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RECLAMATION PRACTICES IN THE
NORTHERN GREAT PLAINS

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TABLE OF CONTENTS

Title ................................................................. 1
Vita ................................................................. 11
Acknowledgment .................................................. 111
Abstract ............................................................ v
Introduction ......................................................... 1
Pre-planning ......................................................... 2
Topsoiling ........................................................... 3
Soil Amendments ................................................... 6
Surface Manipulation .............................................. 7
Methods of Seeding and Planting ................................. 13
Fertilizers .......................................................... 24
Mulches ............................................................... 26
Summary ............................................................ 29
Literature Cited .................................................... 31
ABSTRACT

This paper is a literature review of coal strip mine reclamation practices in the Northern Great Plains. The reclamation practices reviewed include pre-planning, topsoiling, soil amendments, surface manipulation techniques, methods of seeding and planting fertilization and use of mulches. The primary literature covered is that related to work that has been performed on the Northern Great Plains.
INTRODUCTION

The increased strip mining of coal in the Northern Great Plains will probably impact several thousand acres of range and farm land in the next decade. When the coal has been mined, these acres should not be abandoned, but rather should be reclaimed for productive use. The primary objective of reclamation is to restore this land to a productive state as quickly as possible at feasible economic cost.

Reclamation practices throughout the Northern Great Plains vary. Practices which succeed in one area may fail in others; however, the common goal of all techniques is to stabilize the soil with a productive permanent plant cover.

Surface Reclamation for rangeland land use is more than simply establishing vegetation on mine spoils. It involves establishing an ecologically stable cover which at least approaches the productive potential for which the reclaimed area is to be used.

Initial problems in reclamation include not only establishing a vegetational cover, but also providing a stable soil for further vegetation development. Another
major problem in the Northern Great Plains is the amount of plant available water for establishing vegetation. This paper primarily deals with these problems and some potential or proven remedies.

PRE-PLANNING

In a strict sense, there exists in the Northern Great Plains no "stable" ecosystem since periods of time of stable climate have been too short and soils are too immature to provide for maximum efficiency of utilization of energy flowing through these ecosystems (Curry, 1975). With adequate baseline geological, soil chemical, plant ecological, and soil ecological data, possibilities for reclamation through various mining plan options can be assessed and specific soil handling and reconstruction plans can be determined (Dollhopf et al., 1977). In other words, an area to be mined should have data collected that will be beneficial to the reclamation process of that mine prior to any actual mining activity. Pre-planning will help to solve the problems and judge the potentials for success or failure of reclamation.
Reclamation should start before the actual mining operation is initiated and continue through a management plan after vegetation reestablishment (Cook, 1976, Lang, 1975). Pre-planning for proper disposition of problem spoil material (Dollhopf et al., 1977), adapted species (Plummer, 1977), proper planting or seeding techniques (Hodder, 1976), and management after revegetation is essential for ultimately establishing a stable and productive reclaimed area. Pre-planning is just as important as the actual planting or seeding and fertilizing of the reshaped mined area and is essential in order to have successful reclamation.

**TOPSOILING**

In the Northern Great Plains, several states require topsoiling as part of their strip mine reclamation program. This is the process of removing variously defined desirable layers of surface soil material from areas to be mined, and ultimately placing this material back on reshaped spoil banks.
Topsoil is defined here as the unconsolidated mineral matter naturally present on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate, macro- and microorganism, and topography, all acting over a period of time, and is beneficial for the growth and regeneration of vegetation of the surface (Grim and Hill, 1974).

In certain areas, topsoil may not always be desirable due to inimical chemical and/or physical properties. Some studies have shown that material other than topsoil can be used as a medium for plant growth which is superior to topsoil, especially when the topsoil is sodic (Schuman et al., 1976). However, if topsoil is suitable for plant growth, many studies have shown benefits of its use in top dressing spoils.

