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# Reclamation Design for a Hypothetical Coal Strip-Mine Dunn County, North Dakota

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# RECLAMATION DESIGN FOR A HYPOTHETICAL COAL STRIP-MINE DUNN COUNTY, NORTH DAKOTA

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## Introduction

This document is a plan and design for the reclamation of a coal strip-mine in Dunn County, North Dakota, where lignite mining is likely to occur in the future.

### Location

Dunn County is in the central part of western North Dakota, near the center of the Williston Basin. It is part of the Missouri Slope uplands of the Great Plains Province, which is characterized by gently rolling topography interrupted by isolated buttes. The site in Dunn County covers 1900 acres of land in T144N, R93W. The coal appears to be relatively thick in this area, which makes it the most likely site for a coal strip-mine. Figure 1 shows the exact location in map view.

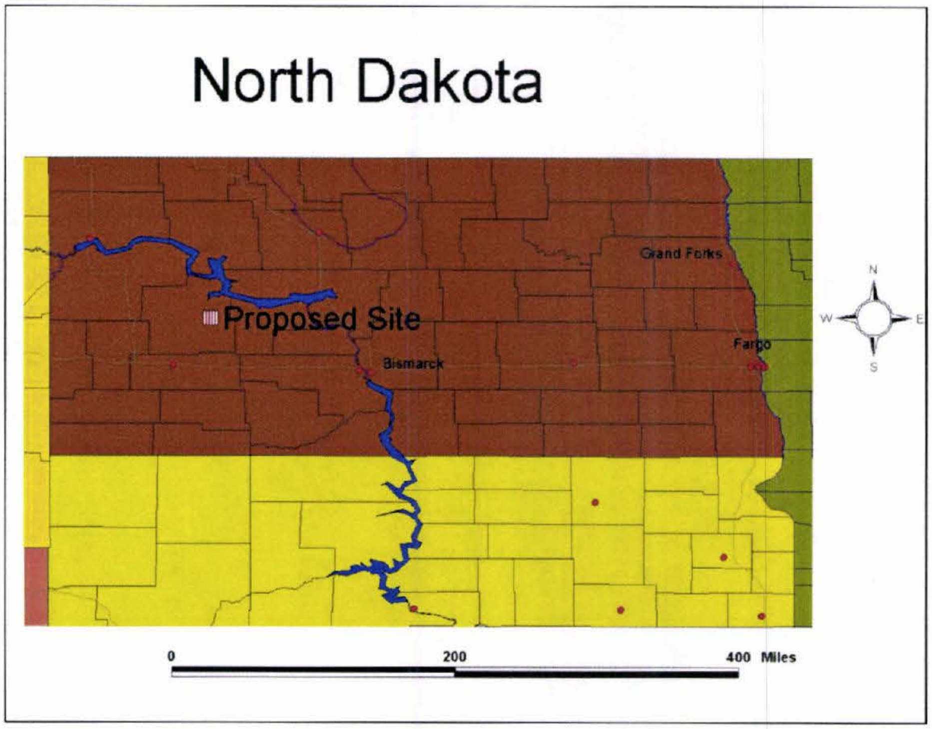



**Figure 1: Location of the proposed site (Wyatt, 2002)**

Background

Growing demands for energy and existing and projected shortages in petroleum and natural gas drove interest in the vast lignite coal in the western United States. Mines were opened and enlarged to ship increasing quantities of low sulfur coal to electric generating stations as far away as Eastern Europe.

Along with the growing interest in coal, there is a growing interest in the preservation of the environment in areas of mining. Surface mining has a far more conspicuous impact upon the environment than does deep mining, but surface mining allows the coal to be more fully extracted when it is technically and economically feasible to remove the overlying material. In North Dakota the concern is to not compromise the agricultural productivity of the land. Any change in the landscape, soil, or subsoil may adversely affect water holding capacity, erodibility, or fertility of the soil. In response to this, Congress has passed legislation to minimize the impact of coal development on the environment.

As a result, various federal and state agencies promulgated regulations governing the reclamation of mined land. Geologists, soil scientists, biologists, and agronomists determined methods to successfully return strip-mined lands to a vegetative productivity equal to or better than before mining. Their concerns were revegetation, root-zone hydrology and chemical and physical characterization of overburden materials. They were also concerned with developing geological techniques to aid in the design of strip-mine reclamation.

## Objectives

Farming is not successful in this area because of the dry conditions. Dryland cattle ranching is the primary land use in this area. The design objectives and goals are as follows:

- Return the land to a state where it will be capable of supporting dryland cattle ranching
- Return the land to full vegetative productivity
- Contour the cast-overburden to prevent erosion and permit access with farm equipment
- Place suitable plant growth material over the surface, and seed the surface with appropriate community of plants
- monitor for a period of two years to permit vegetation to become well established

## Preliminary Analysis

Pre-planning prior to applying for a permit is needed to determine whether the area once disturbed can be stabilized. If it is determined that satisfactory stabilization is possible (and the decision is made to go ahead with mining), then the objectives of pre-planning are the control of off-site erosion, effective silt control, proper spoil placement as determined by physical and chemical characteristics of the site, and the establishment of protective vegetative cover over the disturbed mine area.

Since the reclamation of a strip-mine is most likely taking place immediately following mining, it is important to understand the mining processes. Figure 2 shows a simplified strip-mining and reclamation process.

