REVEGETATION

Section Editor: Mickey Steward

Handbook of Western Reclamation Techniques, Second Edition

TABLE OF CONTENTS

SECTION 5: VEGETATION

A. INTRODUCTION

Section editor: Larry H. Kleinman revised by Mickey Steward

Successful revegetation is essential to successful postmining land use, a fundamental requirement of the Surface Mining Control and Reclamation Act. Revegetation is the basis for most mined land reclamation programs. The revegetated mined area must meet two basic objectives: forage and habitat must be provided and erosion must be controlled. Forage and habitat resources are most commonly used for grazing and wildlife. Erosion control must result in an erosion regime that is similar to that found on adjacent undisturbed native lands. The variety of postmining land uses and undisturbed landscapes associated with surface coal mining ensures that no single "best" method can fit all circumstances. However, the procedures and techniques described in this section have been found to be successful and are broadly applicable.

Subsection B deals with establishing and implementing a revegetation program. The objective of the revegetation program is to establish the desired vegetation. The procedures described are seed-bed preparation, farming practices, seed handling, planting, mulching, shrub establishment, and reforestation.

Subsection C addresses seed ordering. Seed quality is vitally important to successful revegetation. Topics such as seed ordering, preparing a seed purchase request, origins and quality of seed, seed tags (certified and common seed), seed testing, and determining "Pure Live Seed" are discussed.

Surface stabilization is discussed in Subsection D. A stable surface will control erosion. Vegetative and non-vegetative methods for stabilizing the land surface or controlling erosion are described.

After vegetation is established, husbandry (management) becomes critical for its survival and longevity (Subsection E). Revegetation may deteriorate to less than desirable cover and production and to a less desired species composition without some type of management to sustain it. Native plant species evolved under some type of foraging pressure. Non-use is not natural for the species used in the revegetation programs. Therefore, some type of management that at least simulates "use" is vital for the maintenance of revegetated areas. The husbandry practices described in this fourth set of subsections include mowing for weed control, grazing, and burning.

Vegetation monitoring practices are described in Subsection F. Monitoring is essential for optimization of the revegetation program and for demonstrating progress toward conditions suitable for release of the Final Reclamation Liability Bond. All state regulatory agencies require that specific monitoring methods be approved and form part of the Mining Permit Application. To a large extent, State regulatory agencies specify vegetation monitoring practices. This section addresses non-regulated concerns such as specifics of vegetation sampling, recordkeeping of the total operation, and Electronic Document Management in Mining.

Many authors contributed to this section, each with a particular expertise and experience. The methods recommended here are not intended to be prescriptive or all-inclusive, but do represent tested and usable methods for addressing the topic at hand. In this revision, changes and additions have been made to the original document, but these changes and additions are designed to reflect new information and advances in technology, not to change the fundamental method or practice originally recommended by the author.

B. Establishing and Implementing a Revegetation Program

1. Preparing a Revegetation Package

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Adequate preparation and planning are vital to the success of any revegetation program. A revegetation package prepared for each planting season is a useful tool that will ensure sufficient planning as well as provide clear, concise instructions to those performing the actual revegetation work. It will also provide documentation for work accomplished, and serve as a record of revegetation activities.

Special Considerations

Inadequate preparation can lead to inefficient utilization of optimum weather conditions, as well as improper fertilization, soil preparation, planting, or mulching methods. Proper planning by outlining exact instructions or tolerances for each variable listed in the revegetation package ensures suitable implementation of revegetation practices.

Requirements of seed per acre for each area in the revegetation package provide a base for preparing a seed bid request. Husbandry practices, such as mowing, haying, interseeding, and burning should also be included in the revegetation package.

Techniques

a. Field Tour

The first step in the preparation of a revegetation package is to decide which areas (or revegetation units) need work. A field tour is always necessary to ascertain the status of these units. The field technicians who will be performing the planting can often be helpful at this stage in providing input regarding possible methods.

b. Decisions and Planning

First, the units to be included in the current revegetation season must be selected. Then, each unit must be categorized as permanent or temporary. Planning for permanent units must be done with forethought about **postmining land use requirements**. Decisions must be made regarding each of the variables that make up the revegetation package. Table 1 provides an example of the variables that are typically included in the revegetation package.

c. Revegetation Package

Revegetation packages are composed of maps, revegetation unit requirements, and information on seed mixes and revegetation practices to be used.

(1) Maps

Each revegetation unit is identified on a map of the mine area (optimum is an ortho-photo overlain with topographic information) and given a number (see "Unit Number" below). Each unit is digitized to determine its acreage. The map is included in the revegetation package.

(2) Revegetation Unit Requirements

Table B-1-1 is an example page from a revegetation package with the information required for the reclamation of each unit. A database is the best environment to use in assembling this information. Units can then be sorted by category, seed mix, etc., and requirements for mulch, fertilizer, and seed can be easily totaled. The package also provides a base for recordkeeping and reporting of exact work accomplished. If retained, the revegetation packages can serve as a history of unit-by-unit revegetation practices. The following variables may be included for each revegetation unit:

(a) Unit Number — One method of numbering that works well combines year (96), Spring or Fall (S), and number (01); 96S01. These numbers coincide with numbers placed on the corresponding map.

(b) General Area — Each unit can be given a name or a description.

(c) Category — Permanent Grazingland, Topsoil Temporary, Long-term Temporary, Husbandry, etc., are examples of categories that may be used.

(d) Acres — Acreages are determined by digitizing each unit on the map.

(e) Date work may begin — The earliest date work may commence for reclamation of that unit.

(f) Task — List in order exact reclamation practices to be used for each unit. Task and equipment requirements are best listed in a multi-records table embedded in the master table.

(g) Suggested Equipment

(i) A dual-wheel tractor is needed for safe operation on slopes steeper than 4:1.

ii) A hydroseeder may be required to ensure successful seeding of small and trashy seed, and seed whose germination is enhanced by light. It is also required on slopes too steep for drill seeding, and for application of wood, paper, or synthetic fiber mulch.

TABLE B-1-1. Example of Unit Activities from a Revegetation Package

2003 SPRING REVEGETATION PACKAGE	
UNIT NUMBER	2003S01
GENERAL AREA	Jack's Flat
CATEGORY*	Permanent Grazingland
ACRES	91.1
ACCEPTABLE WORK WINDOW	15 March – 15 June 2003
Task Disc Cultipack Roll before Seeding Seed Hydroseed Roll after Seeding Mulch	**Suggested Equipment** Offset Disc, 6-inch Cultipacker 48-inch Roller Multi-box Drill w/Depth Bands Hydroseeder Tubgrinder Crimper
Seed Mix: Permanent Grazingland	
Nitrogen	10 # per acre
Phosphorus	20 # per acre
Potassium	10 # per acre
Mulch Type	Straw
Mulch Rate	1 ton per acre
Remarks: Rockpick where necessary	

iii) A multi-box drill may be required to ensure proper seeding and coverage for a variety of seeds.

iv) A grain drill may be needed where grains are planted as a cover crop.

v) A 48-inch roller can be used to ensure a firm and evenly compacted seed-bed, and optimum seed/soil contact. The roller can be used before and after seeding. Rolling is particularly useful in dry conditions where soil moisture is limited.

vi) A tubgrinder is used for the even application of grass and straw mulch.

vii) A crimper is used for the adequate anchoring of grass and straw mulch.

viii) A rotary mower may be required for certain husbandry practices.

ix) One or more of the following cultivation implements may be required for seed-bed preparation. More detail on these implements, is provided in the subsection "Cultivation Practices".

a) Plow
b) Chisel plow
c) Disk
d) Rotary hoe
e) Subsoiler
f) Harrow
g) Cultipacker
h) Seed Mix
The named seed mix to be used for specific areas. Exact specifications for each seed mix to be used are inserted separately in the package.
i) Mulch Type
The type of mulch to be used on that unit.
(j) Mulch Rate
Tons per acre of mulch to be applied.
(k) Nitrogen
Any requirements for fertilizer are determined from soil samples taken after topsoil is laid.
(l) Phosphorus
Fertilizer requirement
(m) Potassium
Fertilizer requirement
(n) Remarks
Any specific requirements for the unit (may include safety specifications).

(3) Seed Mixes

Specific requirements for each seed mix to be used in reclamation are included in each package. Table 2 shows an example page used in this portion of the package. This spreadsheet shows pure live seed (PLS) per acre of each seed in the mix, lists and totals acreages of the units requiring this seed mix, and multiplies the two to show the total PLS required for each seed. This information is used in ordering the seed required for revegetation during that season.

TABLE B-1-2. EXAMPLE OF SEED MIX DESIGNATION: PERMANENT GRAZINGLAND

COMMON NAME	SEEDER BOX*	PLS RATE	TOTAL PLS #
ALFALFA	L	2	186.20
BIG SAGEBRUSH	H	0.3	27.93
BLUE GRAMA	L	2	186.20
BUFFALO GRASS	M	2	186.20
FOUR WING	M	0.5	46.55
FRINGED SAGE	L	0.5	46.55
GREEN NEEDLE	B	4	372.40
PRAIRIE	H	.5	46.55
SLENDER	B	2.5	232.75
SUNFLOWER	L	0.5	46.55
THICKSPIKE	B	3.5	325.85
WESTERN	B	4	372.40
WINTERFAT	M	1	93.10
YARROW	L	0.5	46.55

UNIT	ACRES
96S01	91.1
96S02	2

TOTAL ACRES 93.1

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*B - Back Box
L - Legume Box
M - Middle Box
H – Hydroseed

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2. Cultivation Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Cultivation practices break and loosen the soil surface to prepare a proper seed-bed. Cultivation is necessary to provide a suitable environment for seed germination and root growth, as well as for weed and moisture control.

Special Considerations

Because initial surface conditions vary, as does the response of different seed species to soil conditions, there are many methods of cultivation. The equipment used for cultivation will depend on the method and magnitude of the cultivation practice.

Technique

a. Methods of Cultivation

Fields should be cultivated parallel to the contour on slopes, and perpendicular to prevailing winds on flat areas. This reduces the likelihood of erosion. The methods of cultivation that may be used on the reclaimed surface include:

(1) Plowing

Plowing is used to initiate preparation of extremely hard or previously untilled ground. The plow cuts, lifts, and turns ground, burying crop residue or vegetation, and aerating the soil. Plowing can also be used to control weeds or incorporate fertilizer.

Variations in design of the plow bottom can allow for plowing in heavy clay or sticky soil. Safety devices available include a safety trip release mechanism and a hydraulic auto-reset, both of which prevent damage to the plow in rocky soils.

(2) Chisel Plowing

A chisel plow cuts through the soil without turning over the surface. This encourages water infiltration and retention, and limits surface evaporation.

The chisel plow can be operated just deep enough to cut off weeds with a minimum of surface disturbance. The cutting depth is dependent on soil conditions and desired results. A wide variety of soil-engaging tools are available for varied depths and tillage results.

(3) Disking

Disking cuts, lifts, and rolls the soil. Disking can be used for primary tillage of heavy soils, for mulching crop residue, or to pulverize lumps and close air spaces after plowing.

Disk scrapers can be added when necessary for use in sticky soil. Disking can also be done in rocky soil, as disk blades will roll over obstructions. A tandem disk tills the soil twice, leaving a more level surface. An offset disk moves soil in opposing directions while also tilling the soil twice and leaving a level surface.

(4) Rotary Hoeing

A rotary hoe tills the surface of the ground with an implement that mimics the action of a hoe. The resulting disturbance is only one to three inches in depth. Rotary hoeing is good for shredding and mixing stubble, and for removing undesired vegetation.

(5) Subsoiling

Subsoiling breaks up compacted soil layers beneath the surface without turning the soil over. This improves water infiltration and drainage, and aerates subsoil layers to encourage root penetration. Subsoiling can range in depth from 6 to 24 inches, and at shallow depths can be used to control undesirable vegetation. Subsoiling works best in dry soil.

(6) Harrowing

A harrow scratches the surface of the ground to loosen a thin surface layer. Three types are the spike-tooth, tine-tooth, and spring-tooth harrows. Harrows kill undesirable vegetation by ripping out the plants roots. Harrowing also prepares the surface of the soil for seeding by breaking up the top crust, shattering dirt clods, and closing air pockets. Harrows prepare an excellent seed-bed for small seeds that require fine, loose soil for good seed/soil contact and moisture absorption.

(7) Cultipacking

A cultipacker breaks clods and firms the soil surface better than most other machines. It leaves a well pulverized, firmly packed soil for excellent seed/soil contact.

The front rollers of a cultipacker crush clods and level the surface. Spring-teeth then close air pockets and bring up buried clods for the rear roller to crush, leaving a firm, level surface.

(8) Rolling

Rolling applies even pressure to a surface that has been previously cultivated. The purpose of rolling is to create a firm planting bed for maximum seed/soil contact without excessive compaction. Flexible frames will allow the roller to follow ground contours for the best possible performance.

b. Husbandry

Seed-bed preparation often includes methods other than cultivation to prepare the surface for planting. Rock removal, controlled burning, and biomass removal, such as is accomplished by haying or combining, are seed-bed techniques that may be used on a reclaimed surface. Other subsections within this section provide more information on husbandry methods.

c. Safety

Safety should always be a consideration in decisions of revegetation practices for a given area. As a general rule, loose slopes steeper than 4:1, and firm slopes steeper than 3:1, will require dual four wheel drive tractors for cultivation, drill seeding, and mulching. Loose slopes steeper than 3:1, and firm slopes steeper than 2.5:1, will generally require hydroseeding and hydromulching.

d. Tolerances

The primary purpose of the tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for work performance. The application of tolerance criteria is expected to be the exception rather than the rule.

(1) Disking

(a) Ridges and Valleys

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the height of ridges and depth of valleys left as a result of disking shall not exceed two inches, for a maximum total difference from top to bottom of four inches. Measurement is made by both the contractor and the mine supervisor in randomly selected locations. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soil scientist or agricultural engineer.

(b) Depth of Cultivation

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the depth of disk harrowing shall be six inches plus or minus two inches. Depth will be assessed by excavation of a test hole and subsequent measuring. Measurement shall be made by both the contractor and the mine supervisor in randomly selected locations. If contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soils scientist or agricultural engineer.

(2) Cultipacking

(a) Ridges and Valleys

Based on the average of one sample per acre per unit (minimum two samples per unit), the height of ridges and depth of valleys left as a result of cultipacking shall not exceed one inch, for a maximum total difference from top to bottom of two inches. Measurement shall be made by both the contractor and the mine supervisor in randomly selected locations. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soil scientist or agricultural engineer.

(b) Size of Clods

Based on the average of one sample per acre per unit (minimum two samples per unit), the size of clods that remain after harrowing shall not exceed three inches in the greatest dimension. Clod size will be assessed by measurement of the largest clod within three feet of randomly located points within the unit. Measurement shall be made by both the contractor and the mine supervisor in randomly selected locations. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soils scientist or agricultural engineer.

(3) Rolling

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average depth of three footsteps (made by an approximately 170 pound person) closest to randomly located points in the unit may not exceed 3/4 inch. Measurement shall be made by both the contractor and the mine supervisor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a soils scientist or agricultural engineer.

3. Drill Seeding Practices

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Applicability

Drill seeding is generally the most effective method of planting most seed types for both permanent and temporary reclamation. However, a combination of drill seeding and hydroseeding is one preferred method of seeding permanent reclamation. While most seed is best drill seeded, hydroseeding may be preferred for certain species such as shrub seed, which, because of low purity and germination, must be seeded in large amounts. For safety purposes, most slopes steeper than 2.5:1 will require hydroseeding rather than drill seeding.

Weather and soil conditions permitting, permanent seeding should be accomplished as soon as practicable after topsoil is laid on reclaimed ground. A season or more of annual grains cropping may enhance seeding success by improving soil tilth and soil moisture. Temporary seeding, which should not be performed when the probability of adequate moisture for seedling establishment is low, is necessary for erosion control on areas such as topsoil stockpiles. All revegetation must be conducted in the manner most efficient for moisture retention and erosion control.

Special Considerations

Antecedent soil moisture has a large impact on seeding success. It is undesirable to seed into powder-dry earth, unless there is a high probability of a significant period of post-seeding precipitation. Soil with moisture as close as possible to field capacity, but which can also be seeded without undue compaction, is most likely to support successful germination.

In Wyoming, seeding early in the spring, even in January or February, has consistently resulted in successful establishment, particularly of cool season grasses and shrubs.

Technique

a. Three common types of drill seeders are:

(1) Grain Drill

The grain drill is for flowable seeds such as oats and wheat. It should have a legume box and a drill range that adjusts from six to fifty pounds per acre.