Topsoiled areas may promote more rapid vegetation establishment, thus reducing mass erosion and sloughing (Hodder, 1973; Dollhopf et al., 1977). In highly sodic spoils without topsoil, grass seedings have sometimes failed (Power et al., 1975). Therefore, it seems highly desirable to topsoil mine overburden in order to quickly establish vegetation.
A question often raised is that of how much topsoil is needed to promote revegetation. Growth and production of grass has been noted to increase as thickness of topsoil applied on highly sodic spoils was increased (ARS and NDAES, 1977). Productivity in this case was thus directly related to the thickness of a good quality soil material placed over poor quality spoil. Power et al. (1975) in North Dakota reported that with only 2 inches of topsoil such spoils yielded up to two thousand pounds of dry matter per acre, whereas Sindelar et al. (1973) suggested that at least 4 inches of topsoil were necessary to promote mine spoil revegetation in Montana. Sindelar et al. (1973), further stated that topsoil aided in rapid establishment of stabilizing vegetative cover, and that 8 inches of topsoil did not produce significantly more plant material than 4 inches of topsoil. However, in some areas topsoil should be applied at a minimum depth of 6 to 8 inches over suitable subsoil material so that a plant growth medium of at least 18 inches in depth is provided (Cook et al., 1974). The reasoning behind this was to achieve greater amounts of water storage. By topsoiling the rate of surface infiltration typically increases because of increased organic matter content (Hodder, 1977).
It has been suggested that topsoil may be a seed source for reseeding strip mine spoils. Beauchamp et al. (1975) found sufficient seed in the top 2 inches of topsoil to vegetate an area with more than the original density, but that the plant species that were present were that of those for secondary succession. This seed, however typically does not germinate readily. The greatest concentrations of viable seed were usually in the top 1 inch of soil with the second inch contributing a substantial amount.

SOIL AMENDMENTS

Some areas that will be mined will have salt (especially sodium) problems, no matter how carefully the mine has been preplanned. In such cases there may also be a shortage of quality topsoil. The chemical amendment gypsum (Ca SO₄) is one possible partial solution to the sodium problem, although secondary to replaced topsoil as a means of overcoming the undesirable effects of sodium (ARS and NDAES, 1977).
Gypsum as a soil amendment has been noted to alleviate the high exchangeable sodium problem on spoils (Schuman et al., 1976). It tends to be slow acting, however resulting in moderate vegetation yields and sodium reduction. Gypsum takes 3 to 4 years to reach equilibrium and has resulted in about a 40% reduction of sodium in the spoil (Schuman et al., 1976). Amendments such as gypsum may be justified where acceptable topsoil is not available or limited in quantity.

**SURFACE MANIPULATION**

The first intent and obligation of reclamation of disturbed areas is to achieve soil stability and control soil erosion (Hodder, 1975). In the Northern Great Plains plant available water is also a critical factor. The problems of soil erosion and available water can sometimes be alleviated through surface manipulation techniques. Jensen et al. (1975) reported definite advantages in manipulating the surface of shaped spoils into configurations which limit runoff and encourage infiltration of precipitation. Vegetating and contouring the land may also play a
major role in controlling wind erosion (Ellison, 1976). Therefore by manipulating the soil surface and subsequently establishing a vegetative cover, a degree of soil stability and erosion control can be achieved.

Three specific surface manipulation techniques have been studied on mine spoils of the Colstrip area of Montana: gouging, dozer basins and deep chiseling. These methods are applied after the spoils have been reshaped and usually topsoiled. Gouging is a surface manipulation treatment which results in a pattern of many depressions, and is accomplished by a specially constructed machine that has hydraulically operated, 25 inch diameter disc scoops that alternately raise and lower while being drawn by a tractor. The disc scoops create elongated basins on the contour approximately 14 to 16 inches wide, 3 to 4 feet long, and 6 to 8 inches deep (Sindelar, et al., 1973). This method works well on gradual slopes and flat areas. It creates a rough seedbed ideal for broadcast seeding.

Dozer basins are larger depressions, 15 to 20 feet long and are formed by dropping the bulldozer blade at an angle at intervals and bulldozing on a slope contour. These elongated basins are approximately 20 to 25 feet from
center to center and are about 3 to 4 feet in depth (Sindelar et al., 1973). Basins are constructed in parallel rows with about 20 feet between the rows. This method is better adapted to steeper slopes.

Deep chiseling loosens compacted spoils to a depth of 6 to 8 inches. This process creates a series of parallel slots on the contour which tends to impede water flow and increase the infiltration rate. A modified Graham-Hoeme plow with 12 chisels has been used to produce deep chisels to form a rough cloddy seedbed (Sindelar et al., 1973). This method is also better adapted to gradual slopes.

All three of these treatments are conducive to broadcast seeding, while the deep chiseling treatment may also be drill seeded. For maximum effectiveness of treatment, treated areas should be seeded immediately after manipulation. With the surface roughened, the broadcasted seeds are easily buried by the slight sloughing of the basins and chisel grooves.

