earliest possible date (See Marr et al., this workshop).

With increased activity in the high-altitude areas we can anticipate larger areas of disturbed lands and more soil problems. This workshop is a step in the right direction to help in pointing out and hopefully suggesting methods to avoid soil problems in revegetation of disturbed areas. I would also like to mention that there is a great opportunity to learn from experience by re-evaluating our past revegetation efforts.

BIBLIOGRAPHY

Marr, John W. 1964. Utilization of the Front Range Tundra, Colorado, pp. 109-18 in Grazing in Terrestrial and Marine Environments, Ed. D. J. Cresp. Blackwell Scientific Publications, Oxford, XVI. 332 p.

Nimlos, T. J. and R. C. McConnell. 1965. Alpine Soils in Montana. Soil Science 99:310-321.

Retzer, J. L. 1956. Alpine Soils of the Rocky Mountains. J. Soil Sci. 7:1-32.

Retzer, J. L. 1962. Soil Survey Fraser Alpine Area Colorado. Series 1956 No. 20. USDA. 47 p. and maps.

Smith, Dixie R. 1969. Vegetation, Soils, and Their Interrelationships at Timberline in the Medicine Bow Mountains, Wyoming. U. of Wyoming, Laramie, Agri. Expt. Station, Science Monograph 17. 13 p.

Tiedemann, Arthur R. and Klock, Glen O. 1973. First-Year Vegetation After Fire, Reseeding, and Fertilization on the Entiat Experimental Forest, U.S.D.A. - Forest Service, Research Note, West Forest and Range Exp. Station, PNW-195, March.

U. S. Forest Service. 1973. Soil survey, a tool for planning and re-vegetation on ski slopes. Soils Report. Div. of Watershed Management Region 2, Denver. 23 p.

ECOLOGICAL MODIFICATION OF ALPINE TUNDRA BY PIPELINE CONSTRUCTION

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Many ridges and peaks of the Southern Rocky Mountain System in Colorado rise above the upper climatic limit of tree growth and are covered by alpine tundra ecosystems. Details on this ecological region are available in the literature listed at the end of this paper.

In the course of their activities, people have found it desirable to cross the tundra for many reasons and in numerous places. Tundra, like many other ecosystems of the earth's biosphere, evolved for millions of years in the absence of any component comparable to human beings; addition of this species to tundra ecosystems usually results in their modification. Beginning with prehistoric people, the changes have been generated by human activities related to hunting, grazing domestic animals, recreation, watershed management, and the construction of roads and utility corridors. Since it is inevitable that we will continue at least some of those activities, it is essential that we learn how to carry them on with a minimum of modification. In addition, we must learn how to generate acceptable new types of ecosystems for use where modifications are extreme. The present paper is based on research which seeks to provide information essential for wise planning for the use of tundra landscape.

In the late 1960's, it became necessary for the Western Slope Gas Company to extend pipelines into the rapidly developing Middle Park and Blue River areas of western Colorado. This was a formidable task because the line would have to cross the Front Range which rises above treelimit (approximately 11,600 feet elevation) into the Alpine Tundra Region throughout its length with the exception of approximately one mile at Berthoud Pass. The steepness of approaches to that Pass make it undesirable for a utility line. Since all possible routes for a pipeline would involve crossing national forest lands, the company arranged with the U.S. Forest service to locate a suitable corridor. After exploring all possible alternatives, it was decided that a line across Rollins Pass, where a railroad had once crossed the Continental Divide, would result in the least amount of modification of the environment.

Discussions with interested citizens regarding the above decision followed. Additionally, public meetings were held to explain the plan to all interested persons and to receive and integrate their suggestions. Strong general concern developed for one segment of the proposed route because it crossed alpine tundra adjacent to the scenic Rollins Pass tour road and could easily create a visual scar and initiate erosion. Although only 1500 feet long, the area is visible from several points on the road and from the valley below, and it is steep enough to experience rapid erosion by running water. Since it appeared likely that an ecologist could help reduce the impact of the pipeline on this especially valuable landscape, it was agreed that one should be added to the planning team. John Marr, of the University of Colorado, was invited to participate. He worked with the foresters and engineers in selecting the precise route and in planning the construction procedures.

ECOLOGY OF THE PIPELINE AREA

Ecological study of the Rollins Pass area, and an area near Fremont Pass (which was crossed by an older pipeline), and our previous research on tundra ecosystems provided the following information:

The great amount of wind to which the west slope is exposed has profound effects on the local distribution of snow. Some sites are blown free of snow soon after each snow storm while others have a deep cover of snow all winter; there are sites with all degrees of snow cover between those two extremes. The present study area has a shallow cover of snow which melts off in the spring. Much of resulting snow-melt water flows as sheets and rivulets over the ground surface because only a thin layer of soil is unfrozen in this season.

The soil is largely residual although there has been some "churning" and movement of soils down slope by freeze-thaw processes, and the surface layer in some ecosystems was probably carried in by wind. There are probably two types of soil parent-material along the transect, the division between the two being approximately 350 feet below the road. Rocks are more abundant and the parent material is somewhat lighter in color in the higher segment.

Two animals, human beings and the pocket gopher (*Thomomys talpoides fossor*), have significantly affected the ecology of the area. There is little evidence today of human activities, but it seems unlikely that the construction and operation of the railroad could have been accomplished without some modification of areas adjacent to the road. In addition, domestic sheep have grazed the area for many years although we found no specific evidence of their effects at the time the pipeline was being built.

The effects of the pocket gopher, which have modified approximately 90 per cent of this study area, are described by Marr (1961), Miller (1964), and Turner, et al. (1973).

Hairgrass Meadow, dominated by *Deschampsia caespitosa*, is the potential persistent stand-type of the study area with the possible exception of the lower elevation where *Danthonia intermedia* and *Trisetum spicatum* form a dense turf. Gophers have destroyed the hairgrass in patches of a few to several square meters in size. This destruction is followed by a rebuilding sequence carried out by transitory or succession ecosystems which completes the dynamic cycle initiated by the feeding animals. The cycle is potentially terminated by reestablishment of the persisting species of the hairgrass meadow.

The numerous stand ecosystems intergrade in a complex manner. Each stand's characteristics depend on the extent of gopher activity, the length of time since gophers moved on to other areas, and the availability of plant disseminules for reinvasion. It is possible, however, to pick out the following stand-types as representatives of relatively distinct steps in the ecosystem cycle: (1) *Deschampsia*, (2) *Sibbaldia-Erigeron*, (3) *Sibbaldia-Artemisia*, (4) *Sibbaldia-Vaccinium* and (5) *Sibbaldia-Artemisia-Danthonia*. Types 2, 3, and 4 are in the cycle of ecosystems which has a potential to develop a persisting (or climax) *Deschampsia* meadow stand, the number 5 type may be in the same cycle but there is some evidence that, instead, it tends to develop toward a *Sibbaldia-Artemisia-Danthonia* persisting stand.

Additional details on alpine tundra ecology are available in the selected references in the literature section.

ECOLOGICAL CONSIDERATION CONCERNING THE CONSTRUCTION PLAN

The heterogeneity created by the mosaic of stands produces serious problems in management of the tundra. In the present project, the objective was to erase the evidence of the pipe line as quickly as possible. Obviously, any single treatment of the entire length of the line, such as revegetation with plants of any one ecosystem, would produce a conspicuous contrast and not hide the scar. Consequently it was decided that the turf of each stand crossed should be carefully removed, preserved, and replaced in its original position.

Other details of the construction plan follow:

1. The abundant snow melt-water which typically rushes across the ground in hairgrass meadows in the spring has a high potential for eroding turf and mineral soil. The volume of water is great and little is absorbed by the soil because it is frozen. In the pipeline area, the eroding process is accelerated by the pocket gopher activity which loosens the soil, destroys the vegetation and provides tunnels in which runoff concentrates.

Consequently, a construction route intersected by a minimum of the existing drainage channels was selected.

2. We knew from abundant observations during previous operations on the tundra that damage to the turf by vehicles was less when the turf was dry, and that rubber tires did less damage than metal tracks. Therefore, it was agreed that construction would be delayed until the turf was thoroughly dry; since this condition normally was not reached until late

summer, it required careful planning by the contractor so as to complete the work before the early fall snowstorms. Since vehicles with rubber tires were specified, a rubber tired "back hoe" machine was employed.

3. The desirability of expediting rehabilitation by "replanting" the turf into its pre-construction position as precisely as possible required special plans. The problems and plans for rehabilitation were explained to the machine operator, and a special team of men was employed to handle the turf. A plastic sheet was laid down parallel to the line of construction. The machine operator first "peeled" off the turf which the workers carefully removed from the hoe and placed on the sheet of plastic. Thereafter the operator excavated the required ditch, depositing the soil and rocks on the plastic adjacent to the turf. The turf was covered with burlap to reduce loss of water from the soil and plants.

4. The individual segments of the pipe are normally welded together with machinery which moves along the construction route as required. In order to reduce the movement of vehicles across the tundra, the back hoe pulled a cable down the ditch as it moved. The pipes were then welded together at the bottom of the slope and a winch at the top pulled the pipe up using the cable provided by the back hoe.

5. The project area is subject to both wind and water erosion. Therefore, attempts were made to anticipate the degree of backfill settling in the trench so as to avoid both depressions which could generate water erosion channels and elevations which would be exposed to wind erosion.

RESEARCH ON THE ECOLOGICAL IMPACT OF THE PIPELINE

It was generally agreed that the ecological studies should be continued after construction in order to identify possible problems needing attention, and also to detect and record features of impact that would be helpful in similar projects in the future. Marr made arrangements for such research with both the Company and the Forest Service and carried out general observations the first year after construction. In addition, two of Marr's graduate students, Buckner and Johnson, the co-authors of this paper, undertook detailed research on the pipeline. The Company is now financing this research through annual gifts to the University, support which we appreciate very much.

The impact research was begun at Rollins Pass by establishing 90 permanently located transects, each 6 m long, centered on the pipeline and at right angles to it. These transects were spaced at 5 m intervals down the length of the pipeline and consisted of 12 contiguous 2 x 5 dm plots. Each transect began in undisturbed tundra on one side of the ditch and extended to similarly undisturbed tundra on the other side. Data on plant cover, litter, soil, and rock were recorded and used for the calculation of frequency and cover values. Buckner and Johnson have developed a technique for using computer punch cards to record data in the field and a computer program for storage and analysis of the data.

RESULTS

The observations in 1970 revealed the following details:

1. There was essentially no apparent damage to the vegetation by machines except, of course, along the ditch itself. Two small boulders had been tipped over resulting in damage to one square foot of vegetation. Some type of oil, probably hydraulic fluid, had spilled here and there along the route but plants growing up through the oiled soil showed no evidence of damage.

2. Plant growth in the strip covered by the plastic sheet for a period of a few weeks was retarded but not obviously damaged seriously. Some plants were damaged by scraping as the soil was returned to the ditch.

3. Water erosion in and across the ditch site was comparable to that in the unmodified adjacent areas.

4. Wind erosion on the south side of two areas of the ditch fill material is inhibiting plant growth in an area of a few square feet near the lower end of the line.

5. Turf was drying out and breaking up in areas where the fill rises several inches above the general ground level.

6. Feeding on roots and underground stems of the turf by pocket gophers depleted rehabilitation capacity of the turf. It appeared from field observations that the areas of gopher activity increased in number from 2 to approximately 9 during the fall of construction. Gopher mounds and ridges were scattered along 80 per cent of the pipeline length, their soil covering an estimated 5 to 10 per cent of the vegetation. This degree of disturbance along the pipeline appeared to be approximately the same as in adjacent tundra unmodified by construction. However, in gopher activity areas intersected by the pipeline, gophers concentrated their feeding on the replaced turf.

In 1970, qualitative observations on the amount of erosion along the pipeline were as follows: Towards the top of the pipeline, near the road, there was a slight erosion channel (maximum depth 1") along the north side of the sod ridge. No marked erosion appeared for the next approximate 300 meters, but as the gradient steepened along the next 100 meters, slight erosion occurred along the replaced sod (less than 1") deep. At an approximated distance of 400 meters from the road a small natural drainage channel intersected the pipeline route and followed this course for about 10 meters, before going off in its natural direction. Another natural drainage ditch similarly intersected the pipeline about 25 meters farther down. The soil surrounding the coarse rock in the fill covering the pipeline was extensively eroded (about 1') in some sections, especially in those stretches confluent with the direction of the natural drainage.

Early snow storms prevented data collection in 1971. Data were collected in 1970, 1972, and 1973.

Table 1 illustrates the reaction of the species of each stand-type to the particular modification present directly over the pipeline trench (that is, the area which is now raised 10 or 15 cm throughout most of the study area). Only 1973 data were used in compiling Table 1. Table 2 lists coverage and frequency figures for the dominant species of each stand-type. The figures in Table 2 are averages of 1972 and 1973 data. It is evident that revegetation is proceeding at a reasonable rate.

CONCLUSIONS

The different species of plants reacted in various ways to the modification, and a given species often reacted differently in the various types of stands. The following examples illustrate those reactions:

1. Hairgrass, the dominant species in the persisting or climax stand-type, tolerated the modification with little change in its own stand-type, and pioneered vigorously in other stand-types.

2. Three conspicuous species, *Geum rossii*, *Vaccinium scoparium*, and *Sibbaldia procumbens*, were much reduced in cover by the modification in all stand-types in which they occurred before modification.

3. *Sibbaldia procumbens* reacts differently to environmental modification by gophers and that produced by pipeline construction; although it maintained relatively high cover in most of the gopher modified stands, it <u>did</u> <u>not</u> pioneer in stands modified by construction.

4. All stand-types lost some species.

5. Several species invaded stands they had occupied previously but all species occurring in the study plots could also be found in the stands of the immediate area.

6. Several species increased in cover in the modified areas.

7. Rock and bare soil surfaces still cover two to three times as much area in the modified as in the unmodified areas after 3 growing seasons.

8. *Viola bellidifolia*, *Thlaspi montanum*, *Ranunculus adoneus*, *Poa glauca*, *Carex ebenea* increased adjacent to the pipeline ridge but decreased on top of it while *Minuartia obtusiloba*, *Bistorta bistortoides*, and *Deschampsia caespitosa* reacted in the opposite way.

9. Any revegetation effort in the tundra region encounters problems related to both wind and water erosion. In places where the salvaged turf was placed on fill material which rose above the surrounding ground, wind

erosion inhibited revegetation; any depression in the fill, on the other hand, resulted in washing by surface runoff. It appears likely that water erosion can be more easily controlled (by diversion structures) than can wind erosion. We suggest, therefore, that the replaced turf should be level with or slightly depressed from the general ground surface.

BIBLIOGRAPHY

Billings, W. D. and H. A. Mooney. 1968. The ecology of arctic and alpine plants. Biol. Rev. 43:481-530.

Bliss, L. C. 1958. Seed germination in arctic and alpine species. Arctic. 11:180-188.

Bonde, E. K. 1969. Plant disseminules in wind-blown debris from a glacier in Colorado. Arctic & Alpine Research. 1(2):135-140.

Cox, C. F. 1933. Alpine plant succession on James Peak, Colorado. Eco. Monogr. 3(3):300-372.

Griggs, R. F. 1956. Competition and succession on a Rocky Mountain Fellfield. Ecol. 37:8-20.

Harrington, H. D. 1946. Results of a seedling experiment at high altitudes in the Rocky Mountain National Park. Ecol. 27:375-377.

Kiener, W. 1967. Sociological studies of the alpine vegetation on Longs Peak. Univ. of Nebraska Stud: New Ser. 34, Lincoln. 75 p.

Marr, J. W. 1961. Ecosystems on the east slope of the Front Range in Colorado. Univ. Colo. Stud. Ser. in Biol. No. 8 IV + 133 p.

Marr, J. W. 1964. Utilization of the Front Range tundra, Colorado. Grazing in terrestrial and marine environments. Blackwells Sci, Pub. 109-118 p.

Marr, J. W. and B. E. Willard. 1970. Persisting vegetation in an alpine recreation area in the Southern Rocky Mountains, Colorado. Biol. Conserv. 2(2):97-104.

Miller, R. S. 1964. Ecology and distribution of pocket gophers (Geomyidae) in Colorado. Ecol. 45(2):256-272.

Paulsen, H. A. Jr. 1960. Plant cover and forage use of alpine sheep ranges in the Central Rocky Mountain. Iowa State Journ. of Sci. 34(4):731-748.

Schwan, H. E. and D. J. Costello. 1951. The Rocky Mountain alpine type. U.S.D.A. Forest Service. v + 18 p.

Smith, D. R. and W. M. Johnson. 1965. Vegetation characteristics on a high altitude sheep range in Wyoming. Univ. of Wyom. Agric. Exp. Sta. Bul. 430. 14 p.

Turner, G. T., R. M. Hansen, B. H. Reid, H. P. Tietjen, and A. L. Ward. 1973. Pocket gophers and Colorado Mountain Rangeland. Colo. State Univ. Exp. Sta. Bul. 554 S. ix + 90 p.

Ward, R. F. 1969. Ecotypic variation in *Deschampsia caespitosa* (L.) Beauv. from Colorado. Ecol. 50(3):519-522.

Willard, B. E. and J. W. Marr. 1970. Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park, Colo. Biol. Conserv. 2(4):257-265.

Willard, B. E. and J. W. Marr. 1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biol. Conserv. 3(3):181-198.

Zwinger, A. H. and B. E. Willard. 1972. Land above the trees. Harper & Row. 489 p.

Table 1. Reaction of Species to Modification Directly Above Pipeline Trench.

Deschampsia Stand-type

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Achillea lanulosa			x		
Agoseris glauca		x			
Androsace septentrionalis			x		
Artemisia scopulorum			x		
Bistorta bistortoides	x				
Carex ebenea			x		
Castilleja occidentalis				x	
Cerastium arvense					x
Deschampsia caespitosa			x		
Draba crassifolia			x		
Erigeron peregrinus & *Aster foliaceus* var. *apricus*		x			
Erigeron simplex			x		
Geum rossii			x		
Juncus drummondii				x	
Lewisia pygmaea			x		
Minuartia obtusiloba				x	
Phleum alpinum	x				
Poa reflexa			x		
Polygonum douglasii			x		
Potentilla diversifolia			x		
Ranunculus alismaefolius					x
Saxifraga rhomboidea				x	
Senecio crassulus					x
Sibbaldia procumbens		x			
Taraxacum officinale					x
Thlaspi montanum			x		
Trifolium parryi	x				
Trisetum spicatum & *Danthonia intermedia*			x		
Biola bellidifolia		x			
Mosses				x	
Lichens				x	

Sibbaldia-Erigeron Stand-type

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Agoseris glauca			x		
Androsace septentrionalis				x	
Artemisia scopulorum	x				
Bistorta bistortoides	x				
Carex ebenea			x		
Deschampsia caespitosa			x		
Erigeron peregrinus & *Aster foliaceus* var. *apricus*			x		
Erigeron simplex			x		
Festuca brachyphylla & *Poa glauca*				x	
Juncus drummondii		x			
Lewisia pygmaea				x	
Phleum alpinum				x	
Poa reflexa					x
Polygonum douglasii					x
Potentilla diversifolia			x		
Ranunculus adoneus			x		
Sibbaldia procumbens		x			
Thlaspi montanum			x		
Trifolium parryi			x		
Trisetum spicatum & *Danthonia intermedia*				x	
Vaccinium scoparium				x	
Veronica wormskjoldii				x	
Viola bellidifolia	x				

Sibbaldia-Artemisia Stand-type

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Achillea lanulosa	x				
Agoseris glauca			x		
Agropyron latiglume			x		
Androsace septentrionalis			x		
Antennaria alpina & *A. rosea*			x		
Arnica mollis			x		
Artemisia scopulorum			x		
Bistorta bistortoides			x		
Carex ebenea		x			
Castilleja occidentalis				x	
Cerastium arvense			x		
Deschampsia caespitosa	x				

Table 1. (Cont'd)

Sibbaldia-Artemisia
Stand-type (Cont'd)

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Draba crassifolia			x		
Erigeron peregrinus & Aster foliacius var. *apricus*			x		
Erigeron simplex			x		
Festuca brachyphylla & Poa glauca			x		
Gentianella amarella				x	
Geum rossii		x			
Lewisia pygmaea			x		
Luzula spicata			x		
Minuartia obtusiloba			x		
Pedicularis groenlandica			x		
Phleum alpinum	x				
Poa reflexa			x		
Polygonum douglasii			x		
Potentilla diversifolia			x		
Ranunculus adoneus			x		
Ranunculus alismaefolius				x	
Saxifraga rhomboidea			x		
Sedum lanceolatum			x		
Selaginella densa			x		
Senecio crassulus			x		
Sibbaldia procumbens		x			
Solidago spathulata			x		
Taraxacum officinale			x		
Thlaspi montanum			x		
Trifolium parryi		x			
Trisetum spicatum & Danthonia intermedia			x		
Vaccinium scoparium		x			
Veronica wormskjoldii			x		
Viola bellidifolia		x			
Mosses				x	
Lichens				x	

Sibbaldia-Vaccinium
Stand-type

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Achillea lanulosa				x	
Agoseris glauca		x			
Androsace septentrionalis			x		
Antennaria alpina & A. rosea			x		
Artemisia scopulorum			x		

Sibbaldia-Vaccinium
Stand-type (Cont'd)

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Bistorta bistortoides	x				
Carex ebenea		x			
Cerastium arvense			x		
Deschampsia caespitosa	x				
Draba crassifolia			x		
Erigeron peregrinus & Aster foliaceus var. *apricus*			x		
Erigeron simplex			x		
Festuca brachyphylla & Poa glauca			x		
Geum rossii		x			
Lewisia pygmaea		x			
Luzula spicata			x		
Minuartia obtusiloba			x		
Phleum alpinum			x		
Poa reflexa		x			
Polygonum douglasii			x		
Potentilla diversifolia		x			
Ranunculus adoneus		x			
Saxifraga rhomboidea			x		
Sedum lanceolatum			x		
Selaginella densa			x		
Sibbaldia procumbens		x			
Solidago spathulata			x		
Thlaspi montanum			x		
Trifolium parryi		x			
Trisetum spicatum & Danthonia intermedia			x		
Vaccinium scoparium		x			
Veronica wormskjoldii				x	
Viola bellidifolia			x		
Lichens					x

Sibbaldia-Artemisia-Danthonia
Stand-type

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Agoseris glauca			x		
Agropyron latiglume				x	
Androsace septentrionalis			x		
Antennaria alpina & A. rosea			x		
Artemisia scopulorum		x			
Bistorta bistortoides	x				

Table 1. (Cont'd)

Sibbaldia-Artemisia-Danthonia
Stand-type (Cont'd)

SPECIES	Cover Increased[1]	Cover Decreased[1]	Little Change In Cover[2]	Species Lost[3]	Species New[4]
Carex ebenea		x			
Castilleja occidentalis				x	
Cerastium arvense					x
Deschampsia caespitosa	x				
Draba crassifolia			x		
Erigeron peregrinus & *Aster foliaceus* var. *apricus*	x				
Erigeron simplex			x		
Festuca brachyphylla & *Poa glauca*		x			
Gentianella amarella				x	
Geum rossii		x			
Lewisia pygmaea		x			
Luzula spicata	x				
Minuartia obtusiloba			x		
Pedicularis groenlandica				x	
Poa reflexa			x		
Polygonum douglasii				x	
Potentilla diversifolia			x		
Ranunculus adoneus			x		
Saxifraga rhomboidea			x		
Sedum lanceolatum				x	
Selaginella densa		x			
Sibbaldia procumbens		x			
Solidago spathulata			x		
Thlaspi montanum			x		
Trifolium parryi	x				
Trisetum spicatum & *Danthonia intermedia*			x		
Vaccinium scoparium		x			
Veronica wormskjoldii			x		
Viola bellidifolia		x			
Mosses		x			
Lichens			x		

[1] Coverage values for a species differing between modified and unmodified areas by 1 per cent or more, if values in question are less than 10 per cent; if values more than 10 per cent, they must differ by 5 per cent or more.