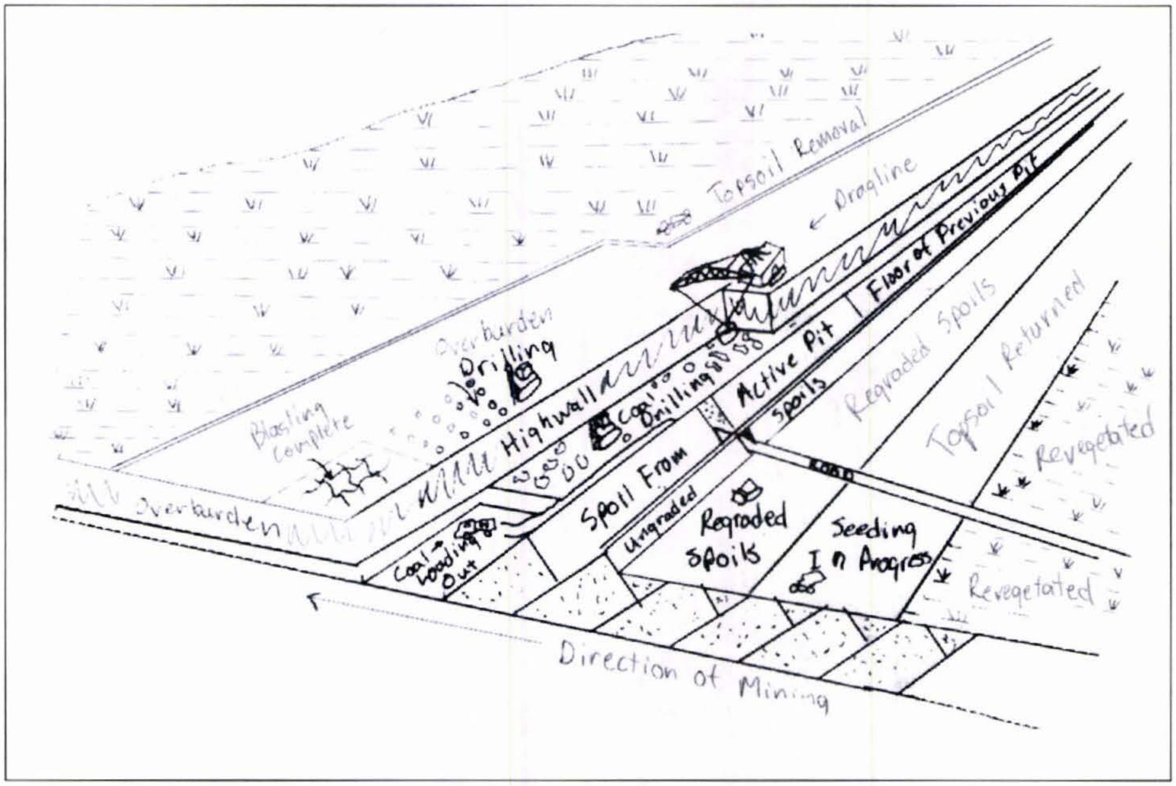



**Figure 2: Operation and reclamation of a coal strip-mine**

An important component of preliminary analysis for reclamation potential is site characterization. The remainder of this section will deal with the geological, hydrological, biological, and climatic conditions of this site.

Weather Conditions and Climate

The climate of Dunn County is continental and semiarid. In this climate there are long, cold winters and short, warm summers. Most of the precipitation falls during the growing season.

Tectonic Setting

This site is just east of the center of the Williston Basin, so the best way to describe the tectonic setting would be to describe the main features of the Williston

Basin. It is a structural-sedimentary intracratonic basin located on the western shelf of the Paleozoic North American craton. It is approximately 202,000 square miles, in extent. The basin began subsiding during the late Cambrian / early Ordovician and has continued to this day, with the center in roughly the same position throughout.

Topography

The topography at this site generally consists of gently rolling hills interrupted by isolated buttes. There is a persistent northeast-trending structural ridge flanked on the southeast and northwest by structural depressions. These depressions are thought to be a result of the dissolution of underlying salt beds, or salt subsidence. The area has a few structural high and low areas. A thinning of the beds caused the low areas. In the river valley and in glacial meltwater trenches, landsliding may have caused an irregular lowering of the beds.

Stratigraphy

It is important to know what materials we are going to be working with and their structural characteristics. This subsection will discuss these items.

Dunn County was near the edge of the Epicontinental Sea during the early Cenozoic Era. The coast was continually transgressing and regressing. This resulted in varying types of sediments deposited. When the coast was further west, away from the site, swamp vegetation existed. When the coast was to the east, coastal deposition occurred. This dynamic process was responsible for the varying sedimentary layers that we see today. Figures 3 and 4 show the east-west and north-south stratigraphic cross-sections at this site. They are intended to show the diversity of the stratigraphic layers.

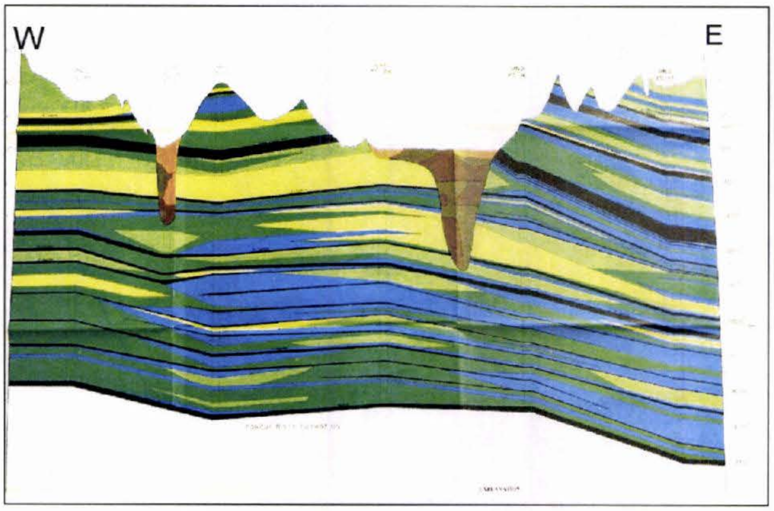



**Figure 3: East-west stratigraphic cross-section (Murphy, 2001)**

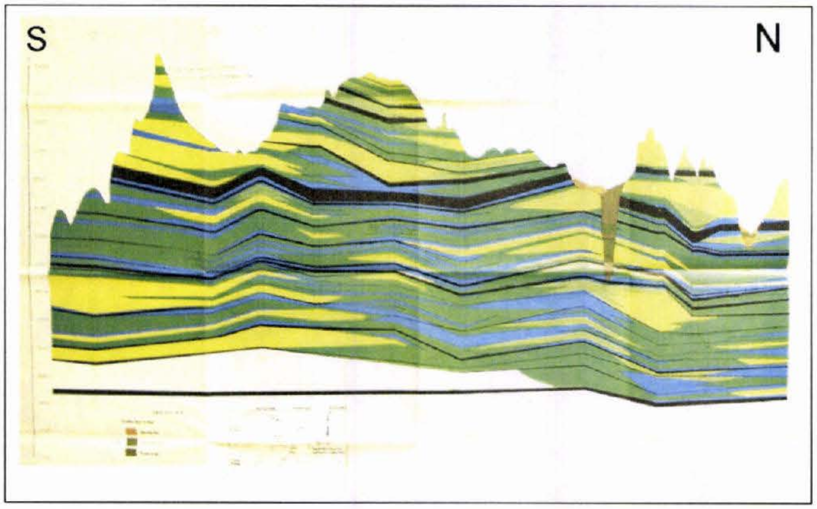



**Figure 4: North-south stratigraphic cross-section (Murphy, 2001)**

The formations of specific interest for this site are those that overlie the Dunn Center lignite. They are the Coleharbor Group, the Golden Valley formation, and the Sentinnel Butte formation. The Dunn Center lignite actually lies within the Sentinnel Butte formation. The Coleharbor Group at this site includes all the unconsolidated gravel, sand, silt, clay, and till that overlies the Golden Valley and Sentinnel Butte formations. The Golden Valley formation is made up of two members. The lower member is 30 feet thick, and is made of gray silt and clay. The upper member is made of crossbedded micaceous sand, sandstone, and silty fine-grained sand. The Sentinnel Butte formation is comprised of alternating beds of grayish brown to gray sandstone, siltstone, mudstone, claystone, and lignite.

Sedimentology

This section will discuss the nature and deposition of the sediments present at the site. Again, it is important to have a grasp of the engineering characteristics of these materials when working with them.