Gouging reduced moisture stress days significantly, allowed storage of more water in the upper four feet of soil, and resulted in greater initial plant survival than chiseling or dozer basins (Sindelar et al., 1973). Schuman et al. (1976) reported that surface modification techniques
such as contour furrowing, benches, pitting, dozer basins, gouges, and other methods of increasing surface roughness, reduce wind and water erosion and increased moisture retention for onsite plant use.

Other methods that help to reduce surface runoff and retain precipitation include soil ripping and snow fencing.

Ripping tends to reduce surface runoff and erosion by promoting deep water infiltration and percolation. Mechanical ripping to a 2 foot depth with a minimum of 8 feet between rip lines followed by deep chiseling is beneficial in improving infiltration and penetration by plant roots in overly dense spoils (Hodder, 1975). Aldon (1976) reported that ripping effects on runoff are short-lived, but that forage production patterns may persist for up to 10 years. Ripping may be a beneficial practice proceeding any surface manipulation treatment to break up compacted spoils to a greater depth, thus making possible deeper root penetration and water infiltration.

Snow fences can be used to collect snow which would otherwise be lost and retain the snow for increased soil moisture. However, depending on soil conditions moisture for snow accumulation may not all infiltrate into the soil (Schuman et al., 1976). May (1975) reported that
Snow fences are effective in accumulating water for some areas. He stated a standard 4 foot high snow fence retains 90 cubic feet of water per running foot of fence and that with 12 foot high snow fence 1,100 cubic feet of water could be retained per running foot of fence. Infiltration may be a problem with use of snow fence. If infiltration is slow or non-existent, melting snow retained by the fence may cause high amounts of surface runoff and soil erosion. After vegetation is established, snow fencing can easily be removed and re-used.

Hodder (1975) stated several principles for controlling erosion on mine spoils. These include: 1) protection of the soil surface from particle displacement, 2) reduction of the flow of air or water over the soil surface and 3) increasing the soil water infiltration rate so that it equals or exceed most rates of precipitation. These principles for controlling erosion can be employed through surface manipulation, which causes an interaction of water, soil and plant factors that determine the ultimate success or failure of reclamation. Surface manipulation may not be necessary on flat areas with a loose seedbed. Surface manipulation treatment applicability will strongly vary from site to site depending on topsoil, spoil, climatic and
topographic factors (DePuit, 1977). Reclamation practices throughout the Northern Great Plains will vary due to many factors that change from one mine site to another and even from one spoil bank to another. Of the five factors of soil formation -- climate, living organism, parent material, topography and time -- only climate is not altered by the mining process (ARS and NDAES, 1977). Since these factors change from site to site, it may be necessary to use more than one surface manipulation treatment or a combination of treatments that may fit each site. Therefore no single treatment can be regarded as an all-inclusive solution to reclamation problems of the Northern Great Plains.
METHODS OF SEEDING AND PLANTING

A number of seeding techniques are available for establishing vegetative cover on mine spoil. Seed can be distributed from the air over large areas of prepared seedbeds. Seeding on the ground can be accomplished by hand spreader, broadcast seeding machines or by drill seeding.

Grim and Hill (1974) noted that many factors must be considered when selecting the process for seeding and planting. These include:

1. Access to the area by vehicles.
2. Location—availability of water, distance to the airport.
3. Seedbed conditions—age of spoil, rainfall, and time since final grading.
4. Slope—especially steep outslopes.
5. Topsoiling
6. Size of Area
7. Time of year.

The conditions of each site where seeding is to be accomplished will determine the method to be used.
If an area is easily accessible by vehicles, conventional farming equipment can be used, such as mechanical tree planters, seeding drills and hydraulic seeders. However, use of this equipment may be limited during wet and muddy weather, which is commonly the ideal time to seed.

Aerial broadcast seeding has been used successfully in rugged terrain and in places where wheeled vehicles cannot operate because of wet, muddy spoil (Grim and Hill, 1974).

Drill and broadcast seeding are commonly used in seeding of mined areas in the Northern Great Plains. Both seeding methods have been successful in this region, providing that they have been conducted under proper conditions and with suitable seeded species. Broadcast seeding may be successful if a properly loose seedbed is obtainable. However, if feasible, drill seeding has often been recommended for the best results, especially if adapted types of drill seeders (e.g. rangeland drill) are used, (Cook et al., 1974; Cook, 1976). Seed of most species utilized should be drilled at depths of 1/4 to 1/2 inch, with 7 to 14 inch spacing between the rows. However, depth and spacing
varies widely according to different situations of soil, climate and topography. There are some problems with drill seeding. Many native species seeds are small and fluffy, hence sometimes causing drills to clog. Also, seeds of a species mixture vary in size and texture and thus require different seeding depths, while with the use of a drill the seeding depth remains constant.