[2] Coverage values for a species differing between modified and unmodified areas by less than 1 per cent if values in question are less than 10 per cent; if values are more than 10 per cent, they differ by less than 5 per cent.

[3] Species present in unmodified area samples, absent in modified area samples.

[4] Species absent in unmodified area samples, but present in modified area samples.

Table 2. Coverage and Frequency Data for the Dominant Species in Each Stand-type.[1]

Stand-type: *Deschampsia*

Species	Unmodified		Modified					
			Pipeline Ridge		Adjacent to Ridge		Backfill & Turf Piling Area	
	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq
Deschampsia caespitosa	31	88	30	86	36	9	26	84
Sibbaldia procumbens	11	37	1	16	2	13	7	47
Erigeron[3] *peregrinus*	7	46	5	39	7	40	6	44
Agoseris glauca	4	22	1	13	2	25	2	27
Carex ebenea	2	16	2	18	2	20	2	22
Trifolium parryii	1	28	2	30	4	28	1	20
Total Veg. Cover	69	--	58	--	68	--	68	--
Rock	5	44	14	82	8	85	9	66
Soil	22	73	34	86	39	95	27	88
Litter	15	79	10	73	9	75	12	78
Total Number of Species[3]	28		22		25		24	
Number of Species Gained[4]	--		2		4		4	
Number of Species Lost[4]	--		8		7		8	

Stand-type: *Sibbaldia-Erigeron*

Species	Unmodified		Modified					
			Pipeline Ridge		Adjacent to Ridge		Backfill & Turf Piling Area	
	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq
Sibbaldia procumbens	45	86	16	75	40	89	37	88
Deschampsia caespitosa	14	84	15	82	13	85	9	62
Erigeron[2] *peregrinus*	6	28	4	33	4	45	6	28
Juncus drummondii	2	23	1	7	4	26	7	41
Artemisia scopulorum	1	17	1	18	1	7	2	26
Total Veg. Cover	8	--	43	--	68	--	73	--
Rock	1	20	7	68	66	48	12	71
Soil	24	88	61	100	35	100	26	100
Litter	10	68	7	72	10	60	4	60
Total Number of Species[3]	22		14		18		17	
Number of Species Gained[4]	0		2		3		1	
Number of Species Lost[4]	0		10		7		6	

Table 2 (Continued)

Stand-type: *Sibbaldia-Artemisia*

Species	Unmodified		Modified					
			Pipeline Ridge		Adjacent to Ridge		Backfill & Turf Piling Area	
	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq
Artemisia scopulorum	9	55	8	54	8	55	10	58
Sibbaldia procumbens	8	56	3	37	5	42	7	55
Deschampsia caespitosa	7	44	11	54	10	52	7	46
Poa reflexa	3	38	3	33	4	37	4	38
Carex ebonea	3	30	3	24	3	26	4	29
Geum rossii	2	18	1	8	2	14	3	21
Trifolium parryi	2	30	1	17	1	20	2	30
Potentilla diversifolia	2	38	2	37	2	36	2	44
Festuca brachyphylla & *Poa glauca*	1	14	1	14	1	14	1	11
Total Veg. Cover	61	--	49	--	54	--	63	--
Rock	10	60	21	88	21	83	14	72
Soil	23	68	39	92	31	88	23	73
Litter	16	75	9	76	11	71	13	78
Total Number of Species[3]	43		39		38		41	
Number of Species Gained[4]	0		1		0		2	

Stand-type: *Sibbaldia-Artemisia-Danthonia*

Species	Unmodified		Modified					
			Pipeline Ridge		Adjacent to Ridge		Backfill & Turf Piling Area	
	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq
Sibbaldia procumbens	11	66	5	52	5	50	10	71
Artemisia scopulorum	10	64	7	45	10	61	9	51
Danthonia intermedia & *Trisetum spicatum*	7	42	4	33	6	37	6	39
Deschampsia caespitosa	7	42	15	60	12	42	7	40
Geum rossii	5	42	1	19	4	33	3	29
Mosses[5]	2	23	1	10	1	13	1	12
Total Veg. Cover	69	--	56	--	63	--	63	--
Rock	4	42	15	86	11	68	7	62
Soil	16	65	43	95	34	89	26	79
Litter	18	79	13	83	12	92	15	82
Total Number of Species[3]	36		29		30		33	
Number of Species Gained[4]	0		1		1		2	
Number of Species Lost[4]	0		8		7		5	

Table 2 (Continued)

Stand-type: *Sibbaldia-Vaccinium*

Species	Unmodified		Modified: Pipeline Ridge		Modified: Adjacent to Ridge		Modified: Backfill & Turf Piling Area	
	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq	%Cov	%Freq
Sibbaldia procumbens	8	48	3	36	7	43	9	52
Vaccinium scopulorum	7	52	1	6	4	29	5	33
Artemisia scopulorum	7	45	7	46	6	45	7	46
Deschampsia caespitosa	6	46	4	45	4	43	5	41
Ranunculus adoneus	3	29	2	19	3	28	3	34
Agoseris glauca	2	31	2	31	3	37	2	26
Bistorta bistortoides	1	27	3	24	3	39	2	28
Total Veg. Cover	58	--	37	--	49	--	60	--
Rock	9	59	17	89	21	89	16	83
Soil	22	76	51	95	36	89	28	91
Litter	17	70	10	76	10	71	11	69
Total Number of Species[3]	33		29		32		33	
Number of Species Gained[4]	0		0		1		3	
Number of Species Lost[4]	0		4		2		3	

[1] The data were taken using 2 x 5 dm microplots laid end to end for 6m, perpendicular to the pipeline and centered on it, extending from unmodified area on one side across the modified areas and into unmodified territory again. Five stand-types were identified within the area although the *Deschampsia* type has the potential to dominate the entire area in the absence of disturbance for a long enough period. Based on data from 1972 and 1973 except as indicated.

[2] *Erigeron peregrinus* as well as *E. simplex* and *Aster foliaceus* var. *apricus*.

[3] 1973 data only.

[4] With respect to the unmodified area; 1973 data only.

[5] Principally *Polytrichum piliferum*.

WATER AND EROSION CONTROL IN RELATION TO REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS

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Runoff and erosion are functions of water force and resistance thereto. The water is from rainfall, snowmelt or combinations of rain and snowmelt. The resistance factors are soil, vegetation, and landform. These resistance factors are highly interactive, and successful control of runoff and erosion depends on the skill with which we manipulate these interactions by our management techniques. In this workshop we are focusing on the problems of revegetation and thus we are especially interested in the role of vegetation in controlling runoff and erosion and in the practices we might use to control runoff and erosion to enhance vegetation establishment. In the presentation that follows we will first discuss the role of vegetation and then some practices for water and erosion control.

ROLE OF VEGETATION IN WATER AND EROSION CONTROL

Canopy and litter protect the soil from the direct impact of rain, decrease velocity of surface runoff and thereby decrease its soil detaching and transporting capacity, and help maintain soil porosity. Perhaps the key concept for the manager to consider is that very often there is a threshold volume of ground cover by canopy and litter below which runoff and erosion are accelerated at an increasing rate. There is no magic number for all conditions because these thresholds are highly dependent on the site-specific climate, landform, soil, and vegetation characteristics. The interaction of ground cover with slope as it influences erosion has been documented recently by Meeuwig (1971). The relationship between ground cover and both runoff and erosion has been demonstrated by Copeland (1963) and discussed by Colman (1953). Figure 1 is a generalized schematic relating sediment yield to ground cover density.

Roots have a direct soil stabilizing influence by binding and holding soil particles against the detaching and transporting action of water. We know that roots increase soil porosity directly and, indirectly, through their effects on soil biologic activity and thereby on soil structure. Roots also influence infiltration and erosion indirectly through their effect on soil moisture.

Several important implications can be drawn from the above discussion of the role of vegetation pertinent to runoff and erosion on high elevation watersheds. One of these is that even small increases in ground cover can result in significant reductions in erosion and runoff. This should encourage us to keep trying even under the difficult conditions we often face. Another important implication is that

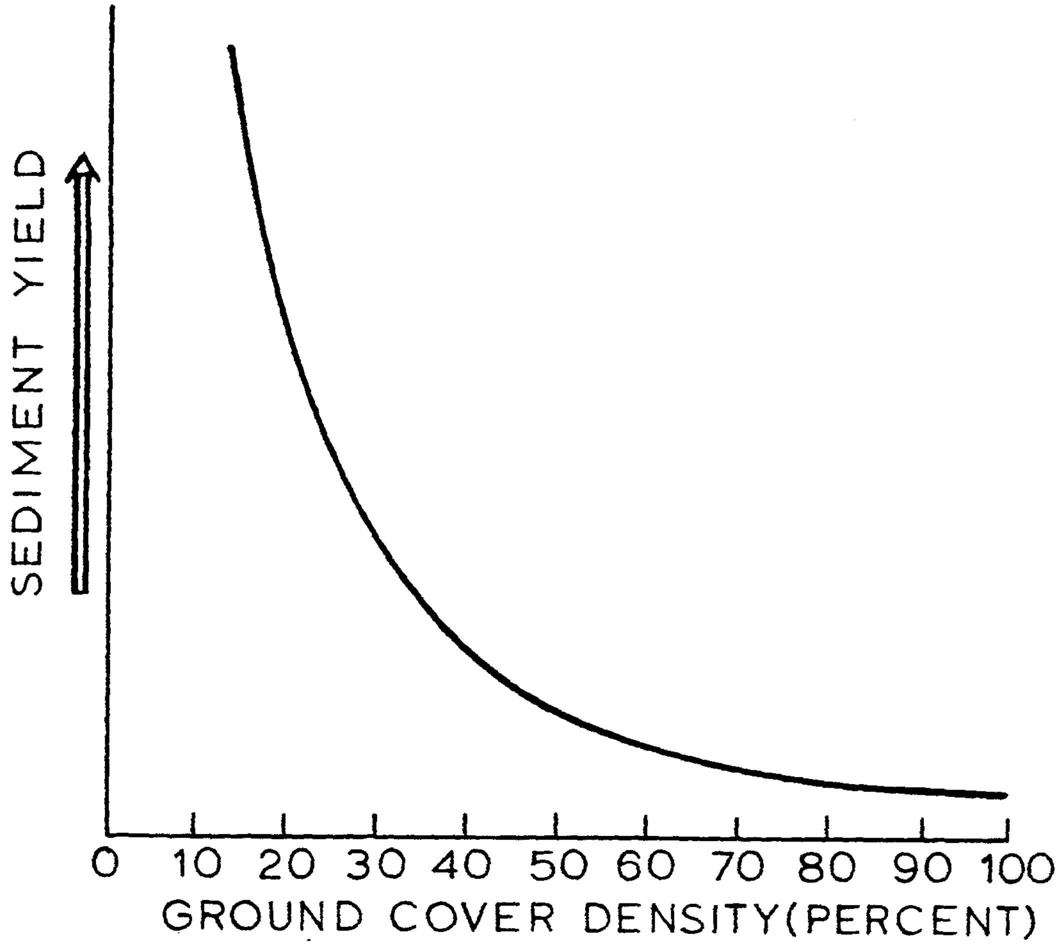

Fig. 1. Generalized schematic of sediment yield as a function of ground cover density.

sites often have "sensitive" or "threshold" amounts of ground cover. If ground cover is depleted below this amount, dramatic increases in runoff and erosion may result. This should instill in us a constant vigilance to protect watershed cover at or above this sensitive level.

WATER AND EROSION CONTROL PRACTICES

As already emphasized, the best practice is maintenance of adequate vegetation on a site. When something more is needed because of inadequate natural vegetative cover there are a number of options available. Several of these practices will be discussed with special reference to high elevation conditions.

Mulches

Characteristics of various mulching materials were reviewed recently by Springfield (1971). Straw or hay applied at the rate of about two tons per acre is a common standard. The Highway Research Board's recent report (1973), "Erosion Control on Highway Construction", includes a brief discussion of experimental sprays for erosion control. Such materials could be especially appealing for high elevation areas where the logistics of moving large amounts of bulky materials can be a critical problem. From a water and erosion control standpoint, it is highly important that whatever material is used is installed in such a manner to resist movement by running water. Straw and light weight materials work best when crimped into the soil. Various types of mats, if not anchored tightly to the soil, may permit erosion to occur beneath them, especially under conditions of snowmelt where a steady supply of meltwater may occur over several weeks time. Also, it is important that mulching materials are compatible with drainage system design to prevent clogging of diversions, culverts, or drop inlet structures.

Diversions

The basic design requirements for construction of diversions may be found in Schwab et. al. (1966) or in the Engineering handbooks of the various land management agencies such as the U. S. Soil Conservation Service and the U. S. Forest Service. A simplified design approach is outlined by Hudson (1971). A key consideration in any diversion scheme is the availability of a safe outlet and disposal area. Without safe disposal, more damage may result from installation of diversions than would occur without them. This becomes especially critical when a system of diversions, as for example on a ski slope, are installed.

Planning for diversions requires an estimate of peak runoff from either rainfall or snowmelt. For most areas the design peak is based on rainfall events. Rainfall design information can be obtained from U. S. Weather bureau Publications, as for example, "Design Storm Isopluvial Maps for Colorado", U. S. Weather Bureau (1967). In using such information a decision must be made regarding the design period and the risk of exceeding the design storm during the design period. The probability (P) of a rainfall with a recurrence interval (N) occurring at least once during N years is

$$P = 1-(1-1/N)^N$$

Thus, the probability that a 100 year storm might occur at least once during the next 100 years is 0.63 or almost 2 chances out of 3. These relations have been plotted in a calculated risk diagram by Hershfield and Kohler (1960). Information on soil characteristics, slope, ground cover, rainfall characteristics, and calculated risk in diversion design has been combined by Russell (1973) in an example problem in ski area development.

One important consideration in design of diversions in snowpack zones is the need to consider ice blockage. To prevent iceing of the diversions it may be necessary to increase the gradient in excess of those usually recommended. This may require tolerance of some scouring in the diversion and special provisions for sediment trapping at the diversion outlet.

Contour Trenches

Contour trenches have been applied successfully in watershed rehabilitation projects but they are an expensive and often a risky practice. They are used to prevent concentration of surface runoff and to facilitate recovery of vegetation. Copeland (1969) has traced the development of application of contour trenches on forest and rangelands. Doty (1971) has reported on the effects of contour trenching on streamflow. Detailed information on construction may be found in the "Land Treatment Measures Handbook" of the U. S. Forest Service (1959) and in other land management agency manuals.

Important considerations in using contour trenches in high elevation areas are the design of adequate storage capacity to accommodate large volumes of snowmelt and provision for regular maintenance. Contour trenches are usually designed for dry mantle floods that occur as a result of summer precipitation, at higher elevations the volume of meltwater may be a more important design criterion. An example of adaptation of trenches for a high snowpack zone is the Sheep Creek project on the Grand Mesa National Forest in Colorado (U. S. Forest Service, undated).

All earth structures require regular, frequent maintenance. Contour trenches are subject to breakage because of rodent damage, excessive settling, shrinkage cracks, and overtopping because of excessive accumulation of snow and ice. Contour trenches should not be considered unless the site is adaptable, the very high cost can be justified, and continued maintenance can be applied. Failure of a trench system can result in greater damage than if no trenches were applied because of the resulting concentration of water when failure occurs.

Contour Furrowing, Pitting, and Ripping

Contour furrowing is preferable to contour trenching on most high elevation lands because of reduced cost and less risk from failure. Branson et. al. (1966) evaluated a wide range of land treatments in Montana, Wyoming, Colorado, Utah, New Mexico, and Arizona. They reported that contour furrows at 3 to 5 foot intervals and broadbase furrowing were most effective. Greatest beneficial response (to vegetation) occurred on medium to fine textured soils. Branson et. al. describes one contour furrowing machine developed by the U. S. Forest Service that makes two furrows 5 feet apart, 8 to 12 inches deep, and 20 to 30 inches wide and dammed at intervals of 4 to 20 feet.

Application of these practices on high elevation watersheds is often limited by steep slopes, rockiness, and access by mechanical equipment. A key question in deciding whether to apply such practices, where adapted, is if they will accelerate establishment of vegetation enough to offset the additional cost and disturbance.

Channel Stabilization

Protection of drainageways should be part of the overall water and erosion control plan. This is particularly important in cases where water is diverted and concentrated in a pattern different from the natural drainage pattern. Often the excess runoff from poorly vegetated areas results in gully erosion, thus gully control structures are required as part of the watershed rehabilitation scheme. A basic reference for determination of permissible velocities in earth and vegetated channels of various cross sections is "Design Charts for Open-Channel Flow" (U. S. Department of Commerce, 1961).

Gully stabilization on smaller headwater drainages often requires small check dams. Although a variety of materials are available for their construction, rock check dams are the more practical types of structures for many of the higher elevation forest and range watersheds. Rock check dams, if properly designed and located, can provide the long-term, low-maintenance gully control structures required for high elevation remote areas subject to freeze-thaw mechanisms. Heede (1966) reporting on the design, construction, and costs of rock check dams recommends use of good quality, well-graded rock to resist high flows, keying into gully banks, coring into gully bottom, splash aprons, trapezoidal spillway sections, side slope protection, and wire mesh reinforcement.

When rock is not readily available, alternative types of material are required. Brush and logs are not recommended for permanent structures. They may be used for temporary control if kept to an effective height of less than 1 or 2 feet and if the erosion cycle will not be reinitiated when they decay. Prefabricated concrete sections of various configurations have been used successfully. Heede (1965) has reported on the testing of a prefabricated concrete check dam for smaller channels. Concrete will not have the endurance of native rock; this is especially critical under the rigorous climatic conditions in high elevation watersheds.

The design and construction of larger dams and drop structures is beyond the scope of this review. An excellent reference for larger structures of this nature including runoff estimation procedures is the "Design of Small Dams" by the U. S. Bureau of Reclamation, 1973.

The designs of culverts, energy dissipators, and filter systems are discussed thoroughly in "Highway Research Record No. 373", Highway Research Board, 1971.