The sediments at the site are >90% loam of varying types, with slopes ranging from 1 to 15%. The loam is a poorly sorted mixture of sand, silt, and clay. In general, there are three main types of loams present:

1) Morton-Rhodes-Savage association: well drained and moderately deep and deep, medium textured and moderately fine textured soils which formed in material weathered from shale and siltstone or which formed in alluvium.
2) Vebar-Parshall association: well drained, moderately deep and deep, moderately coarse textured soils which formed in material weathered from sandstone or which formed in alluvium.
3) Savage-Lawther-Rhodes association: well drained and moderately well drained, deep, medium to fine textured soils that formed in alluvium and clayey sediment.

Glacial deposition accounts for the soil in place in Dunn County. Dunn County is near the extent of the area glaciated, and much sediment was deposited. Post-glaciation, there were melt-water lakes and channels present, and these melt-waters deposited clay-sized particles.

There is also a good amount of organic material present, which is due to the high amounts of vegetation present now and in the past. The decaying material makes the soil quite humic.

Soil Profile

This section will discuss the physical characteristics of each component of the soil profile. This information will be useful when we consider blending the reclaimed area with the surrounding areas.

The most common series of soil encountered at the site is the Morton series. The soil profile for the Morton series is summarized below (Wright, 1982).

- A – 0 to 5 inches. This is dark grayish brown silt loam. When moist, it is very dark brown. It has a moderate granular structure. It is slightly hard, friable, slightly sticky and slightly plastic. It supports many very fine and medium roots. It is neutral in acidity. It has an abrupt smooth boundary.
- B – 5 to 11 inches. This is dark yellowish brown silt loam. When moist, it is dark brown. It has a moderate medium prismatic structure parting to strong medium blocky. It is very hard, firm, sticky and plastic. It supports fine roots. It has many moderately thick clay films on the faces of peds. It is neutral in acidity. It has a gradual wavy boundary.
- B – 11 to 27 inches. This is light yellowish brown silt loam. When moist, it is olive brown. It has a moderate medium prismatic structure parting to moderate medium

blocky. It is hard, firm, sticky and plastic. It supports fine roots. It has thin clay films. It is neutral in acidity. It has a gradual irregular boundary.

- C – 27 to 37 inches. This is light olive-gray silt loam. When moist, it remains olive-gray. It has a few fine distinct yellowish brown mottles. It has a weak, thin, platy structure. It is hard, firm, slightly sticky and slightly plastic. It supports a few fine roots. It commonly contains fine soft masses of carbonates, which gives it violent effervescence. It is moderately alkaline. It has a gradual irregular boundary.
- C – 37 to 60 inches. This is light olive-gray, soft, platy siltstone. When moist, it is olive-gray. It supports a few fine roots. It exhibits a slight effervescence when exposed to acid, and it is moderately alkaline.

Geochemistry

Geochemistry deals with the interaction of earth fluids and earth solids, specifically the chemical reactions that take place. The geochemical processes that occur in the unsaturated zone control the chemistry of the groundwater. This is a topic that should be considered when reclaiming the area. We want to avoid drastically altering the geochemistry of the area.

It is understood that the redistribution of overburden will likely generate a more chemically reactive landscape than was present before mining. This is because dragline removal of overburden promotes "overturning" of the overburden materials. As a result, we can expect a twofold to threefold increase in the mineralization of groundwater in the spoils, and thus a decrease in groundwater quality. The highly mineralized conditions could continue for hundreds of years. The only way to minimize the mineralization of groundwater in the spoils is to selectively place geochemically distinct overburden, which would be far too costly.

In this area water is the medium through which most chemical reactions take place. The amount of rainfall that the area receives controls the chemistry of the groundwater. If there is an exceptional amount of rainfall or snowmelt, several processes occur in the unsaturated zone. Carbon dioxide is produced, pyrite is oxidized, and the carbonates, calcite and dolomite, dissolve. There is a cation exchange with the soil, and salts that accumulated in the root zone move downward and dissolve in the groundwater.

It is most probable that there will be rainfall or snowmelt insufficient to result in groundwater recharge. Under these conditions evapotranspiration is greater than the water present due to precipitation. The salts present in the water remain in the root zone after the water is evapotranspired.

A large portion of the geochemistry of the area is the ion exchange that takes place in the interaction of groundwater and clay particles. Groundwater does not flow through aquitards quickly enough for them to be of geochemical significance, so we will deal mainly with aquifers. The Sentinnel Butte formation contributes to the groundwater of Dunn County. It contributes large amounts of $Na^{+}$, $Ca^{2+}$, and $Mg^{2+}$.

It is possible that methane gas is present in the Dunn Center bed. It would mainly be stored in the micropores of the lignite, and some amount would likely be dissolved in the water.

<u>Hydrology</u>

The main surface water bodies in this drainage basin are Marshall Slough and the Knife River. The surface water flows through several local, intermittent drainage channels. These channels are located at the topographic low points. The Knife River drains the area. The direction of groundwater flow is to the southeast. We will have to design drainages and gradients that are consistent with this general direction of flow in order to make the hydrology of the mined area blend with the hydrology of the surrounding areas.

Groundwater movement at this site is restricted because most of the units are silt and clay material, or aquitards. The quaternary units of sand and gravel and the lignite are aquifers. In the confining layers, the main direction of flow is downward. Once the groundwater reaches the aquifers, the flow changes direction and magnitude. The water then moves laterally, to the southeast in general, although it may be influenced by the local permeability of the aquifer. It also flows much faster than it did in the clay-silt layers.

Discontinuities

A significant discontinuity consideration at this site is the fracture system of the Dunn Center lignite. The fracture system that occurs naturally is referred to as cleat. The cleat system is the main source of in-situ permeability, allowing hydraulic conductivity values to vary from 1 to 60 millidarcy (mD). These fractures occur in two directions at approximately 90 degrees to each other. These fractures are generally continuous throughout the coal seams.

Other sources of discontinuities include bedding boundaries, the boundaries between formations, burrow holes, and scattered salt lenses.

Flora and Fauna

A basic knowledge of the plants and wildlife present at this site is necessary, if we intend to return the land to a level that can support this life. This section discusses the common plants and wildlife present.

Plants have significantly influenced the formation of the soils on the site. The roots of these plants affect both the mechanical and chemical weathering processes. Water flows through the upper layer of the soils toward the roots, leaching the soil. The roots also provide structural reinforcement to hold the soil together. The most common types of vegetation in this area are short to mid grasses, such as western wheatgrass, slender wheatgrass, tall wheatgrass, and pubescent wheatgrass. Alfalfa and yellow blossom sweet clover are also common among the vegetation of this area. It will be necessary to return the land to this vegetative productivity, so the land can continue to be used for cattle ranching.

Animal life also plays a significant role in this area. Earthworms, small animals and microorganisms all interact with the environment altering it in various ways. Dens and burrow holes are examples of the effects of small animals. Microorganisms affect the environment by breaking down dead plant tissue into humus, giving nutrients for plant growth. The bacteria's ecological niche is in the root zone.