(2) Grass Drill

The grass drill will efficiently seed the majority of seed varieties. This drill should have: chain drags, press wheels, one-half to one inch depth bands, and a drill range that adjust from six to sixty pounds per acre. This will ensure even seeding and proper depth and coverage of seeds. It should also have three seed boxes with agitators to keep seed mixed:

(a) A legume box for small seed

(b) A box with picker wheels for trashy seed

(c) A standard box for flowable seeds such as grains

(3) No-till Drill

The no-till drill has characteristics similar to the grass drill. In addition, it has coulter wheels to cut through surface vegetation and open a narrow path for seeding. The no-till drill may be used where it is desired to minimize surface disturbance.

b. Method

All drill seeding should be done parallel to the contour on slopes, or perpendicular to the prevailing wind on flat areas. Calibration of the drill must be accurate to ensure the correct PLS of each seed is planted. Table 1 gives step-by-step instructions for drill calibration.

c. Tolerances

The primary purpose of the tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for work performance.

(1) Seed Mixing

(a) Computation Tolerance

Acceptable tolerances for mixing seed to be used in drill seeding will be based on the proper computation of bulk pounds of the mix for each box. The record of seed mixing for any individual revegetation unit, including the computation of the proper bulk mix, should indicate a deviation of not greater than ten percent from the properly calculated bulk mix. This tolerance criterion applies to each species seeded by the box being evaluated.

For example, if the proper computation of bulk pounds requires ten bulk pounds of species A in the back box of a three-box drill for each acre seeded, and the computation made by the contractor shows eight pounds, the deviation from the tolerance is greater than ten percent.

(b) Application Tolerance

The tolerance is based on the average of three samples per box per unit, taken before the drill is loaded. The proportion of bulk pounds for each species for the box, compared to total bulk pounds for the box, will be within 50 percent (as estimated visually) of the properly computed ratio described above.

For example, if the bulk pounds of species A is two pounds per acre for the back box of a three-box drill, and the total bulk pounds of the mixed seed for the back box is twenty pounds per acre, the proportion of species A must be between 1/20 (five percent) and 3/20 (fifteen percent), as estimated visually. Species comprising less than five percent of the bulk mix by computation need only be visually present to meet the seed mixing tolerance.

Assessment of seed mixing is made prior to hydroseeding. If the contractor and the mine supervisor cannot agree on the average visual estimate of mixing, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

(c) Seed Density

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average unit density of seeds in a 12 inch wide by 24 inch long block shall be equivalent to plus or minus 30 percent of the pounds of PLS per acre required by the seed mix being applied. The location of the sample squares should be made by the mine supervisor. Computation of pounds of PLS per acre is made for each mix prior to drill seeding.

Seed count can be made by the mine supervisor and confirmed by the contractor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

(2) Seed Depth

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average depth of seeds in a 12 inch wide by 24 inch long block shall be between 1/4 and 1 inch. The sample squares will be randomly located. Seed depth can be measured by the mine supervisor and the contractor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

TABLE B-3-1. SAMPLE DRILL CALIBRATION

- *1 revolution of the drive tire is 7.667 feet. (This depends on tire size, so the circumference of the tire must be calculated.)*
- *The drill seeds 10 feet wide. (This depends on the drill, so it should be measured.)*
- *There are 43,560 square feet per acre.*

Therefore, 568.15 revolutions would equal 1 acre covered:

43,560 sq.ft./acre = 568.15
7.667 ft/rev X 10 ft wide rev/acre

There are 16 furrow openers. (This depends on the drill, so it should be counted.)

2.2 pounds equals 1 kilogram.
1 kilogram = 1,000 grams

BOX	BULK LBS.	PLS LBS.	SPECIES
Middle	1.34	1.0	Little bluestem
Middle	3.78	2.0	Fourwing saltbush
Legume	5.10	2.0	Blue grama
Back	3.36	3.0	Green needle
Middle	1.18	1.0	Side oats grama
Legume	1.05	1.0	Alfalfa
Middle	2.24	2.0	Buffalo grass
Back	3.83	3.0	Slender wheatgrass
Back	2.22	2.0	Thickspike wheatgrass
Back	3.44	3.0	Western wheatgrass
Middle	0.55	0.5	Sanfoin

Note: Bulk needed for the specified PLS will change slightly when using different lots, vendors, etc.

MIDDLE BOX		LEGUME BOX		BACK BOX	
Little bluestem	1.34	Blue grama	5.10	Western	3.44
Fourwing	3.78	Alfalfa	1.05	Thickspike	2.22
Side oats	1.18		**6.15 lbs**.	Slender	3.83
Buffalo grass	2.24		**bulk**	Green needle	3.36
Sanfoin	0.55				**12.85 lbs.**
	9.09 lbs.				**bulk**
	bulk				

9.09 lbs. = 4.132 KG
2.2 KG/lb.

6.15 lbs. = 2.795 KG
2.2 KG/lb.

12.85 lbs. = 5.841 KG
2.2 KG/lb.

To change kilograms to grams multiply by 1,000.

4,132 grams of bulk needed for the middle box per acre.
2,795 grams of bulk needed for the legume box per acre.
5,841 grams of bulk needed for the back box per acre.

TABLE B-3-1 (continued)

Now we want to find out how many grams we need for 1 revolution for 1 seed cup (opener):

$$\frac{\text{4.132 grams/acre}}{\text{16 openers X 568.15 revolution/acre}} = \text{0.4545 grams/revolution for 1 opener}$$

OR

$$\frac{\text{4.132 grams}}{\text{9090.4}} = \text{0.4545 grams}$$

0.4545 grams is too small to weigh on most scales accurately. So we spin the drive tire 10 times when testing, which is more accurate.

4.545 grams is what the middle box seed should weigh for 10 revolutions.

The back box bulk grams required (cutting out the extra numbers) would be:

$$\frac{\text{5,841 grams X 10 revolutions}}{\text{9090.4}} = \text{6.425 grams}$$

$$\frac{\text{2.795 grams X 10 revolutions}}{\text{9090.4}} = \text{3.075 grams}$$

The bulk pounds needed must be calculated from the seed tags*. Add the bulk pounds up for each box, convert to kilograms, then to grams.

$$\frac{\text{bulk grams X 10 revolutions}}{\text{9090.4}} = \text{grams}$$

*In order to figure PLS you will need to MULTIPLY:

Purity from the seed tag X Germination from the seed tag = PLS
PLS pounds / PLS percent will give needed bulk pounds

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4. Hydroseeding Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

A combination of drill seeding and hydroseeding is useful for seeding permanent reclamation. A hydroseeder is also required on slopes too steep for drill seeding, and for application of mulch. It may also be used to ensure successful seeding of small seed, trashy seed, and seed whose germination is enhanced by light.

Special Considerations

A successful seeding program includes both drill seeding and hydroseeding. Several factors must be considered in deciding which method will be most efficient and successful. When hydroseeding is the best choice, it must be done properly to avoid damaging seed.

Technique

a. When to Hydroseed

(1) Trashy Seed

Hydroseeding is an option for trashy seed, such as little bluestem, blue grama, and prairie sandreed. It is often preferred, however, that seed be cleaned and drill seeded when possible.

(2) Seed Enhanced by Light

Hydroseeding may be the best choice for seed such as sand dropseed and sagebrush, which grow best near the surface where light enhances germination.

(3) Seed with Low PLS

Shrub seed, such as sagebrush, rubber rabbitbrush, and winterfat, often has a very low PLS, and must be applied in large quantities. Hydroseeding is the most efficient choice, as one pass with a hydroseeder will seed the required amount, which may take two or more passes with a seed drill.

(4) Mulch Application

Mulch should be applied in a separate step, after hydroseeding. This enhances the seed/soil contact and optimizes seed protection. Wood, paper, and synthetic fiber mulch are applied in a water slurry at recommended rates. Synthetic fiber may also require a hydroseeder, and should be applied according to the manufacturer's instructions.

(5) Safety

On steep slopes, safety considerations make it necessary to apply all seed and mulch with a hydroseeder. Generally, loose slopes steeper than 3H:1V, and firm slopes steeper than 2.5H:1V will require a hydroseeder.

b. Methods

(1) Avoid Seed Damage

Agitation of seed and water in the hydroseeder should be at the lowest possible rate, in order to avoid damage to the seed. Using very high water pressure may also damage seed.

(2) Attain Complete Seed Coverage

Hydroseeding on slopes should be done from both the bottom and top of the hill to ensure complete coverage.

(3) Mulch

Applying the average requirements for mulch with the seed can hinder seed/soil contact. The bulk of the mulch should be applied after all seeding is complete. A small amount of wood or paper mulch, however, works as a good de-foaming agent, especially with shrub seed. An organic hydrocolloid tackifier and dye can be used with paper and wood fiber mulch. Tackifier should not be used with seed, however, as damage may result.

c. Tolerances

The primary purpose of tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for the work performance of the contractor. The application of tolerance criteria is expected to be the exception rather than the rule.

(1) Seed Mixing

Acceptable tolerance for mixing seed to be used for hydroseeding is based on the proper computation of bulk pounds for the hydroseed mix and the record of pounds of seed placed in each hydroseeder load. The record of hydroseeding for any individual unit, including the computation of the proper bulk mix, should not deviate more than ten percent from the properly calculated bulk mix. This criterion applies to each species seeded by the hydroseeder.

For example, if the proper computation of bulk pounds requires ten bulk pounds of species A in the hydroseeder for each acre seeded, and the computation made by the contractor shows eight pounds, the deviation from the tolerance is greater than ten percent.

(2) Seed Density

Based on the average of one sample per acre per unit (minimum two samples per unit, maximum ten), the average unit density of seeds on a cardboard square 12 inches by 12 inches shall be equivalent to plus or minus 30 percent of the number of bulk seed per acre required by the seed mix being applied. For example, if proper computation of the bulk mix calls for 4,356,000 seeds per acre to be applied, the square should contain between 70 and 130 seeds.

The placement of the cardboard square will be made by the contractor or employee in the field as approved by the contractor or the mine supervisor. Computation of pounds of bulk seed per acre will be made for each mix prior to hydroseeding.

Seed count of the cardboard square can be made by the contractor and confirmed by the mine supervisor. If the contractor and the mine supervisor cannot agree on sample locations and measurements, independent measurement by the same means may be made by a vegetation scientist or agricultural engineer.

5. Mulching Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Mulch, made of plant residue or other suitable materials, is placed upon a recently seeded soil surface to aid in soil stabilization and soil moisture conservation.

Special Considerations

Mulch should be applied immediately after seeding, and never with seed; this maximizes contact of soil and seed. Mulch need not be used if seed has been planted into a cover crop or standing stubble.

Technique

a. Application Rates and Methods

Recommended application rates proposed for various conditions of slope and soil are presented in Table 1 (tables are at end of text). One or more of the methods specified for each of the conditions shown in the table should be applied to a seeded surface. Mulch rates will vary, dependent upon the type of mulch used and manufacturer's recommendations. Where mulch is used to control erosion, the amount used will depend upon steepness of the slope. The types of mulch that may be used include:

(1) Nurse Crop

Oats, at no less than six pounds and no more than fifteen pounds per acre, are included in the approved perennial seed mix at the time of planting.

(2) Cover Crop

Oats, at no less than fifteen pounds and no more than sixty pounds per acre, are planted the season prior to the approved perennial mix. The cover crop may be hayed or combined, and the perennial is then planted into the standing stubble.

(3) Native Hay

Hay is applied with a tub grinder or similar blower, at a rate of between 1/2 and two tons per acre, and then crimped into the ground with a flat blade disc crimper. Crimping should be done 1/2 to 2 inches deep, on eight to twelve inch centers.

(4) Straw

Certified weed-free straw is applied and crimped in a fashion similar to native hay mulch.

(5) Wood Fiber

Wood fiber is applied as a hydromulch at a rate of between 1/2 and 1 ton per acre. An organic hydrocolloid tackifier and dye should be used with wood fiber.

(6) Paper Fiber

Paper fiber is applied similar to wood fiber, with tackifier and dye.

(7) Wood/Paper Fiber

A mixture of fiber is applied similar to wood fiber, with tackifier and dye.

(8) Synthetic Fiber

Synthetic mulch is applied in accordance with manufacturer's instructions.

b. Equipment

(1) A hydroseeder is used for application of wood, paper, or synthetic fiber mulch.

(2) A tubgrinder is required for even application of grass and straw mulch.

(3) A crimper is needed for the adequate anchoring of grass and straw mulch.

(4) A smooth-fronted roller is used in place of, or in conjunction with, other methods of mulching to meet desired performance standards.

c. Tolerances

The primary purpose of the tolerance criteria is to provide an objective means of dispute resolution, should such resolution become necessary between the mine supervisor and a revegetation contractor. In addition, the tolerance criteria provide a means for the mine supervisor to set a quantifiable standard for work performance. The application of tolerance criteria is normally the exception rather than the rule.

Evaluation of mulching is made from the records of the contractor, who must report the bags or tons of mulch applied per unit. The amount of mulch applied must be within plus or minus 20 percent of the prescribed amount for the unit. For example, if hydromulching of the unit calls for the application of 0.5 ton of mulch per acre and the records show less than 0.4 or more than 0.6 ton per acre was applied, the contractor will have failed to meet the tolerance for that unit.

In the case of insufficient mulch, additional mulch should be applied at the discretion of the supervisor. If too much mulch has been applied, the area may require re-seeding, depending on seeding success. In no case should payment be made for more than the specified amount of mulch.

TABLE B-5-1. Mulch Application Rates

MULCH	SOIL TYPE		
	Primarily Sandy - "Light"	**Primarily Silty or "Medium"**	**Primarily Clayey or "Heavy"**
Mulch Application - Slope less than 2.5H:1V			
Nurse crop rate	12 lbs	12 lbs	12 lbs
Cover crop rate	40 lbs	40 lbs	40 lbs
Native hay rate	1 ton	1 ton	1 ton
Straw rate	1 ton	1 ton	1 ton
Fiber rate	2 tons	2 tons	2 tons
Synthetic rate	Manufacturer's specifications	Manufacturer's specifications	Manufacturer's specifications
Mulch Application - Slope 2.5H:1V to 5H:1V			
Nurse crop rate	12 lbs	12 lbs	12 lbs
Cover crop rate	30 lbs	40 lbs	40 lbs
Native hay rate	1 ton	1 ton	1 ton
Straw rate	1 ton	1 ton	1 ton
Fiber rate	2 tons	2 tons	2 tons
Synthetic rate	Manufacturer's specifications	Manufacturer's specifications	Manufacturers specifications
Mulch Application - Slope greater than 5H:1V			
Nurse crop rate	12 lbs	12 lbs	12 lbs
Cover crop rate	40 lbs	40 lbs	40 lbs
Native hay rate	1 ton	1 ton	1 ton
Straw rate	1 ton	1 ton	1 ton
Fiber rate	2 tons	2 tons	2 tons
Synthetic rate	Manufacturer's specifications	Manufacturer's specifications	Manufacturer's specifications

6. Seed Handling

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Before seed is received by reclamation personnel, careful handling, ordering, and testing ensures the best possible quality. Proper care must continue after seed is received to maintain this high quality.

Special Considerations

Seed storage facilities must be adequate to maintain seed quality. Expertise is necessary in the preparation of seed mixes to ensure the proper PLS of each seed is included in the mix, and to prevent damage to seed.

Technique

Seed must be stored in a temperature-controlled, moisture-free environment. This will prevent mold, heat damage, and premature germination of seed. The use of a rat poison is usually necessary to control vermin.

Once seed has been delivered to the storage area, additional testing may be required for verification of purity, germination, and weed content. Employing a state seed inspector for obtaining samples will assure both the vendor and the buyer that this is done properly. Samples should be sent to a certified seed laboratory for testing. More details on seed testing are presented in the subsection entitled "Understanding Seed Tests".

Familiarity with the physical characteristics of different species is necessary in determining the best method of seeding. Visual assessment is possible with the use of a seed library. To make a seed library, fill small, clear bottles (like spice jars) with seed samples. Label each with seed name, number of seeds per bulk pound, or other data desired. The seed library can be very helpful in seed mixing and drill calibration.

Table 6-1 lists some common species used in reclamation, with the drill box or method preferred for best results in planting. Species to be used in each seed box must be mixed according to PLS requirements per acre and total acreage to be seeded. Seed to be mixed in the hydroseeder should be agitated gently to avoid damage. Care must also be exercised when using a hopper wagon for mixing seed, as mixing too long and hard can easily cause damage to seed. With extremely dusty seed such as saltbush, it may be preferred to mix by hand in the seed box.