CONCLUDING REMARKS

This review has concentrated on soil and water control directly related to revegetation problems and the associated land treatment measures. Problems of mass failure of slopes, roads, stream stabilization, and wind erosion were not included.

The objective of this review was to identify some general principles and literature sources. As in all field problems, field observation and experience are paramount. Each site has its own peculiar set of requirements within a geomorphic-soil-vegetation-climatic setting. Careful observation of where and how snow drifts, whether iceing of diversions and culverts is a problem, where erosion begins on a slope down from the crest, whether rill erosion is occurring between diversions, the amount of sediment delivered by diversion ditches, and the effectiveness of different kinds and rates of mulch on rill and sheet erosion are examples of the valuable information that can be gained by careful observation. In this context, it is very important to observe soil erosion and runoff during times of storms and snowmelt. The planner should do some of the routine maintenance inspection so he can learn from his mistakes.

Because of the potentially high risks from failure, soil and water control systems should be thought of in terms of a coordinated approach of planning, careful supervision during installation, regular inspection, and thorough maintenance. Anything less can result not only in loss of investment but could bring about greater damages or costs than if no action were taken.

BIBLIOGRAPHY

Branson, F. A. et. al. 1966. Contour furrowing, pitting, and ripping on rangelands of the western United States. Jour. of Range Management 19(4): 182-190.

Colman, E. A. 1953. Vegetation and Watershed Management. Ronald Press. 412 p.

Copeland, Otis L. Jr. 1963. Land use and ecological factors in relation to sediment yields. in Proceedings of the Federal Inter-Agency Sedimentation Conference. USDA Agr. Res. Service Misc. Publ. No. 970. U. S. Govt. Printing Office. 933 p.

______________. 1969. Forest service research in erosion control. Trans. Amer. Soc. of Agr. Eng. 12(1): 75-79.

Doty, Robert D. 1971. Contour Trenching Effects on Streamflow from a Utah Watershed. USDA Forest Service Research Paper INT-95. 19 p.

Heede, Burchard H. 1966. Design, Construction, and Cost of Rock Check Dams. U. S. Forest Service Research Paper RM-20. 24 p.

______________. 1965. Multipurpose Prefabricated Concrete Check Dam. U. S. Forest Service Research Paper RM-12. 16 p.

Hershfield, D. M. and M. A. Kohler. 1960. An empirical appraisal of the Gumbel extreme-value procedure. Jour. of Geophys. Research 65(6): 1737-1746.

Highway Research Board. 1973. Erosion Control on Highway Construction. Natl. Res. Council, Natl. Acad. Sciences. Wash. D. C. 52 p. ($4.00).

_______________. 1971. Design of Culverts, Energy Dissipators, and Filter Systems. Hwy. Research Record No. 373. 112 p. (8 reports).

Hudson, Norman. 1971. Soil Conservation. Cornell Univ. Press, Ithaca, New York. 320 p. ($9.75).

Meeuwig, Richard O. 1971. Soil stability on high-elevation rangeland in the Intermountain area. USDA Forest Service Research Paper INT-94. 10 p.

Russell, Ronald L. 1973. Hydrology criteria for ski area development. in National Winter Sports Symposium. U. S. Forest Service, Denver, Colo. Feb. 26-March 2, 1973. 15 p.

Schwab, G. O. et. al. 1966. Soil and Water Conservation Engineering (2nd Ed.). Wiley, New York.

Springfield, H. W. 1971. Selection and limitations of mulching materials for stabilizing critical areas. in Proceedings, Critical Area Stabilization Workshop, Albuquerque, New Mexico. April 27-29, 1971. USDA Agr. Res. Service, PO Box 698, Las Cruces, New Mexico 88001. 197 p.

U. S. Bureau of Reclamation. 1973. Design of Small Dams. Denver Federal Center, Colo. 80225, Attn. 922 ($12.65 postpaid). 816 p.

U. S. Dept. of Commerce. 1961. Design Charts for Open-Channel Flow. Bur. of Public Roads, Hydraulic Design Series No. 3. U. S. Govt. Printing Office, Wash. D. C. 105 p. (70¢).

U. S. Forest Service. 1959. Land Treatment Measures Handbook. U. S. Govt. Printing Office.

_______________. Undated. Sheep Creek Soil and Watershed Rehabilitation Project 1946-1962, Grand Mesa National Forest. U. S. Forest Service, Denver, Colo.

U. S. Weather Bureau. 1967. Design Storm Isopluvial Maps for Colorado. Special Studies Branch, Office of Hydrology, ESSA, October 1967.

GRASSES AND LEGUMES FOR REVEGETATION OF DISTURBED SUBALPINE AREAS

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If there were a choice, adapted native species would usually be used to seed disturbed subalpine areas. However, for land disturbed today, the choice of species and variety is limited to what is commercially available and to those species that can be established on disturbed soil. A number of grasses are available from which satisfactory stands can be obtained in the subalpine if good cultural practices are used on suitable soil. Most of these are introduced species and even the commercially available native species are from selections made at much lower altitudes. Thus, good initial establishment of some of these species and selections does not insure long-term adaptability under severe subalpine conditions.

The species selected for seeding should reflect long-term land use objectives and a knowledge of the growth characteristics, longevity, reproduction potential, and special problems involved with each species.

The immediate objective in revegetation of disturbed areas is usually to establish a ground cover to control erosion and for aesthetics. Longer term land-use objectives may vary considerably -- some are listed below:

The situation where invasion of natives, including woody species, is desired. Here, one may seed a ground cover of fast-establishing bunchgrasses which in time will give way to the natives. The limitations are sources of the natives and if the transition can occur with little or tolerable site degradation. On the other extreme, consider areas such as ski runs where invasion by woody species is not desired -- here, a ground cover of herbaceous species that will dominate the site and prevent invasion is desired. Highly-competitive, long-lived, rhizomatous species might be the choice.

On certain disturbed areas the objective may be to establish forage species for livestock or big game. On other areas, less palatable species might be chosen to avoid traffic hazards to, as well as from, deer and domestic livestock or to prevent depletion of vegetation on critical areas.

Species with a short growth habit may be desired on areas receiving foot traffic or on road shoulders; on other areas, tall-growing species may be appropriate to deter foot traffic.

It must also be recognized that there are considerable site differences significant to plant growth within the subalpine. One should mention aspect, slope position, altitude, shading, snow collection areas, and soil depth, texture and fertility. Thus, species seeded should be selected for adaptation to individual sites within the subalpine. Mixes of species are recommended from both the stability of plant community and aesthetic standpoints.

Past experience in Colorado (McGinnies et al., 1963); Utah (Plummer et al., 1968, Hull 1974); and in Montana (Gomm, 1962) enable one to make generalizations about commercially available species for seeding in the subalpine, particularly at the 9,000 to 10,000-foot altitudes. These reports plus observations on species adaptability plots at Climax (11,300 feet) and on Snowmass ski area are the basis of the following discussions.

SPECIES WHICH USUALLY ESTABLISH WELL AND HAVE PROVEN TO BE PERSISTENT IN THE SUBALPINE

Foxtails, meadow (*Alopecurus pratensis*) and creeping (*A. arundinaceus*). Stands of these species are the most or among the more persistent of commercially-available species grown at the high altitudes. These are probably the only commercially available species able to set viable seed in the higher subalpine. Foxtails are among the earliest species to green up and they remain palatable throughout the growing season. Seedling vigor is poor to fair for creeping foxtail and fair to good for meadow foxtail. The seed is fluffy and will not seed in common drills unless an inert material (e.g. rice hulls) is used as a carrier. Meadow foxtail is a bunchgrass, whereas, as the name implies, 'Garrison' creeping foxtail is rhizomatous. The latter is a recent release and the seed is as yet quite expensive. The growth habit, depending upon the site and growing conditions, is medium to tall. Introduced.

Smooth brome (*Bromus inermis*). This species, particularly the variety 'Manchar', has consistently proven to be persistent in subalpine seedings. The persistence probably is due to vegetative reproduction by rhizomes. Because of the somewhat fleshy rhizomes, this species is susceptible to damage by pocket gophers. Seedling vigor and palatability are good. This species has a high nitrogen requirement and will tend to dominate stands if fertilized intensively. It greens up early and is one of the first species to give indication of the coming fall by purpling. The seed is relatively inexpensive and easy to handle. Growth habit is medium to tall. Introduced.

SPECIES THAT USUALLY ESTABLISH WELL BUT ARE NOT PERSISTENT IN THE SUBALPINE

Timothy (*Phleum pratense*). Timothy is usually included in high altitude seeding mixes that are broadcast. This is because timothy has a small round seed that will catch and establish in small cracks where larger or fluffy seeds will not. Seedling vigor is good, as is palatability. It is a bunchgrass that will not produce viable seed at the higher elevations, thus stands begin to die out after 5 to 6 years, but it may last longer on moist sites. Medium to tall growth habit. Introduced.

Slender wheatgrass (*Agropyron trachycaulum*). This species is a bunchgrass native to the subalpine. However, plants from the commercially available seed will not set viable seed in the upper subalpine, thus stands began to die out after 4 to 5 years. Stands from locally collected seed may last up to 10 years and reseed themselves, particularly on disturbed sites. Seedling vigor is good. Late season palatability is probably less than the species mentioned above. Medium growth habit.

Tall fescue (*Festuca arundinacea*). A bunchgrass somewhat similar in growth habit to the above two species, probably not as persistent. However, palatability is lower and persistence under heavy foot traffic at the lower elevations may be greater. Introduced.

Orchardgrass (*Dactylis glomerata*). A bunchgrass more subject to winterkill than timothy or slender wheatgrass. Palatable, tall growth habit. Introduced.

Ryegrass (*Lolium perenne*). A bunchgrass, outstanding in seedling vigor and early establishment, very short lived, very palatable. A problem that may arise in use of ryegrass is that it may be so competitive that the establishment of more desirable species is inhibited. Introduced.

SPECIES THAT SHOW PROMISE UNDER CERTAIN CONDITIONS

Red fescue (*Festuca rubra*). This species may belong in group I, however, observations on it are more limited. It looks like one of the better species on upper subalpine sites that have long periods of snow cover. The dark green color, fine leaves, and medium to moderately low growth habit may make it desirable on areas carrying foot traffic. Fair to good seedling vigor, rhizomatous to tufted form, probably average palatability. Many varieties are available. Testing among varieties is needed. Introduced.

Chewing's fescue (*F. rubra* var. *commutata*). Similar to red fescue but more of a bunchgrass. Probably the most shade tolerant of grasses mentioned here. Introduced.

Bluegrass (*Poa*). Poor seedling vigor when compared to any of the above species. Persistent once established, spreads by rhizomes. Kentucky bluegrass (*P. pratensis*) grows better on the more moist sites and has a medium to moderately low growth habit. Canada bluegrass (*P. compressa*) may be more difficult to establish than Kentucky bluegrass, however it is adapted to drier sites, moderately low growth habit. Introduced.

SPECIES THAT MAY HAVE A SPECIAL USE

Hard fescue (*Festuca ovina* var. *duriuscula*). A bunchgrass with moderate to weak seedling vigor. On the plots at Climax the performance has been disappointing with considerable winterkill the first two years. The delicate tufted form and gracefulness of this species usually make it a desirable addition to other more serviceable species in a high-altitude seeding mix. A relatively low growth habit, and adaptation to somewhat drier sites, may make this species useful in certain situations at 9,000 - 10,000 feet. 'Durar' is the variety commercially available. Introduced.

Mountain brome (*Bromus marginatus*). Short-lived bunchgrass, rather poor seedling vigor. Graceful drooping seed heads may make it an aesthetically desirable addition to seed mixes. Native, although the commercially available variety 'Bromar' was selected at a much lower altitude.

Reed canarygrass (*Phalaris arundinacea*). Coarse, rhizomatous, adapted to quite moist sites, often difficult to establish from seed, might consider transplanting, limited palatability. Native, but the seed in commerce is usually from Iowa or Minnesota sources.

Intermediate wheatgrass (*Agropyron intermedium*). Will not persist in the higher subalpine. Adapted to the lower subalpine, especially drier sites. Excellent seedling vigor. It is rhizomatous, however it tends to be bunchy with a tall growth habit. Palatable early in the season. Introduced. Pubescent wheatgrass (*A. trichophorum*) similar to intermediate wheatgrass except less palatable but usually more spreading.

Streambank wheatgrass (*Agropyron riparium*). Not adapted to the higher subalpine. Fair seedling vigor, rhizomatous, limited palatability, moderately low to medium growth habit. May be an alternative in the lower subalpine where the taller growing, more palatable, intermediate wheatgrass is not desired. Native. The variety commercially available is 'Sodar'.

Western wheatgrass (*Agropyron smithii*). Similar to streambank wheatgrass. The commercially available seed sources are from the Great Plains. A strongly rhizomatous ecotype has been observed to invade disturbed soils and certain mill tailings in the subalpine. Fair seedling vigor, sometimes difficult to establish. Native.

LEGUMES

Disturbed lands are deficient to extremely deficient in nitrogen, thus establishment of species with the ability to fix nitrogen from the atmosphere is desirable. However, the commercially available legumes that can be considered for use in the upper subalpine are limited both in number and in adaptability and all are introduced. Inoculation with the proper Rhizobium for the species is mandatory.

Alfalfa (*Medicago sativa*). Good seedling vigor, not adapted to the upper subalpine but does well at lower elevations, can grow on drier sites. Highly palatable to deer as well as domestic livestock, can cause bloat in domestic livestock. Damaged by pocket gophers. Medium to tall growth habit.

White clover (*Trifolium repens*). Fair to poor seedling vigor, will persist for a few years in upper subalpine. Low growth habit, grows better on moist sites.

Cicer milkvetch (*Astragalus cicer*). Adaptability similar to alfalfa, weak seedling vigor, rhizomatous, thus a thin initial stand can thicken. Low palatability, damaged by pocket gophers, non-bloat. Medium growth habit.

Birdsfoot trefoil (*Lotus corniculatus*). May persist for a few years in the upper subalpine, palatable, non-bloat. The distinct foliage, delicate yellow flowers, and moderately low growth habit may make this species a desirable addition to some mixes.

Crownvetch (*Coronilla varia*). Most reports of performance in the subalpine are 'poor' with the exception of Hull (1974). Very difficult to establish from seed. Poor seedling vigor, rhizomatous, palatability less than alfalfa or birdsfoot trefoil, non-bloat.

Red and Alsike clovers (*Trifolium pratense* and *T. hybridum*). Short lived, seedling vigor better than other legumes mentioned except for alfalfa, palatable, not rhizomatous (see also paper on legumes by Townsend).

BIBLIOGRAPHY

Gomm, F. B. 1962. Reseeding studies at a small high-altitude park in southwestern Montana. Mont. Ag. Expt. Sta. Bull. 568. 15 p.

Hafenrichter, A. L., J. L. Schwendiman, H. L. Harris, R. S. MacLauchlan, and H. W. Miller. 1968. Grasses and legumes for soil conservation in the Pacific Northwest and Great Basin states. USDA Agri. Handbook 339:69 p.

Hull, A. C. 1964. Species for seeding mountain rangelands in southeastern Idaho, northeastern Utah, and western Wyoming. J. Range Mgt. 27: 150-153.

McGinnies, W. J., D. F. Hervey, J. A. Downs and A. C. Everson. 1963. A summary of range grass seeding trials in Colorado. Colo. Agr. Exp. Station Bull. 73:81 p.

Plummer, A. P., D. R. Christensen and S. B. Monsen. 1968. Restoring big-game range in Utah. Pub. 68-3. Utah Div. of Fish and Game. 183 p.

LEGUME SELECTION AND BREEDING RESEARCH IN COLORADO

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Over the past 18 years a cooperative research program on forage legume improvement has been conducted by the Agricultural Research Service, USDA, and the Colorado State University Experiment Station. Initially, major emphasis was placed on the selection of legumes for high-altitude meadows. During the last six years our efforts have concentrated on the selection and breeding of legumes for the dryland areas of the Great Plains. The primary objective of this program has been forage production, but many of the findings are appropriate to selection of species for revegetation of disturbed lands.

There are many species of forage legumes and they grow in very diverse environments ranging from sea level to the alpine. Some grow in very moist areas while others are native to desert regions. In Colorado, native legumes can be found growing in the shortgrass prairie, in the foothills, montane, subalpine, and alpine. Most, if not all, of the native species have seeding habits which prevent the collection of reasonable amounts of seed. In addition, the seedling vigor of these species is generally poor and satisfactory stands cannot be obtained.

Some introduced species have excellent seedling vigor. In addition, there is also a commercial seed supply. In the late 1950's several varieties of alfalfa, red clover, and alsike clover were grown under irrigation in high-altitude meadows near Hayden, Gunnison, and Fairplay, Colorado. These sites are about 6300, 7700, and 9500 feet above sea level. The legumes were evaluated for general vigor, persistence, forage production, disease reaction, and date of flowering. The most extensive test was with red clover (Townsend, 1963) where 55 varieties, mostly of Swedish origin, were grown. The Swedish varieties had been grown on the same farms for 50 to 100 years in Sweden and natural selection had occurred for local adaptation. Red clover persisted for two to five years depending on location. Persistence was best at Hayden and poorest at Gunnison. Persistence of alfalfa was excellent at all locations (Grable, et al., unreported), but alsike clover did not persist more than two years at any location (Grable, et al., 1965; Townsend, 1962).

Many legume studies have been conducted in the mountain meadow areas, but a more recent one concerned the comparison of several species for persistence and forage production near Gunnison (Siemer & Willhite, 1972). The species evaluated included alfalfa, red clover, white clover, alsike clover, sainfoin, birdsfoot trefoil, and crownvetch. Alfalfa had the best persistence of all species and it yielded well. Red clover and alsike clover yielded well, but persistence was poor. The other species performed poorly.

There is seed of many varieties of alfalfa on the market. 'Ladak', an old variety, is one of the best overall varieties because of its winterhardiness and drought tolerance. There may be considerable variability among different seed lots of 'Ladak'; therefore, 'Ladak 65', a selection from 'Ladak', should be seeded. Other varieties such as 'Vernal' which have excellent winterhardiness and have been developed for northern areas of the United States are recommended also.

We have carried out limited work with several native alpine species, namely *Trifolium parryi*, *T. dasyphyllum*, and *T. nanum*. The prospects for using these species for rehabilitation purposes are not encouraging because of seed production problems and poor seedling vigor.

Of the 14 species of native and introduced legumes evaluated for adaptability to dryland conditions of the Central Great Plains, alfalfa was the most promising on both sandy and loam soils (Townsend, in press). In addition, *Astragalus falcatus*, *A. galegiformis* and cicer milkvetch (*A. Cicer*) appeared to be adapted to the region. Of the latter three species, cicer milkvetch has the most potential and *A. galegiformis* has the least potential. One native species, *A striatus*, appeared to have some potential on sandy soils. The sainfoins and crown vetches performed poorly. In Oklahoma, alfalfa was the legume best adapted to range conditions (Kneebone, 1959).

Interest in cicer milkvetch has increased in recent years because of bloat problems associated with grazing alfalfa. Cicer milkvetch, a long-lived perennial, has several desirable characters such as spreading by rhizomes and no evidence of causing bloat (Stroh, 1972). The spreading characteristic permits a relatively poor initial stand of cicer to become a reasonably good stand if sufficient moisture is available. Efforts are being made to overcome the poor seedling vigor aspect by plant breeding (Townsend, 1974). We are attempting to improve seedling vigor by selecting for speed of germination at different temperatures in the laboratory, for rate of seedling emergence in the greenhouse and field, and for rate of seedling growth in controlled environmental chambers. The prospects for improving seedling vigor are promising. 'Lutana' is the best variety of cicer milkvetch available for seeding in Colorado at the present time. This species has very hard seeds and it is important to make certain that the seed has been properly scarified or else the seed will not germinate and a poor stand will result.

In seeding legumes, time and depth of planting are extremely important. In the plains area of Colorado, seeding may be done any time when moisture is available from early April to mid-May. In the mountain areas, fall seedings should give the best results. Every effort should be made to seed in a prepared seedbed because poor seedbed preparation is one of the primary reasons for seeding failures. Do not plant deeper than 3/4 of an inch except somewhat deeper seedings (up to one inch) can be made in sandy soils (Townsend & McGinnies, 1972). It is imperative that the seed be covered with soil and that the seedbed be firm and have a relatively rough surface.

Soils in disturbed areas are frequently deficient in nitrogen and if legumes are not grown, nitrogen fertilizer may need to be applied. When legumes are grown in a symbiotic association with the proper species of bacterium, they will fix atmospheric nitrogen. As a result, commercial nitrogen fertilizer is not needed. However, it is necessary to inoculate the legume seed with the proper Rhizobium species before seeding.

Seed of the above recommended varieties as well as the inoculum can be obtained from most seed dealers. However, it may be necessary to give the seed dealer some lead time in obtaining your supplies. Do not attempt to purchase the seed and inoculum the same day you want to begin seeding.