A special drilling technique of cross seeding may be effective in intercepting and retaining snow and rain, thus increasing available soil moisture (Hodder, 1977). Cross seeding is a process of drilling grasses in rows at 2 feet intervals in a direction crosswise to the prevailing winds and over seeding by drilling legumes in rows at a 90 degree angle to the grass seeding (Hodder, 1977). Minimum tillage is another specialized seeding technique which requires drill or broadcast seeding directly into the stubble of a stabilizing crop.

In some ways broadcast seeding may be more acceptable than drill seeding, due to such things as more uniform seed spread (i.e., lack of drill row bare interspaces) (Plummer, 1977). Hodder (1976) stated that broadcast seeding has produced very satisfactory results. Some advantages of
broadcasting are that it is quick, conducive to steep slopes and that hand collected seed does not have to be cleaned before using. It is also more conducive to diverse mixtures having widely variable-sized seeds with varying seed depth requirements, in that a more proper, variable depth orientation is ultimately achieved. This assumes that a properly "rough" seedbed has been prepared. In the west, it has been found to be better to broadcast the seed and cover the seed with soil prior to applying mulch; otherwise the seed is held in the mulch and loses its viability by frequent wetting and drying (Cook, 1976). Surface manipulation is very amenable to broadcast seeding.

Other factors affecting the choice of seeding methods are time of seeding, seeding rates, and species seeded.

In general, the best time of seeding for species with specific germination and growth requirements is that just preceding the most desirable moisture-temperature regime. Under the climatic regime of the Northern Great Plains seeding cool season grasses and legumes or cool season grasses alone may be best suited to fall or very early spring seeding (Cook et al., 1974); Hodder, 1976). Best
success with warm season species may be obtained with seeding in mid to late spring (Cook et al., 1974). However, as mining progresses at a given site it may not always be possible to immediately seed at the proper time. In such cases, the seeding of temporary stabilizing species may protect a given site in the interim period prior to the proper time of seeding for the desired permanent revegetation species. Drill seeding is sometimes used for seeding into the stubble of temporary stabilizers (Cook, 1976). Annual grasses and grains have been used as temporary stabilizing crops. In Montana Meyn et al (1975) concluded that wintergraze and barley demonstrated superiority over previously tested warm season grasses for stabilization purposes.

Seeding rates may vary with the topography of regraded spoils as well as with other site factors. Drill seeding rates of 4 to 5 pounds of PLS (Pure Live Seed) per acre for small seeds and 7 to 10 pounds of PLS per acre for larger seeds have been proposed in the past (Cook et al., 1974). However, many researchers and mine companies are now employing much heavier drill seeding rates in the range of 20 to 35 pounds PLS per acre. Typically in Montana, seedings at
rates less than the latter range have not been successful. Depuit et al., (in prep.) states that evidence now shows that extremely heavy seeding rates may be desirable for reasonably rapid establishment of slower developing species such as many native species, and that doubling the drill rate for broadcast seeding may not always be valid. When the conditions become more severe, such as on steeper slopes and south facing slopes, rates of seeding should be increased accordingly.

Selection of plant species, varieties or ecotypes for different sites on areas to be reclaimed is a prerequisite to a sound reclamation program (Lang, 1975). Species must be adapted to an area's soil and climate. Both introduced and native species have been used that have been adapted to certain sites. However, long term considerations tend to favor native species as being most likely to maintain the site in spite of drought, insects, and diseases (Farmer et al., 1974). In Montana, reclamation achievement cannot be called successful in a legal sense until predominantly native vegetation is re-established which can sustain production and maintain a non-erodible cover under grazing use by wildlife and livestock (Hodder, 1976). Native species
seeding is made difficult because of somewhat limited seed availability and quality for many native species (Aldon, 1976).

Seeding mixtures containing a variety of grass, legumes, and shrub species have been shown to offer benefits not possible with plantings of a single species in Montana (Meyn et al., 1975). The need for establishment of diverse plant communities has a sound ecological (as well as legal) basis in Montana.

In Montana, introduced grass species were stimulated to a greater extent than native grass species by increased fertilization. Although overall productivity and/or initial stand success was typically lower, stand diversity was highest when mixtures with no or low proportion of vigorous introduced species were seeded (DePuit et al., in prep.). Certain introduced grass species have been shown to be initially more competitive than native grasses. However, increased germination and survival rates may be obtainable for many native grass species by development of improved varieties (DePuit et al., in prep.). Introduced grasses may have a place in reclamation where plant re-establishment may
be difficult because of typically rapid initial establishment, greater response to fertilizers and utility for special purpose pastures (DePuit et al., in prep.).