Larger animals present include reptiles, rodents and waterfowl. Snakes are the primary reptile species present. Mammals common to this area include weasels and prairie dogs. Ducks, geese, and pheasants also frequent this area.

## Design Constraints

### Legal

The laws regulating surface mining have changed considerably since their inception in the early $20^{th}$ century. Before 1977, three federal agencies regulated surface mining on federal lands. The Bureau of Land Management leased all federal lands. The Bureau of Indian Affairs helped tribes lease their lands. The U.S. Geological Survey (USGS) inspected both federal and Indian lands leased for coal mining. The USGS reported quarterly on the acreage of land disturbed and reclaimed, the seed mix used to reclaim the land, and the equipment inventory. Because the USGS's main interest was in revenue, other issues such as the placement of toxic materials, topsoil, water quality, revegetation procedures, and land use were not usually included in these inspections.

The passage of the federal *Surface Mining Control and Reclamation Act* (SMCA) in August 1977 significantly changed the regulatory requirements for the surface mining industry. The law established federal legal controls where few, if any, had existed and provided a uniform program to control surface mining in states where regulations may not have existed. The SMCRA created the *Office of Surface Mining* (OSM) to develop and administer federal regulations for surface coal mining.

In May 1978 interim regulations took effect for all surface coal mining in the United States. At the same time, agency officials began inspecting mines unannounced to monitor the compliance with all permit conditions. These officials check earthmoving techniques, preservation of water systems, and land productivity.

The *Environmental Protection Agency* (EPA) requires that the mine operator obtain a *National Pollutant Discharge Elimination System* (NPDES) permit and submit quarterly *Discharge Monitoring Reports*. The NPDES permit is a lengthy document, which specifies permissible levels of pollutants in the water discharged from a mine site and required the method and frequency of monitoring these levels. Discharge Monitoring Reports are filed with the EPA to record the range of water quality and the levels of total suspended solids in the water.

Hydrological

Low soil water quality is probably the greatest single factor inhibiting reclamation for this area. It is the result of low erratic rainfall patterns, very high or very low permeability, and high salt loads that increase osmotic stress acting against water uptake by plants. Little water falls on the spoil, and of the water that does fall, much soaks in very rapidly or runs off. Water that does come in contact with plants is so salt-laden that plants cannot use it. It is impossible to increase the amount or pattern of natural precipitation; therefore much of the research has to be concerned with methods of retaining that which does occur.

In areas where spoils have a high clay content, a method of increasing the quantity of water absorbed by the spoil is to increase permeability. This is accomplished by additions of sand or organic material, such as straw, slack coal, sawdust, sewage solids or manure. Top-soiling also tends to increase permeability, since the surface material is usually significantly lower in clay than the subsurface materials.

At this site the addition of organic matter, whether in topsoil or as an amendment, tends to soak up water and release it slowly, decreasing the effect of the erratic precipitation pattern. Organic materials also tend to provide for complex macro- and micro- nutrients to make them more available to plants.

Some form of additional fertilization is necessary at least for the first few growing seasons. A further significant feature in increasing the water retention of the spoil is a resultant decrease in surface runoff and erosional losses.

Another method of counteracting the water stress problem is to select or adapt economically important ecotype plants to survive the high water stress conditions so often encountered.

More complex than estimating the effect of disturbance and reclamation on a single component of the landscape is the understanding of interactions between components. Because the entire watershed has developed as a coordinated system, a disturbance such as mining and reclamation may have effects upslope, downslope, and laterally. These effects may be especially complex when several mines occur on the same watershed. Areas not directly disturbed by mining may become unstable until the entire system has had time to adjust. Conversely, we must look out for disturbances which are unrelated to mining and which occur outside the reclaimed areas, or even outside the mine lease. Disturbances in this category can adversely influence reclamation regardless of the procedures used for revegetation and stabilization.

Geological

There is geological importance in determining the success or failure of a reclamation program. The reclamation of this site must be planned according to the site's soil, precipitation, and vegetative characteristics. A successful reclamation program at a different site cannot be transposed to this site because of the differences between the soil, precipitation, and vegetative characteristics.

Aesthetic

Few public officials deny that a reclaimed area that is both aesthetically attractive as well as useful may be more desirable to the community than was the original shape.

For the mine operator, returning the land to other than the original contour may cause him to risk time and effort to create the original design for the site, only to have the approval held up for a lengthy time or rejected outright. So he, as well as many environmentalists, may prefer simply to return the area to its original contour.

Aesthetics is one aspect of surface mine reclamation that has received virtually no attention in planning strategies, although it may well receive the most attention upon the completion of reclamation. While aesthetics is a frequent subject of discussion among reclamation officials, regulatory agencies, and environmentalists, aesthetic quality and criteria and standards by which they are evaluated seem to be one of the least understood facets of surface mining.

Confusion regarding the standards of aesthetic quality often conflicts with sound reclamation goals and objectives. The public wants the mined site to be returned to an attractive, useful state that is equal to or greater than its pre-mined state. This goal has become equated with "return to original contour", as if the policy were the only legitimate approach to high-quality reclamation, regardless of specific conditions of the site and of opportunities by an improved after-use.

A return to original contour appears to be simplicity itself, which goes a long way towards explaining its overwhelming popularity. For the surface mine operator, it has the attraction of making it unnecessary to risk uncertainties of creating an original design for the site.

For reclamation authorities, a return to the original contour has the advantage of simplifying their considerations. Reclamation either approximates what was there before, or it does not (and if it does not, discrepancy is at least apparent). For legislators, too, the original contour concept has merit of its simplicity, a feature that makes it unnecessary to complicate the surface mine legislation with many qualifying conditions, exceptions, and variances. In view of these attractions for those on all sides of the reclamation issue, it is hardly surprising that a return to the original contour has won so much support.

**Design Approach**

The following items are considered in the design approach:

- Movement of topsoil, while it is still fresh from the opening of new areas, to areas being reclaimed is crucial. The elimination of lengthy periods of stockpiling gives roots and seeds in the topsoil a better chance to survive.
- Irrigation will not be used to any extent to allow the grasses and trees to establish on their own.
- Fertilizer may be used to stimulate growth.
- Hydromulching of slopes may be used. Planting spring wheat or oats may be practiced to allow stubble to grow. Grass seeds may be planted in the stubble.
- Ripping slopes, as well as other recontoured area, may be created to reduce erosion and compaction.

**Design Assumptions**

In this design we assume that the refilling of overburden at the depth where there was once a coal aquifer will have a major effect on the quality and availability of water flowing in the area. Groundwater is a crucial land disturbance issue related to surface mining. Coal seams provide pathways in which water flows underground. Because refilling and grading mine pits does not return the subsurface geologic layers precisely to their pre-mining positions, it can be expected that mineralization of the groundwater will increase by two to three times. A brief discussion on the effects on groundwater is presented in the "Preliminary Analysis" section under "Geochemistry".