BIBLIOGRAPHY

Grable, A. R., F. M. Willhite, and W. L. McCuistion. 1965. Hay production and nutrient uptake at high altitudes in Colorado with different grasses in conjunction with alsike clover or nitrogen fertilizer. Agron. J. 57:543-547 p.

Grable, A. R., F. M. Willhite, and W. L. McCuistion. Unreported studies.

Kneebone, W. R. 1959. An evaluation of legumes for western Oklahoma rangelands. Okla. Agr. Expt. Bull. B-539. 13 p.

Siemer, E. G. and F. M. Willhite. 1972. Long-term grass and legume productivity at Gunnison. Colorado State University Experiment Station Progress Report 14.

Stroh, J. R., A. E. Carleton, and W. J. Seamands. 1972. Management of Lutana cicer milkvetch for hay, pasture, seed, and conservation uses. Montana Agricultural Experiment Station Bulletin 666. 17 p.

Townsend, C. E. 1962. Performance of alsike clover varieties in a high-altitude meadow. Crop Science 2:80-81 p.

Townsend, C. E. 1963. Performance of red clover varieties under irrigation in high-altitude meadows of Colorado. Colo. Agr. Expt. Sta. Bull. 515-S. 13 p.

Townsend, C. E. 1974. Selection for seedling vigor in *Astragalus cicer L.* Agron. J. 66:241-245 p.

Townsend, C. E. Evaluation of forage legumes for rangelands of the Central Great Plains. Gen. Ser. Pub., Colo. State Univ. (in press)

Townsend, C. E., and W. J. McGinnies. 1972. Establishment of nine forage legumes in the Central Great Plains. Agron. J. 64:699-702 p.

PLANT SPECIES POTENTIALS FOR HIGH-ALTITUDE REVEGETATION

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The opportunity to participate in this interesting and important Colorado workshop is greatly appreciated. My part in the program will be understood, I hope, to be that of pointing out some of the potentials among species useful for revegetation of high-altitude sites.

It was necessary to explore some plant science literature in search of published accounts of revegetation of high-altitude disturbed lands.

At this point in the program it is a good idea to redefine the area we are discussing. We were to focus on the sub-alpine and alpine zone in the Rockies, on lands over 9,000 feet in elevation. These kinds of lands have very little published about them in this connection, as compared to the abundance of research and applied practice in zones at lower elevations. An explanation of this situation possibly lies in the fact that the Hudsonian and Alpine life zones in the Rocky Mountains have (1) a low incidence of permanent human habitation (apparently we tend to know more about habitats where we spend more of our time); (2) snow cover, short frost-free periods, thin soils, steep slopes, strong winds, and other climatic factors imposing significant restrictions on what might be described as "normal agronomic activity".

My subject involves many families, genera, and species of plants. You will agree with me when you see long lists of plants of subalpine and alpine zones of the Rocky Mountains. Pond and Smith (1971) refer to 65 species having high frequencies of occurrence in subalpine ranges of Wyoming. My count of species listed by Marr (1961) together with those in Colorado range site descriptions of the Soil Conservation Service (1961-1973) adds up to well over 100. Ellison (1954) in his subalpine vegetation studies in the Wasatch Plateau in Utah, listed 204 plant species. Nearly all of these high-elevation plants have potentials for revegetating high-altitude disturbed areas of the Rockies. It is safe for me to make this statement, because these plants meet one of the first requirements of any species to be used for revegetation. They have proven their adaptability for growth in the environment under consideration. Because of the need here to limit the species to a reasonable number, I have confined my coverage to a few of the grasses. Grasses have a long history of use in reseeding. More is known about them, by and large, than is known about forbs and shrubs. Forbs, shrubs, and trees have excellent potentials. They should not by any means be ruled out. Future attention will need to include members of the buttercup, rose, willow, aster, borage, legume and other plant families, in addition to grasses. This is in order to reach a desired degree of restoration of stable plant communities containing the many diverse individuals of the ecosystem.

Before entering further into the subject of plant species potentials, we can look for guidance from basic plant ecology. To have a potential for revegetation in high-altitude zones, a plant must be:

(1) A perennial. The almost total absence of "invading" annual plants in the sub-alpine and alpine zones indicates the severity of the environment for the germination, establishment and completion of the plant life cycle (through seed maturity). The high-altitude plant community consists almost entirely of long-lived perennial grasses, forbs, shrubs and trees. Even such ubiquitous annuals as cheatgrass, Russian thistle, kochia, pigweed, lambsquarters and cockleburs, all highly adapted for growing on bare, disturbed places, do not find suitable homes in subalpine and alpine zones.

To continue with the annual vs. perennial thinking, let us consider some of the favorable aspects of the subject. One of these is the freedom from competition from annuals in high altitude seedlings. Annual weeds are often a major cause of failures in revegetation projects. Another point here, is that such annuals as cereal rye, oats, barley, and wheat can be used to produce needed temporary cover on disturbed high-altitude sites. They would present little, if any, persisting competition from their "volunteering" from seed.

(2) Environmentally adapted. High altitude revegetation projects are no place for experimenting with plant materials of unknown or uncertain adaptability. If this guideline is taken literally, our plant materials choices are virtually limited to native species unless trial and experience has proven the suitability of an exotic species.

(3) Primitive in the evolutionary scale. This category is covered in (1) and (2) above, but further mention is in line. A high percentage of plants indigenous to subalpine and alpine areas are "primitive", in terms of their evolution or advancement from the simple to the more complex. This is evident in the grass family wherein species of the more primitive sub-family *Festucoideae* are present and species of the more advanced sub-family *Panicoideae* are absent.

(4) Available. If needed plant materials are not available in the necessary quantity at the time specifications for a project are drawn up, they cannot be included in any revegetation work. On the other hand, we cannot look toward progress or improvement in availability of plant materials, unless we give planned attention to their need. The Soil Conservation Service recognizes a growing need for adding many species in its plant materials programs.

Subalpine and alpine species should be included. It is now recognized that SCS has the need to expand beyond the aim for forage production alone, as has been the intention in much of the work of the past. Colorado, located in a region having a wide range in ecosystems should, it is hoped, have an SCS plant materials facility.

A discussion of availability must bring out the need for understanding the time delay between release of a selection and its having seed available in any quantity. At least three to four years are necessary for development of seed supplies through the process of seed production, even after promising source materials have been tested for adaptation. Several exotic species are available and have been used by agencies and individuals, in high-altitude plantings, but seed is available for only a very few adapted native grasses.

Hardly a list of high-altitude plants of the Rocky Mountains omits tufted hairgrass (*Deschampsia caespitosa* [L.] Beauv.). Circumpolar in distribution, this grass grows in cool, humid sites on all continents except Africa and Australia. It dominates many plant communities of Colorado Mountain meadows and alpine sites. The SCS plant materials center in Bridger, Montana has reported good seed production from a strain of tufted hairgrass (M-926). Ecotype studies, without consideration of seeding potential, were made on 20 populations from Colorado, Wyoming and Montana by Pearcy and Ward (1972).

Another grass, almost as widely distributed, is sheep fescue (*Festuca ovina* L.). The Durar selection of the subspecies *duriuscula* has performed well in numerous high altitude plantings. Several plantings in Colorado are over 20 years old.

A recently released selection of the native Arizona tescue (*Festuca arizonica* Vasey) is "Redondo" which was formerly NM-5 at the Los Lunas plant materials center. Tests and evaluations at several locations in Colorado have indicated promising potentials of this grass. A planting in a low-producing site in South Park has totaled over 1,500 pounds per acre of air-dry forage per year for several years. Merkel et al. (1973) reported this Arizona fescue produced 3,112 pounds per acre at Meeker, where it was the highest producer at that field evaluation planting.

Thurber fescue (*Festuca thurberi* Vasey) has a potential for seeding in Colorado. Thurber fescue deserves testing because of the potential it has for grassing road cuts, embankments, ski slopes and other high country areas. The seed-hay method may be applicable for establishing this grass, until seed sources are available.

Parry oatgrass (*Danthonia parryi* Scribn.) forms a large percentage of the composition of Subalpine Loam range sites in parts of Colorado.

Hundred-year-old cemetery enclosures at Dory Hill above Blackhawk and at Cripple Creek, Colorado have Parry oatgrass dominating much of the cover. Parry oatgrass is a true citizen of the Rocky Mountains, Hitchcock (1950). Its distribution is New Mexico, Colorado, Wyoming and Montana. Its adaptation and large oat-like spikelets and caryopses, put it in the running as a likely candidate for revegetating high-altitude sites.

About the only native grass species that have been planted to any extent for high elevations are mountain brome (*Bromus marginatus* Nees), slender wheatgrass (*Agropyron trachycaulum* [Link] Malte.), blue wildrye (*Elymus glaucus* Buckl.) and big bluegrass (*Poa ampla* Merr.). Gates (1962) made tests on five grasses, including two of the native species listed above. His tests were made with high-altitude soils brought to the greenhouse for plant establishment. Out of 50 seeds planted for each grass, the number of plants established for each species were:

Orchard grass (*Dactylis glomerata* L.)	43
Slender wheatgrass	40
Smooth brome (*Bromus inermis* Leyss.)	38
Timothy (*Phleum pratense* L.)	23
Mountain brome	12

The two native grasses of this group, slender wheatgrass and mountain brome, differed significantly in establishing seedlings although their environmental adaptation is quite similar. Experience in stand establishment with field plantings has been comparable with these greenhouse tests. Slender wheat-rass is easily established, but is not a long-lived grass. Smooth brome and orchard grass are understandably popular grasses for high country plantings, as the above test bears out.

Most all Rocky Mountain grass revegetation programs to date, have used smooth brome, orchard grass, timothy, intermediate wheatgrass (*Agropyron intermedium* [Host.] Beauv.), pubescent wheatgrass (*Agropyron trichophorum* [Link.] Richt.), Russian wildrye (*Elymus junceus* Fisch), Kentucky bluegrass (*Poa pratensis* L.) and other introduced grasses. Trial seedings which used timothy, pubescent wheatgrass, orchard grass, blue wildrye, meadow brome (*Bromus biebersteinii* Roem. and Schult.) and slender wheatgrass were made by J. G. Smith (1963). These were on subalpine grasslands in Washington. All were rated excellent or good after eight growing seasons. Hull (1966) and other range scientists, agronomists and research workers have made many high-altitude seedings using various species and methods.

These and other studies and projects only begin to touch upon the subject. To date the results from research and practical application are inadequate to provide needed information for choosing grasses, either native or introduced, having the highest potentials for stabilizing soils on disturbed sites of high altitudes in the Rocky Mountains.

BIBLIOGRAPHY

Ellison, Lincoln. 1954. Subalpine Vegetation of the Wasatch Plateau, Utah. Ecol. Monographs. 24:89-184.

Gates, D. H. 1962. Revegetation of a High-Altitude, Barren Slope in Northern Idaho. J. Range Manag. 15:314-318.

Hitchcock, A. S. 1950. Manual of the Grasses of the United States. U.S. Govt. Printing Office. Washington, D.C. 1051 p.

Hull, A. C., Jr. 1966. Emergence and Survival of Intermediate Wheatgrass and Smooth Brome Seeded on a Mountain Range. J. Range Manag. 12:279-284.

Marr, J. W. 1961. Ecosystems of the East Slope of the Front Range in Colorado. Univ. of Colo. Press, Boulder, Colo. 134 p.

Merkel, D. L., Jesse W. Hale, and Phillip L. Sims. 1973. Performance of Seeded Grasses in Northwestern Colorado. Gen. Series 926, Colo. Agr. Exper. Station, Fort Collins, Colo.

Pearcy, R. W. and R. T. Ward. 1972. Phenology and growth of Rocky Mountain populations of *Deschampsia caespitosa* at three elevations in Colorado. Ecology 53:1171-1178.

Pond, F. W. and D. R. Smith. 1971. Ecology and Management of Subalpine Ranges on the Big Horn Mountains of Wyoming. Wyo. Agr. Exp. Sta. Research Journ. 53.

Smith, J. G. 1963. A Subalpine Grassland Seeding Trial. J. Range Management. 16:208-210.

Soil Conservation Service. USDA. 1961-73. Range Site Descriptions and Condition Guides. Technical Guides. Denver, Colorado.

PLANT BREEDING AND ITS ROLE IN SUPPLYING NEW PLANT MATERIALS

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The role of plant breeding is to improve the genetic stock, be it for food, livestock feed, fiber, erosion control, or aesthetics. The task includes seed production so that the improved strains are commercially available to the user.

The general method of operation of a plant breeder falls under six headings:

Objectives: yield, dependability, quality.
Source Materials: species, ecotypes, "land" varieties, bred strains.
Methods of Recombination and Progeny Types for Tests
Evaluation: different years and locations, moderate or strict selection.
Improvement of seed production: a character in its own right.
Multiplication and release: registered crop varieties, role of commercial seed producers.

Since we are dealing here with plant materials for revegetation at high altitudes we need to re-examine each of the six basic aspects of a plant breeder's work, pointing out the changes in emphasis that must be made in producing plants for use in subalpine and alpine disturbed soils.

OBJECTIVES FOR PLANT MATERIAL SELECTION

Dependability and soil stabilization. These characters come first, rather than yield. They are comprised of the features of efficiency of establishment through germination and seedling vigor, survival through drought, cold, wind-blown sand, and tolerance to chemical toxicity in soils or other plant growth media such as alluvium, spoils, and tailings. A second objective may be ability to reseed themselves if they do not multiply and cover the ground by rhizomes or other vegetative growth. Only third should we consider yield of leafy forage, although that may be a valuable feature for wildlife or livestock forage. On the other hand, it is often undesirable to have palatable species along roadsides, for they may attract deer and add to highway hazards.

Seed-production ability in the seed growing area. Efficiency of multiplication at lower altitudes is important to keep down seed costs while still giving fair return to the producer whose business is seed production.

SOURCE MATERIALS: CHOICE OF SPECIES

Exotic or native? If the situation calls for, or will accept, the use of an exotic species there may be a variety (already in commercial seed production) which will do satisfactorily or can be improved with minimal breeding procedures. If, on the other hand, it is found that natives have to be used or will actually perform better regardless of legal constrictions, we face a situation in which essentially no plant breeding has been done on high-altitude species. The first step then is an ecotype survey using as many likely sources as possible, including those which appear already adapted to the disturbed sites, e.g., the western wheatgrass from the gold tailings at Victor mentioned by Dr. Berg. See also Plummer et al. (1968) for ways of harvesting native seed of at least 61 species.

Tables 1 and 2 list native and exotic grasses growing in Utah and Colorado which have been recommended or show promise for revegetation projects. Further suggestions are found in the papers of Berg, Eaman and others at the Workshop, and in the Plant Materials Discussion Group report.

One argument on exotic versus native has to do with the definition of an exotic. Is a species found in the northern Rockies or Alaska to be considered exotic to the central Rockies? It might very well tolerate the high altitude winters. What about plants from Siberia, Scandinavia, the Alps, or the Andes? If they will survive and control soil erosion better than natives, why not make use of them, except in wilderness areas, nature preserves, and National Parks where biological and legal considerations dictate "natives only."

Assembling the range of material needed for testing and breeding. Having chosen one or two species to work on, the plant breeder assembles as many sources of germplasm as possible to make use of the genetic variability which will give him the maximum improvement possibilities. Promising sources include:

- Plant introduction stations of the USDA.
- Plant materials centers of the Soil Conservation Service.
- Collections of natives made in the field, e.g., A. Slinkard (*Festuca idahoensis*), Smoliak and Johnson (*Agropyron smithii* and *Agr. dasystachyum*), and Ward and Pearcy (*Deschampsia caespitosa*).
- Bred strains from other states and continents, e.g., 'Polar' bromegrass from Alaska and 'Sac' bromegrass from Wisconsin.

Number of plants to have in a source nursery. To make a worthwhile advance in several traits, one should aim at 2,000 to 10,000 individual, spaced plants in a breeding nursery and expect to discard half of them quite early and to use only a few percent of the rest in a breeding program.

Table 1. Characteristic Grasses of Utah.

Zone	Native Grasses	Suggested for Seeding
Canadian 8500'	Slender wheatgrass Mountain brome	Meadow foxtail Slender wheatgrass Intermediate wheatgrass Kentucky bluegrass Smooth brome Mountain brome Subalpine brome Reed canarygrass Hard fescue Basin wildrye
Hudsonian 9800'	Letterman needlegrass Mountain brome	
Arctic-Alpine 10,800'	Scribner wheatgrass	

(Plummer et al., 1968)

Table 2. Grasses Recommended for Colorado - Aspen Zone.

Species	Common Name	Named Varieties
Agropyron intermedium	Intermediate wheatgrass	3+
Agropyron subsecundum	Bearded wheatgrass	C
Agropyron trachycaulum	Slender wheatgrass	1
Bromus inermis	Smooth brome	4+
Bromus marginatus	Mountain brome	1
Dactylis glomerata	Orchardgrass	3+
Festuca arizonica	Arizona fescue	1
Festuca idahoensis	Idaho fescue	-
Festuca rubra var *commutata*	Chewings fescue	C-T
Phleum pratense	Timothy	1+
Poa pratensis	Kentucky bluegrass	C-T

(Dept. of Range Sci., CSU, 1972)

C = Commercial seed but no named varieties.
C-T = Commercial turf grass seed of several named varieties.
Numbers indicate named, improved varieties listed by Hanson (1972). There is also "commercial" unimproved seed of these species apart from the named varieties which are often commercially available.

METHODS OF RECOMBINATION AND PROGENY TYPES FOR TESTS

The progeny type to be used will depend on the reproductive system of the plant. Broadly speaking, plants can be divided into vegetative, self-pollinated and cross-pollinated and will be discussed in that order. We leave the most common and interesting cross-pollinated type to the last, so that it leads into a description of our breeding program with smooth brome for high altitudes.

Vegetative. A few species can be multiplied and established by sprigging, sodding, and budding, (e.g., reed canarygrass from stems disked into drainage channels; ornamental and fruit-bearing shrubs). Some grasses like Kentucky bluegrass have seeds which copy the type of the mother plant exactly. In vegetative propagation the considerations are:

1. Only need one superior plant and it is a new variety.
2. Have to test thousands of introductions and possible crosses to find a few superior clones (mother plants).
3. If sprigging will work on critical high-altitude areas, may be able to dispense with seed production, but will still need nursery to raise the stock and lots of hand work for the planting if on uneven ground. (Machinery is available for sprigging farm land).

Self-pollinated species (Pure lines). Plant is naturally self-pollinating and exists in the form of hundreds or thousands of individually distinct varieties as in wheat. Another example of a pure line is slender wheatgrass (*Agropyron trachycaulum*), a cool season bunchgrass. This was the first native grass widely used for reseeding in western Canada and the United States. The alkali tolerant 'Primar' strain was bred at Pullman, Washington, by selection from Montana seed. Once a cross has been made between chosen parents some five to ten generations are needed for purification and testing of the progeny lines, but somewhere along this series a single plant will give rise to a whole new variety. Every test which compares a number of progeny rows can serve as the seed source for the lines chosen as superior. In any generation several desirable lines can be harvested as a bulk and constitute breeders seed of a new variety.

Cross-pollinated species. The main difference between a hybrid, a synthetic variety, and a variety produced by mass selection is in the number of components put together in the final product and the carefulness of their evaluation as to genetic value. Their use also depends on the ease of controlling the pollination.

Hybrids are made from two to four parents, each selected for general value as well as for the individual "specific" combination. (The best examples in crops are corn and sorghum.)

Synthetics are usually made of 5 to 25 parents, each tested for their general genetic value by some kind of a progeny test, usually a cross to all the other selected and some unselected parents, these parents being only a small proportion of the total source material. (See Fig. 1 for the scheme.)

Mass selection involves keeping seed of 10 to 70 per cent of the total source material, retaining certain favorable traits and culling unfavorable ones as displayed on the plants in the nursery. No attempt is made to test the progeny of every individual plant kept, but rather the seed of all selected plants is bulked; or sometimes the plants are left free to pollinate each other while the rejected plants are cut back before flowering.

It can be seen that the exactness of the procedure depends on the time available and the amount of effort put into keeping and testing individual progenies. Many grass and legume forage varieties have been bred by one of these procedures. Parent plants saved for future use can be propagated in rows for the production of seed for testing and as breeders' seed. One important difference from the "hybrid-corn" system is that a selected strain can be multiplied over three or four generations without losing its essential qualities. It can also serve as the start of another cycle of selection which could involve more rigorous selection or progeny testing for a different set of characters.

An example of a variety produced by mass selection is 'Manchar' smooth brome (which is being further improved for use at the high altitude sites). A description of its history follows:

'Manchar'--selected at Plant Materials Center, SCS, Pullman, Washington. Original introduction in 1935 from an experiment station in Manchuria as P.I. 109812. Grown in SCS nurseries from 1935 to 1943 and was mass-selected and included in strain tests from 1937 to 1943. Selection was for intermediate spreading rhizomes, maintaining good balance with associated legumes, good yields of seed and forage, heavier seed than common smooth brome, and seedling vigor. Released by agricultural experiment stations of Idaho and Washington and SCS in 1943 and given the name 'Manchar' in 1946 as a registered variety of *Bromus inermis* (Hanson, 1972).