TABLE 6-1. SEED PLANTING METHODS

SCIENTIFIC NAME	*COMMON NAME*	*DRILL BOX or METHOD**
Achillea lanulosa	*WESTERN YARROW*	*L*
Agropyron dasystachyum	*THICKSPIKE WHEATGRASS*	*R*
Agropyron elongatum	*TALL WHEATGRASS*	*R*
Agropyron intermedium	*INTERMEDIATE WHEATGRASS*	*R*
Agropyron riparium	*STREAMBANK WHEATGRASS*	*R*
Agropyron smithii	*WESTERN WHEATGRASS*	*R*
Agropyron trachycaulum	*SLENDER WHEATGRASS*	*R*
Agropyron trichophorum	*PUBESCENT WHEATGRASS*	*R*
Artemisia cana	*SILVER SAGEBRUSH*	*H/P*
Artemisia frigida	*FRINGED SAGEWORT*	*L*
Artemisia tridentata	*BIG SAGEBRUSH*	*H/P*
Astragalus cicer	*CICER MILKVETCH*	*R*
Atriplex canescens	*FOUR WING SALTBUSH*	*P*
Atriplex gardneri	*GARDNER'S SALTBUSH*	*P*
Avena fatua	*OATS*	*G*
Bouteloua curtipendula	*SIDE OATS GRAMA*	*P*
Bouteloua gracilis	*BLUE GRAMA*	*L*
Bromus enermis	*SMOOTH BROME*	*R*
Buchloe dactyloides	*BUFFALO GRASS*	*P*
Calamovilfa longifolia	*PRAIRIE SANDREED*	*R*
Ceratoides lanata	*WINTERFAT*	*H/P*
Chrysothamnus nauseosus	*RUBBER RABBITBRUSH*	*H/P*
Distichlis stricta	*INLAND SALTGRASS*	*R*
Helianthus annuus	*SUNFLOWER*	*P*
Lupinus caudatus	*LUPINE*	*P*
Medicago sativa	*ALFALFA*	*L*
Melilotus officinale	*YELLOW SWEET CLOVER*	*L*
Onobrychis viciaefolia	*SAINFOIN*	*P*
Oryzopsis hymenoides	*INDIAN RICEGRASS*	*R*
Petalostemum purpureum	*PURPLE PRAIRIE CLOVER*	*L*
Phalaris arundinacea	*REED CANARYGRASS*	*R*
Poa canbyi	*CANBY BLUEGRASS*	*R*
Poa pratensis	*BLUEGRASS*	*L*
Ratibida columnifera (columnaris)	*PRAIRIE CONEFLOWER*	*L*
Schizachyrium scoparium	*LITTLE BLUESTEM*	*P*
Secale cereale	*RYE*	*G*
Spartina pectinata	*PRAIRIE CORDGRASS*	*R*
Sporobolus airoides	*ALKALI SACATON*	*L*
Stipa viridula	*GREEN NEEDLE*	*R*
Triticum aestivum - Spring	*SPRING WHEAT*	*G*
Triticum aestivum - Winter	*WINTER WHEAT*	*G*

* G - Grain drill
H - Hydroseeder
L - Legume box - grass drill
P - Seed box with picker wheels - grass drill
R - Regular box

7. Planting Methods for Permanent Reclamation

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

Choosing the proper methods for cultivation and planting of reclaimed ground is vital to revegetation success. The order of these methods is also important in producing a properly prepared seed-bed for the best possible germination of seed.

Special Considerations

Reclaimed ground must receive adequate tillage, but excess tillage should be avoided. The final seed-bed should be finely pulverized, but firmly packed. The different seeds should be planted at depths appropriate to the seed type, with the best possible contact between seed and soil.

Technique

The following steps have proven successful in permanent revegetation in the Powder River Basin, and should be completed in the order given. For detail on methods, refer to the individual subsections that cover each of these steps.

(1) Disk

Plowing freshly laid topsoil is usually unnecessary. Disking is typically the best initial measure for soil preparation.

(2) Cultipack

Using a cultipacker is the next step in seed-bed preparation. Cultipacking will ensure that the soil is finely pulverized, firmly packed, and ready to receive seed.

(3) Hydroseed

Hydroseeding (without mulch!) is the most efficient choice for shrub seed, which, because of low PLS, must be applied in large quantities. Hydroseeding is also efficient for fluffy or trashy seeds. Hydroseeding is especially good for seeds such as sagebrush, whose germination is enhanced by light. Hydroseeding should follow cultipacking.

(4) Roll

Rolling is done after hydroseeding to firm the soil and ensure maximum seed/soil contact. This is an essential practice. A typical smooth front roller is three feet in diameter and can be filled with water for weight.

(5) Drill

A multi-box grass drill is required for seeding the species not seeded with the hydroseeder. For details on determining the best seed box to use for each species, refer to the subsection entitled "Seed Handling". The drill should have a chain-drag attached to ensure even coverage of seed.

(6) Roll

Rolling should be done once again after all seed has been planted. This will firm the soil adequately and ensure the best possible seed/soil contact.

(7) Mulch

Mulching, where necessary, should be done after all seed is in the ground. It is desirable to avoid the use of mulch over species that require light to germinate, such as shrub seed, and species that have a shallow planting depth, as mulching may destroy seed/soil contact and/or increase surface drying.

8. Broadcast Seeding

Section editor: Larry H. Kleinman *Subsection author: Laurel E. Vicklund*

Applicability

There are occasionally areas requiring seeding that are not accessible with a pull-type seed drill. Not all of the areas that require seeding will be final reclamation; special-use areas may be small, rocky, have a steep slope, have peculiar seeding requirements, or be inaccessible to a tractor and drill. Using various methods to broadcast the seed ensures that the area is planted to stabilize the surface.

Special Considerations

Areas with excessive slopes should be evaluated for safe access before using tractors and other equipment. Establishment of vegetative cover in "fringe" areas reduces erosion, sediment runoff, and the potential for noxious weed invasion as well as improving air quality by reducing wind erosion. When hydroseeding is not essential, broadcast seeding is more economical.

Technique

a. Mechanical Broadcast Seeding

A seed broadcaster that fits on a three-point tractor hitch and runs off the power-take-off is very convenient for seeding small areas. Vegetation establishment may be required on areas not scheduled for final reclamation, such as overburden areas, sediment ditches or ponds, around rockpiles, or other open areas of disturbance.

Some areas may be too rough to pull an expensive seed drill over. This may be especially true of backfill requiring interim stabilization, which is often too rocky. Using a broadcaster to seed these areas reduces excessive wear on a pull-type drill. Other areas may be inaccessible to a pull-type drill, such as scraper-built sediment control ditches or other small "fringe" areas around the pit.

(1) Seeding Rate

Generally, regular reclamation seed mixtures can be used for broadcast seeding by doubling the rate. The rate is increased to compensate for seed not placed at the proper depth, that may be washed away, or that will not germinate.

A harrow or a chain drag is pulled behind the seed broadcaster to aid in covering seed. Calibration varies with the brand of seed broadcaster, and the type of seed used. Follow the instructions for calibration that comes with the seed broadcaster.

(2) Shrub Seeding

A seed broadcaster can be used in conjunction with a pull-type seed drill. This procedure has been used when the seeding rate of a shrub species could not be applied through a conventional drill. The grass component of the seed mixture is drilled into a standing stubble mulch. The shrub portion of the mixture is then broadcast into the same area, however a harrow or chain drag is not used behind the broadcaster in this instance.

b. Hand Broadcasting

Hand broadcasting is useful in small areas where access is limited, or in areas where a small amount of a specific seed is to be planted. A hand type seed broadcaster may be used, or seed may simply be scattered by hand. Hand seeding works well around rockpiles, wetland areas, and other small areas inaccessible to pull-type drills or mechanical seed broadcasters.

Calibration is less accurate with these methods of seeding. Calculate the acreage of the area to be seeded and the volume of seed required for the area, and distribute the seed as evenly as possible. As with the mechanical broadcaster, the amount of seed applied should be doubled.

9. Transplanting Live Plants and Planting Plant Parts

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

Planting and transplanting are sometimes necessary to establish a seed source of shrubs and trees for further enrichment of a revegetated stand. Certain shrub and tree seeds germinate only sporadically in the wild and those species should be included in the revegetation as transplants.

Special Considerations

Planting and transplanting may take place prior to seeding of the normal seed mixtures, after seeding, or even with no seeding whatsoever. Several of the methods described are labor intensive, expensive, and may require specialized equipment; others are relatively inexpensive, easily performed, and require no specialized equipment. The methods that are described in this subsection are: containerized stock, bareroot stock, shrub/tree pads, and sprigs or cuttings.

Moisture competition by grasses and weedy plants may be the most probable cause of shrub and tree transplant failure. When planting or transplanting into an already established stand or a newly seeded area, the existing living plant material should be removed from the soil immediately around the transplants. This can be done by scalping to just below bare ground or by herbicidal control. Normal seed mixtures may be inter-seeded into the plantings; preferably after the new plants are well established.

Methods that can be utilized for the seeding include no-till drills, grass seeders such as the "Brillion" (raise the roller packers so that they do not disturb the transplants), hydroseeders, or broadcast seeders such as the "Cyclone" seeder. It is recommended to reduce the normal interseeding mixture by as much as one-half to reduce competition. If directly placed topsoil is used for the top

dressing before transplanting, no additional seeding may be necessary. Match the directly-placed topsoil with the type of plantings. For example, chances of success would be improved if ponderosa pine transplants were planted into directly placed pine soils.

The planting and transplanting of live plants may be undertaken in the spring or fall, provided certain precautions are taken. The plants should be hardened (dormant), and there should be adequate soil moisture, or at least the chance for adequate soil moisture.

Technique

a. Containerized Stock

Containerized transplants of shrubs or trees may be obtained in almost any size desired, from six cubic-inch cones to five gallon buckets. Many nurserymen and planters prefer a ten cubic inch cone container, as they are easily handled and planted with small chance of root disturbance. They produce vigorous and straight root growth. The above-ground portion of the plant is vigorous, well formed, and generally one year old stock.

Containerized plants are quite expensive to get into the ground. Each individual plant may cost up to approximately $2.00 per plant to buy and have planted by professional planters. If mine laborers do the planting, the cost may be several times the $2.00 per individual plant. Care must be taken to plant the transplant correctly without bending the roots, without leaving too much airspace around the roots, and to put the plant in the most appropriate niche.

There are mechanical rotary tree planters available that are pulled behind a tractor. These reduce the final cost considerably if several thousand trees or shrubs are to be planted per day. A professional planter is able to plant 400 to 600 trees per day in a precise location, whereas a mechanical planter is able to plant up to 2,000 or more trees per day.

b. Bareroot Stock

The same considerations and techniques given for containerized plants are appropriate for bareroot transplants. In general, bareroot stock is less expensive to buy but more care must be taken to keep the roots from drying out before planting. There are fewer fine root hairs to immediately begin growth than with containerized plants. Thus the plants must utilize more stored carbohydrates to initiate growth of root hairs for water and nutrient uptake. More care must be taken to keep from bending the roots than for containerized plants, and in some cases the roots and the crown should be pruned before planting.

c. Shrub/Tree Pads - Front-End Loader Bucket

This technique is a simple, inexpensive, and rapid method of transplanting a whole pad or clone of certain trees and shrubs. Plant species that spread by rhizomes, adventitious stems, or root sprouting are the most successful in establishing by this technique. Species that may be successfully established using this technique include willow, cottonwood, snowberry, and skunkbush sumac.

Specialized front-end loader buckets with flat bottoms that protrude out in front of the bucket may be purchased or built on site. However, a normal bucket such as on a Cat 966 Front-End Loader has proven very successful without modification.

A small, accessible patch of the desired plants (seedlings one to three years old, preferably) must be located. It would be best if the plants were in an area where the topsoil was to be stripped or an area of already disturbed ground. The bucket is lowered and tipped forward so as to dig with the front edge of the bucket. Dig with the front edge approximately six to ten inches deep, slide the edge of the bucket under the plants, and lift the bucket when full. Transport in the bucket to the desired location on reclaimed ground.

Tilt the bucket edge until the plant/soil pad starts to slide out and slowly back the loader, continuing to tilt the bucket until the pad is out. If desired, a little topsoil can be banked around the pad so that the roots are not exposed; however, just leaving the pad with no extra topsoil around it has been successful. The pad may be deposited on top of respread topsoil or on top of regraded spoil with topsoil banked around it. If desired, the pad may be deposited inside a pre-gouged depression the depth of the pad. This technique is most successful while the plants are dormant, but has also proven successful in the late spring or early fall while the plants were actively growing.

d. Plant Parts - Cuttings and Sprigs

Sprigs and cuttings are labor intensive. An undisturbed area is rototilled and the sprigs and roots are removed and relocated to reclaimed ground. The equipment used is a modified potato harvester with an undercutting blade that loosens and cuts the roots. The disturbed soil, which includes the cuttings and sprigs of root/plant material, is conveyed to a truck bed or trailer and transported to the reclamation site. The plant material is re-spread by means of a manure spreader.

It is desirable that the plant material be re-spread onto topsoil because there will be very little topsoil adhering to the sprigs and roots. After the sprigs and cuttings are in place, a light covering of sand or topsoil should be spread on top and lightly compacted with a roller packer to assure soil contact by the roots and cuttings. Reception of moisture soon after planting is very important to initiate growth of new roots and stems. Scrapers have been utilized to pick up the cuttings and sprigs and respread them on the reclamation site with only limited success.

10. Reforestation

Section editor: Larry H. Kleinman *Subsection author: Roy L. Garrison*

Applicability

Centralia Mining Company operates a surface coal mine located seven miles east of Centralia, Washington. It is an uncommon example of a mine where reforestation is a standard revegetation practice. Conifer and hardwood species dominate cover on the hills and the poorly drained valleys accommodate grasses and various riparian species: Red alder is the most prevalent hardwood species found in pure stands and mixed throughout conifer stands. Mine disturbed lands

will be returned to their primary land use, in most cases tree farming on the uplands and pasture/riparian areas in the valley bottoms.

Special Considerations

Centralia is located 50 miles east of the Pacific Northwest coastline, which receives significant precipitation in the range of 30 to 56 inches annually with 24-hour events ranging between a trace to 4.5 inches. Generally rains begin in October and continue intermittently through April, accompanied by mild temperatures ranging from 0^0 F to 95^0 F (-18^0 C to 35^0 C).

Technique

a. Soils Handling

Proper reclamation and soils handling play a very important role in the success of establishing a forestry land use. Slopes are backfilled, graded, and shaped to adequately drain. Four feet of suitable soil is then placed over final graded slopes to ensure a productive rooting medium. Overburden suitability programs ensure the quality of the rooting medium.

All reclamation field operations are carried out during the drier months, June through September. Soil moisture conditions prohibit any surface travel or soil handling on reclaimed areas during the remainder of the year.

(1) Drainage Design

Temporary and permanent drainage structures are designed in the final topography to control and transfer surface runoff. Terraces are placed on the contour of the slope at a 1% gradient to intercept surface runoff and direct flow to waterways designed to carry the water off the slope. Drainage control is critical in providing for a stable slope and minimizing soil erosion in this high rainfall region.

(2) Cultivation

Prior to reforestation, the rooting medium is ripped on the contour to an average depth of three feet. Ripping promotes internal drainage, root penetration, and mixing of topsoil with underlying subsoil. Ripping appears to provide these benefits initially but does not demonstrate long term effectiveness.

b. Reforestation

Conifer and hardwood species are planted on prescribed slopes to achieve stocking levels of 400 and 435 trees per acre respectively. Typically Douglas-fir (*Pseudotsuga menzesii*) is planted on ridge tops, and southerly or westerly reclaimed slopes. Red alder (*Alnus ruba*) is typically planted on northerly and easterly slopes. These species are best suited for the climatic conditions of the prescribed slopes. Riparian species are planted along waterway channels for stabilization and diverse habitat for wildlife. Small open spaces are encouraged in pure stands of conifer or hardwoods to enhance species diversity and wildlife feeding areas.

c. Challenges to Reforestation Success

One of the major challenges to reforesting reclaimed lands in the Pacific Northwest is controlling the invading grass species after topsoil distribution. The grass itself is not the

main threat to young tree seedlings, but heavy stands of grass provide an environment for large populations of rodents. The Townsend vole (*Microtus townsendii*) is the primary deterrent to the survival of young tree seedlings. The voles feed on the bark at the base of the young tree, which, in most cases, kills or severely damages the tree.

Trees are most susceptible to rodent damage during the first five years after planting. Foil and netting are placed around the base of young seedlings to prevent rodent damage during this period. In addition, an herbicide program is initiated the spring following planting to control the grass cover. Where high rodent populations persist, rodenticide may be used to control the pests.