Transplanting trees and shrubs is another method of vegetation establishment on mine spoils. Techniques for this include shrub pads, tree transplants in biodegradable containers, bareroot transplants, root transplanting and use of condensation traps. A shrub pad is a variably sized pad of soil, roots and plant crowns approximately 10 to 12 inches thick (Hodder, 1976). Such pads may be excavated on native rangeland and placed on the surface of reshaped spoils.

Small tree transplantation can be approached in a number of ways, either in biodegradable containers or as bareroot stock transplants. Tree seedlings grown in a nursery are often transplanted in biodegradable containers. Bareroot stock may come from a nursery or from surrounding areas of the mine. The use of specialized tree spade equipment may make possible transplantation of larger tree seedlings or shrubs with their original soil to where the tree is to be relocated on mine spoils.
Various types of transplantation containers have been developed, including the following type of tubling developed by the Montana Agriculture Experiment Station. These tubelings are a 2 ply paper tube reinforced with a mesh sleeve. The tube has a 2-1/2 inch diameter that is 2 feet long. Some species that may be adaptable to this method are honeysuckle, three leaf sumac, chokecherry, carragana, old man wormwood, and Siberian peashrub (Hodder, 1977).

Supplemental root transplanting is a specific transplantation method that can only be accomplished with rhizomatous shrub species. Two plants connected by a rhizome are used. The top of one plant is removed and planted the deepest, while the second connected plant is planted above at a normal planting depth. The two plant transplants will thus have additional moisture available not only from the upper roots of the shallow-planted shrub but also from roots of the deep planted root stock (Hodder, 1977).

Condensation traps may also be used in tree and shrub transplantation when plant moisture is especially limiting. The procedure is to plant a seedling in a basin and cover the basin with plastic, weighing it down at the base of the
seedling and on the outer sides of the basin. The principle behind this method is that of causing the water that evaporates to condense and water the seedling by dripping off at the lowest point of the plastic "trap" at the base of the seedling (Hodder, 1976).

Besides altering the soil complex to improve soil water availability, supplementing natural precipitation with the addition of limited amounts of water through irrigation appears to have potential in promoting vegetation establishment (ARS and NDAES, 1977). Cook (1976) reported that it may be necessary to supply additional water to trees and shrubs that are transplanted. Supplying additional water only during the first and second year may be required to achieve transplant establishment.

One question with irrigation is that of response of vegetation when the irrigation is terminated. Vegetation response could conceivably be irreversibly negative if irrigation is stopped too soon. For example, supplemental water for at least the first 2 years may be essential to establish tree and shrub transplants, whereas after the
second year roots may be developed to a point where supplemental water may no longer be necessary, (ARS and NDAES, 1977; Cook et al., 1974).

Wildlife browsing may be a problem with newly transplanted trees and shrubs. Certain animal species often utilize fresh new growth of many tree and shrub species for forage to the detriment of the plants. Deer may also utilize trees for rubbing their antlers, thus causing severe damage to the transplanted trees and shrubs. A possible solution to this problem would be to fence off the entire area until these trees and shrubs are well established.
Soil analyses of spoil and applied topsoil in many parts of the Northern Great Plains region generally show low supplies of available nutrients necessary for plant establishment and growth. The two most commonly deficient nutrients are nitrogen and phosphorus (Sindelar et al., 1973). However, analysis of fresh spoil material has often revealed that there is an adequate nitrogen level present from exchangeable ammonium-nitrogen naturally found in freshly mined spoils (Wali and Sandoval, 1975). However, in older spoil material nitrogen may no longer be sufficient.

It is therefore, usually necessary to have a fertilization program to achieve successful reclamation. To determine fertilization needs, reclamation should begin with examination of topsoil and overburden before mining. It has been reported that Paleocene shales found in the Fort Union Formation in North Dakota contain large quantities of exchangeable NH$_4^+$ which, when exposed to the atmosphere by mining, may be transformed to NO$_3^-$ in concentrations adequate to meet requirements of most plants.
(Meyn et al., 1975). Meyn et al. (1975) further report that nitrogen levels in spoil material generally ranges from 20 to 40 ppm (parts per million) and at the Colstrip area of Montana the levels are 10 ppm or greater.