Breeding Smooth Brome at Climax and Fort Collins. In plantings by Dr. William Berg at Climax in 1969, 'Manchar' was outstanding in vigor and survival; and it was considered worthwhile by the author to capitalize on its general adaptation to see what further improvement could be made and whether three other bromegrasses of intermediate or northern type might also offer germplasm of value. The other varieties tested were: 'Sac', a Wisconsin second-cycle synthetic based on 81 clones with growth similar to southern strains but northern seed quality; 'Saratoga', a New York synthetic based on 5 clones of superior type selected for seedling vigor and quick spring and aftermath growth; 'Polar', an Alaskan type derived from intercrossing among northern smooth brome and plants

SOURCE NURSERY

Several thousand plants are assembled from many sources. Superior plants may be inbred one or more generations to fix desirable characters.

CLONAL LINES

Established from 200 to 400 superior plants.

POLYCROSS

Twenty-five to fifty superior clones are grown in an isolated nursery and random cross-pollination between clones permitted. Seed is harvested and bulked by clones.

POLYCROSS PROGENY TEST

Seed from polycross grown in performance tests. Clones are evaluated on basis of polycross progeny performance.

ESTABLISHING SYNTHETIC

On the basis of the polycross progeny performance, 4 to 10 of the original clones are selected to establish a synthetic. Clones are isolated and random interpollination is permitted.

INCREASING SEED OF NEW SYNTHETIC

Equal quantities of seed are harvested from each clone and bulked to grow synthetic 1 generation. Open-pollinated seed is harvested to grow synthetic 2 and succeeding generations of new variety.

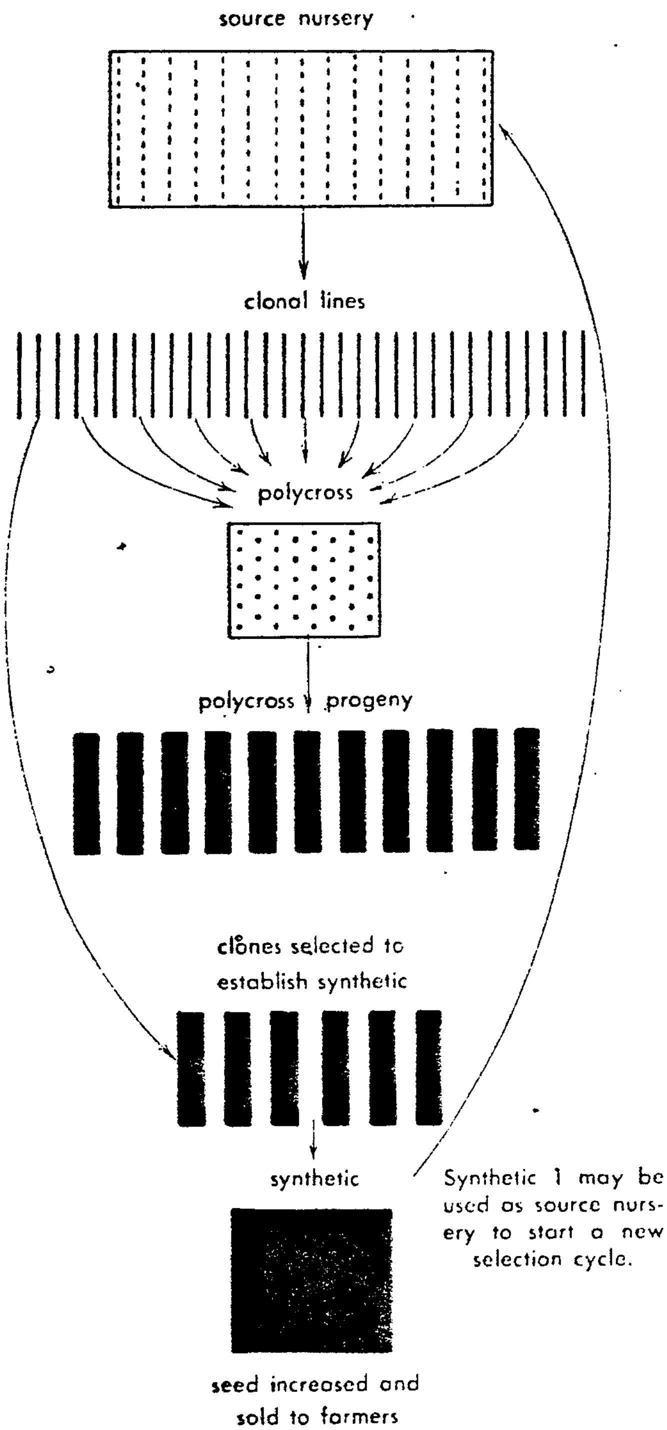

Fig. 1. Simplified procedure for development of a multiplant synthetic (Poehlman, 1959).

of a species native to Alaska (and the Rockies), *Bromus pumpellianus* (sent by L. J. Klebesadel of Alaska Experiment Station). Our procedure follows:

Nursery establishment. Seeds sown in plant bands in sterilized soil in the greenhouse in spring 1970, one seed in each 2" x 2" asbestos-paper plant band. Plants transported to Climax, Colorado, 11,300 feet above sea level and planted into a disturbed forest soil near timberline and adjacent to the tailings pond of American Metals Climax. Spaced plants were established at two-foot spacing (a total of 480 plants of each of the four sources) in June 1970.

Nursery management and observations. The plot was fertilized with 12-12-12 at the rate of 800 pounds per acre in the spring of 1970. There is continuous snow cover on the plots for over 200 days per year. Survival and vigor notes were made in July 1971 and June 1972. At the latter date the desirable plants were divided and a piece of each of 40 clones from 'Manchar', 9 from 'Sac', and 30 from 'Polar' was transplanted to the Agronomy Research Center at Fort Collins.

Seed production and clonal evaluation. A few seed heads were formed at Fort Collins in the fall of 1972, but the main seed harvest and notes on clonal characteristics were made in the summer of 1973. Cleaned seed of individual plants were weighed and stored to await progeny seeding trials in the late spring of 1974, the earliest practicable time.

Establishment of rhizomatous crossing block. On April 13, 1973, we examined the 79 plants for spreading tendency, and the nine plants with the most rhizomes were divided to give three pieces of each clone for establishment of three contiguous replications of a nine-clone crossing block (Fig. 2). The isolation produces polycross progenies which can be evaluated and composited as necessary to make a first-cycle rhizomatous synthetic with probably five to nine parents. In 1974 one or more clones may be cut out of the recombination process before flowering for reasons of less-than ideal spreading capacity or poor seed production as measured by 1973 seed yield.

Other crossing blocks. Based on 1973 and 1974 observations of the clones in the 79-plant nursery, other recombinations of characters may be set up as appropriate. One obvious possibility, for example, is to assess seedling vigor of the 79 seed lots and set up a crossing block with the top vigor-expressing parent clones.

Smooth Brome Recombination for Spreading Habit								
2	4	7	24	42	57	7	41	42
24	39	41	2	39	45	4	57	24
42	45	57	4	7	41	45	39	2

Origin	Clone	Date of Flower (June 1973)	gm. Seed
'Manchar'	2	13 - 30	12
	4	12 - 31	7
	7	12 - 29	14
	24	10 - 28	9
	39	13 - 30	4
'Sac'	41	18 - 30	3
	42	13 - 28	6
	45	21 - 30+	10
'Polar'	57	19 - 30+	13

Fig. 1. Plot layout and some results of a 9-clone smooth brome recombination block.

EVALUATION METHODS

Whatever the breeding system used, the plant materials have to be constantly and accurately evaluated. At the least, every item has to be planted in two or three replications at two or more locations and in two or more different years (because seasonal conditions affecting establishment differ from year to year).

The method of planting will vary with the objective. If winter hardiness is to be evaluated, clonal pieces or transplanted seedlings may serve; but if persistence of seedlings under natural conditions in a problem area is the goal, seedling progenies must be evaluated under those conditions. On the other hand, seedling vigor in low-pH media can probably be better tested in greenhouse studies during winter when field work is impossible. The quantity of seed available may govern the type and size of field plot. For small amounts of a large number of selections (ecotypes, progenies, etc.) short rows may be best; but when the screening has narrowed the choice, larger broadcast or machine-planted plots will be needed to duplicate field practices.

Observations needed will range from estimates of vigor or spread to measurements of height and even to weighing the clipped growth from a measured area. Seed-size measurements may be expected to correlate with seedling vigor and ability to emerge from deeper plantings where they are less liable to dry out.

The intensity of selection will vary with the size of the source nursery and the breeding system (the latter determines the number of parent plants needed for a new strain, as already stated). Mass selection may eliminate only 1/4 to 1/2 of the sources or may be used to select the best 10 per cent. If the number of progenies to be tested exceed 100, the field plots will take a lot of work; so it is suggested that selection for plant and seed characters displayed in the source nursery be made to limit the number put into field trials. A simple but efficient type of mass selection in the field by "feeling" the seed spikes for seed fill in intermediate wheatgrass was used in Saskatchewan to choos 50 parents in each cycle from 1,000 plants, i.e., the best 5 per cent (Knowles, 1971). Pieces of the 50 plants were dug and grown in the greenhouse for mass-cross pollination. After five successive cycles the seed yield was 185 per cent of the parent variety.

Simplicity of evaluation should not, however, lead us to lose sight of the need to test material in the problem areas. We expect to test progenies of the selected smooth brome plants from Climax, currently growing in the Fort Collins nursery, as seeded rows on the disturbed soils at Climax and as seeded rows in the Mountain Meadow Research Center at Gunnison (8,000 feet). If there is an advance possible in forage productivity at Gunnison, it will be a spin-off from the original research; we do not expect to make one selection do the double job of erosion control and forage production.

IMPROVEMENT IN SEED PRODUCTION

When breeding cereals and feed grains, the seed is the crop. In forages the leafiness and regrowth characteristics of the plant are more important than its seed production. Some strains of grasses may be good seed producers but mediocre forage plants or vice versa. In the field of erosion-control plants, the present situation is that not many are commercially available, let alone as improved (selected or bred) varieties. If we are going to breed plants for their ability to grow and tie down the soil then we as breeders have also to make sure that the stocks can be multiplied, and preferably as a private enterpise by farmers who know how to raise seed crops, harvest, and clean the seed so that it is true to varietal type and free from other contaminants. We have a number of such growers in both the western and eastern slopes of Colorado, where there are climatic advantages for such specialized agriculture. We also have, as do other states, a Seed Growers Association and an Official Seed Certifying Agency. It will take the cooperation of breeder, agronomist (and horticulturist for some plants) to determine the best way of growing the crop for seed production. In grasses this is normally in rows three feet apart which can be cultivated to remove weeds and volunteer seedlings so that the seed harvested is only one generation removed from that planted in the field. The breeder should test his new synthetic variety or line for its seed productivity as a trait in its own right. He may even need to test for this in individual progenies before deciding which parents to use for the final synthetic product.

As a geneticist, the breeder may also need to advise on the problems in seed production on native plants, whether they are selected or merely being propagated en masse. Sterility is frequently a problem in native perennials, but there may or may not be genetic solutions.

RELEASE AND MULTIPLICATION

The final product of the plant breeder's art must be available in quality and quantity to the consumer; this is insured by a series of actions taken cooperatively:

Release by the originating state, federal agency, or in some cases by private industry. Release implies the adequate testing of a variety, including the promise that it will not change appreciably during multiplication.

Registration is a formality by which the details of origin, method of breeding, and improved characteristics are published by the Crop Science Society of America under an agreement with the USDA (see Hanson, 1972, for more details) and the variety is given a serial number for the record as well as a name, e.g., 'Manchar' smooth brome; 'Primar' slender wheatgrass, and 'Ladak' alfalfa.

CONCLUSION

In this paper I discussed the role of plant breeding in the improvement of supplies and quality of plant materials for revegetation, including details of work on smooth brome selected at Climax. Grasses have also been the plants most studied by the Soil Conservation Service, whose Plant Materials Center operations were described by Robert Lohmiller in his illustrated talk. For more details on grass breeding and utilization for multiple purposes, see the references by Hanson and Carnahan (1956), and Heath et al. (1973). Two other works dealing more generally with plant breeding are Briggs and Knowles (1967) and Poehlman (1959).

Little has been said about breeding of forbs and shrubs, but Townsend's paper in this report discusses some of the possibilities and problems with legumes at high altitudes, as well as in the great plains. Not much is known about breeding of native forbs and shrubs, but some information has recently been gathered in a symposium (McKell et al., 1972). Undoubtedly we shall need to see more work in this direction if we are to reach the goal of successful rehabilitation of disturbed areas.

BIBLIOGRAPHY

Briggs, F. N. and P. F. Knowles. 1967. Introduction to Plant Breeding. Reinhold Publ. Corp., New York. 426 p.

Department of Range Science, C.S.U. 1972. Seed Species for Colorado Rangelands. Colo. State. Univ. 5 p.

Hanson, A. A. 1972. Grass Varieties in the United States. U.S.D.A. Agriculture Handbook No. 170. Supt. of Documents, GPO.

Hanson, A. A. and H. L. Carnahan. 1956. Breeding Perennial Forage Grasse U.S.D.A. Technical Bulletin No. 1145. Supt. of Documents, GPO.

Heath, M. E., D. S. Metcalfe, and R. F. Barnes (eds.). 1973. Forages: The Science of Grassland Agriculture. Illus. Iowa State Univ. Press, Ames. 755 p.

McKell, C. M., J. R. Blaisdell, and J. R. Goodin (eds.). 1972. Wildland Shrubs, their Biology and Utilization. U.S.D.A. Forest Serv., Gen. Tech. Rept. INT-1. 494 p. (Obtainable from Intermountain Forest and Range Expt. Sta., Ogden, Utah 84401.)

Plummer, A. Perry, D. R. Christensen, and S. B. Monsen. 1968. Restoring Big-Game Range in Utah. Publ. 68-3, Utah Div. of Fish and Game. 183 p.

Poehlman, J. M. 1959. Breeding Field Crops, Ch. 17, Breeding Forage Crop Holt, Rinehart and Winston, Inc., New York. 353-386 pp.

REHABILITATION OF SURFACE MINED LAND

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Many task forces have evaluated rehabilitation of disturbed western lands as they relate to extraction of fossil fuels. In all cases, problems have arisen concerning the identification of rehabilitation standards and lease or reclamation specifications or procedures.

It is obvious that demand for fuels will result in pressures for extraction by all available methods. The extraction of fuel materials in the West by surface mining will perhaps equal or exceed 1.5 million acres. It has been recognized that the Federal Government may establish regulations which would prohibit surface mining on areas where environmental impact is critical or where rehabilitation by conventional means is doubtful. In the following discussion some definitions are necessary:

<u>Restoration</u> implies that the condition of the site before disturbance will be duplicated after mining.

<u>Reclamation</u> implies that the site is habitable by organisms that were originally present or others that approximate the original inhabitants.

<u>Rehabilitation</u> implies that the land will be returned to a form and productivity in conformity with a prior land use plan toward a balanced ecological state that does not contribute substantially to environmental deterioration and is consistant with aesthetic values.

ECOLOGICAL TYPES AND REHABILITATION POTENTIAL

Climate, especially rainfall, is to a large degree the determining factor in rehabilitation of disturbed land surfaces. It is responsible for what was present before land disturbance and will be responsible for what can be maintained there naturally after disturbance.

Vegetation types with a high potential for rehabilitation include the <u>subalpine</u> ecosystem, the <u>ponderosa pine</u> sites and the <u>mountain shrub</u> types which grow in altitudinal zones where precipitation is favorable for plant growth and where rather deep fertile soils have developed. Therefore, unless substrata of undesirable character are left exposed, the probability of satisfactory revegetation is high. This, of course, presumes that the best possible management methods will be used. In these higher elevation zones ecological stability could reasonably be expected within three to five years.

Vegetation types with moderate potential for rehabilitation include the entire foothill zone of the Rocky Mountain system. This broad type is highly variable, including valley basins and alluvial plains with intricate dissected drainage systems. The substrata are likewise highly variable. This poses a delicate reconstruction problem for favorable rehabilitation, with respect to handling substrata and topsoil. Precipitation is erratic and varies widely by seasons and among years. However, past history of rangeland seeding has shown that satisfactory results can be accomplished if the best known methodology is practiced. In some cases parts of the seeding process may have to be redone when unfavorable climatic conditions occur during the rehabilitation period. Most of this zone can be identified by the presence of big sagebrush as the dominant species. Steep slopes, south and west slopes and unsuitable substrata underlying the replaced topsoil can present unsurmountable problems.

Difficult areas where immediate reclamation is doubtful with present technology include the desert areas of the West which appear as broad valley basins or small local areas lying among low elevated relief of hills, ridges or mesas. These areas receive low annual precipitation, are often alkaline or sodic, and possess no A horizon. The topsoil may be unsuited in some cases as a plant growth medium for imposed cultural seeding procedures. In these desert areas natural regeneration of the dominant plant species occurs only every five to seven years, perhaps taking place only when two years with better than average precipitation occur in succession.

In any event the reestablished cover should not be expected to be more dense than the original and this can occur only through an implemented process of natural ecological succession. Experience shows that such a process requires from perhaps twenty to fifty years even when a parent seed source is close by and the disturbed areas are not extensive.

METHODS OF SEEDING SPOIL MATERIALS

It appears that revegetation studies on disturbed lands of the West have been conducted on most all major vegetation types but many seeding trials have been disappointing either because of the inherent harsh site conditions or because of poor and haphazard methodology. The use of the best techniques in every seeding project would increase the probability of receiving satisfactory results and in a shorter period of time.

Considerations for the application of best techniques in revegetation of disturbed landscapes in the West include: (1) replacing topsoil and then preparation of the seedbed which would involve grading to a moderate slope, terracing, pitting or constructing small basins, adding needed fertilizer and controlling weed competition; (2) using the proper planting procedure that provides for seed coverage by soil at the proper depth. Many people have thought that seed has magic powers to grow and establish vegetation on almost any site. Therefore they have simply thrown seed upon the bare ground without any planting technology. The planting method should include the best time or season to seed, and covering the seed with soil so as to increase seed germination and seedling survival; (3) selecting adapted species for planting on any particular site is paramount to the success or failure of all seeding projects. The selection should consider several life forms, at least grasses, forbs and shrubs. In like manner both introduced and native species might be included depending upon future uses to be made of the area; (4) adding irrigation water sparingly if needed during the seedling establishment period is desirable since erratic climatic conditions still remain the predominant factor determining success or failure on arid rangeland ecosystems of the West; and (5) management of the land area following planting, which involves controlling the destructive consumption of photosynthetic tissue of plants by rodents, rabbits, livestock and big game animals. In many cases fencing to exclude the herbivore population causing the problem is desirable.

REHABILITATION GUIDE LINES

Rehabilitation specifications by most state and federal laws are vague and contain numerous weasel words such as: reclaim to a balanced state, a stable condition, a similar or identical ecological expression, or a use as high or higher than before mining.

These terms are not well understood nor can they be objectively measured. It is therefore better to write out the procedures or rehabilitation practices that will be required to meet rehabilitation standards. Even then a stand or cover of vegetation of a certain nature must be obtained, otherwise, part of or the entire procedure must be redone.

Many lease specifications are going to require primarily native species. This presents a rather serious problem because there is no commercially available seed source for many native plants. Furthermore, the germination percentages of the seed from many native species are rather low and not suited to use in revegetation projects.

It is a general practice to recommend a mixture of species in order to obtain diversity of vegetation that supposedly will support a diversity of native animal life. If possible, specifications should require that all life forms of planted vegetation be included if the area supported a variety of life forms before. In other words if the area had trees, shrubs, forbs and grasses before disturbance, the same life forms should be reestablished after disturbance.

COMPONENTS TO BE CONSIDERED IN REHABILITATION

It is understood that all components of the ecosystem must be considered in the rehabilitation process. These are generally identified but no means are suggested for actually monitoring the success or failure of obtaining accepted standards for all the components.

Configuration of spoils: Very little is actually known about what constitutes an aesthetically pleasing rehabilitation project. Certainly it is most difficult to write these requirements into a rehabilitation lease agreement. With our present state of knowledge we are not going to please everybody and in many cases we may please very few.

Erosion and Runoff: In general terms "Stable condition" infers no loss of soil or water from the rehabilitated area. However, in some states it is actually unlawful to prevent normal runoff by impounding water, by means of water spreaders or contour furrows. Certainly all rehabilitation efforts should strive to minimize soil erosion and water runoff.

Plant and Animal Life: At this point in time, most people are content with the philosophy that diversity of plant cover which resembles the vegetation composition before mining will, by nature, provide for a diversity of animal life which will resemble what was there before the area was disturbed. Sometimes unknowledgeable people in charge of supervising rehabilitation procedures have been content to approve a rehabilitation project simply if the site is growing any plants that were initially planted, including domestic annual crops such as rye or barley. This may or may not satisfy their concept of a stable ecological expression of plant and animal life, but it shows little understanding of the real requirements.