High soil moisture conditions can also be threatening to the survival of young tree seedlings. This condition is prevalent where slope gradients are less than five percent. To eliminate this problem, Centralia Mining Company has developed a tool that creates a mound of soil for every tree planting site. The mound is approximately two feet in diameter and provides eight to twelve inches of relief in the surface topography. This allows the tree seedling to establish its roots in a suitable moisture regime during its initial growing years.

d. Monitoring

Continual monitoring of reforested lands ensures that the requirements of OSM regulations are met, and identifies any remedial work necessary. New practices are monitored very closely and assessed for their effectiveness. Revegetation surveys are taken periodically throughout the bonding period to document stocking levels and ground cover percentage.

11. Seeding Shrub Seed

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

Small, trashy shrub seed is difficult to seed by normal drill seeding. The seed is generally collected from native stands and therefore rather expensive. Most of the "compositae" seed such as sagebrush and rabbitbrush are very low in viability and purity and have a very poor storage life. The seeds are so small that when cleaned the seed may be lost and the hulls kept. Please refer to the subsection entitled "Selecting Good Shrub Seed", by Richard Dunne.

Most mine operations are regulated by State agencies which require that a certain amount of revegetation be dominated by large shrubs. Therefore, the successful seeding of shrubs is a serious concern for reclamation specialists and government agency personnel.

Special Considerations

Artemisia and *Chrysothamnus* seed (sagebrush and rabbitbrush) are very sensitive to being planted too deep. They are also sensitive to inadequate moisture. The seed should be planted onto the surface of a very compacted seed-bed, or at most less than 1/4 inch deep. The seed will over-winter on the ground and in the soil and germinate early the next spring (March). Not all of the seed will germinate at the first opportunity, but may germinate the second or even the third year.

The seed seems to hold viability while in the soil but not when in storage in a bag. The seeding of these species has been especially successful when seeded into green or non-stockpiled topsoil because of the mycorhizal fungi in the soil. These species are somewhat sensitive to grass competition, especially cool season grasses which also germinate in the spring. Because of this, these shrubs should be planted without accompanying grass seed, with a reduced cool season grass mixture, or with only warm season grasses which germinate in the early summer.

A drill seeding technique used in the past by Chet Skillbred at Glenrock Coal Company and a hand broadcast technique used by the author at Big Horn Coal Company are described in the following subsection.

Technique

a. Drill Seeding of Sagebrush Seed

Sagebrush is generally seeded with no other species in the mixture. However, light rates of blue grama and sandberg bluegrass have been added with successful results.

Areas that have been excessively compacted by scraper tires are areas where shrub seed can be seeded with good success. The grass species in the usual seed mixture generally have a difficult time establishing because of the compaction of the soil.

(1) Brillion Grass Seeder

The Brillion grass seeder is essentially a broadcast seeder with an attached rear roller packer. In this case the rear roller packer can either be removed or the tension set at the minimum.

The seed boxes should be enlarged to accommodate the lighter, bulkier seed. Holes, which are 7/8 inch diameter, are drilled in the bottom of the boxes, which bypass the normal wire agitator, and are open at all times. Therefore, the seed should be poured into the seed boxes only when at the actual location to be seeded. Only the correct amount of seed needed for the acreage to be revegetated should be put into the seed boxes at any one time.

Every possible advantage should be provided for the shrub seeding. Four feet of shrub-suitable soil material, with a top dressing of green or directly placed shrub soil, is laid down. The green shrub soil contains mychorrizal fungi which will inoculate the newly germinated shrub seed and provide for better seedling survival. The seed-bed is made very firm after disking by the use of a roller packer.

Sagebrush should be seeded at a rate of 10 PLS pounds per acre when seeding in November or December. Snowfall is assured after seeding, and the seed will break dormancy by over-wintering and germinate in the spring. Seeding in March at a rate of 6 PLS pounds per acre has also been successful.

(2) Truax Grass Seeder

The Truax grass seeder has been used to seed sagebrush during December and January when the soil surface is frozen. This assures a very firm seed-

bed and snowfall after seeding. The Truax drill has disk furrow openers with press wheels behind. The furrow openers are set at minimum pressure.

The center seed box on the drill is used and the seed metering is set wide open. The sagebrush is seeded at a rate of 5 PLS pounds per acre during December or January when the soil is frozen. However, choose a nice sunny day to seed so that the very top surface film of soil is friable. The disk openers will not cut too deep and the press wheel will cover the seed with a very thin layer of soil.

b. Hand Broadcast Seeding Sagebrush

Hand broadcast seeding of sagebrush is simple and inexpensive, especially when small shrub patches less than one acre in size are the desired result. The only equipment needed is a five gallon plastic bucket to carry the seed. The correct amount of seed for the desired acreage of sagebrush seeding must be determined and that amount of seed is spread over the desired area by throwing handfuls of seed onto the ground.

A person may follow behind the equipment used to seed the other species of the seed mixture. The seed may be broadcast onto specific locations where more shrubs may be desired, such as swales for extra moisture, ridge tops where there will be less grass competition, or in and around rock piles.

While this method has been successful, it must be realized that much of the shrub seed may not germinate for one to three years after seeding, or there may be staggered germination and establishment over a three year period.

The best results have been by hand broadcasting in similar areas and situations as described in the drill seeding subsection.

(1) Accompanying Species

The seed may be broadcast into an area that has not been seeded with other species, especially if the topsoil is directly placed, or green. There usually is sufficient residual grass seed in the topsoil to fill in between the established shrub seedlings without crowding the shrub seedlings for available moisture.

(2) Topsoil

If the topsoil has been stockpiled for more than one year, a choice must be made to either seed only shrubs and hope that the other species invade and fill in, or drill a very light rate of the other species before hand broadcasting the shrub seed. A seeding rate of 1/4 to 1/2 PLS pounds per acre has been successful in establishing shrub stands.

(3) Compaction

Excessively compacted areas are ideal for shrub patches because of the ability of the shrub seed to germinate and establish without being covered by soil.

(4) Timing of Seeding

The timing of seeding is similar to drill seeding. The best results have been from seeding in November and December. Big Horn Coal has not seeded shrubs in January, though there may be no reason not to try it.

(5) Shrub Seed Used

Shrub seed purchased from the previous years' collection may be used, or if desired, seed may be collected from adjacent shrub stands and seeded even the same day. The seed should be collected after seed hardening and ripening (see the subsection entitled "Selecting Good Shrub Seed"), usually in November or December. The seed may be stripped from the seed plant into a plastic five gallon bucket.

c. General Considerations

There are several critical points to be considered in both of these techniques. The seed-bed must be very firm. The seed must be placed on the soil surface, or with only a very thin covering of soil at the most. The seed should be seeded soon before the prolonged winter snowfall for adequate moisture. Quality seed that has been cleaned properly and has not been stored for more than one year should be used. Finally, grass competition should be reduced by seeding a lesser grass rate than normal or by not seeding any grasses in the shrub areas at all.

C. SEED ORDERING METHODS

1. Ordering Seed

Section editor: Larry H. Kleinman *Subsection author: Richard Dunne*

Applicability

Timing a seed order to coincide with cash-flow or collection cycles of seed vendors can improve the price, availability and quality of seed offered.

Special Considerations

When ordering seed, ample time must be allowed for vendor response and delivery. Seed may be ordered pre-mixed; the advantages of ordering pre-mixed versus mixing your own are discussed in this subsection.

Technique

a. When to Order

To purchase the best seed at the lowest prices, order during slow seasons and time the order to coincide with the entry of new seed lots onto the market. Most grass seed is harvested and tested by January 1, and most shrub seed is available by February 1 of each year. January-February is a slow cash-flow period for most seed vendors, which increases the chances of purchasing superior quality seed at lower prices. June, July, and August are also slow months for seed dealers and a good time to buy, except in a year of shortages when quality and availability decrease.

Some native seeds are chronically scarce and may be available only for a short time following harvest. Seeds such as winterfat, northern-origin fourwing saltbush, silver sage, globemallow, black samson, thermopsis, prairie cordgrass, northern sweetvetch, prairie rose, prairie sage, dotted gayfeather, and western snowberry are often sold out by fall.

b. Lead Time

For large, complicated bids, allow vendors two weeks to bid and at least two weeks to deliver. Compressing this time frame will increase the chances of errors or delays.

c. Mix Your Own Versus Pre-mixed

A seed company can mix seed cheaper than it can be mixed at the reclamation site. Mixing costs are usually included in a bid when a mix is specified, and often a seed company will absorb mixing costs to win the bid. The ease of ordering pre-mixed seed makes this a practical buying strategy, but there are hidden risks the buyer should be aware of:

(1) When ordering blue-tagged, Certified seed to be blended in a mix, there is no assurance that Certified seed will be used in the mix. The buyer should request receipt of the blue tags from the Certified Seed bags emptied into the mix.

(2) Scarce or expensive items may be omitted from the mix.

(3) Weedy lots can be blended into a mix without the buyer's knowledge.

(4) Cheaper varieties may be substituted for more expensive varieties.

These are not common practices in the seed trade, but are common practices among unscrupulous vendors. Keep in mind that testing a mix involves greater margins of error than testing species individually. These problems can be compounded when a contractor is employed for revegetation, as his practices may exacerbate bad seed mixing practices. If a seeding contractor is used, it may be best to let choices regarding mixing be made by the contractor, with the client concentrating on setting and evaluating tolerance criteria.

The advantages of mixing your own seed include the ability to verify receipt of expensive or scarce seeds, and to isolate and replace individual seed lots which contain unacceptable weeds or have germination problems. Some seed lots may be used in different mixes at different times; so, buying seed in individual lots gives more flexibility in planting. This is especially important when readiness of individual sites cannot be pre-planned.

2. Preparing a Seed Purchase Request

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

A seed buyer can experience difficulty in evaluating competitive seed bids, unless enough information is requested to determine the relative quality of the seed lots offered.

Special Considerations

This subsection outlines the information that must be requested in order to properly evaluate seed bids, and includes a sample bid request sheet.

Technique

The attached sample bid sheet (Figure C-2-1) shows one way to prepare a seed bid request. The following variables should be considered when purchasing seed (numbers correspond with figure):

--- Select a named variety or a native collection. (2)

--- Is it Blue-tag Certified or Yellow-tag Source Identified? (2)

--- Is it offered on a Pure Live Seed (PLS) basis? (5)

--- Is the purity high enough to reduce problems with stems, and fluffy or non-debearded seed? (7)

--- Is the germination high enough to indicate vigorous seed? (8)

--- What kinds of other crop seed? e.g., 4% yellow sweet clover could pose a problem. (10)

--- How many and what kinds of weed seeds? Even if the weed is not legally listed as noxious, certain "common" weeds, such as the weedy bromes, cheat grass, and chess could affect revegetation. (11)

--- Origin is important with warm-season grasses such as sand dropseed, blue grama, sideoats grama, alkali sacaton; and some shrubs such as fourwing saltbush, sagebrush, and winterfat. (13)

--- Date tested. Although most seed stores well, sagebrush, winterfat, rabbitbrush, and greasewood often start to drop in viability after 9 months. If the seed is not the previous year's crop, request a new germination test completed within 3 months. (14)

--- All germinations may be based on Tetrazolium (TZ) tests for shrub seed.

--- All grasses to be sold on the basis of germination test, except Indian ricegrass.

--- Indicate year collected for shrubs.

--- Buyer may request an official seed laboratory analysis, signed by a certified seed analyst, for each lot of seed offered.

If the buyer notifies the vendor that he intends to purchase all the seed from a single vendor, rather than pick-and-choose, he will usually get a better package price. If a certain species is in short supply, such as *Atriplex gardneri*, *Ceratoides lanata*, or *Sphaeralcea coccinea*, it will often be high priced or not offered at all on a pick-and-choose bid.

The following schedule provides for submitting offers for either certified or non-certified seed or both. The buyer reserves the right to award on any item offered. All awards will be based upon the lowest pure live seed (PLS) price offered on each item. Award may be made on a higher PLS priced certified seed versus a non-certified PLS priced seed of the same species and variety; or may be made on the basis of weed content, other crop content, or origin.

TABLE BID SCHEDULE - Bidder must complete Column (4) through (14) So

Item No.	SEED. Agricultural (type)	QUANTITY IN PLS POUNDS		PLS PRICE PER POUND	TOTAL AMOUNT	BIDDER'S SPECIFICATION						SEED ORIGIN (STATE)	DATE TESTED
		NEEDED	OFFERED			PUR	GERM	PLS RATING	% CROP	% WEED	WEED & OTHER CROP NUMBER SEEDS/LB.		
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**
1A	Certified *Agropyron dasystachyum* Thickspike wheatgrass Critana	2,000											
1B	Non-Certified *Agropyron dasystachyum* Thickspike wheatgrass Critana	2,000											
2A	Source Identified *Artemesia tridentata* Wyoming Big Sagebrush Wyomingensis	1,000											
2B	Non-Source Identified *Artemesia tridentata* Wyoming Big Sagebrush Wyomingensis	1,000											

3. Warm Season Grasses -- The Importance of Origin of Named Varieties and Native Harvests

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

Grasses can be categorized as either warm- or cool-season, depending upon their germination and growth temperature requirements. Warm-season grasses germinate in the late spring when soil temperatures are warmer, and grow during the heat of the summer. Cool-season grasses, on the other hand, germinate early in cool soils and grow in the spring and the fall. In general, cool-season varieties can be moved farther from their origin (the location from which the breeder originally collected seed) than can warm-season varieties.

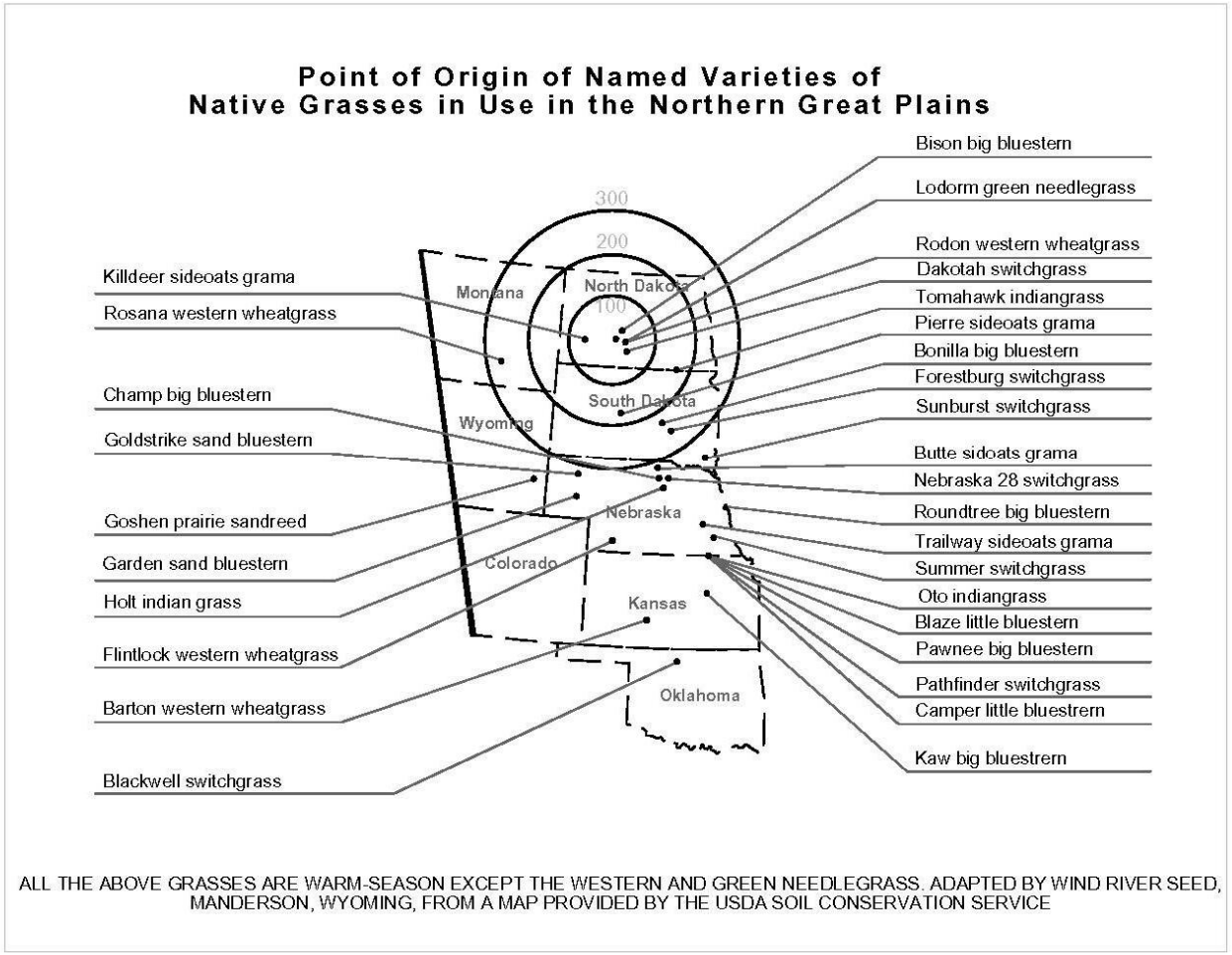
Special Considerations

Current named varieties of native plants are selected ecotypes that exhibit superior performance for defined areas of adaptation. The experience of the Soil Conservation Service indicates that a warm-season ecotype can be moved about 300 miles north or 200 miles south of its origin without having serious problems of winter hardiness, longevity, and disease. Movement east or west can cause problems due to changes in precipitation and elevation. Generally, an increase of 1,000 feet in elevation is equivalent to a move of 175 miles north. However, the rule is not universally applicable as photoperiod changes with changes in latitude, while it remains the same despite elevation changes.