We will also assume that there will be enough coal production to make this reclamation design economically feasible. This means that we assume the benefits from coal production will greatly outweigh the costs of reclamation.

**Preliminary Design Options**

Grading and contouring

Grading and contouring are simple earthmoving operations using huge and powerful bulldozers to smooth large amounts of soil and rock. After several spoil piles have been created, they must be contoured and shaped to the surrounding topography. This is the first step in returning the area to a topography consistent with that which existed before mining. Bulldozers flatten and smooth the ridges created by spoil piles. The goal is to ensure that the particulars of an individual topographical feature, such as the slope of a valley, and of the entire site, blend with the surrounding topography. Figure 5 shows a cross-section of partially contoured spoil-piles.

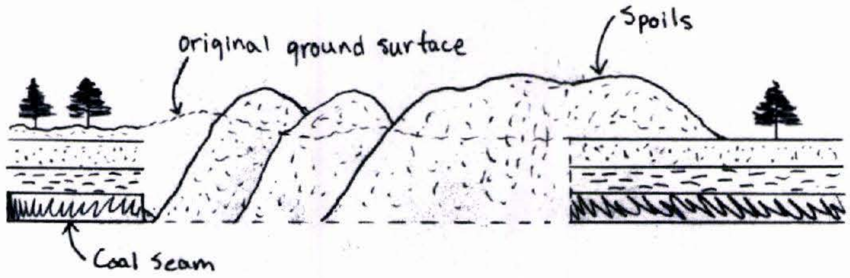



**Figure 5: Cross-section of partially contoured spoil piles**

Replacing topsoil

Once some contouring has been completed, the land is available for scrapers to replace topsoil to a uniform depth. As the scraper moves over the area where topsoil is to be replaced, topsoil is mechanically ejected from the interior of the vehicle onto the graded surface. To preserve the segregation and sequence in which topsoil has been removed, topsoil should be replaced in two horizons. Most topsoil should be spread on the mined land immediately after the land has been graded, to avoid extensive stockpiling. If the topsoil is stockpiled extensively, it would take additional time and expense to replace it.

Selection of species for revegetation

Proper selection of species for revegetation is of major importance in successfully establishing vegetation in the reclamation of mined lands. Method of seeding, depth of seed placement, seeding date, application of mulch, seeding rate, and other factors influence the ability to successfully establish vegetation. Even if all the factors are optimized, if the species selected are not suitable for the area, the planting is doomed to failure.

On-site research with plant communities has been done to select and apply a seed mixture to ensure that the recreated plant community can support long-term rangeland use. A successful seeding program relies on a knowledgeable choice of plant species, the quantity of seed, the seeding method, and the approximate time for sowing seeds.

Seeding techniques

There are three basic seeding techniques: drill seeding, broadcast seeding, and hydroseeding. A drill-seeding device digs small furrows in the ground, channels seed into them, and rakes the surrounding topsoil over the seed to cover it. Broadcast seeding is a process in which a tractor tows a seed-filled bin. As the bin is pulled, its wheels turn a set of rotary blades within the bin to dispense the seed. In hydroseeding, a water-based mixture of seed and fertilizer or mulch is sprayed onto the land.

Mulching

Hay mulch fosters germination of the seeds and growth by stabilizing and preventing evaporation of water from the soil. Hay is shredded in a mulcher and distributed about the land. A crimper presses the mulch into the ground and anchors the seed.

Fertilization

Fertilizer is usually composed of nitrogen and phosphorus. It is typically applied at a rate of 20 to 30 pounds per acre. Fertilization usually ceases once the permanent species are growing.

Tree and Shrub Planting

There are four kinds of growing techniques: bare-root or tree-spade transplants, direct seeding, and containerized transplants. Bare-root seedlings are transplanted by hand. Tree-spade transplants are performed by a machine that lifts the tree, roots, and soil at once and places it in the desired location. Direct seeding and containerized plantings are both usually done by hand, planting and covering either a seed or a containerized unit of plant, soil, and nutrients.

**Final Design**

Task 1: Site characterization

A detailed investigation of the site has been done and is presented in the "Preliminary Analysis" section (above).

Task 2: Planning and design

This task dominates the remainder of this paper.

A performance bond of 10 million dollars will be issued to the Public Service Commission before any mining takes place. It insures that the land will be reclaimed at no cost to the State or to the public.

Task 3: Grading and contouring

Immediately after the overburden is removed from the active pit, it will be transported to the previous pit. Prompt return of the mined land to productive use will minimize the adverse environmental impact that earthmoving operations can create. This strategy includes the protection and reuse of topsoil and subsoil found on the mine site. Also, to encourage the most favorable medium for plants to grow, as well as protect water resources, any toxic or acidic materials exposed in the mining process must be segregated from the plant root zones and groundwater.

We will grade within three spoil ridges of the active mine pit to ensure that seeding operations closely follow coal production. Earth and rock that are removed from the working pit will be placed in the nearest empty and abandoned pit. In effect, the last hole dug will be filled with earth and rock, or overburden, from the pit being mined. Overburden from the first hole dug must be placed on the surface, as no other hole yet exists.

Before the overburden is removed, it is tightly compacted by the weight of soil and rock above it. Removal operations will break up the overburden and increase its volume as air fills in areas of decreased pressure. Thus, the amount of overburden will likely exceed the capacity of the hole to be filled. This will create spoil ridges, which will be graded to the reclaimed area's final contour before the topsoil is replaced and planting begins. The grading will be done to prevent wind and water from eroding the spoil ridges and increasing sedimentation off the site.

The land will be graded to approximately its pre-mining contour to ensure adequate drainage of surface water and the land's ability to support post-mining use. The shape of the graded land will complement that of the surrounding lands so that surface water flow and drainage patterns are similar. North Dakota law requires that grading and backfilling "be carried out so as to produce gently undulating topography or such other topography as is consistent with the proposed end use of the area" (Wiener, 1980).

Task 4: Seed bed preparation

The topsoil will be removed and segregated from the subsoil to provide the best soil for revegetation. Topsoil is the one medium on the mine site that definitely will support plant life, as it was doing before mining began. Thus topsoil and soil layers or "horizons" directly beneath it will be removed separately and replaced on top of the graded overburden to establish vegetation.

The topsoil will immediately be replaced on the graded land to protect the quality of topsoil. We will stockpile only that topsoil removed to create the first mine pit and seed the stockpile until it is ready to be used. The topsoil removed in digging the first mine pit cannot be placed on any graded areas (as none yet exist), this topsoil would best be stockpiled in an area that would not be disturbed until it can be used, and seeded to vegetate and stabilize the stockpile for that period. Roots and stumps will be removed before it is stockpiled because they impede the removal of soil from the stockpile. Once grading begins, topsoil will be immediately spread over the graded land without being placed in a stockpile, then seeded. This direct haulback process will require less vegetation to be removed from the topsoil. Organic materials in the topsoil will improve its quality and add nutrients to the soil as they decompose. Micro-flora and fauna will also be preserved when the soils are directly replaced on graded lands, and the topsoil may be a minor contributor of native seeds. The major reasons not to stockpile topsoil are presented below:

- It can only be stockpiled for a limited time or it will lose its ability to enhance vegetative growth
- topsoil placed directly without stockpiling would produce a much greater percentage of growth from salvaged seeds and plant materials

- continuous handling of topsoil is desirable in order to preserve nutrient storage equilibria and soil micro-organisms

The topsoil and subsoil will be replaced to a uniform depth to create an opportunity for successful revegetation over the entire mine area. The topsoil may not have been uniformly distributed over the entire mine area before mining began, but it will be replaced in uniform fashion to equalize the revegetation potential of all of the disturbed areas. Natural forces will eventually determine which areas will accumulate more topsoil and which will lose replaced soil.