SUMMARY

It is apparent that as much as 1.5 million acres of western lands may be disturbed by surface mining for the extraction of fossil fuels. Numerous task forces have made various evaluations with respect to the impact this may have upon our environment. It has been generally agreed that rehabilitation potential should be identified with climate, soil, and vegetation types.

The first approach to this has identified soil-plant response units with areas that have a high potential, a moderate potential or those that will be difficult to rehabilitate even when all the better methods are used. These criteria are based upon the probability of complete rehabilitation when carried out with recommended methods. Difficult sites may have a low probability of success unless fertilizers and water are used, at least, for a period of time to complement natural plant succession.

It is important to formulate a preplan for rehabilitation that considers aesthetics, soil stability, and plant and animal establishment for every site that will be disturbed in the mining operation.

BIBLIOGRAPHY

Box, T. W. (Chairman). 1974. Rehabilitation potential of western coal lands. National Academy of Sciences. Ballinger Publishing Co., Cambridge, Mass.

CULTURAL PRACTICES FOR REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS

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Revegetation activities at Climax encounter a variety of adverse conditions and influences. The property is approximately 11,000 acres (of which 5,700 acres have a history of disturbance prior to 1969) located at an elevation range of 10,350 feet to over 13,500 feet. The growing season is approximately 60 days for cool season herbaceous species. Annual precipitation over a five-year period averaged 25 inches, with 74 per cent of this in the form of snow.

Soils on the property are relatively infertile and for the most part are derived from glacial till with isolated, scattered pockets of peat, and sand deposits. The soil is thin and spotty due to past disturbances and limited soil development in certain areas. Slopes and aspect are typical for high mountainous terrain.

Land disturbance in the Tenmile Mining District began in 1859 with the first gold prospectors and continues to the present (Emmons et al., 1927; Griswold, 1958). The various activities which have created surface disturbance include timbering, sheep grazing, mining, recreation, and construction of railroads, canals, trails, and highways (Eberhardt, 1969; Kindig et al., 1959).

Plantings of trees, shrubs, and grasses to determine survival and growth began in 1955. Formal research for reclamation started with a Climax grant to Colorado State University in 1964 for work on vegetative stabilization of tailings. Grass species adaptability plots on disturbed soil were initiated in 1969 by Dr. W. A. Berg, Colorado State University, and observations have been continued to the present.

An overall reclamation plan for the Climax property was developed to fulfill requirements of the 1969 Colorado Mined Land Reclamation Law. The plan, written in reclamation phases, covers the period of time from now past the eventual closing of the mine (Climax Mo. Co., 1972).

A computerized land inventory system was developed to describe by ten-acre parcels the past use and shows what reclamation, if any, is needed, along with projected costs. As each parcel receives treatment, this is recorded in the computer.

GRASS ESTABLISHMENT

Over twenty species of grasses have been seeded in plots at Climax. From the results of these plots the following grass mixture was derived for seeding in disturbed subalpine areas:

Species	Percent	Species	Percent
Hard Fescue	10	Smooth Brome ('Manchar')	20
White Dutch Clover	10	Timothy	15
Orchardgrass	10	Redtop	15
Meadow Foxtail	10	Red Fescue	10

The above mixture is applied at thirty pounds per acre, with five to ten pounds of 'Balbo' rye as a nurse crop.

Several seeding methods in addition to hydroseeding are used in June and early October. If the site is relatively flat, fertilizer and seed are broadcast and the area is disked lightly. For rougher terrain a Helix five-bushel, P.T.O., three point, single spinner seeder is used to spread both seed and fertilizer. As each application is made, a length of chain link fence is pulled by the tractor to mix fertilizer and soil, and to cover seed. A Brillion grass drill was tried, but due to the variability of seed size in the mix a drill was not practical. Steep terrain not adjacent to flat ground is planted by hand, using cyclone seeders.

Hydroseeding is used on slopes adjacent to areas which are flat and firm enough on which to operate a truck carrying a 1,500 gallon Bowie Hydroseeder. At the present time, the hydroseeding mixture contains 400 pounds of wood fiber, 100 pounds of 12-12-12 fertilizer, 10 pounds of seed mix, 5 pounds of native seed (when available), and 3.5 pounds of 'Balbo' rye. This mixture covers one-third of an acre. During the past summer, a chemical was used experimentally in place of fiber to stabilize seed placement. This placement chemical covered one acre per load. Evaluation of the material will be made in 1974.

Hydroseeding is done primarily on slopes, as other seeding techniques are cheaper where the terrain is compatible to such practices. Hydroseeding on slopes where a seedbed can be prepared in advance has been very successful. When hydroseeding slopes on which a seedbed cannot be prepared in advance, several application may have to be made in consecutive years. Hydroseeding is done during June, July and again after freezing in September.

Soils derived from glacial till have a tendency to crust. Formation of this crust prevents seed-soil contact when hydroseeding, preventing rooting and reducing the chances of a successful planting. Whenever possible, a long chain-like piece of equipment with spikes (called a Klodbuster*) is drawn along the face of the slope and effectively breaks up the crust. The Klodbuster also puts a more finished look on the slope. Hydroseeding is done immediately after the Klodbuster treatment and success is comparable to any other dressed area.

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*Manufactured by Finn Equipment Co., Cincinnati, Ohio.

Native seed has been collected with a rotary lawn mower with a mounted bag collector. The seed is mixed in the hydroseeder to increase the rate of encroachment by native species. This practice is too new to be evaluated. In one area, after ten years, native grasses and forbs from natural succession constitute approximately 50 per cent of the ground cover.

REFORESTATION

The most successful species used to date in reforestation are Englemann spruce, lodgepole pine, aspen, prostrate juniper, and shrubby cinquefoil. Blue spruce, Douglas fir, narrow-leafed cottonwood, balsam poplar, and Hansen rose proved not hardy enough for the Climax elevation.

Tree planting begins early in June and is completed that month. Spruce and pine are potted stock purchased from the Colorado State Forest Service nursery. The aspen are crosses of quaking aspen from Canada, Northern United States, and Sweden made at the Institute of Paper Chemistry in Appleton, Wisconsin. The above species are shipped to Climax while still dormant and stored until planting. The cinquefoil and juniper are purchased in the summer from a commercial grower in Golden and used for landscaping purposes.

The technique for planting is the same in all cases. Seedlings are planted on a ten by ten foot spacing, although care is taken to prevent straight lines. Wooden shingles are placed on the sides exposed to sun and wind. Mortality on spruce and pine is about 20 per cent, whereas aspen has a 3 per cent mortality. Native types of aspen would be preferred and a source needs to be developed.

Two to five feet tall spruce and pine have been balled and burlapped and transplanted for landscaping purposes. Mortality was six trees out of two hundred and twenty moved. Trees grown in the open and removed before breaking dormancy are the most adaptable to this transplanting method.

In the spring of 1974, willow cuttings from native stands are to be rooted in the Climax greenhouse constructed in 1973. The willows will be used for revegetation of an aggregate pit and other disturbed sites.

FERTILIZER

Local soils are relatively infertile, especially when disturbance has made it necessary to vegetate soil exposed below the original "A" horizon. Nutrient experiments have continued in conjunction with vegetative experiments and will continue until satisfactory mixtures and application rates are determined.

Macronutrients were of course first on the list. Two hundred pounds per acre of 12-12-12 has been the initial application when seeding. Soil analyses indicate the need for more phosphorus, so different percentages will be tried in the future. After several growing seasons, a maintenance application of 60 pounds per acre of nitrogen is needed. Micronutrients so far have been confined to research on vegetation establishment on abandoned tailing ponds.

For the past three years urea-formaldehyde was used both as 38-0-0 and mixed as 13-15-20. In 1973 ammonium nitrate 33-0-0 was applied on plots adjacent to the urea-formaldehyde plots. The results indicated that not enough nitrogen is released from the urea-formaldehyde to meet plant requirements. Soil temperatures are low, and either the population of soil bacteria is low or not active enough (or a combination of both), but the result is not enough available nitrogen. Ammonium nitrate will be used as a top dressing and a mixture of 11-15-20, with nitrogen supplied as ammonium nitrate, will be used when seeding.

Fertilizer as a top dressing is applied in June, July, late September, or October. Past applications have been too low, so 60 pounds per acre of available nitrogen will be the starting level in 1974.

Nutrient maintenance programs are imperative to maintain a stand of vegetation on exposed subsoils. The initial costs of vegetative establishment are high and for a small per-acre expenditure, the established cover can be maintained. Climax's maintenance program is directed to top-dressing fertilizer not less than every other year until an "A" horizon is reestablished, or until the stand has shown the ability to maintain adequate ground cover to control erosion without further nitrogen fertilization.

EQUIPMENT

Terrain, weather, high altitude, and ground conditions dictate the type of equipment used. The loss of power on non-supercharged engines at 11,000 feet is 33 per cent of the sea level rating. Supercharged engines lose 1 per cent at this elevation. Snow, bogs, tailing, and slopes all demand specialized or modified wheel or track components.

A Ford farm tractor is operated with dual wheels filled with saline solution to lower the center of gravity. High flotation C-47 aircraft tires were used successfully on a mulch spreader. Tracks without grouser bars have definite limitations on slopes, especially when wet.

Most of the equipment such as disks, seeders, spreaders, etc., are drawbar type hookups, so that any equipment available for the conditions can be used for pulling.

Mountainous terrain also creates some additional safety hazards for operators and crews. An accident prevention program becomes an important part of the revegetation endeavor.

BIBLIOGRAPHY

Butler, B. S., and J. W. Vanderwilt. 1933. The Climax Molybdenum Deposit Colorado. U. S. Department of the Interior, Bulletin 846-C.

Climax Molybdenum Company. 1972. Comprehensive plans for land reclamation and stabilization at the Climax Mine, Climax, Colorado. 48 p.

Eberhardt, P. 1969. Colorado Ghost Towns and Mining Camps. Swallow Press, Inc., Denver.

Emmons, S. F., J. D. Irving, and G. F. Laughlin. 1927. Geology and Ore Deposits of the Leadville Mining District. U.S.G.S. Professional Paper No. 148. 368 p.

Griswold, Don and Jean. 1958. Colorado Century of Cities. Smith-Brooks Printing Co., Denver.

Havens, R., and Karl C. Dean. 1969. Chemical Stabilization of the Uranium Tailings at Tuba City, Arizona. U. S. Department of the Interior, Bureau of Mines Report 7288.

Kindig, R. H., E. J. Haley and M. C. Poor. 1959. Pictorial Supplement to Denver, South Park & Pacific. Rocky Mountain Railroad Club, Denver.

King, O. A. 1959. Gray Gold. Big Mountain Press, Denver.

CULTURAL PROBLEMS AND APPROACHES IN A SKI AREA

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The Vail Ski Area is located in eastern Eagle County, Colorado. It is bounded geographically on the east by the Ten-Mile Range, the Gore Range bounds the north, and the Sawatch Range the southwest.

The Pennsylvanian-age Minturn formation constitutes bedrock beneath the entire ski area. This formation incorporates a thick sequence of interbedded shales, claystones, sandstones, and conglomerates, as well as a few cliff-forming limestones and dolomites. The strata dip generally northward although locally westward at angles of about 5 and occasionally to 15 degrees.

Sandstone and limestone outcrop in ridges and as rimrocks surmounting the bowls. However, for the most part, bedrock is blanketed by moraine, slope wash, and residual soils across the slopes of the ridges, and by stream-deposited alluvial soils along the bottom of the creeks. The soils derived from the sedimentary strata have a limited compositional range. For the most part, they are silty and clay sands, locally, cobbley and bouldery. Talus composed of angular blocks of sandstone apron the foot of several of the steep slopes within the topographic bowls but these have relatively small areal extent.

Since most of the revegetation work is necessary because of ski trail construction, let's look briefly at the anatomy of a ski trail.

SKI TRAILS

In the planning of a ski area, one of the major resource inventories was the mapping of skiability of the terrain. The terrain was classified either as eminently skiable, developable with special considerations, or marginal to unskiable. The eminently skiable terrain was characterized by a slope of between 15-60%. The terrain contained few surface rocks or rocks that were at potential trail locations were not important due to the probable deep snows. Terrain developable with special consideration had a slope of 10-15%, or greater than 60%, a skiable intermittent drainage, or perhaps there were large rocks, ledges, or benches. Marginal to unskiable terrain is either flat, cliffy, very rocky or sharp 'V' shaped gulleys.

The usual ski trails are about 1 mile in length and are chosen for the ability of the terrain to hold snow, provide interesting skiing, and for ease of construction. However, many trails that are predominantly eminently skiable have a section that must be recontoured due to rocks, ledges or benches. This is where revegetation comes into play at a ski area. Currently at Vail, about 1,500 acres of terrain are skied. Of this, 500 acres have been cleared from timbered slopes. The balance of the ski trails were either open mountain meadows or parks in timbered areas. In total, somewhere around 80 acres have been modified by bulldozers.

Consultants have provided us with several studies on soil erosion; however, these studies have not been valuable to the guys doing the work on the hill. We do know that the steeper the ski trail the greater the potential for erosion. Also, the thinner the top soil the greater the potential for erosion.

As ski area operators, we have a great deal of interest in the revegetation of disturbed areas. First, our business is to sell a quality ski experience. However, if the constructed trails quickly erode, this causes a significant quality decrease in skiing. Much of the ski area's annual revenue comes at the Thanksgiving, Christmas and New Year holidays. The snow cover is usually sparse in the early season, no one wants to ski rocks with their Christmas present. Furthermore, the guests staying at Vail expect a quality environment in summer as well as winter. Finally, we are a very highly visible industry and the quality of the local environment is closely watched by local people and governmental agencies. Finally, the staff that plans, designs and constructs ski trails at Vail has been at Vail in the neighborhood of 10-13 years and we frankly like our mountain.

Since the research, technical, and assorted test tube rattler point of view has been well represented at this workshop, I will not go into any great detail into soil tests, seedplots and the like. At Vail, we had the opportunity to try new approaches, hence I will dig into the nuts and bolts aspects of revegetation. The uniqueness of some of our approaches has to do with the fact that we are four-season farmers; that is, that we are on the hill literally every day of the year.

ECOSYSTEMS

To give you some insight into the ecosystems and climate at Vail, we ski on literally all slope exposures. The Vail Ski area is unique in that much of the skiable terrain is untimbered generally south-facing slopes with native grasses and forbs. These same bowls have scattered spruce/fir at the top and aspen/lodgepole stands in the lower drainage courses. The north slopes of the ski area tributary to Gore Creek are either spruce/fir, lodgepole pine, or Aspen/evergreen slopes. The annual precipitation is around 30 inches. The October through April precipitation averages at 21 inches. At higher elevations, the April 1st snowpack averages 78 inches.

Most of the slope modification by bulldozer has been done on the timbered north slopes. The soil here has moderate to high inherent fertility, and being on the north slopes tends to hold summer and fall moisture very well. We have found that revegetation on south and southwest facing slopes is much more difficult, apparently because the soil dries much more easily due to the effects of sun and wind.

DRAINAGE

Because of the steep slopes and the rapid runoff in the springtime, drainage is the most important aspect when planning for revegetation of a ski trail. On a mountain that does not receive any ski traffic, the snow line merely creeps up the slope in the spring. This is not true in an intensively utilized alpine ski area as the intensive skiing develops moguls. These are mounds of snow piled up by the skiers. The skiers tend to turn at about the same rhythm and a uniformaly distributed mogul field develops. These piles of snow can become quite large by the spring of the year. During the runoff, the troughs of the moguls melt off first, exposing the soil and its vegetative cover. The remaining piles of ice presents an island of resistance to water rapidly running downslope, hence the rilling and eroding is greatly decreased. Furthermore, the same ski action that creates moguls tends to push the snow downhill. As a result, intensively used ski slopes greater than 40% retain very little of the annual snowfall. Hence, the most critical slope angles for runoff on the ski trail is from 35-15%. Incidentally, the most popular ski trails are also about 35-15% slope.

During the winter by the use of skis, shovels and snow vehicles, considerable maintenance and snow movement is done to provide a better ski surface. The object of much of the maintenance is flattening the moguls. In the last 30 or 40 days of the ski season, we let the moguls grow on trails where we suspect runoff erosion problems. Then after the closing of the ski season, snow roads are dozed across the slope. These roads approximate the location of the water bars built into the trail. This is normally done for 2 or 3 seasons. We found that this procedure gives us a great deal of protection against erosion. It is difficult to pin down the exact reasons why this helps; however, the windrow of snow indubitably provides barrier to the runoff much earlier, and finally the existing vegetation has a much longer growing season. On this last point, it is very easy to see for a week or two after the snow has left, the stips of green across the trail where the snowbars had been dozed.

We also assign a crew to spring "irrigation". The responsibility of this crew is to manually unplug waterbars, culverts and borrow ditches as the snow melts. The irrigating work is required only from noon until slightly before dark. We do have a 2-5 day period in the area of melting when the ground is saturated and literally covered with sheets of water.

PARABOLIC WATERBARS

The most important consideration in the design of waterbars is the location of discharge points so that the water will dissipate before it can cause problems on the new construction, adjacent trails or construction sites. Obviously, the most difficult problem in the design of waterbars is protecting ski trails that are either dished or gulley forms; that is, the waterbars must be carried hundreds of feet away from the trail edge before the water is adequately dispersed. I feel the spacing of waterbars should be governed by the reasonable places to discharge water versus any particular calculation of rainfall intensity and slope. The usual ski trail is from 100-300 feet wide and on this basis, we lay our waterbars out at intervals of 60-200 feet, depending on the terrain and opportunities for the discharge of the water. Most waterbar spacing, however, is in the magnitude of 80 - 120 feet. If we did not provide the spring irrigation program, I would anticipate that waterbar spacing would be closer to those values given suggested by the U.S. Forest Service.

We found that the accepted design of a waterbar at 1 to 4% slope does not work on a ski trail. Mulch used in revegetation can dam and cause the bar to breech. These bars also failed because snow compaction creates a rather dense snow which in places can actually be ice. Therefore, it is possible for the ice to dam a waterbar. We found that somewhat steeper waterbars gave us a required margin for error on construction. The best profile for a waterbar appears to be one of ever increasing slope. The idea being that once sticks, rocks or mulch enter the bar, the debris will keep moving. As a practical matter, the high end of our waterbars start at about 2%. The discharges of the bar are in the magnitude of 10-16%. You may be concerned however, that waterbars of this steepness would cause a lot of erosion; it's true that sediment will move through these waterbars. However, we feel that it is better for some erosion in the waterbar compared to the breeching of the waterbar and the serious rilling that would result on a 30% slope. Furthermore, the soils in our ski area contain much cobble and angular rock. Slight erosion exposes this material and the waterbar tends to become self arming. Also, if you are prudent with the location of the discharge points, most of the silt will be caught in the vegetation, needles, and limbs on the forest floor. I would not recommend this waterbar design on disturbed slopes any wider than 300 feet.

The waterbar should always be designed and field staked by someone very familiar with the spring runoff and the topography of the entire ski area. The grade stakes should be on about 25 foot stations. Small bulldozers such as a John Deere 450 with an angle blade can be used for the rough construction of a waterbar if the terrain is not too rocky and if the slope inclination is less than 35%. The idea with the dozer is not to build a road across the trail; if this road were built, the changes in terrain would create very unskiable bumps that are susceptible to losing their snow cover. Instead, the dozer operator should set the cat sideways on the slope and then angle his blade downward at the downward track. The blade need penetrate the soil only 4-6 inches, if the operator has a good eye for grade. If the dozer operator hits a rock with the corner of his blade, he must back up, pick up the blade and cross over the rock. If he tries to remove the rock he will probably lose his grade and possibly tip the cat over. The finishing of the waterbar is a handwork proposition and the rocks that are left by the dozer must be manually blasted. The cross section of the waterbar should be trapezoidal with the bottom of the bar one shovel wide and at least four inches deep.

On the steeper trails we also use the pick and shovel method. This is reasonably easy for the ski area to do because of the abundance of young people wishing to "work on the mountain for a while". The staking out is the same as for the dozer method. A 15-man crew is used. The supervisor should be familiar with the use of an abney level and have a good eye for grade. A man should be with the crew who is experienced in the use of dynamite for rock removal. We have found that the maintenance of a uniform grade is more difficult with the pick-and-shovel method than the dozer method. On extremely steep slopes, that is slopes greater than 60%, there is a hazard that the waterbar cutbank when saturated with the spring runoff will slough into the waterbar and dam it. The correction of these situations is a prime function of the runoff irrigating crew. It is most important that the pick-and-shovel crew do not bury big rocks on the fillside of the waterbar. Rather, they should be carried out to the woods. We further instruct the pick-and shovel crew to walk on the fill bank of the waterbar to provide compaction of the fill section.