Varieties developed from northern ecotypes mature earlier, are shorter, are lower in total forage production, and are more susceptible to leaf and stem diseases when moved southeastward from their point of origin. Varieties developed from southern ecotypes generally mature later, are taller, and produce higher yields of forage. These differences become more visible when moved north from the original area of collection. However, varieties moved too far north may not be winter hardy and stands may be reduced or completely lost during the year of establishment or under stress conditions applied by climate or management factors.

Technique

When seeding native species, use certified, blue-tagged seed of selected varieties known to be adapted to your site (Figure C-3-1). Certified seed assures proper identity and genetic purity of the selected variety. An alternative is to use seed harvested from range or native haylands within your zone of adaptation. Care must be exercised, however, as range-collected seed may be contaminated with noxious weeds. The guidelines for native species do not apply to introduced species; however, each introduced species and/or variety has a definite, though greater, range of adaptation.



ALL THE ABOVE GRASSES ARE WARM-SEASON EXCEPT THE WESTERN AND GREEN NEEDLEGRASS. ADAPTED BY WIND RIVER SEED, MANDERSON, WYOMING, FROM A MAP PROVIDED BY THE USDA SOIL CONSERVATION SERVICE

Figure C-3-1

4. Certified Blue-tag Versus Non-certified (Common) Seed

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

In the seed industry, Seed Certification is the means of maintaining the pedigree of a specific variety of seed (such as the named variety “Goldar,” which is a variety of blue bunch wheatgrass). Each variety is released for propagation because it is deemed superior in one or more characteristics, such as seedling vigor, low dormancy, broad range of adaptability, seed production, form and color, or palatability. Each state has a Seed Certifying Agency (or Crop Improvement Association) which writes the rules for seed produced in its state. Some seed growers voluntarily use certification to assure their customers that extra care has been taken to provide them with:

1. Correctly identified, genetically pure seed
2. High mechanical purity and germination
3. Freedom from the worry of noxious weeds

Special Considerations

Even though a bag may not have a blue tag, it may still contain the variety claimed. A seed lot may fail certification merely because the mechanical purity was proven to be slightly lower than the standard for that variety; or, since certified seed often does not command a much higher price than common seed, a grower may not go to the trouble and expense of having his field and cleaning plant inspected by the seed certifying agency. Since varieties cannot be determined by observing the seed in the laboratory, the integrity of the grower and the seed dealer determine whether the seed is truly the variety claimed on the label.

The blue tag assures the buyer that the seed in the bag meets high purity and germination standards, as well as low levels of other crop seed and weed seed (usually less than 0.25%). There are no standards for non-certified seed other than state limitations on weed seed (often as high as 2.00%).

Freedom from worry over noxious weeds is another benefit of field inspection. Common or native fields are not walked by the inspector, and a "clear tag" laboratory test will be based on only 25,000 seeds (about 60 grams). A noxious weed missed in the sample may show up in subsequent samples (if they are taken), or after the seed is in the ground, when a costly spray control program is the only course remaining. Eradication is difficult to achieve once noxious weeds become established.

Technique

Many seeders have already found that quality seed pays in better establishment, permanence, and absence of noxious weeds. The trend toward blue-tagged seed supports reputable seed companies and encourages growers to produce enough high quality seed to meet the demand.

To ensure receipt of certified seed, specify on seed orders:

> "Certified blue-tagged seed shall be supplied where a named variety is specified. Vendor shall indicate on the bid whether certified or common seed is being offered, as well as the origin of the seed. The blue tags removed when the seed is mixed

shall be given to the revegetation engineer; in addition, mix tags showing the weighted averages of the ingredients shall be attached to each bag."

5. Source-identified Yellow-tagged Seed

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

Until the advent of the “Source-Identified” class of certified seed, a buyer had no way to verify the actual collection site of native harvest seed. For example, cheaper southern origin seed would be relabeled and sold as northern origin to garner higher prices. At the request of buyers and reputable seed collectors, national standards have been set by the Tree, Shrub, and Native Grass Committee of the Association of Official Seed Certifying Agencies (AOSCA). The Source-Identified system is in place in Wyoming, Utah, Colorado, Montana, and New Mexico.

Special Considerations

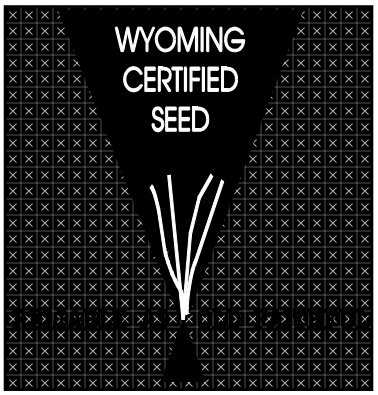
On-site inspection is done by the seed certifying agency to verify the county and elevation of the collection site, and the identity of the species. There is no guaranteed freedom from noxious weeds; the buyer should refer to the supplier's label for analysis and weed content. The certifying agency will issue the collector enough yellow tags (Figure C-5-1) to tag the number of bags of cleaned seed collected.

Technique

When asking for prices of native shrubs, have vendors indicate on their bids whether the seed is Yellow-tag Source-Identified, and the state, county, and elevation of the collection site. If the seed is to be mixed, have the vendor provide the yellow tags.

FIGURE C-5-1

SOURCE-IDENTIFIED CLASS



Species *Artemisia tridentata Wyomingensis*

Common Name WYOMING BIG SAGEBRUSH

Geographic Source LINCOLN COUNTY, WYOMING

Elevation **6800 FT.** ***Lot # 1029***

MEMBER OF ASSOCIATION OF OFFICIAL SEED CERTIFYING AGENCIES, INC.

LIMITATIONS OF LIABILITY APPLICABLE: CALL FOR COPIES

6. Understanding Seed Tests

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

The use of seed tests is often helpful in evaluating seed quality and vendor claims; however, the limitations of seed testing are also important to understand.

Special Considerations

Seed is tested to monitor the veracity of claims made by vendors on the bag label, to monitor storage conditions, or to check for weeds. There are vendors who are sloppy, who cheat, or who are unable to meet the rigors imposed by demanding buyers. A savvy buyer needs to test for purity, germination, and weed content to verify the quality of the seed. Using blue-tagged Certified seed reduces the need to test, since a paper trail of independent verification exists for each blue-tagged lot.

Certified seed older than one year should be retested for germination by the vendor. Seed with a very short shelf life, such as sage, rabbitbrush, winterfat, or greasewood, should be tested for germination frequently. Chaffy native harvests, such as blue grama, should be tested for noxious weeds and undesirable common weeds. Reclamation specialists should be extremely wary of introducing noxious weeds and excessive numbers of weedy annual brome species. Unwanted infestations interfere with the establishment of desirable revegetation species, can be expensive and sometimes impossible to eradicate, and could create litigation exposure if the noxious weed spreads to adjacent landowners.

Technique

a. How to Test

Most state agriculture departments employ inspectors who will sample seed and send it to the state seed lab. With advance notice, seed inspectors will come to a warehouse free of charge. Make sure the inspector has a probe long enough to reach lengthwise through a bag. The probe may be critical for sampling mixes in which small seed may migrate through larger seed during shipping and concentrate on the margins. The seed inspector should randomly sample bags in the following way:

(1) Sample at least five bags, plus 10% of the bags in a given lot.

(2) With very chaffy, non-flowing seed such as winterfat or blue grama, sample by hand, rather than probe, from various parts of the bags. Use the same sampling formula as above.

(3) Sample should weigh 100 grams, or contain at least 25,000 seeds.

(4) Indicate which tests to perform; usually purity and tetrazolium (TZ).

(5) Box samples to avoid crushing in the mail.

(6) Do not subject samples to temperature or humidity extremes. Do not place samples in auto trunks or on dashboards on hot days.

If time is a consideration, a buyer can draw their own samples with a probe and send them to the chosen seed lab; however, the results are less open to dispute if a

Department of Agriculture employee is called. If questions arise over a lab result, the vendor should be allowed to suggest labs or tests to verify his claims.

b. What Tests to Order

Often, when the buyer wants to get the seed in the ground immediately, or when the vendor needs to be paid, time dictates what tests to order. Germination tests are the most accurate tests for most grass species, but may take up to 25 days to complete. The TZ test is a 48-hour test which estimates germination through a process in which live seeds are chemically stained. Purity (which includes the weed test) can be done as soon as an analyst gets to it, sometimes becoming available the same day a sample is received.

Fees for tests vary by lab and by species tested. For an extra charge a sample may be "Rushed". A full seed test of purity and germination may cost anywhere from $30 to $70 per sample for a single species. Shrub seed and TZ tests cost somewhat more than grass seed and germination tests.

It is strongly recommend that if seed is to be tested, it be done before being mixed with other lots. Some grass seed and most native shrub seed should be sent for a TZ test rather than for germination. Not all species react favorably to standard germination techniques, and standardized rules for germination don't exist for unusual wildland species. For instance, some species exhibit a high degree of dormancy, which may not respond to germination techniques, or may be susceptible to fungal attack under laboratory germination settings. The following is a list of species which should be tested for TZ rather than germination:

> Indian ricegrass, green needlegrass, fourwing saltbush, gardner saltbush, mat saltbush, skunkbush sumac, woods rose, Rocky Mountain juniper, bitterbrush, chokecherry, northern sweetvetch, lupine, Rocky Mountain bee plant, thermopsis, and sagebrush.

During a time of seed shortage, or when dealing with unusual species, seed may be sold on the basis of a cut test, or utricle fill. No claim is being made about germinative potential or dormancy, only that the seed is filled; in fact, the seed may not even be alive. Any vendor selling seed by fill should make this clear to the buyer.

c. Interpreting Test Results

Germination results are statements of statistical probability, and can be influenced by many factors. As an example, the sample may not be representative of the entire lot of seed. Especially with trashy seed such as sagebrush, samples tend to be far from homogeneous; two samples from the same bag can vary widely in both purity and germination. Tables of variance used by seed labs to assess seed quality (Table 1), are based on the degree of homogeneity found in flowable seeds such as corn and wheat. From the standpoint of homogeneity, western wheatgrass would be considered trashy; sagebrush approaches statistical anarchy.

Tolerance tables (Tables C-6-1 and C-6-2) are used to compare different analyses of purity and germination. The analysis stated on a seed bag label can be compared with additional analyses to decide whether there is a real deficiency. Obviously, incorrect

analyses are discarded and remaining tests averaged. If the difference between the averaged tests and the analysis stated on the label exceed tolerances established for that level of purity and germination, then the original sample is considered deficient. The tolerances have a probability of error of 5% and are meant to compare testing averages. The use of tolerances to determine the variation between only two tests should be done with great caution, recognizing that the probability of error is higher than if several tests are averaged.

Uncertainty in sampling and testing increases as purity and germination decrease, with the greatest uncertainty between 40% and 60% purity and germination below 60%. Tests of trashy seed usually have a larger margin of error than do those for non-trashy seed. However, as PLS approaches zero, sample homogeneity once again increases, as does statistical certainty. Samples of non-chaffy seed averaging 99.00% pure with a 99% germination actually reflect a 95% probability that test samples will show a purity of between 98.41% and 99.59% (Table 1), and 95% probability that the test samples will show a germination between 94% and 100% (Table 2). Reading from those same tables, a test series with an average 25% purity and 60% germination could be interpreted in this manner: A 95% probability that a test result will fall within the tolerance range of 21.96% to 28.04% purity and a germination range of 51% to 69%.

Due to several factors, variations within native-collected trashy seed lots may exceed the tolerances on Tables 1 and 2. Seed quality may vary substantially depending on the time of day collected, soil properties, competition among plants collected within the same patch, and access to moisture by individual plants. Variation may become more pronounced within a stand of shrubs when a limiting factor such as rainfall influences seed set. Given the high variation of seed within a native stand during collection, and given the difficulty of mixing trashy seed lots to achieve homogeneity, expect variations in shrub tests beyond tolerances.

Although seed testing requires expertise and time, and sometimes yields ambiguous results, it is an important tool in helping to guarantee the desired outcome.

TABLE C-6-1. Regular tolerances for any component of a purity analysis.

SOURCE: ASSOCIATION OF OFFICIAL ANALYSTS

Average Analysis Purity		Nonchaffy Seeds	Chaffy Seeds
A	B	C	D
99.95 - 100.00	0.00 - 0.04	0.13	0.16
99.90 - 99.94	.05 - .09	.20	.23
99.85 - 99.89	.10 - .14	.24	.29
99.80 - 99.84	.15 - .19	.28	.34
99.75 - 99.79	.20 - .24	.32	.37
99.70 - 99.74	.25 - .29	.35	.41
99.65 - 99.69	.30 - .34	.37	.45
99.60 - 99.64	.35 - .39	.40	.48
99.55 - 99.59	.40 - .44	.42	.50
99.50 - 99.54	.45 - .49	.44	.53
99.40 - 99.49	.50 - .59	.47	.57
99.30 - 99.39	.60 - .69	.51	.60
99.20 - 99.29	.70 - .79	.54	.64
99.10 - 99.19	.80 - .89	.57	.66
99.00 - 99.09	.90 - .99	.59	.70
98.75 - 98.99	1.00 - 1.24	.64	.75
98.50 - 98.74	1.25 - 1.49	.71	.82
98.25 - 98.49	1.50 - 1.74	.76	.89
98.00 - 98.24	1.75 - 1.99	.82	.95
97.75 - 97.99	2.00 - 2.24	.87	1.01
97.50 - 97.74	2.25 - 2.49	.92	1.07
97.25 - 97.49	2.50 - 2.74	.96	1.12
97.00 - 97.24	2.75 - 2.99	1.00	1.17
96.50 - 96.99	3.00 - 3.49	1.06	1.24
96.00 - 96.49	3.50 - 3.99	1.14	1.34
95.50 - 95.99	4.00 - 4.49	1.21	1.41
95.00 - 95.49	4.50 - 4.99	1.27	1.49
94.00 - 94.99	5.00 - 5.99	1.36	1.60
93.00 - 93.99	6.00 - 6.99	1.47	1.73
92.00 - 92.99	7.00 - 7.99	1.58	1.85
91.00 - 91.99	8.00 - 8.99	1.67	1.96
90.00 - 90.99	9.00 - 9.99	1.75	2.06
88.00 - 89.99	10.00 - 11.99	1.87	2.19
86.00 - 87.99	12.00 - 13.99	2.01	2.36
84.00 - 85.99	14.00 - 15.99	2.14	2.51
82.00 - 83.99	16.00 - 17.99	2.24	2.64
80.00 - 81.99	18.00 - 19.99	2.35	2.76
78.00 - 79.99	20.00 - 21.99	2.44	2.86
76.00 - 77.99	22.00 - 23.99	2.52	2.96
74.00 - 75.99	24.00 - 25.99	2.59	3.04
72.00 - 73.99	26.00 - 27.99	2.65	3.12
70.00 - 71.99	28.00 - 29.99	2.71	3.19
65.00 - 69.99	30.00 - 34.99	2.80	3.29
60.00 - 64.99	35.00 - 39.99	2.89	3.40
50.00 - 59.99	40.00 - 49.99	2.96	3.48

EXAMPLE: A lot is of unmixed non-chaffy seed. The tolerance for non-chaffy seed is in column C. The percentage of pure seed in the first and second analyses, respectively, are 89.65 and 87.55; the average is 88.60; and the apparent deficiency is 2.10 (89.65-87.55). The average is between 88.00 and 89.99, which are on a line in column A. Therefore, the tolerance is 2.19. Since the apparent deficiency does not exceed the tolerance, the deficiency is not considered real and the percentage of pure seed given on the label may be considered satisfactory.