Levels of macronutrients such as nitrogen and phosphorus are typically low in native soils and almost non-existent in older mine spoils (Hodder, 1975), due to the fact that older mine spoils that have lost the more ample nitrogen typical of fresher mine spoils through volatilization and leaching processes.

In Montana Sindelar et al., (1973) found that it was necessary to fertilize mine spoils with nitrogen and phosphorus to obtain satisfactory vegetation establishment. The absence of either applied nutrient limited plant production regardless of the concentration of the other nutrient. Added nitrogen primarily stimulates grasses, while phosphorus benefits both legumes and grasses. Legumes are generally more sensitive to added phosphorous than to added nitrogen, because many legumes can symbiotically fix nitrogen.
Applying fertilizers during the first year of growing gives the best results (Cook et al., 1974). If fertilizer is applied prior to seedling emergence, there may be a serious problem of weed competition depending on the season of fertilization. Adding fertilizers before the second growing season has substantially increased the vigor of seedlings and reduced the mortality of these young plants substantially (Cook, 1976).

Fertilization rates vary in the Northern Great Plains, but it seems that between 50 to 75 pounds per acre of available nitrogen and 50 to 80 pounds per acre of P$_2$O$_4$ may be sufficient to establish a vegetative cover (Meyn et al., 1975; Cook et al., 1974). Actual rate prescriptions will depend on determined nutrient content of spoils and/or applied topsoil.

**MULCHES**

Erosion is a constant problem in the Northern Great Plains. Specific means of modifying the microclimate may tend to alleviate the problem of wind and water erosion. The use of surface mulches after seeding and leaving soil
surface rough (i.e., surface manipulation) helps to protect seedlings from wind and drought, accumulates additional moisture and helps to prevent excessive erosion (Lang, 1975). Mulching encourages infiltration by impeding runoff, lowering soil temperature, reducing evaporation, and minimizing raindrop splash, surface puddling and sealing (Hodder, 1977).

Mulches of various types are generally beneficial in establishing vegetation on spoils, and may be especially important on harsh sites. They may conserve soil moisture to a depth of 12 inches or more resulting in a greater number of established seedlings, thus helping to minimize erosion (Cook et al., 1974). Organic mulches also break down after ground cover establishment, supplying valuable organic matter to the soil, which in turn promotes microorganism buildup and increased water infiltration.

Straw or hay mulches are often anchored to the soil by crimping with a disc. They may be effective for 1 to 2 years then decompose because of abrasion by the wind. These organic mulches are most effective on sandy and clayey spoils (Schuman et al., 1976).
Jute, wood chips, and other fibrous material are more expensive as mulch material. Wood fiber and synthetic organic sprays may be relatively easily applied in difficult terrain, however, and wood fibers such as silverfiber are often applied at 1500 pounds per acre (Cook et al., 1974); however, use of such materials may not be successful in areas which experience excessive frost heaving.

Other mulches such as jute mesh, excelsior mats, and fiberglass mats are all effective under the proper conditions (Cook, 1976). Again some mulch treatments are more adaptable to certain sites than others. In the west, it has been found that it is better to broadcast and cover the seed prior to applying the mulch. If seeding follows mulching the seed may be held in the mulch and lose viability by frequent wetting and drying.

As noted previously, seeded small grain and annual species will provide quick temporary stabilization until permanent cover is established. Temporary stabilizers also add organic matter to the soil in the form of roots and dead leaves, above ground plant materials may provide considerable surface mulch. Due to harsh climatic conditions and danger of soil erosion, it is desireable to
seed with annual grasses and grains until a permanent
vegetative cover can be established.

SUMMARY

Many reclamation practices have been used with vary-
ing degrees of success throughout the Northern Great
Plains. Each of these practices used should not be indi-
vidually, singly viewed as a clear cut means of achieving
reclamation. A combination of these practices in most
cases may offer greatest potential for successful reclama-
tion. Reclamation should begin at the same time mining
plans are formulated. Careful pre-planning and research
must be conducted on an area to be mined and reclaimed;
only in this manner can a decision be made to judge which
option is the best in order to achieve a successfully
reclaimed area.

If single purpose reclamation is attempted where the
only concern is short term results, the problem of long
term instability and poor resiliency of re-established
ecosystems made ultimately be faced. This could result in
a continual need for excessive and ongoing fertilization and erosion control, as in agricultural areas. In no cases should reclamation be achieved at this cost if its goal is re-establishment of self-perpetuating ecosystems.
LITERATURE CITED