REVEGETATION

Over the last three construction seasons, we have been reasonably successful in the revegetation of the ski slopes up to angles of 1 1/2:1. This corresponds to the slope percentage of 67% which is about as steep as a ski trail should be. Fertile soil, north exposure and short slopes, such as road banks, as steep as 1 1/4:1 (equivalent to 80% slope) have a good chance for successful revegetation. On slopes as steep as 1:1, it is probable that the top soil, vegetation and all will slump off during the saturation period in the springtime.

The revegetation work is done with a 20-man crew and basically with hand tools. The crew must be supported by a large truck or helicopter for the delivery of materials. Here the critical element is starting the revegetation immediately after the final grading operation. The maximum size of the area to be revegetated should probably not exceed 4 or 5 acres. It is my feeling that two days after the final grading operation may be too late. The important factor is fertilizing, seeding and raking while the soil is still somewhat moist and quite fluffy.

After the final grading, we first spread fertilizer with a cyclone seeder; another man follows, broadcasting the seed mixture with the cyclone seeder; and the balance of the crew follow raking the rocks off of the surface. The majority of the larger rock is then handpicked and removed to the edges of the trail. The next operation is the mulching from top to bottom. Usually wheat straw is applied at the rate of about 2 tons per acre. The only disadvantage to wheat straw is that it is somewhat susceptible to blowing off for the first week or so after application. We have tried using locally-produced hay with well-developed seed heads. However, this material is much more difficult to spread uniformly. This cohesiveness, however, could probably be used to good advantage in windy locations. If the crew is large enough, this revegetation technique goes reasonably fast and will give you good protection against most sudden rain storms. Assuming reasonable proximity of roads the technique we have just discussed will have a unit cost of $300 per acre for labor and materials.

Sometimes due to the lack of precipitation, slash piles are not burned at the time that the revegetation operation is begun. When the slash piles are ultimately burned, it takes a great deal of effort to keep the fire out of the mulch. In several instances, we have simply restrawed and the germination of the grasses seemed about normal after the straw fire.

Next, the waterbars are laid out and staked. We do not attempt the immediate construction of waterbars. It is most probable that the waterbar will not be needed until the spring runoff.

SEEDS AND FERTILIZATION

The following table gives those mixtures of seeds used for the 1973 construction season on Vail mountain.

SEED RECOMMENDED FOR VAIL MOUNTAIN (1973)

Below 10,000 feet elevation	Above 10,000 feet elevation
20% Smooth Brome (Manchar)	20% Smooth Brome (Manchar)
20% Intermediate Wheatgrass	20% Slender Wheatgrass
15% Orchard Grass	15% Timothy
15% Bluegrass	15% Bluegrass
15% Clover (Alsike or White)	15% Meadow Foxtail
15% Winter Wheat	15% Perennial Ryegrass

In the summer of 1973, I made many qualitative inventories of the grasses on trails constructed from 1962 to 1972. The grass mixtures used in former years were not well documented as to area of application. However, it was obvious in walking over the mountain that the predominant grasses were brome, orchard grass and perennial rye. I am sure that bluegrass has been a component of all mixtures; however, you could walk for several hours across Vail mountain without finding a clump of bluegrass. Clover in the mixtures may or may not work well and the reason behind the success or failure of the clover to grow is not understood.

The winter wheat appears to be an excellent companion crop at all elevations. The first year it gives us a quick cover of green and the succeeding spring it comes on very strong behind the snowmelt. It has occurred to me that perhaps one additional seed should be looked at in our mixture and that would be a lowly dandelion. This plant seems to grow at all elevations, all aspects and in very harsh or infertile sites.

In the summer of 1969, we experimented with the aerial application of fertilizer. The south frontage road of I-70 adjacent to the golf course was used as a landing strip and the process was very exciting because of the tree-level flights of the fixed-wing aircraft but was probably a waste of money. The soil on our mountain is reasonably fertile and the only problem we have with maintenance fertilization is where there is little or no top-soil left. The other 95 percent of the trail has sufficient top-soil and maintenance fertilization is not particularly necessary. It is better to send an experienced crew chief with cyclone seeders for the spring application of maintenance nitrogen in those areas where the top soil is thin and the crop is not vigorous.

CONCLUSION

In conclusion, if our ski slope is not too steep for skiing, it can be successfully revegetated. The most critical aspect is the time urgency of the application of seed, fertilizer and mulch after the final grading operation. Finally, the slope must be guarded against spring runoff by a series of parabolic profile waterbars. The waterbars are most critical on slope angles from 35 to 15%. In an intensively used alpine ski area, spring will find little snow left on slopes in excess of 40%.

ECOLOGICAL PROBLEMS IN THE REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS: HIGHWAYS

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The highway presents specialized problems in ecosystem management because of the diversity of ecosystems through which it passes and because of the extent of disturbance caused by construction. The relationship between vegetation and roadway construction in high-altitude areas encompasses the majority of the types of problems that are encountered in any revegetation project because of the diversity and sensitivity of the plant communities. These include problems of adjusting construction practices to consider vegetation and landscapes. We can speak about these in terms of applied ecology. A good place to start is by comparing what we know with what we do not know.

We know that it is a good idea to conserve as much variety as possible; variety is more comfortable esthetically and there is an ecological security in numbers.

We also know enough about ecosystems to be able to measure their changes and to be able to predict their direction of change, and even to influence it.

We know that vegetation at high altitudes functions by an assortment of specialized adaptations which are realized in the ability of vegetation to tolerate and exploit the alpine and subalpine environment. The effects of climate and geomorphic process are unique as well, causing the nature of changes and balances in vegetation to differ significantly from vegetation at lower elevations. Illustrating these things are extreme diurnal variations in temperature; unstable soil conditions; great diversity in micro-environmental conditions; specialized growth forms such as extensive root development, underground storage organs, low, tufted growth form, preformed over-wintering buds, physiological adaptations, including the ability to photosynthesize at low temperatures, seed dormancy at low temperature, high daily nutrient production, drought resistance (especially protection in winter from frozen soils and dry winds), cold resistance, flower buds preformed the year before actual flowering, vegetative reproduction, high light saturation values in photosynthesis, rapid growth during favorable periods, successional events that are often marked by changes in dominance rather than by compositional changes, soil formation processes that include frost action phenomena, bacteria-deficient soils that are often quite low in fertility (nitrogen and phosphorus are limiting in cold soils); and climax conditions that are controlled by a balance between vegetation and cyclic disturbance (Bliss, 1962; Billings and Mooney, 1968).

The replacement of natural vegetation must provide the necessary cover to prevent erosion and to produce an esthetic appeal. The replacement of vegetation must also be built upon an ecological framework. The framework must be made up of an understanding of the function of the system so that we may aim at really restoring the vegetation we have removed and the environment we have altered. We know that restoration is a composite of form and function, and neither of these alone. We know that our putting back must involve a knowledge of productivity, stratification, gene-flow, soil-plant relationships, dominance, environmental gradients, niches, foodchains, diversity, mineral cycles, the relationship of foreign bodies (like concrete and asphalt) to vegetation, the effect of altered microclimate, slope, exposure, hydrological factors, physical factors, and the relationship of these factors to vegetation trends and patterns.

We know that replacing the conditions and composition of high-altitude plant communities takes additional knowledge and special practices and considerations. The special practices and considerations are much of what we do not know or do.

In attempting to develop a revegetation program that will satisfy the conditions of conserving the environment where it is being used for highways, there are more questions than there are answers. Here are some of the questions that need answers:

1. Are sources of native seed available for high-altitude revegetation projects? Can sources be developed, for instance, for seed of *Deschampsia caespitosa* and *Poa alpina*? These grasses are recommended for their pioneering ability by Berg and Colbert (1972). If sources of native seed cannot be provided, what are the species that are now available for use at high altitudes whose functional role will not itself be an impact to adjacent vegetation or to invasion by natives? Information about exotic plants should include how the introduced species will interact with native vegetation and what kind of system can be expected to develop from the exotic plantings. Have any ecological studies been done on these artificial ecosystems? What diseases might be introduced? How will we influence competition structure when we disturb an area and then revegetate it, particularly when the replacements used are not an evolved part of the system? Is there a real possibility of using native hay for mulch in order to introduce a source of native seed?

2. Conserving natural vegetation means conserving the environment that it depends on. The diversity of the subalpine environment makes a consideration of environmental gradients highly important. What do we know about the recovery of these gradients? Can we assess the importance of primary (construction) and secondary (revegetation) impacts on these gradients? In construction new gradients will be created. Can we establish anything about these new gradients

and coordinate them with the vegetation we plant? How do changes in the water table and other hydrological factors affect successional patterns? What trigger factors might reside in topsoiling? Conversely, what factors are to be considered when planting on subsoils? What are the effects of maintenance, such as mowing, watering, and salt-laden snow on interrupting natural succession. How do we initiate a restoration of proper microclimate?

3. The act of reseeding an area is in itself an unnatural act in that the methods used can establish a community structure that is determined by machine rather than by competition. Drilling seed is an example. What are the phytosociological relationships set up by different seeding practices, and are these effects temporary or permanent, and what is the time lag likely to be? Questions need to be directed particularly at the relationship between seeding methods and the dynamics of the surface, such as soil erosion, wind stress, and soil-frost activity. In the subalpine and the alpine, cover, soil moisture, relief, and exposure have interrelated effects regarding the stability and fertility of the soil. We need information on methods and seed mixtures suited for restoring structure in the plant community. Also, in reference to plant sociology, should we include more forb species in seed mixtures? This brings up a larger question: can we make generalizations about whether or not to replace a majority of the plant community, or to replace the conditions for the plant community and limit planting to satisfying erosion control necessities?

4. Transplanting native vegetation into disturbed areas might be a real alternative to seeding. However, will transplanting satisfy the criterion of quick erosion control? What combination of transplanting and seeding can be used? What methods can be used to make transplanting a better technique? What kinds of vegetation are transplantable at high altitudes and what are the details? (See Marr's paper at this workshop.)

5. Baseline inventories are essential in establishing predictions of change in the environment that a project deals with. What should the criteria for these inventories be? Can we develop techniques that will enable us to make short-term determinations of vegetation dynamics? What are the best ways of cataloging the changes we are initiating so that we can compensate for them? What are the methods to be used to achieve protection for the diversity and fragility of high altitude ecosystems? How good are we at manipulating for a purpose?

These questions, and many others that have not been thought of here, require creative answers. The gauge of our competence and success is how well we deal with the changes that we are directly causing or initiating. The whole subject of revegetation is change. There is a real need for a marriage between horticulture and plant ecology so that we can create a conservation of function as well as of form. There is a real need for application of ideas and the generation of new ideas. Here is a study of succession in action. Revegetation is a process that goes beyond planting alone. Revegetation is vegetation planning. As such, it must deal with larger units of the landscape than just the impacted area (McCarg, 1967).

Planning vegetation on a disturbed site will be benefitted by developing a working model. For example, the restoration of plant communities in a mountainous area where a road is to be built will be primarily concerned with replacing vegetation on cut and fill slopes. The environment created by mechanical cutting and filling will be different from the original environment. This new environment will be altered in terms of ground water, surface drainage, soil, micro-climate and environmental gradients. If the replaced vegetation is to make a good fit with adjacent vegetation and the new environment, the principles inherent in the local environment will have to be used. This is the potential for a working systems model that can be developed on-site. Careful consideration of existing environmental characteristics will give valuable information about the range of environments that construction will create. Ecological inventories, together with models of the new and old environments, will provide a basis for intelligent and systematic planning for vegetation and its changes.

Some methods that might be applied in modeling revegetation programs include: gradient analysis models (Whittaker, 1967); the polygraph techniques of Hutchinson (1936, 1940); factorial approaches like those of Major (1951) and Jenny (1958); and computer models. Gradient analysis and polygraph techniques might be more applicable as easy-to-use field tools. The first involves analysis of environmental factors, species populations and community characteristics that change along lines drawn either in space or time. This method is highly applicable to the consideration of environments altered by construction practices and has the added advantage of combining well with other methods, including computer-generated similarity values and polygraph analysis. Hutchinson's polygraphs are a method of plotting many types of data on a circular graph in order to show the relationship of one type of information to another. This, in modified form, has been used in geomorphology (Benedict, 1970) and in ecology (Olgeirson, 1972). The method is very graphic, can be applied to a wide variety of data and data-gathering methods, and can indicate the presence of relationships that are not intuitively obvious from raw data.

A great deal of erosion control and revegetation has been and is being done. The completed projects are vantage points for systematic studies of the revegetation process. Here the interaction of natural processes and human control on nature can be looked at. We can evaluate what is happening, what can happen, and how compatible the happenings are. These follow-up programs will be a source of additional information and a constant check on the original ideas and theories applied.

BIBLIOGRAPHY

Benedict, J. B. 1970. Downslope soil movement in a Colorado alpine region: Rates, processes, and climatic significance. Arct. Alp. Res. 2:165-226.

Berg, W. A., and T. A. Colbert. 1972. Unpubl. report, Dept. of Agronomy, Colo. State Univ.

Billings, W. D., and H. A. Mooney. 1958. The ecology of arctic and alpine plants. Biol. Rev. 43:481-529.

Bliss, L. C. 1962. Adaptations of arctic and alpine plants to environmental conditions. Arctic 15:117-144.

Hutchinson, A. H. 1936. The polygonal presentation of polyphase phenomena. Trans. Royal Soc. Canada 30:19-26.

_____. 1940. Polygonal graphing of ecological data. Ecol. 21:475-487.

Jenny, H. 1958. The role of the plant factor in the pedologic functions. Ecol. 39:5-16.

Major, J. 1951. A functional factorial approach to plant ecology. Ecol. 32:392-412.

McCarg, I. L. 1967. An ecological method for landscape architecture. Landscape Architecture. 57:105-107.

Odum, E. P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Olgeirson, E. R. 1972. Comparative physiognomic trends in vegetation and soil on a bald near tree-line in Colorado. Ph.D. Dissert., Univ. of Colo., Boulder.

Whittaker, R. H. 1964. Gradient Analysis of vegetation, Biol. Rev. 42: 207-264.

LANDSCAPE MANAGEMENT CONSIDERATIONS IN REVEGETATION OF HIGH-ALTITUDE DISTURBED LANDS

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From the previous discussions, one is aware that progress is being made by on-site experience and research in revegetation of high-altitude disturbed lands. However, the problem is complex and finding solutions to all the revegetation and rehabilitation problems is not going to be easy and will take time.

There is something that can be done now if we want to prevent major additional damage to our high-altitude lands. We must plan our actions well in advance, involving all necessary disciplines. This is necessary to recognize problem areas and to find solutions or alternative approaches to the problems. Such planning must be based on information from a thorough inventory.

Basic inventory and analysis items should include but not be limited to: ecosystems, soils, hydrology, geology, vegetation, wildlife, topography, climate and all important landscape elements. This all raises a major question, "Why are we doing this?" Although basically interrelated, the answer is twofold. First, we are doing it to keep the natural system in balance as much as possible, thus preventing ecosystem upsets and disasters which could result from vegetative as well as mineral surface alteration. Secondly, we are doing this to protect the visual integrity of the scenic aspects of our mountain landscape. This is where landscape management comes in as a major part of the planning process.

> "National Forest Landscape Management is the art and science of planning and administering the use of forest lands in such ways that the visual effects maintain or upgrade man's psychological welfare. It is the planning and design of the visual aspects of multiple use land management." (USDA, 1973, p. 4)

Our instructions are that throughout the National Forest System, the visual resource will be inventoried, evaluated, and managed as a fully integrated part of the land planning and management process. It will be treated as an essential part of, and receive equal consideration with, the other basic resources of the land. In accordance with the National Environmental Policy Act of 1969, National Forest land planning and management will utilize a "systematic interdisciplinary approach which insures the integrated use of the environmental design arts." The basic concepts, elements, principles, and variables involved in the management of the visual resource on the National Forests are described in the handbook National Forest Landscape Management (USDA, 1973).

The main reason why there is so much emphasis on the visual aspects is that it has been established that 87 per cent of man's perception is by sight. Three basic concepts are involved with man's visual reaction to his environment:

Characteristic Landscape.
Variety.
Deviations.

Characteristic Landscape. Regardless of the size or segment of the landscape being viewed, it has an identifiable character which is usually an overall impression created by its unique combination of visual features such as land, vegetation, water and structures. These are usually seen in terms of form, line, color, and texture which we call the four dominance elements. From an overlook we usually observe a large or macro landscape. Within a forest or confined area the landscape is usually confined to a micro landscape as visibility is usually restricted to a short distance. Burton Litton, Jr. (1968) has developed a terminology which describes the character of different landscape such as: Panoramic, Feature, Enclosed, Focal, Canopied, Detail, Ephemeral. Thus for purposes of planning, the character of a landscape can be established and an analysis made.

Variety. A landscape which is object-rich usually has variety which is desirable from the visual standpoint. The amount of variety which will make a landscape visually desirable usually depends on specific local conditions. Garrett Eckbo (1950) stated that "Harmony results from the inclusion of neither too few nor too many parts, ideas, qualities or materials. The proportioning of the parts is based on the size of the whole." To blend management activities into the landscape usually requires a certain amount of variety in the landscape. Thus the less variety that exists in a landscape the harder it is to harmonize our management activities.

Deviations. Human activity on the landscape causes deviations from the characteristic landscape. To create minimum visual impact, the line, form, color and texture from the characteristic landscape must be borrowed and incorporated in the design of the human activity. These three basic concepts can now be discussed in terms of Dominance Elements and Dominance Principles.

Dominance Elements are: line, form, color, and texture. All four elements are usually present, however they exert differing degrees of visual influence, power, or dominance.

Line - It is anything that is arranged in a row or sequence. Treeline, ridgeline, shoreline, powerline, or even tree trunks as vertical lines in a micro landscape.

- **Form** - The mass of an object or combination of objects that appears unified.
- **Color** - Enables us to differentiate objects even though they have identical form, line and texture. Distance colors are usually muted by a blueish haze, foreground colors are the sharpest.
- **Texture** - Texture in the landscape depends very much on the size of the objects in the overall landscape. For example, the texture of a tree from close to far ranges from leaf-patterns to identification of branch textures to groups of trees in the landscape.

To analyze the characteristic landscape and the visual impact of a proposed action, six dominance principles should be used because they affect the visual dominance of line, form, color and texture in the landscape.

Dominance Principles are: Contrast, Sequence, Axis, Convergence, Co-dominance and Enframement.

- **Contrast** - The more contrast is created by an activity, the easier it is perceived.
- **Sequence** - If there is a natural sequence established, it should not be destroyed or interrupted by man's activities. There can be a line sequence (trees), form sequence (tree openings), color sequence (dark evergrees-light green aspen) or texture sequence (sagebrush to oak brush).
- **Axis** - Is the main line of direction established by natural features or man-made such as a clearing for a ski lift. The axis concept has been used extensively since early civilization to emphasize.
- **Convergence** - Natural as well as man-made lines can converge on a certain point. Visually people are drawn to this point. Any activity taking place at this point is greatly emphasized.
- **Co-dominance** - This usually happens when two or more nearly identical major objects compete for dominance. Visually co-dominance is not desirable.
- **Enframement** - Enframement usually creates strong focal points, it features certain portions of the landscape, directs attention to one point.

After all these elements and principles have been considered, we have to deal with other factors which are quite complicated and need to be considered in detail when planning any activity on the land.

VARIABLE FACTORS

Eight factors affect how the dominance elements - Line, Form, Color and Texture are seen; they are: motion, light, atmospheric conditions, season, distance, observer position, scale and time. I think most of these are self-explanatory, however by matching them with natural features they might be clearer.

Motion	- Waterfall, stream, river.
Light	- South exposure, north exposure, morning sun, noon sun.
Atmospheric Conditions	- Fog, clouds, rain.
Seasons	- Fall color, winter snow.
Distance	- Foreground, midground, background.
Observer Position	- Above, below, on the same level.
Scale	- How does it compare to humans.
Time	- Observation time, travel speed.

By using the three basic concepts plus the dominance elements, dominance principles, and variable factors, the landscape character can be analyzed and landscape management alternatives can be proposed which would create the least visual impact. Illustrations of these concepts and their application in landscape management have recently been published in handbook form (USDA, 1973).

I would like to reemphasize that good interdisciplinary planning is the only way to prevent major land disturbance or, if there is no other way, keep it to a minimum. Revegetation technology and methodology must be an integral part of the planning and design process.

BIBLIOGRAPHY

Eckbo, Garrett. 1950. Landscape for Living. New York, F. W. Dodge Corp. 268 p.

Litton, Burton V., Jr. 1968. Forest Landscape Description and Inventories - A basis for land planning and design. U.S.D.A. Forest Service Research Paper PSW-49. 64 p.

U.S.D.A., Forest Service. 1973. National Forest Landscape Management. Vol. 1. Ag. Handbook 434. U.S. Govt. Printing Office. 77 p.

SEEDING, PLANTING AND MULCHING WORK GROUP SUMMARY

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SUMMARY OF ITEMS DISCUSSED

1. Seeding, planting and mulching are much more difficult on high-altitude (above 9,000 ft.) sites, than on sites at lower elevations.