TABLE C-6-2. Germination tolerances

The following tolerances are applicable to the percentages of germination, and also to the sum of the germination plus the hard seed, when 400 or more seeds are tested:

Mean	Tolerance
96 or over	5
90 or over but less than 96	6
80 or over but less than 90	7
70 or over but less than 80	8
60 or over but less than 70	9
Less than 60	10

When only 200 seeds of a mixture are tested, 2% shall be added to the above germination tolerances.

7. Determining Pure Live Seed

Section editor: Larry H. Kleinman *Subsection author: Claire Gabriel Dunne*

Applicability

When purchasing seed by bulk pounds, a buyer is paying for not only Pure Live Seed (PLS), but also inert materials such as dust and chaff, and other crop seed or weed seed. Buyers can obtain a much better dollar value through purchasing seed by the PLS pound.

Special Considerations

Since every seed lot has a different analysis, a system has been devised that allows customers to buy only the pure, live seed in a bag.

Technique

To figure the Pure Live Seed percentage, multiply the purity percentage by the germination percentage of the seed lot. By then multiplying the Pure Live Seed percentage by the weight of the bag, one can determine the amount of pure live seed in the bag. Let us compare two lots of seed to determine the best value:

Lot A is labeled 98% pure with a 95% germination and costs $5.00 per bulk pound.
Lot B is labeled 89% pure with a 92% germination and costs $4.75 per bulk pound.

Lot A: .98 x .95 = .931 PLS
Lot B: .89 x .92 = .819 PLS

Now divide the seed cost by the PLS percentage to determine the Pure Live Seed cost:

Lot A: $5.00 ÷ .931 = $5.37 per PLS pound

Lot B: $4.75 ÷ .819 = $5.80 per PLS pound

As you can see, the seed lot that was less expensive on a bulk seed basis actually represents an inferior value on a PLS basis. Seed with a higher PLS rate tends to have more vigorous, healthy seed than seed with a lower PLS rate. Also, higher quality seed costs less to ship. Let's see how many pounds of seed would be shipped if one ordered 1000 PLS pounds from these seed lots:

Lot A: 1000 ÷ .931 = 1074 bulk pounds

Lot B: 1000 ÷ .819 = 1221 bulk pounds

In order for a purchaser to adequately evaluate seed value, Pure Live Seed prices must be determined before seed is purchased.

8. Selecting Good Shrub Seed

Section editor: Larry H. Kleinman *Subsection author: Richard Dunne*

Applicability

Purchasing and evaluating seed requires an understanding of species peculiarities and pitfalls. This subsection is a general guide for shrub seed evaluation.

Special Considerations

Each species has different characteristics for adaptability, shelf life, purity, germination, and planting. Seed tests are important in evaluating a seed lot, and ocular inspection may detect irregularities requiring further attention.

Technique

a. Sagebrush

(1) Origin

Whenever possible, select seed of northern, locally adapted ecotypes. Yellow-tagged, Source-Identified seed is becoming available and is the best guarantee that the origin is correctly stated. Although some species are not site specific, the best choice is within your geographic area and elevation.

(2) PLS

Ask the vendor what year the seed was harvested; the older the seed, the more frequently the seed should be retested for germination. Seed collected in November and germinated in December or January will have a test that will carry it through the following fall. Beyond that time, the buyer should insist on seed tests no older than three months to assure that it is still viable. Sage is usually tested by tetrazolium (TZ). A good purity is 12% or better; a good TZ is 65% or better. As with all range-collected shrub seed, purity and TZ may be much lower in drought-year crops. Poor test results during good crop years may be a sign of a "troubled" seed lot.

(3) Seeding

Seed should be sown on the soil surface. As with most surface shrub seedings, late fall or early spring seeding capitalizes on snow melt to create conditions favorable for germination.

(4) When purchasing sagebrush seed, look for the following warnings signs:

(a) A stale, musty smell may indicate the seed is not from a new crop.

(b) Seed rubbed out of its pericarp or inert material, or ground very fine may indicate over-processing and heat or mechanical damage.

(c) Less expensive Basin big sage is sometimes passed off as silver sage, which has a much larger seed and a different smell. There should be no trident leaves in a bag of silver sage, which has smooth-tipped leaves.

b. Fourwing Saltbush

(1) Origin

Northern adapted ecotypes are now coming onto the market as yellow-tagged, Source-Identified seed, which generally has more resistance to winterkill and a greater ability to regenerate. Avoid New Mexico or Arizona ecotypes, whenever possible. Utah, Colorado, and Wyoming ecotypes are often more expensive and frequently unavailable.

(2) PLS

This seed stores well, so testing every 12-months is adequate. Fourwing is usually tested by Tetrazolium, which is more indicative of viability than mere utricle fill. A good purity is 95%; a good TZ is 40%.

(3) Seeding

Fourwing should be drill seeded 1/2-inch deep.

(4) When purchasing fourwing seed, look for the following warning signs:

(a) Some seed from New Mexico and southern Utah has been known to be infested with field bindweed or wild morning glory (*Convolvulus arvensis*).

(b) Watch for broken utricles as a sign of over-processing.

(c) Watch for greyed or discolored seed. This may indicate a post-harvest drying problem.

(d) Native fourwing rarely tests over 70% viable by TZ; question a high TZ.

c. Winterfat

(1) Origin

Northern adapted ecotypes are not likely to be available for several years. Most seed originates in New Mexico or Arizona as Sonoran Desert transition ecotypes. Expect chronic shortages as greater demand chases available seed. "Hatch" is a selected cultivar from a Utah ecotype.

(2) PLS

Seed storage life is one to two years. Beyond September of the year following collection, the buyer should insist on tests no older than three months. Winterfat is usually tested by Tetrazolium. A good purity is 70%; a good TZ is 55%.

(3) Seeding

Seed should be sown on the soil surface.

(4) When purchasing winterfat seed, look for the following warning signs:

(a) Yellowing fluff on the seed may indicate age, improper drying, or premature collection.

(b) Utricle breakage reduces viability and storage life significantly. There will be some breakage in all lots, but more than 10% should be cause for further scrutiny.

d. Rabbitbrush

(1) Origin

Rabbitbrush seems to be more amenable to being moved than other shrub species. Any source from a neighboring state is probably adequate, and is usually readily available.

(2) PLS

Rabbitbrush often has a very poor storage life, with significant loss of viability possible at any time, and with a high likelihood of serious viability loss within one year of collection. Purity can be as high as 50%, but is usually about 20%. A good TZ would be 65% or better.

(3) Seeding

Seed should be broadcast on the soil surface.

(4) When purchasing rabbitbrush seed, look for the following warning signs:

(a) Broken seed indicates over-processing. The remaining seed may be microscopically cracked.

(b) Yellowing of inert material (fuzz) may indicate aging.

(c) Good seed should snap when bent; unfilled seed bends without snapping.

e. Greasewood

(1) Origin

The ecotype sensitivity of greasewood is poorly understood. Select the nearest origin possible.

(2) PLS

Seed has a shelf-life of one to two years. A purity of 40% to 60% can be expected, and a TZ above 40% is acceptable.

(3) Seeding

Greasewood should be drill seeded to a shallow depth.

(4) When purchasing greasewood seed, look for the following warning signs:

(a) Broken utricles or excessively rubbed wings may indicated processing damage.

(b) Holes in utricle sides are signs of insect damage. If seed is labeled as 60% TZ, but 50% of the utricles have holes, the seed may be mislabeled.

D. SURFACE STABILIZATION

1. Vegetative Surface Stabilization

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

One of the greatest threats to the physical integrity and ability of re-topsoiled spoil to support plant growth is surface erosion. Steep, smooth, and unrevegetated spoils are subject to high rates of water and wind erosion. The stability of the site is lessened, valuable topsoil is lost, and the cost of repair is very high. In addition, State and Federal regulations govern the amount of acceptable erosion.

There are several factors that increase the amount of erosion or lessen the stability of a reclaimed site. The more important factors are probably: slope steepness, slope length, type of drainage provided, lack of and/or type of control structures, lack of vegetation, and the physical properties of the spoil and soils material.

Special Considerations

Soils and slopes are stabilized and erosion reduced by intercepting and reducing raindrop impact, and by slowing down, redirecting, and allowing infiltration of surface runoff. There are many successful methods for stabilizing soil. Only the methods that have been tried and proven successful on surface mined lands will be presented. Surface manipulation (non-vegetative) methods are mentioned in a separate subsection. Vegetative techniques for soil stabilization will be discussed here.

Technique

a. Establishment of a Vegetative Cover

The establishment of a vegetative cover is basic to successful soil stabilization. The raindrop impact energy is expended on vegetation rather than soil. Surface flow velocity is decreased by the vegetation and infiltration is increased. The root system binds soil particles together, which reduces particle movement and transport. Therefore, the goal is to provide a vegetal cover as quickly as possible.

The timing of vegetation establishment is vital for success. The optimum planting season is just before the longest period of favorable growing conditions. This period is the longest period of sufficient soil moisture and when the soil temperature is high enough to initiate seed germination but not so high as to retard growth.

Techniques for stabilizing slopes and soils include immediate vegetation establishment, and mulching. There is no need for a detailed description of these methods in this

subsection. The goal and concern is to revegetate the soil surface as quickly as possible. The methods listed here and described in other subsections have been tried and proven successful in stabilizing soils and slopes with the very least amount of erosion and soil loss.

(1) Immediate Vegetation Establishment

(a) Drill Seeding
Drill seeding places the seed in the soil surface at a prescribed depth. Exact methods are described in the subsection entitled "Drill Seeding Practices".

(b) Hydroseeding
Hydroseeding is a method of placing the seed on the soil surface in a water slurry mixture. More exact methods are described in the subsection entitled "Hydroseeding Practices".

(c) Broadcast Seeding
Broadcast seeding places the seed on the soil surface by means of a whirly bird type of seeder (cyclone seeder), by hand, by seed dribblers, or even by airplane. Needless to say, there not many mines that reseed by airplanes. The other methods are used extensively for light fluffy seed, such as sagebrush and rabbitbrush. More exact methods are described in the subsection entitled "Broadcast Seeding".

(d) Transplanting Live Plants and Planting Plant Parts
These methods include containerized stock, bareroot stock, shrub/tree pads, and sprigs or cuttings. These methods are described elsewhere in this section.

(2) Mulching

Mulching places a layer of inorganic or (most preferred) organic material on the soil surface and on top of the seed to increase soil moisture, prevent erosion, moderate the soil temperature, and increase the potential for seedling establishment. These methods of mulching are described in detail in a previous subsection and are only listed here:

(a) Nurse Crop
(b) Cover Crop
(c) Native Hay Mulch
(d) Straw Mulch
(e) Wood Fiber Mulch
(f) Paper Fiber
(g) Wood/Paper Fiber
(h) Synthetic Fiber

2. Non-vegetative Surface Stabilization

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

One of the greatest threats to the physical integrity and ability of retopsoiled spoil to support plant growth is surface erosion. Steep, smooth, and unrevegetated spoils are subject to high rates of water and wind erosion. The stability of the site is lessened, valuable topsoil is lost, and the cost of repair is very high. In addition, State and Federal regulations govern the amount of acceptable erosion.

There are several factors which increase the amount of erosion or lessen the stability of a reclaimed site. The more important factors are probably: slope steepness, slope length, type of drainage provided, lack of and/or type of control structures, lack of vegetation, and the physical properties of the spoil and soils material.

Special Considerations

Soils and slopes are stabilized (erosion reduced) by intercepting and reducing raindrop impact, and by slowing down, redirecting, and allowing infiltration of surface runoff. There are many successful methods for stabilizing soil. Only the techniques that have been tried and proven successful on surface mined lands will be mentioned here. Surface manipulation (non-vegetative) techniques are also discussed in the Hydrology section of this handbook. Those techniques include most types of control structures except for contour furrowing.

Technique

a. Contour Furrowing

Contour furrowing across the slope has been used to intercept surface runoff and redirect it back into the uphill side of the slope. The contour furrows are generally cut into slopes that have gradients from 5H:1V to 3H:1V. The furrows (ditches) are generally cut with a small track dozer such as a D-6, because a motor grader with a 14 or 16-foot blade cannot safely traverse the steep slope.

b. Sequence of Operations

The furrow may be cut into the slope before farming, seeding, and mulching; however, these operations are more easily and safely accomplished without the furrows in place. Some seed and mulch will be lost in the bottom of the furrow, but will be placed on the berm or outside edge of the furrow. The extra mulch and vegetation on the berm better stabilize the structure with less cutting through. The vegetation will soon spread into the bottom of the furrow because of increased moisture supply.

(1) Before Furrowing

(a) The spoils are regraded to the desired gradient and topography.

(b) The regraded spoils are retopsoiled to the desired depth.

(c) The area is farmed and reseeded with the desired species.

(d) The area is then mulched with native hay and crimped. Other types of mulches may be used if desired. It is easier to mulch before furrows are cut, thus eliminating running equipment across the furrows.

(2) Steps of Operations in Building the Contour Furrows

(a) The contour furrows are cut into the slope with the D-6 dozer at a gradient of two to three percent. The furrows should not be "0" gradient as the runoff needs to gradually drain back into the slope of the hill. If it does not drain back, runoff will pond and cut through the furrow causing rilling and gullying downslope.

(b) The furrow should be cut to a depth of one to two feet and a width of five to six feet.

(c) A contour furrow should be cut into the slope approximately every 50 to 100 foot run of the slope. Therefore, a slope with a length of 400 feet should have four or five contour furrows cut into it.

E. HUSBANDRY

1. Mowing for Weed Control

Section editor: Larry H. Kleinman *Subsection author: Laurel E. Vicklund*

Applicability

Annual weeds can present problems in newly seeded areas. Chemical control is costly and sometimes not feasible. Mowing offers an economical option for weed control.

Special Considerations

Areas seeded to permanent grass should be evaluated periodically during the first few growing seasons. Noxious weeds and other problems need to be identified and dealt with as soon as they develop.

Once permanent vegetation is seeded, treatment options for the area are limited so as not to affect the bonding clock. Mowing to control annual weeds provides good results with low environmental impact on the area, and does not restart the bonding clock. Mowing maintains a stubble cover, but prevents seed set for the year and knocks back the weeds that take available moisture from the developing grasses.

Technique

Annual weeds are a prevalent feature of reclaimed areas. They serve the function of shading small grass seedlings, collecting snow, reducing wind erosion, and aid in the stabilization of the ground against water erosion until the permanent grass seedlings are established. However, abundant annual weed growth utilizes soil moisture and chokes out new seedlings.

During the first summer after permanent grass mixtures have been seeded, a rotary deck type mower can be used to cut the annual weeds. This should be done prior to weed flowering and seed production. The weeds usually have enough height to be cut by May or early June. If the year is moist enough, the area may need additional mowing later in the summer. Multiple mowing reduces the size of the windrow created.

2. Burning to Enhance Vegetation

Section editor: Larry H. Kleinman *Subsection author: Laurel E. Vicklund*

Applicability

Successful reclamation depends on moisture received during the year in the form of rain and snow. Without adequate moisture, even with the best tillage and seeding techniques, reclamation will fail. Often the failure is not immediately identified. By the time a seeding failure is noticed, the area can be covered with too much vegetative matter to make drill seeding or hydroseeding possible.

A firm seed-bed already exists beneath the vegetative rubble; therefore, it is not advantageous to re-till the area. Burning the vegetative matter removes the surface trash for reseeding to take place with a minimum of seed-bed preparation.

Special Considerations

State Air Quality officials may require a burning permit prior to burning activities. Burn days usually must coincide with air sampling run days. Local county officials will also usually require notification prior to burning an area.

Site specific safety regulations should be followed for a planned burn, and safety equipment and pertinent safety personnel should be advised and on hand. Areas that have steep slopes may need additional protection from erosion after the burn.

Techniques successful for burning to enhance vegetation are very site-specific. The Cordero Mine has had good results from using these techniques. The size of the area will vary from site to site. Do not start a fire larger than you feel you have the personnel and equipment necessary to extinguish.

Weed seeds will not necessarily be destroyed by the fire, so additional weed control methods may be needed. Mowing as weed control is economical, and does not have the environmental concerns associated with chemical weed control. However, perennial noxious weeds cannot be controlled by mowing and need aggressive treatment when found in reclamation.