Task 5: Planting

A mixture of native plants similar to the pre-mining community in both diversity and seasonal variety will be seeded to create and sustain a plant community best adapted to the mine area. Native plant species have become adapted over the years to the area's climate and topography. Introduced plant species usually require continual maintenance, which is not a desired trait of self-sustaining groundcover. The use of introduced species, even in small proportions to the native seed, can cause significant setbacks to the native species because of the short-term competitive advantage of exotics in establishing themselves.

The seed will be planted after the topsoil is replaced. Seeding will begin as soon as possible to keep erosion to a minimum and to start re-establishing plant cover. Seeding immediately after the topsoil is replaced will take advantage of a freshly prepared seedbed. A quick-growing cover of herbaceous species is necessary to obtain quick stabilization of soil and initial protection against erosion. Topsoil left without vegetation is more susceptible to invasion by weeds. The seeding program will ensure that the seed is in the ground before germination is most likely to occur.

We will use machinery that opens a groove in the soil, drops in seed, and covers it in one continuous operation to spread the seed accurately and evenly on the land. In order to create the best environment in which the seeds may germinate and grow, they will be placed in the soil and covered to protect them from heat, winds, and foraging wildlife. Broadcast seeding does not achieve this goal because wind can prevent the even distribution and placement of the seed. Spraying seeds in a mixture of water and mulch and/or fertilizer –hydroseeding—does not selectively place the seeds in the soil, and it creates other problems: seed is immersed in a water-and-fertilizer solution, which can cause early germination, thus rendering the seed useless if planting is done in the fall with the intention of spring germination and growth.

Task 6: Establishment and monitoring

Mulch will be used that contains seeds of the same species as the planted species. Mulch will provide an excellent source of extra seeds on the land. Mulching will facilitate the germination and growth of the vegetation. The mulch will conserve moisture, reduce temperatures, prevent erosion, and supply organic acids and essential plant nutrients.

Fertilizers will supply nutrients such as nitrogen, potassium and phosphates to the soil. The type of fertilizer and amount to be used is determined by studying the composition of the soil chemistry. These specifications will be discussed further in the specifications section.

We will plant trees and shrubs similar to those that were present on the site before mining began. Trees and shrubs represent a higher order of plant in the development of a vegetative community. A mature plant community consists of a mixture of grasses, shrubs and trees. Shrubs and trees will shelter other plants from wind, sun and excess water, protect the soil from heavy rains and hailstorms, and provide habitats and forage for wild and domestic grazing animals.

Task 7: Bond release

The performance bond will be released incrementally. 60 percent will be released following the backfilling, grading and establishment of drainage control, and respreading of subsoil and topsoil. After the eleven-year period of responsibility, the land will be suitable for its pre-mining use, and the remainder of the bond will be released.

**Design Specifications**

Tasks 1, 2, and 7 require no further discussion in this section.

Task 3: Grading and Contouring

The overburden will be removed from the active pit and transported, via dump trucks, to the previous pit. Then the overburden will be graded and contoured, using bulldozers and scrapers, to the site's approximate original contour. This will help preserve the pre-mining drainage patterns. Material from the initial pit will be graded to blend with un-mined land. Figures 6 and 7 show the original and reclaimed surfaces of the site, respectively. Notice that the high and low areas are preserved in their exact locations to ensure adequate drainage.