   Contributing factors:

   a. Greater distance for transportation of labor and materials.

   b. Labor and equipment are less productive at higher elevations and especially on steep slopes.

   c. Shallow and rocky soils.

   d. Extremely steep slopes (greater than 3:1).

   e. Often severe weather conditions including short growing season and high velocity winds.

2. Needs.

   a. Seeding equipment for shallow and rocky sites having extremely steep slopes.

   b. Mulching equipment for applying straw mulch on extremely long and steep slopes.

   c. Means of anchoring straw mulch. Items such as mulch netting requiring pins to be driven into ground are not practicable.

   d. Culture procedures for establishing trees on steep slopes. It is recognized the slopes must be temporarily stabilized with grasses and/or legumes before trees can be planted. Example: would it be feasible to mix tree seed with the grass and legume seed?

   e. Better understanding and cooperation between design engineers and vegetative specialists. Frequently, the least expensive construction creates the most difficult sites to stabilize.

3. Williams presented some basic comparisons of mulches, their effectiveness in controlling erosion and their value in grass establishment. Copies of information on mulches will be sent by Williams upon request.

SOILS AND SOIL FERTILITY WORK GROUP SUMMARY

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Soil fertility and high-altitude plant physiological relationships were the centralized interests in this discussion group.

The major point of concern was the lack of base line information on natural fertility levels of high elevation soils with respect to the mass balance of the environment.

The inadequacy of present methods of fertility analysis were discussed along with the use of introduced plant species which require a continuous "farming" maintenance program. These concerns are based on methods, techniques, and practices developed and used at low elevations and associated with cultivated agriculture which have not been proven in the high country. The subject of revegetation with introduced as well as native species produced a mixed feeling within the group. This is attributed to the specialized interests of the participants and the difference in desired achievement of the revegetation measures. In the views of some, the objectives are to return to the original ecosystem and to others simply a plant cover to minimize erosion.

The interest in plant physiology at high elevations stems from the unknowns of plant nutrient requirements, the effectiveness of legumes as nitrogen fixers, and viable seed production on disturbed soils.

Concern was expressed on probable pollution resulting from fertilization programs. These concerns include questions on the function, role, and effectiveness of micro-organisms in high elevation soils connected with the application of commercial fertilizers and soil amendments. Nutrient loss in surface runoff and leaching in addition to herbicide use for the control of noxious weeds were mentioned as concerns from a water pollution standpoint.

Few research references came from the group relative to these mentioned concerns. This suggests the need of an annotated bibliography on the high altitude environment.

WATER AND EROSION CONTROL WORK GROUP SUMMARY

James R. Meiman
Department of Earth Resources
Colorado State University

Discussion in this work group centered on three major topics: (1) What are the different values or reasons for revegetation? (2) How can communication of information on water and erosion control be improved? and (3) What are some specific problems related to effective water and erosion control?

Vegetative control of water and erosion was of concern to those present for a wide variety of reasons. Much of the concern centered on maintenance of site productivity, aesthetics, and water quality. Maintenance of mass stability of soils and protection of engineering works, especially roads, was discussed. It was also suggested that there even may be situations where erosion may be tolerated as a source of soil material for other, more productive sites.

Special attention was given to the need for centers of information where information that does not appear in the normal publication outlets can be cataloged and made available. The Denver Public Library, Conservation collection was suggested as one possibility. Several workshop participants reported obtaining helpful information from this source. Several persons suggested that one of the universities might logically perform this information pool service. The U. S. Bureau of Mines Metallurgy Center at Salt Lake was mentioned as a source of information on mine tailing stabilization. A different kind of communication need was voiced by a representative of industry who asked for a better definition of research and development problems that need solution. A final suggestion for communication improvement was for more workshops such as this one with emphasis on getting engineers and ecologists together to discuss mutual problems and solutions.

Specific problems identified during the discussion included the following:

1. Game management considerations, particularly the problem of animals on newly seeded areas.
2. Trade-offs between aesthetic and stabilization requirements.
3. Development of better techniques for identification of impacts and presentation of alternatives.
4. Need for machinery designed especially for rehabilitation rather than trying to use machinery designed for other purposes.
5. A better definition of adaptability of techniques for specific problems.
6. Prediction methods for sediment loads.
7. Analysis of the effects of mulches, especially wood products, on water quality.

SEED SUPPLIES AND PLANT MATERIALS WORK GROUP SUMMARY

James W. Echols, Agronomy, C.S.U. and
Secretary, Colo. Seed Growers Assoc.
and
R. L. Cuany, Agronomy, C.S.U.

CHAIRMAN'S REMARKS

Among grasses used for forage and (a few) for soil conservation, seed supplies fall into two classes:

a. Adequate supply, but high-priced (many over $1.00 per pound): Smooth brome, orchardgrass, timothy, Kentucky bluegrass, intermediate wheatgrass, pubescent wheatgrass; and crested wheatgrass for drier areas.

b. Short supply, very high price: Tall wheatgrass, most fescues, perennial ryegrass, meadow foxtail, needlegrasses; (for drier regions) slender wheatgrass, western wheatgrass, Russian wildrye; (for very dry areas) blue grama, buffalo grass, Indian ricegrass.

About the only shrubs listed by seedsmen are fourwing saltbush, bitterbrush, and burnet. Legumes are more available, with alfalfa at $1.50 - $2.00 per pound heading the list; red, alsike, and white clovers, sweetclover, sainfoin, cicer milkvetch, birdsfoot trefoil and crownvetch (some of these up to $4.75 per pound).

The above list dramatically emphasizes the need for other types of grasses, legumes, forbs, and shrubs that are really needed for revegetation projects. Included is the need for more screening of the most desirable types, which has to be done by cooperation among plant scientists and seedsmen, with the Soil Conservation Service participating, as described and illustrated by Robert Lohmiller in his talk at the workshop. The criteria for selection have been explained by Lohmiller, Eaman, Berg, and Cuany in their presentations. Efficiency of establishment and suitability for seed production rank high.

Unfortunately there is at present no SCS Plant Materials Center properly situated to serve central and western Colorado or the peculiar problems of the subalpine and alpine. The establishment of such a center on the western slope, with related expertise of agronomists and farmers and a suitable range of climates for seed production as well as adaptation testing, is vital to the protection and rehabilitation of our environment.

DISCUSSION ON GRASSES AND SEDGES

Why is crested wheatgrass so much used--and misused? Probably because of its availability early in the conservation era, and its ease of establishment. One strain has shown slight tendency to creep, could be retested--Lohmiller. He also said no trials have been made of high altitude *Carex* and *Juncus* spp, which are hard to collect.

Other grasses that may be useful to breed and try to improve seed production are *Deschampsia caespitosa* and *Agropyron smithii*. Among useful alkaligrasses are *Puccinellia airoides*, *P. distans* and *P. lemmoni* (the latter is commercially available). Some work is being done on these and on *Distichlis stricta* (saltgrass) which is unpalatable and a very strong rhizome-former, by J. Butler and J. Fults of C.S.U. Horticulture and Botany Departments. Some of the *Agrostis* (bentgrass) species might be useful.

DISCUSSION ON LEGUMES AND FORBS

Dryas drummondii which invades glacial talus in the high mountains would make a good candidate for rock fill and other disturbances; it is native in Rocky Mountain National Park. *Lupinus argenteus* is native in mixed meadow at Vail. This and other legumes such as *Melilotus* (sweet clover), *Lotus wrightii*, *Trifolium attenuatum*, *T. dasyphyllum*, *T. nanum*, and *T. parryi* (alpine clovers) have had some study near Fairplay, Colorado (at 9,500 feet). A bigger problem is seed production for the native species, as mentioned in Townsend's paper in this report. Appropriate inoculum may have to be developed for the native species.

Some attention is being given to *Sedum* spp. (stonecrops) by J. R. Feucht, the Extension Horticulturist of C.S.U., at the Denver Botanic Garden. They, as well as *Sibbaldia* (false strawberry), are common in tundra meadows as ground cover between tufted grasses. The Rocky Mountain Penstemon (*Penstemon strictus*) has been increased and released by SCS as the variety 'Bandera'; its upper altitude limit is being tested.

DISCUSSION ON SHRUBS

Most of the participants stressed the need for more shrubbery and woody materials in quantities and forms for rehabilitation plantings. Willows are easy to propagate, and could well be taken from adjacent areas to ensure climatic adaptation. Cinquefoils (*Potentilla* and *Pentaphylloides*) are also usefully propagated from soft wood cuttings. There is a species of *Chrysothamnus* (rabbitbrush) which is being multiplied from seed at Los Lunas Plant Materials Center, New Mexico.

Vine-type plants useful from 6,000 - 10,000 feet include *Clematis ligusticifolia* (Western virgin's bower) and *Humulus lupulus* (hop vine).

J. R. Feucht and colleagues in C. S. U.'s Horticulture Department recently made a survey of 35 mountain settlements such as Central City and Leadville and found many interesting and successful garden plants. Noteworthy above 8,500 feet were Tansey (*Tanacetum vulgare*) which will root from cuttings in water and forms hedges which die back and sprout each year. Although rhizomatous and weedy at lower elevations, it might be an asset for roadside plantings in the subalpine. Among 88 species of plants in gardens as high as 10,200 feet were:

Syringa laciniata	Persian lilac
S. vulgaris	common lilac
Caragana arborescens	Siberian peashrub
Cotoneaster acutifolia	Peking cotoneaster
Lonicera involucrata	bearberry honeysuckle (native)
L. tatarica	Tatarian honeysuckle
Populus balsamifera (candicans)	Poplar
Viburnum opulus	European cranberry

A more complete report is being prepared by Feucht.

GENERAL DISCUSSION

Some interest was apparent in use of native hay or native seed harvested with a lawn mower (J. Brown) to put the seed of species typical of the community back into the rehabilitated area. This would preserve its ecological plasticity and succession better than single-species plantings, though some felt that a technique that works is more important than the exact choice of species. Obviously the precise techniques of selection used by plant-breeders (see papers of Townsend and Cuany) cannot be applied to all the possible candidate species. Much valuable work can be done in native seed collection and propagation methods, and we still need an expanded program of strain-testing of available and forthcoming plant materials.

The following references are included for those who desire additional information on shrubs:

Kelly, G. W. 1970. A Guide to the Woody Plants of Colorado. Pruett Publishing Co., Boulder, Colorado. 180 p.

McKell, C. M., J. R. Blaisdell, and J. R. Goodin. 1972. Wildland Shrubs--Their Biology and Utilization. Intermountain Forest and Range Expt. Sta. Gen. Tech. Rept. INT-1 (USDA Forest Service, Ogden, UT). 494 p.

Plummer, A. P., D. R. Christensen and S. B. Morsen. 1968. Restoring Big-Game Range in Utah. Pub. 68-3, Utah Div. of Game and Fish. (This publication is available from the Intermountain Forest and Range Expt. Station, Ogden, UT) 183 p.

APPENDIX

Recommended Planting Rates[1] for Grasses in Terms of Pure Live Seed.[2]

Species	Common Name	Native or Introduced	Seeding Rate[3] lbs/acre PLS	Avg. Seeds Per lb. of PLS	Typical[4] Purity/ Germ. %	Pure Seed Unit
Agropyron cristatum	Fairway wheatgrass	I	4.5	200,000	95/85	Floret
A. *desertorum*	Crested wheatgrass	I	5.0	200,000	95/85	Floret
A. *dasystachyum*	Thickspike wheatgrass	N	5.0	186,000	95/91	Floret
A. *elongatum*	Tall wheatgrass	I	12.0	79,000	95/85	Floret
A. *intermedium*	Intermediate wheatgrass	I	10.0	100,000	90/85	Floret
A. *riparium*	Streambank wheatgrass	N	7.0	170,000	97/92	Floret
A. *sibiricum*	Siberian wheatgrass	I	4.0	250,000	95/85	Floret
A. *smithii*	Western wheatgrass	N	10.0	110,000	85/60	Floret
A. *spicatum*	Bluebunch wheatgrass	N	8.0	117,000	96/31	Floret
A. *trachycaulum*	Slender wheatgrass	N	3.7	160,000	90/85	Floret
A. *trichophorum*	Pubescent wheatgrass	I	12.0	91,000	90/85	Floret
Agrostis alba	Redtop	I	1.0	6,038,000	90/80	Spikelet
Alopecurus arundinaceus	Creeping foxtail	N	2.0	613,000	90/73	Spikelet
A. *pratensis*	Meadow foxtail	I	1.0	900,000	90/80	Spikelet
Bromus biebersteinii	Meadow brome	I	10.0	100,000	92/85	Floret
B. *inermis*	Smooth brome	I	8.0	125,000	92/85	Floret
B. *marginatus*	Mountain brome	N	12.0	90,000	90/85	Floret
Dactylis glomerata	Orchardgrass	I	2.0	540,000	90/80	Floret
Elymus canadensis	Canada wildrye	N	9.0	106,000	80/80	Floret
E. *cinereus*	Basin wildrye	N	6.0	165,000	78/83	Floret
E. *glaucus*	Blue wildrye	N	8.0	131,000	80/85	Floret
E. *junceus*	Russian wildrye	I	6.0	170,000	90/80	Floret
Festuca arizonica	Arizona fescue	N	4.0	250,000	90/50	Floret
F. *arundinacea*	Tall fescue	I	4.0	242,000	96/86	Floret
F. *idahoensis*	Idaho fescue	N	2.0	450,000	90/30	Floret
F. *ovina*	Sheeps fescue	N	2.0	565,000	95/85	Floret
F. *ovina* var. *duriuscula*	Hard fescue	I	2.0	565,000	95/85	Floret
F. *rubra*	Red fescue	I	2.0	479,000	97/80	Floret
F. *rubra* var. *commutata*	Chewing's fescue	I	2.0	479,000	97/80	Floret
F. *thurberi*	Thurber's fescue	N	?	?	?	Floret
F. *viridula*	Green fescue	N	2.0	479,000	90/15	Floret
Lolium perenne	Perennial ryegrass	I	4.0	247,000	98/90	Floret
Oryzopsis hymenoides	Indian ricegrass	N	8.0	141,000	95/90	Floret
Phalaris arundinacea	Reed canarygrass	N	4.5	566,000	95/90	Floret
Phleum pratense	Timothy	I	1.0	1,300,000	97/80	Grain
Poa ampla	Big bluegrass	N	1.0	917,000	90/70	Floret
P. *compressa*	Canada bluegrass	I	1.0	2,500,000	80/80	Floret
P. *pratensis*	Kentucky bluegrass	I	1.0	2,156,000	90/75	Floret
Stipa lettermani	Letterman needlegrass	N	?	?	?	?
S. *viridula*	Green needlegrass	N	5.0	181,000	97/24	Spikelet

Recommended Seeding Rates[1] in Pure Live Seed[2] for Forbs and Legumes

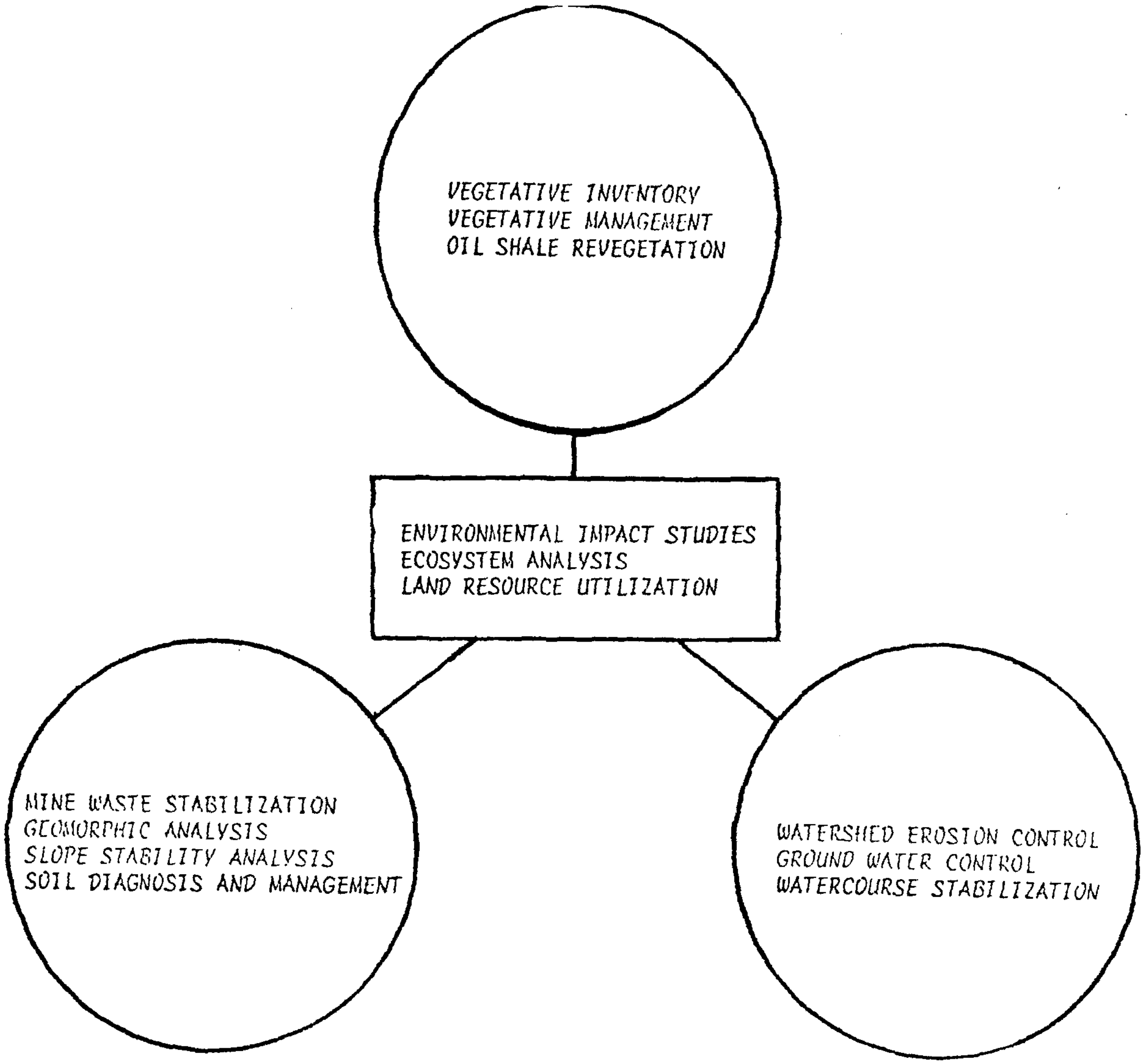
Species	Common Name	Native or Introduced	Seeding Rate[3] lbs/acre PLS	Avg. Seeds Per lb. of PLS	Typical[4] Purity/ Germ. %	Pure Seed Unit
stragalus cicer	Cicer milkvetch	I	8.0	122,000	90/15-50	Seed
'oronilla varia	Crown vetch	I	8.0	119,000	97/80	Seed
otus corniculatus	Birdsfoot trefoil	I	3.0	418,000	96/90	Seed
upinus angustifolius	Blue lupine	I	100.0	2,880	99/90	Seed
. argenteus	Common lupine (Silvery)	N	?	?	?	Seed
edicago falcata	Sickle alfalfa	I	2.0	454,000	97/90	Seed
. lupulina	Black medic	I	1.5	800,000	95/85	Seed
. sativa	Alfalfa	I	4.0	225,000	99/85	Seed
elilotus spp.	Sweetclover	I	6.0	262,000	99/85	Seed
nobrychis viciaefolia	Sainfoin	I	49.0	18,000	97/80	Seed
enstemon strictus	Rocky Mountain penstemon	N	3.0	280,000	93/79	Seed
anguisorba minor	Small burnet	I	16.0	53,000	90/80	Seed
rifolium hybridum	Alsike clover	I	1.5	700,000	99/85	Seed
rifolium repens	White clover	N	1.5	800,000	99/85	Seed

ıdapted from a table prepared for the Plant Materials Sub-committee of the American Society of Range Manage-ment by Armbrust, Currier and Merkel.

'ure Live Seed (PLS) = seed units that contain a germinable seed. If 1 lb. PLS contains 250,000 seed units, :t should produce 250,000 seedlings, and if planted in 1 acre, will give 250,000/43,560 = seedlings per ıquare foot. It is difficult to spread 1 lb. or smaller quantities evenly over an acre even on level ground ɹith good seeding equipment.

tecommended planting rates are calculated in lbs. of PLS required to give 20-25 seedlings per sq. ft. when lrilled. For broadcast seeding, double these rates; for mixtures use only a proportion so that the total of ıll seedlings will be 20-25 per sq. ft.

;eed material is scarcely ever 100% PLS, but typical purity and germination % for seed lots are given. If ıurity/germ. = 80/60, there are only 48% PLS in the material, and slightly over 2 lb. will have to be used, :o apply 1 lb. PLS. Tested purity and germination figures are on the tag of all bags of seed on the market.



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HIGH ALTITUDE REVEGETATION