Technique

Areas to be excluded from the planned burn should be identified. A plan should be developed to ensure the burn will be contained in the identified area. Natural barriers work the best for a planned burn. For example, roads, ditches, rock areas, or other areas devoid of vegetation work well as natural barriers.

When possible, the burn should be planned around a planting season. Most burning is done in the fall or spring, so this fits right in. The less time that elapses between the burn and reseeding, the less chance for erosion to develop before the grass cover is adequately established.

Check the wind direction and velocity prior to starting the fire. Pick a time when vegetative cover in the area is dried but regional burning is not banned. Start the fire in the corner of the area that the wind is coming from, opposite from the corner of the barrier and perimeter of the area. In this way, the wind will carry and spread the fire towards the barrier of the burn. An area seems to burn best with a slight wind, however an excessive wind can spread the fire past the barriers and out of control.

Once the fire has consumed the area, check to ensure that it is completely out. Extinguish any areas that have not burned out. Some areas that had excessive trash cover may need extra attention to ensure a complete burn and reduce the danger of fire spreading after the burn.

Interseed the area at the first available seeding window. Drilling should be done on the contour to reduce erosion.

3. Husbandry Grazing

Section editor: Larry H. Kleinman *Subsection author: Larry H. Kleinman*

Applicability

There are certain circumstances under which livestock grazing can be used to effect changes in the species composition of a revegetated stand once the vegetation has become established. For example, annual bromegrasses are very difficult to control without plowing and refarming the field or utilizing complete herbicidal control. Judicial use of late fall and early spring grazing by livestock has been shown to decrease the amount of annual bromegrasses.

There may be older seeded stands that have a preponderance of introduced species that are suppressing more desirable native species. Smooth bromegrass and crested wheatgrass often begin spring growth several weeks before other cool season grasses and certainly before warm season grasses. Heavy grazing in the early spring can cause a decrease in the early growing cool season grasses and an increase in the later growing grasses.

Litter buildup can occur on revegetated areas that have not been grazed, burned, or hayed. This buildup of litter will continue until the seeded species are suppressed, if no action is taken.

Special Considerations

The livestock owner must be flexible in cooperating with the reclamationist. The reclamationist must be able to bring the cattle onto the revegetation at just the right time and take the cattle off the revegetation with only a day or two notice. The reclamationist must be on hand to determine when the grasses desired for control are ready to be grazed and when the grasses desired for increase begin active growth. The desired species should be dormant at the time of grazing.

Technique

Livestock grazing for the following three described purposes, annual bromegrass control, introduced cool season grass suppression, and litter reduction, may and probably should take place in concert with each other. It must be emphasized that the timing of grazing be flexible and that the reclamationist be cognizant of the timing of plant growth. For additional information on grazing practices, refer to the Postmining Land Use section of this handbook.

a. Annual Bromegrass Control

Annual bromes are considered to be winter germinators. If conditions are favorable during early November, they will germinate and grow to a height of two to four inches before cessation of growth for the winter. If they are grazed at this time, those individuals will not continue growth to seed set the next spring. Cattle will readily graze the available green forage and thus reduce the number of plants that will set new seed

the next spring. The dormant perennial grasses will not be damaged even by heavy grazing.

The annual bromegrasses will germinate earlier in the spring than any of the introduced or native cool season grasses. If the annuals are grazed in the spring after growth has begun and before the desired perennials begin growth, the weed crop for that year will be lost. If the annuals are inhibited, the perennials will increase. A decrease has been noted in the amount of annual bromes within two years by grazing in the early spring or late fall. The cattle must be taken off the revegetation just as the desired perennial species begin substantial growth (leaf height of one to two inches).

b. Introduced Cool Season Perennial Grass Control

Livestock grazing has been used to reduce the amount of introduced cool season grass species in the revegetated stand, including crested wheatgrass and smooth bromegrass. These two species generally initiate growth several weeks earlier in the spring than do the native perennials. The livestock grazing should take place after the introduced grasses have begun growth and before the native species have attained substantial growth (leaf height of one to two inches).

c. Litter Reduction

Livestock grazing can reduce the amount of standing litter and break up the fallen litter in a revegetated stand. The desirable species should be dormant at the time of grazing. Grazing may take place at any time during dormancy from late summer to early spring. The desired species will not be damaged by the heavy grazing necessary to reduce the amount of litter. The grasses can be grazed to a stubble height of one to three inches with no damage to the dormant plant. Enhanced growth will be noted the next growing season.

F. MONITORING

1. Vegetation Sampling

Section editor: Larry H. Kleinman *Subsection author: Greg E. Jones*

Applicability

Vegetation assessments of permanently reclaimed areas should be conducted at specified intervals to document vegetation development, assess readiness for and effects of grazing on reclaimed areas, and to document land uses.

Special Considerations

Sampling methodology should be developed and agreed upon by the operator and regulatory agency prior to initiation of data collection. Consistent methods should be used for baseline and postmining sampling.

Technique

a. Delineation of Reclaimed and Study Areas

Each reclaimed area should be identified with a specific designation, so all activities relating to its development and assessment can be recorded and documented. These designations can correspond to mine site, year of topsoiling, area number (postmining

vegetation type) and sub-area linkage (non-contiguous/same treatment areas). If a permanently reclaimed area is redisturbed (topsoil removed) or drastically altered (tilled under or completely reworked), that portion (acreage) can be removed from the previous designation and/or redesignated to reflect the alterations performed.

Since reclamation activities (acreages) vary from year to year, several similar, although not contiguous, reclaimed areas can be combined to constitute one monitoring area. These monitoring areas would preferably range from 50 to 100 acres in combined size.

During the bond release period, study areas may consist of combined reclaimed areas of similar vegetation types, which may be at differing stages of development. These studies can be summarized as a whole although individual sample locations should be tracked to allow analysis of individual reclaimed areas.

b. Monitoring Plan Parameters

Each reclaimed area should be sampled for the following parameters at specified intervals using those methods described below:

-% vegetation cover by species*
-% total vegetation cover (sum of all species)*
-% total ground cover (vegetation + litter + rock)*
-% bare ground*
-herbaceous production
-shrub density
-list of species observed during sampling

* % values are reported as absolute % cover

c. Sampling Methods

Sampling methods should comply with those accepted by the appropriate regulatory agency of your area. The methods discussed below are provided as examples and can be altered to meet the desired sampling needs.

(1) Cover Data Collection

Cover data can be collected using the line transect/point intercept method. Sample locations for cover are chosen by randomly selecting points within a grid of the revegetated area. Grid intervals should not exceed 100 feet on the ground. Randomly generated sample location coordinates should be plotted on a map and located in the field by pacing from known features or land marks. Random numbers between 1 and 360 should be generated to orient each transect.

Sample locations that encompass non-contiguous reclamation areas or varying vegetation types should be consecutively numbered through each area or vegetation type to allow individual or grouped analysis and comparison of the data collected. Sample hits are taken at 1 meter intervals along the entire length of a 50 meter transect. These first hit (50) data points will constitute the absolute cover values for one full sample set. Additional hits at each meter mark may be recorded separately but not included in

absolute cover values for that particular transect. Multiple hit information can be used to compile the overall plant list for the area and to qualitatively describe the stratified vegetation cover within each respective revegetation area.

Cover by individual species should be collected for the 50 hits within each transect and later combined into total vegetation cover. In addition, litter, rock, and bare ground hits should be recorded and later combined into total ground cover. Transects that exceed designated vegetation boundaries should be randomly reoriented to be within the sampled vegetation area.

(2) Production Data Collection

Production data can be collected using one meter square plots. Sample locations should be chosen by randomly selecting points within a grid of the revegetated areas or by randomly locating plots along a cover transect in those areas monitored for cover. Another method is to locate plots three feet perpendicular and three feet to the right from the 50 meter end of a cover transect. Sample locations should again be consecutively numbered for grouped or individual analysis as described in the paragraph above on cover data.

Should the study areas include lands that will be grazed during the sampling period, the use of grazing exclosures will be required. The number and type of exclosures should be sufficient to provide an adequate sampling area (one meter square) and sample size (maximum samples within the grazed area). When grazing is anticipated, both cover and production can be sampled with the one-meter square plots.

Annual above-ground herbaceous biomass should be clipped by dominant species and remaining minor species by lifeform. Full shrubs, succulents, noxious weeds, and cushion plants should not be clipped. If annual grasses and/or annual forbs are major community components, these life forms should be included in the sampling.

Clipped biomass should be placed in paper bags and dried in a forced air oven (105ºC for 24 hours). Samples should be weighted on an appropriate scale to the nearest 0.10 gram and reported in grams per meter squared and pounds per acre. Clipped samples less than 0.10 gram can be reported as trace samples. Average bag weight must be calculated and subtracted from weighed samples.

(3) Shrub Density Data Collection

Shrub density data can be collected at random locations in conjunction with cover transects on selected revegetation areas. All shrubs (full, half, or sub) should be counted within 50 centimeters either side of the 50 meter cover transect (1 meter by 50 meter belt transect). Shrub counts should be recorded by species and reported as shrubs per meter squared and shrubs per acre.

In those reclaimed areas designated as a shrub mosaic or patch, the plot configuration may vary in order to define the establishment and/or development of the shrub component. When developed and productive stands of shrubs are defined through periodic sampling, permanent transects and/or plots may be established to document trends in shrub development and longevity.

(4) Plant Species List

A list of all plant species observed during cover and production sampling should be recorded by life form and described by scientific and common names. The listing can also include those species observed during the course of sampling although not encountered within a specific cover transect or production plot.

Any federally designated threatened and endangered species, state plants of concern, noxious weeds, and primary selenium indicator species observed should be identified.

(5) Species Diversity

Relative cover percentages calculated from revegetation area cover data can be used to evaluate the species diversity and richness of the area.

(6) Sample Intensity

The intensity or amount of samples collected within each revegetation area should follow those requirements outlined by applicable regulatory requirements. Interim monitoring of revegetated areas may require a set amount of samples per area, dependent upon the size (acres) of the area. An example of sample size could be ten random samples for each study/reclaimed area up to 100 acres in size, with one additional sample for each ten acres of increased acreage within the area.

Should the study area require sampling to statistical adequacy, statistical testing formulas outlined by the applicable regulatory agency should be used. At a minimum, all sampling results should include the computed Z value and confidence level achieved with the number of samples collected.

(7) Sample Frequency

Sampling of individual revegetation areas usually will not begin until the third growing season following the year of permanent seeding. A schedule should be developed which includes three sampling periods during the ten year minimum bonding period. This schedule would serve as a minimum sampling frequency, additional samples may be taken or substituted for determination of grazing readiness and stocking rates or to document special treatments on specific areas.

d. Sample Data Analysis

All data collected should be analyzed and presented in a tabular format acceptable to the applicable regulatory agency. Tables F-1-1, F-1-2, and F-1-3 illustrate the results of cover, production, and shrub density vegetation studies conducted on reclamation areas.

TABLE F-1-1
Report: Cover Summary

Site Identification: R9101
Name: Reclamation Area R9101
Comm. Type/Form: Reclamation/Grassland
Sample Date: 03-Jul-1995

Sample Method: Point Intercept
Sample Size: 50 Meter Transect
Number of Samples: 10
Report Date: 08-Sept-1995

() Represents Second Hit Data

	Cover (%)		Std. Dev.	Frequency (%)			
	Mean Absolute	Relative	(n-1)	Absolute	Relative	I.V.	Rank
Annual Grass							
Bromus japonicus	9.0 (0.2)	12.8	4.3	100.0	9.8	22.7	3
Bromus tectorum	0.6	0.8	1.3	20.0	2.0	2.8	15
Festuca octoflora	0.2	0.3	0.6	10.0	1.0	1.3	22
Total Life Form	9.8 (0.2)	14.0	5.0	100.0			
Cool Season Perennial Grass							
Agropyron cristatum	0.2	0.3	0.6	10.0	1.0	1.3	20
Agropyron dasystachyum	2.2	3.1	1.8	70.0	6.9	9.9	7
Agropyron smithii	15.6 (0.2)	22.1	6.4	100.0	9.8	31.9	1
Agropyron spicatum inerme	9.2	12.8	5.9	100.0	9.8	22.7	4
Agropyron trachycaulum	1.0	1.4	1.9	30.0	2.9	4.3	14
Koeleria macrantha	3.0	4.2	3.2	70.0	6.9	11.1	6
Stipa comata	1.4	2.0	3.1	30.0	2.9	4.9	10
Stipa viridula	12.6	17.6	5.3	100.0	9.8	27.4	2
Total Life Form	45.2 (0.2)	63.4	8.5	100.0			
Warm Season Perennial Grass							
Bouteloua gracilis	1.6	2.2	2.3	40.0	3.9	6.2	12
Total Life Form	1.6	2.2	2.3	40.0			
Annual Forb							
Alyssum alyssoides	0.4	0.6	0.8	20.0	2.0	2.5	16
Alyssum desertorum	6.6 (0.2)	9.5	3.7	90.0	8.8	18.3	5
Camelina microcarpa	1.2	1.7	1.9	40.0	3.9	5.6	11
Descurainia pinnata	0.2	0.3	0.6	10.0	1.0	1.3	19
Descurainia sophia	0.2	0.3	0.6	10.0	1.0	1.3	21
Helianthus annuus	0.2	0.3	0.6	10.0	1.0	1.3	24
Plantago patagonica	0.8 (0.2)	1.4	1.7	30.0	2.9	4.3	13
Sisymbrium altissimum	1.2	1.7	2.1	30.0	2.9	4.6	9
Total Life Form	10.8 (0.4)	15.6	6.3	100.0			

Site Identification: R9101
Name: Reclamation Area R9101
Comm. Type/Form: Reclamation/Grassland
Sample Date: 03-Jul-1995

Sample Method: Point Intercept
Sample Size: 50 Meter Transect
Number of Samples: 10
Report Date: 08-Sept-1995

() Represents Second Hit Data

	Cover (%)		Std. Dev.	Frequency (%)			
	Mean Absolute	Relative	(n-1)	Absolute	Relative	I.V.	Rank
Perennial Forb							
Sphaeralcea coccinea	0.8	1.1	1.9	20.0	2.0	3.1	17
Sphaeralcea munroana	1.8	2.5	2.4	50.0	4.9	7.4	8
Vicia americana	0.2 (0.2)	0.6	1.3	10.0	1.0	1.5	23
Total Life Form	2.8 (0.2)	4.2	4.0	50.0			
Perennial Shrub							
Artemisia tridentata	0.4	0.6	0.8	20.0	2.0	2.5	18
Total Life Form	0.4	0.6	0.8	20.0			
Total Stratified Vegetation Cover	71.6	100.0	6.8	100.0			
Total Non-stratified Vegetation Cover	70.6		7.1				
Litter	17.4		6.2	100.0			
Rock	0.4		0.8	20.0			
Total Ground Cover	88.4		5.1				
Bare Ground	11.6		5.1	100.0			
Total Cover	100.0		0.0				
Species Abundance (# species/sample)	10.2		1.9				

TABLE F-1-2

Report: Production Summary

Site Identification: N8701ALL
Name: Reclamation Area N8701ALL
Comm. Type/Form: Reclamation/Grassland
Sample Date: 27-Jun-1995

Sample Method: Random Plots
Sample Size: 1.0 sq m.
Number of Samples: 10
Report Date: 08-July-1995

	Mean Production (gm/sq.m)	Mean Production (lbs/ac)	Relative Production (%)	Std. Dev. (n-1) (gm/sq.m)
Annual Grass				
Bromus japonicus	0.953	8.502	0.605	2.410
Bromus tectorum	0.650	5.799	0.412	1.598
Total For Life Form	1.603	14.302	1.017	4.008
Cool Season Perennial Grass				
Agropyron cristatum	0.266	2.373	0.169	0.841
Agropyron dasystachyum	58.438	521.372	37.079	46.374
Agropyron riparium	0.341	3.042	0.216	0.782
Agropyron smithii	26.508	236.499	16.820	25.408
Agropyron spicatum	1.647	14.694	1.045	5.208
Bromus inermus	28.544	254.664	18.111	60.805
Stipa viridula	3.496	31.191	2.218	10.372
Total For Life Form	119.240	1063.834	75.659	38.081
Annual Forb				
Alyssum alyssoides	0.721	6.433	0.457	2.280
Alyssum desertorum	3.848	34.331	2.442	4.195
Camelina microcarpa	4.591	40.960	2.913	8.777
Descurainia pinnata	0.053	0.473	0.034	0.168
Thlaspi arvense	0.615	5.487	0.390	1.502
Total For Life Form	9.828	87.683	6.236	14.228
Perennial Forb				
Lithospermum incisum	0.077	0.687	0.049	0.243
Medicago sativa	17.094	152.509	10.846	33.778
Onobrychis viciaefolia	0.307	2.739	0.195	0.971
Ratibida columnifera	0.922	8.226	0.585	2.916
Sphaeralcea munroana	0.077	0.687	0.049	0.243
Vicia americana	0.154	1.374	0.098	0.487
Total For Life Form	18.631	166.222	11.822	33.259
Perennial Sub-shrub				
Artemisia frigida	0.200	1.784	0.127	0.632