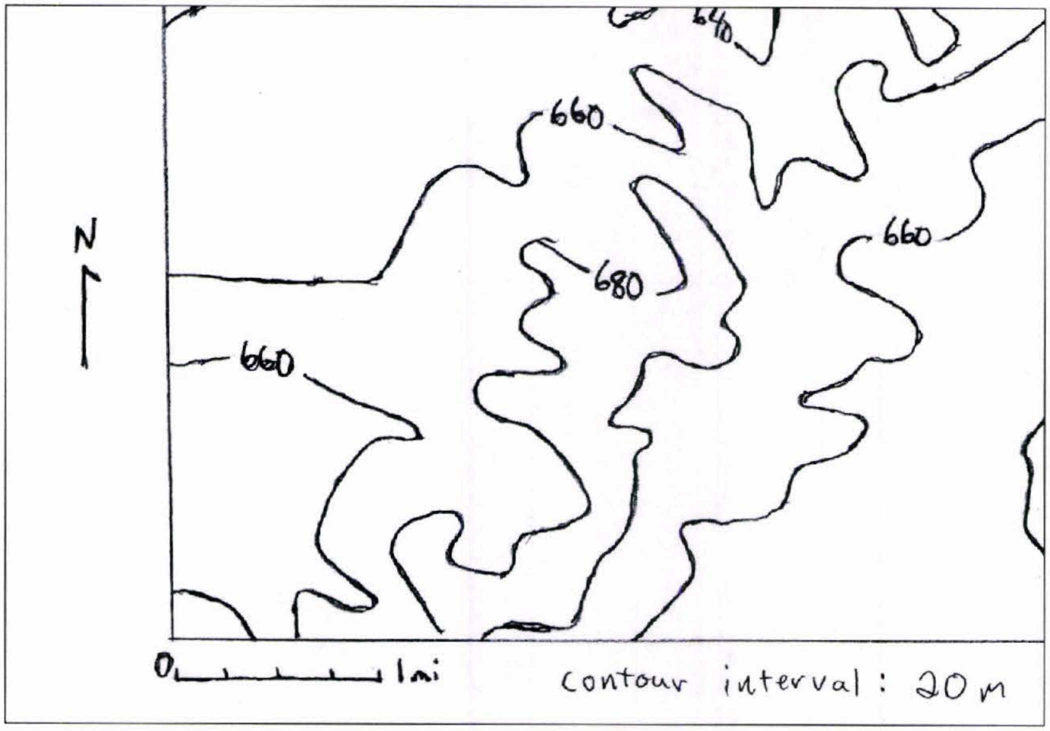



**Figure 6: Pre-mining contour of the site**

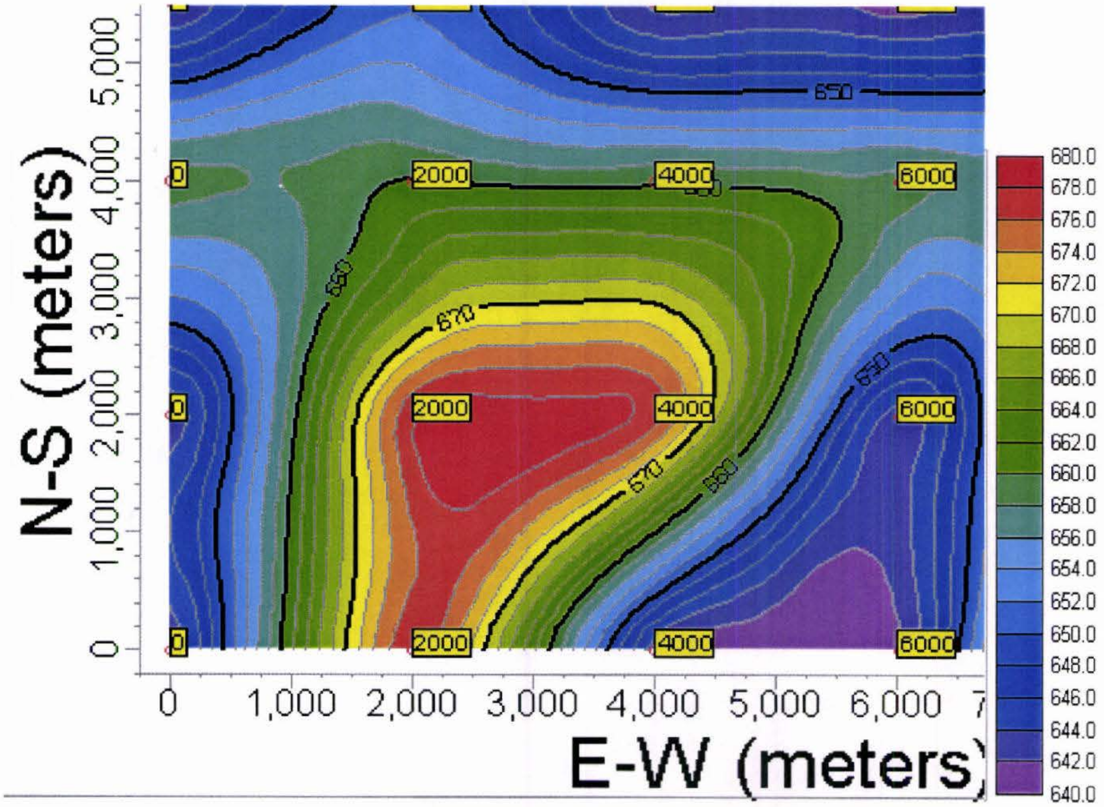



**Figure 7: Contour map of land surface after reclamation**

Task 4: Seed bed preparation

The topsoil and subsoil will be removed separately with scrapers from an active pre-mining area, and hauled, via dump trucks, to the graded overburden of a previous pit. The subsoil will then be applied and spread using rubber-tired scrapers and low ground pressure bulldozers to a uniform depth of 40 inches. Coarse fragments greater than 10 inches will be removed, and the total volume of coarse fragments in the subsoil will not exceed 20 percent. The clay content in the subsoil will not exceed 40 percent. The topsoil will then be applied and spread using rubber-tired scrapers and low ground pressure bulldozers to a uniform depth of eight inches. Figure 8 displays the depth profile for the newly replaced subsoil and topsoil.

Task 5: Planting

We will use the drill-seeding method of planting, because the placement of seed is direct, a minimum amount of seed mixture will be used, and the distribution is even. Drilling provides the best method of obtaining a uniform distribution and depth of seeding.

The seed mixture will be a mixture of grasses native to the pre-mining grassland. The plant species, pounds of seed per acre, and cost of seed per acre are presented in Table 1.

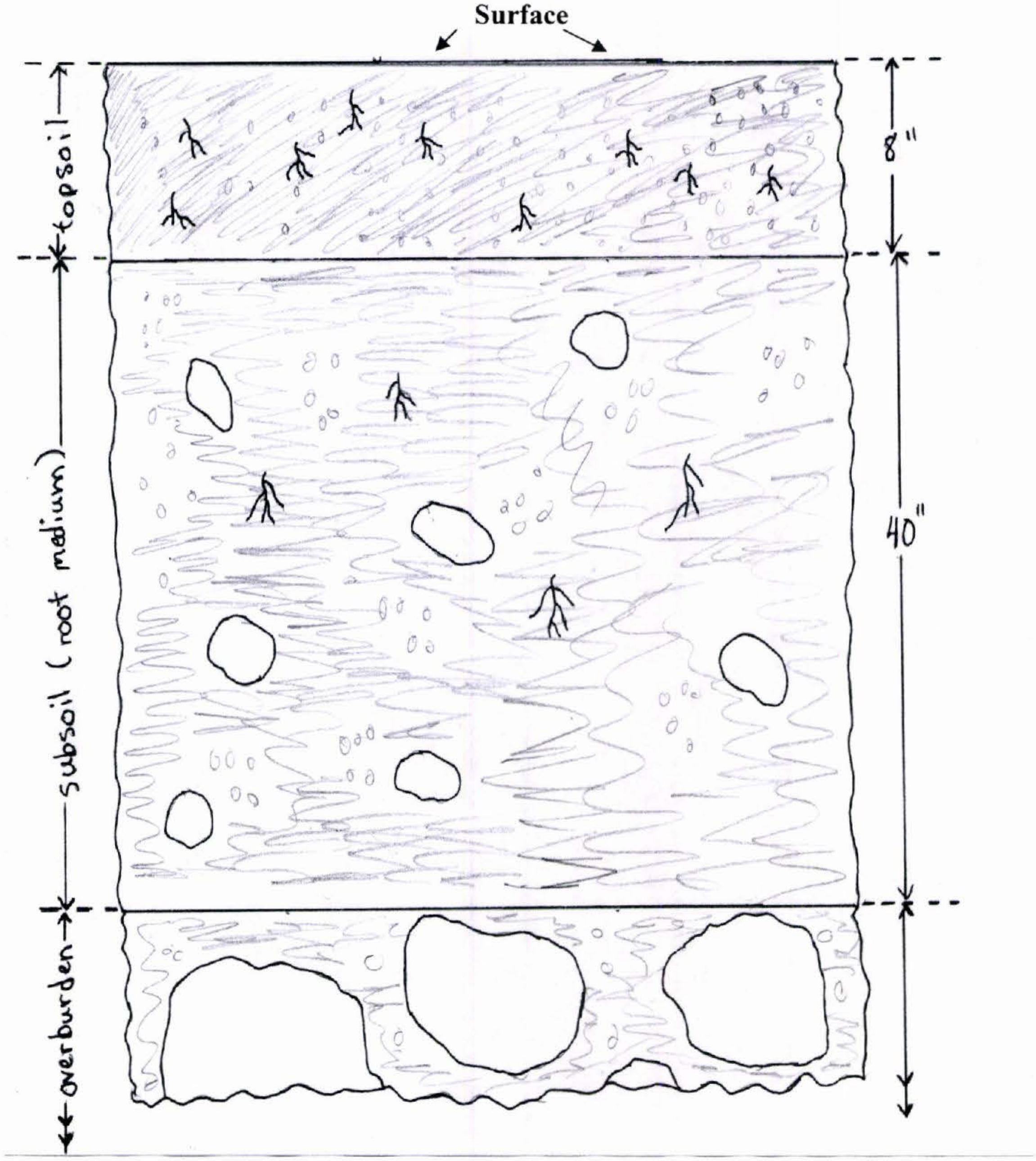



**Figure 8: Depth profile for replaced subsoil and topsoil**

| Table 1: Seed Mixture Specifications | | |
|---|---|---|
| **Plant Species** | **lbs/acre** | **$/acre** |
| Sideoats grama | 1.0 | 8.00 |
| Little bluestem | 2.5 | 21.00 |
| Western wheatgrass | 6.5 | 65.00 |
| Needlegrass | 4.5 | 45.00 |
| Slender wheatgrass | 3.0 | 30.00 |
| Blue grama | 5.0 | 38.00 |
| **Total** | **22.5 pure live seed** | **207.00** |

Task 6: Establishment and Monitoring

We will use fertilizers to enhance the plant-growing capability of the soils. The fertilizer will be distributed from the underside of a fertilizing machine, pulled by a tractor. Table 2 outlines the types of fertilizer, the pounds per acre, and the cost of each fertilizer per acre. The application of these fertilizers would take place over multiple passes per acre.

| Table 2: Fertilizer Specifications | | |
|---|---|---|
| **Type** | **lbs/acre** | **$/acre** |
| organic nitrogen | 20 | 9.00 |
| synthetic nitrogen | 50 | 23.75 |
| organic phosphates | 15 | 6.00 |
| super phosphates | 100 | 43.00 |
| **Total** | **185** | **81.75** |

For the mulching process we will initially feed hay bales into a mulcher and distribute the mulch over the seeded area. When we have some revegetated plots, we will start mowing them and use the clippings for mulch in newly seeded areas. Then a crimper, a tractor-sized vehicle, will pull a drum with hoof-shaped protrusions that will press the mulch into the ground and anchor the seed.

We will not use containerized plantings because it is labor intensive, which would make it too costly. We will use direct seeding to ensure success in establishing the trees and shrubs. Direct seeding will ensure that there are enough seeds available in the area for the propagation of the species.

**Construction Cost**

The heart of the budget problem is that different companies measure reclamation costs differently, and so do independent commentators in the field, including the U.S. Bureau of Mines. The basic distinction between reclamation costs and production costs is itself shadowy, and operators draw the line at different areas.

The broadest approach is simply to state a total cost. The focus may be narrowed by specifying component costs under five or more categories in up to three different measuring units (cost per ton, per acre, or per Btu). Even the use of these units as a cost measurement tends to leave a large information gap.

The total reclamation costs are divided into six categories:

1) Site Characterization. This category includes a detailed analysis of the geologic, hydrologic, biological, and climatic conditions on the site.
2) Planning and Design. This category includes the development of the reclamation plan, surveying and mapping, and additional miscellaneous expense.
3) Grading and Contouring. This category includes backfilling troughs, and rough and fine grading of the spoil.

4) Seed Bed Preparation. This category includes the replacement of the subsoil and topsoil on graded spoils.

5) Revegetation. This category includes seeding and planting, and reseeding and replanting (if necessary).

6) Establishment and Monitoring. This category includes mulching, fertilization, and tree and shrub planting.

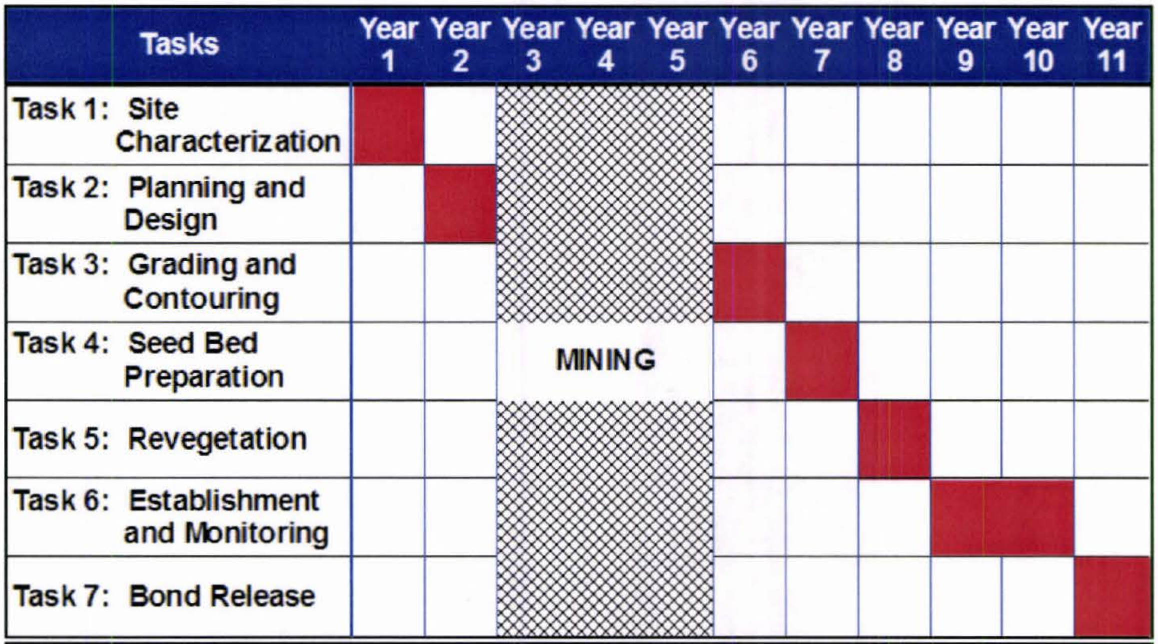
The costs for these activities are given in Appendix A.

## APPENDIX A: CONSTRUCTION COSTS

| Task | $/acre | Total |
|---|---|---|
| Task1: Site Characterization | na | $5,000 |
| Task 2: Planning and Design | na | $5,000 |
| Task 3: Grading and Contouring | $2,500 | |
| equipment | | $4,500,000 |
| labor | | $300,000 |
| Task 4: Seed bed Preparation | $1,700 | |
| equipment | | $3,000,000 |
| labor | | $300,000 |
| Task 5: Revegetation | $1,000 | |
| seed | | $392,000 |
| equipment | | $1,200,000 |
| labor | | $300,000 |
| Task 6: Establishment and Monitoring | $620 | |
| fertilizing | | $307,000 |
| mulching | | $120,000 |
| tree/shrub planting | | $150,000 |
| labor | | $600,000 |
| **Total** | **$6,000** | **$11,179,000** |

*These figures are based on the time estimates shown in Appendix B for 1900 acres of land.

## APPENDIX B: CONSTRUCTION TIME ESTIMATE



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