Site Identification: N8701ALL
Name: Reclamation Area N8701ALL
Comm. Type/Form: Reclamation/Grassland
Sample Date: 27-Jun-1995

Sample Method: Random Plots
Sample Size: 1.0 sq m.
Number of Samples: 10
Report Date: 08-July-1995

	Mean Production (gm/sq.m)	Mean Production (lbs/ac)	Relative Production (%)	Std. Dev. (n-1) (gm/sq.m)
Ceratoides lanata	8.100	72.267	5.140	9.480
Total For Life Form	8.300	74.051	5.266	9.310
TOTALS	157.602	1406.092	100.000	62.542

Site Identification: R9103
Name: Reclamation Area R9103
Comm. Type/Form: Reclamation/Sagebrush Grassland
Sample Date: 27-Jun-1995

Sample Method: Transect Plots
Sample Size: 50.0 sq m.
Number of Samples: 5
Report Date: 08-Sept-1995

	Mean Number/Plot	Relative Density %	Std. Dev. (n-1) Number/Plot	Mean (Number/sq.m.)	Mean (Number/Acre)
Perennial Shrub					
Artemisia cana	42.800	12.3	43.8	0.86	3464.1
Artemisia tridentata	230.200	66.0	222.8	4.6	18631.7
Total For Life Form	273.000	78.3	263.0	5.46	22095.8
Perennial Sub-shrub					
Artemisia frigida	19.000	5.5	19.3	0.38	1537.8
Ceratoides lanata	56.600	16.2	65.6	1.13	4581.0
Total For Life Form	75.600	21.7	53.7	1.51	6118.8
TOTALS	348.600	100.0	229.5	6.97	28214.7

2. Recordkeeping Practices

Section editor: Larry H. Kleinman *Subsection authors: D.G. Steward/Marlys M. Hansen*

Applicability

The release of reclamation bonds depends on quantitative and qualitative reclamation success. Evaluation of this success is meaningless without accurate and comprehensive records. These records can be collected in a set of volumes to make a history of mine reclamation. The Reclamation History is a database of revegetation practices, as well as monitoring and assessment information, from the beginning of reclamation on a minesite.

The widespread availability of geographic information system capabilities, in conjunction with GPS locating capabilities, greatly increases both the accuracy and utility of the reclamation history records. Great care should be exercised in the planning phase of the reclamation history to select the methods used for data identification, data storage, and data retrieval.

Special Considerations

The Reclamation History database expands year by year, serving as a definitive source of data regarding date of permanent reclamation, revegetation practices, revegetation assessment and sampling, topsoil fertility, backfill geochemistry, and postmining land use. Revegetation practices and vegetation cover by species through time constitute a large part of the data array. An organized and retrievable Reclamation History, such as can be found in this database, provides many opportunities for data analysis and interpretation.

In addition, Reclamation History information provides feedback for current practices and thus allows continual improvement of reclamation practices. Revegetation monitoring and research can include investigations into the effects of soil type and fertility on reclamation species, the success of various reclamation species, the effects of postmining land use, the impact of mulching, the success of shrub pads, the success of various methods of sagebrush seeding, and the success of direct-haul topsoil.

Technique

a. Date of Permanent Reclamation

History of reclamation in a given area can be considered to start at the time regraded backfill is topsoiled and the topsoil prepared for revegetation. Backfill replacement and grading is considered a part of the process. Topsoil placement and final surface preparation can be selected to define the date of permanent reclamation, because (except in very rare circumstances) topsoil replacement and final surface preparation are only done once. In contrast, revegetation may be, and often is, conducted over a span of years. Drought, pest infestations, and seed failures all contribute to multiple revegetation efforts.

Many Reclamation Histories also begin at the time of regrading the backfill. Both dates, regrading and topsoiling, should be a part of the Reclamation History.

b. Revegetation Practices

An element that constitutes a significant component of the database is the revegetation practices for all permanently reclaimed units. These practices are presented by season and by year. Revegetation activities are conducted in the spring and the fall; therefore,

each year has two seasons for which information is available. This data can be presented in the same database format shown in Figure 1 of the subsection entitled "Preparing a Revegetation Package". Maps for both seasons of each year, showing the location of all revegetation units, are included. Permanent revegetation can be categorized in the following way.

(1) Permanent Revegetation

Permanent revegetation practices are recorded any time seeding is conducted with the intention that the seeding will serve as the basis for postmining land use. Seeding of grains may occur for agricultural uses such as pastureland and cropland. Thus, seeding of annual grains can be considered, in some cases, "permanent".

(2) Functionally Permanent Revegetation

Functionally permanent revegetation practices are those that occur when the initial intention was for long-term temporary seeding, but where time has shown that the seeding will serve as the basis for postmining land use. The most typical example of functionally permanent revegetation is revegetation of road ditches and rights-of-way that were initially seeded for stabilization, but where the road has been incorporated into the postmining land use plan and the vegetation has become very well established. There is often little likelihood in such a case that these areas will be re-disturbed.

(3) Husbandry Practices

Husbandry records can be included with permanent and functionally permanent practices so that a record of such husbandry exists. Husbandry in an area does not re-initiate the bond time period, and is thus fundamentally different from permanent and functionally permanent practices.

c. Revegetation Assessment and Sampling

Data collected in revegetation research and monitoring conducted at a mine are also included in the Reclamation History. The purpose of revegetation monitoring is to prove establishment of desired vegetation as well as the progress that has been made toward postmining land use goals. As a result of monitoring, modifications and additions can be made to revegetation practices in order to enhance the achievement of those goals.

Geographic locations of vegetation sample locations can be identified using GPS and GIS overlays. Maps of sample locations should be included in the Reclamation History. Figure F-2-1 gives a sample table that can be used to document vegetation sampling results (figure follows text). This table is expanded, year by year, to cover all types of vegetation found and all areas sampled.

d. Topsoil Fertility

State regulations and the mine permit may require that topsoil fertility be assessed where topsoil has been stockpiled for more than one year. Fertility samples are collected in the backfill in those areas over which stockpiled topsoil has been spread. The information collected through the assessment program can also be used to determine fertilization rates.

Topsoil fertility data are usually presented in a spreadsheet that covers all aspects of sampling. Data are added to the spreadsheet as it is collected each year.

e. Backfill Geochemistry

Before topsoil can be replaced, the suitability of the top four feet of backfill must be assessed; thus, backfill geochemistry is another component of the Reclamation History. Geochemical information is collected at intervals from backfill. The cumulative backfill database is presented in the Reclamation History in a spreadsheet that can be updated as data are collected each year.

f. Postmining Land Use

Any postmining land use practices employed by the mine can be summarized in a history. These practices may include wildlife use, production of grains, haying, or livestock grazing. For techniques on these practices, refer to the Postmining Land Use section of this handbook.

FIGURE F-2-1

Vegetation Sampling – or use forms and methods described in preceding section

Unit or Area or Treatment					
OBS or sample number					
Sampler					
Date of sampling					
Easting					
Northing					
Aspect					
Slope					
Quadrant size					
Cover (1) or Production (2)					
% Total desirable vegetation					
% Total vegetation					
% Total litter/rock (or ground)					
% Total bare soil					
% Total cover					
% Bare soil					
% Litter					
% Rock					
Agropyron dasystachyum					
Agropyron intermedium					
Agropyron smithii					
Agropyron trachycaulum					
Alyssum desertorum					
Artemisia tridentate					
Astragalus cicer					
Atriplex canescens					
Avena fatua					
Bouteloua gracilis					
Bromus inermis					
Calamovilfa longifolia					
Ceratoides lanata					
Descurainia richardsonii					
Elymus junceus					
Helianthus annuus					
Lupinus pusillus					
Medicago sativa					
Melilotus officinalis					
Onobrychis vicifolia					
Orysopsis hymenoides					
Plantago patagonica					
Poa pratensis					

Unit or Area or Treatment					
OBS or sample number					
Sampler					
Polygonum convolvulus					
Sphaeralcea coccinea					
Stipa viridula					
Thlaspi arvense					
Tragopogon dubius					
Vicia Americana					

3. Electronic Document Management in Mining

Section editor: Larry H. Kleinman *Subsection author: Greg E. Jones*

Applicability

The following discussion is provided to describe the application of Electronic Document Management (EDM) to electronically capture, store, distribute, annotate, display and print the extensive data required by the Surface Mine Control and Reclamation Act of 1977 (SMCRA).

Special Considerations

The EDM system design may include integration of software compatible with the Technical Information Processing System (TIPS) developed by the Office of Surface Mining and State regulatory agencies. A critical issue for electronic document management is the selection and utilization of data storage and retrieval systems. With sufficient effort and associated utilization of the appropriate program, EDM can create a tangled morass of unusable data from which the only escape is to start over.

There are five commandments for the electronic management of data. The primary caution is “Never use a program that does not translate easily to another program. A corollary to the primary caution is, “Never use a program for data storage and retrieval that requires a specialist to operate.” While mapping and display programs such as Arcview and Autocad require seriously specialized training, it is essential that the “man in the field” be able to access, validate, and correct the database. This is a real-world challenge. One thing about a slow, inefficient, error-prone paper system is that, given the organization of the files is acceptable, anyone can operate the system.

1. Always keep a paper copy of any data input into a data management system, including paper copies of GPS input information and paper copies of any maps generated by CAD or GIS systems. With the avalanche of data confronting the environmental specialist this may seem archaic and inefficient. However, it is the single best safeguard against paralysis of the system. In addition the original field information may be needed for demonstration, litigation, verification, or re-analysis.

2. Spend a lot of time developing and consistently implementing a well-documented filing system for paper copies of data. If hard copies of desired information can not be easilty located and rapidly retrieved, the filing system is inadequate.

3. Always use data management programs that will translate easily and correctly to another program. Programs come and go, and evolve. If the data can not move from one program to another easily, the result will be chaos.

4. Never use a program for data storage and retrieval that requires a specialist to maintain and operate. A simple to operate system may create inefficiencies and limitations, but a good base data set can always be used as input to a more complex program. However, an over-complicated system that no one can operate will lead to inability to retrieve information, or worse, data that appears good and is incorrect.

5. Whatever system is used, keep it current and stay familiar with it. A data management system needs ongoing utilization and analysis just like a dog needs exercise. If you the operator do not have a good intuitive feel for what your data are telling you, neither you nor the system are functioning properly

Technique

a. Electronic Document Management

Through the use of EDM, operators can realize an increase in manpower efficiency along with improved quality, repeatability, and transferability of data collected, reported, and analyzed in State and Federal permit documents.

b. EDM Primary Components

There are four components commonly used to transfer or exchange information relating to permit applications and/or reports.

(1) Computer Aided Drafting (CAD)

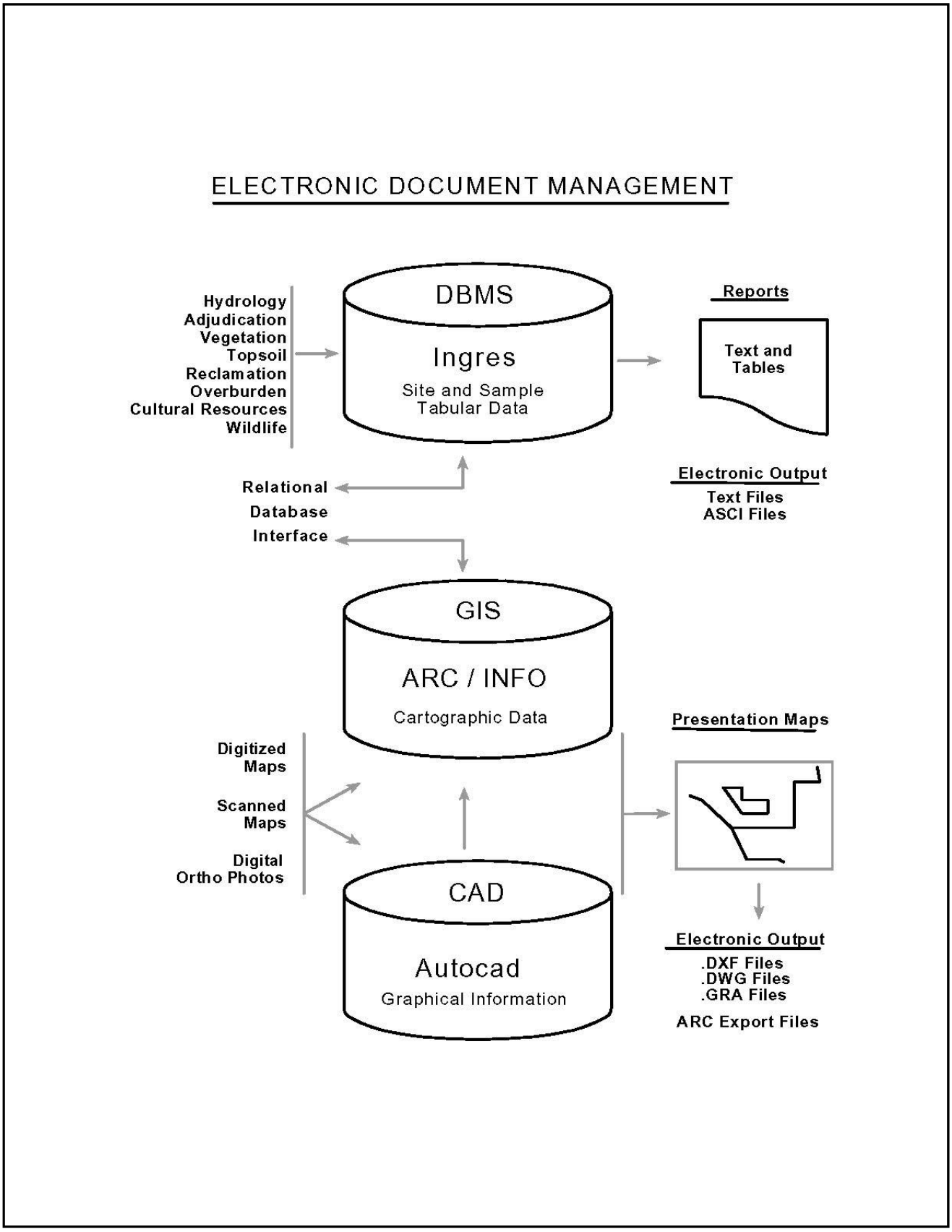
Computer-aided drafting software applies computer graphics technology to automate manual drafting techniques. The primary use of this application is for the design, drafting, and display of graphically oriented information.

(2) Geographical Information System (GIS)

Geographical Information System software is designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced geographic data.

GPS (global positioning system)

GPS techniques enrich the capabilities of both GIS and CAD by increasing the accuracy and speed with which samples, structures, and reclamation units can be located in the field. Electronic transfer of GPS information from the satellite receiver or mapping device directly to the database management system, which is typically integrated with the GIS reduces data transfer error and speeds the data management process.


ELECTRONIC DOCUMENT MANAGEMENT
Hydrology
Adjudication
Vegetation
Topsoil
Reclamation
Overburden
Cultural Resources
Wildlife
DBMS
Ingres
Site and Sample
Tabular Data
Reports
Text and
Tables
Electronic Output
Text Files
ASCI Files
Relational
Database
Interface
GIS
ARC / INFO
Cartographic Data
Presentation Maps
Digitized
Maps
Scanned
Maps
Digital
Ortho Photos
CAD
Autocad
Graphical Information
Electronic Output
.DXF Files
.DWG Files
.GRA Files
ARC Export Files

(4) Database Management System (DBMS)

Database Management System provides an organized set of data that allows flexible query and manipulation of tabular data by selecting portions of the data set for further calculation, analysis, reporting, or data exchange.

(5) Word Processing (WP)

Word Processing software is utilized for all textual portions of permit applications. Through submission of electronic text files, technical personnel may access separate portions of the application at the same time, resulting in more expeditious permit reviews.

c. Individual EDM Topic Applications

The following applications describe how an EDM system can be utilized to prepare permit documents in electronic format for submittal to a regulatory agency.

(1) Baseline Topsoil Surveys

GIS applications can be used to store, illustrate, and analyze specific topsoil information (soil type, soil depth, mapping unit) according to geographical boundaries and parameters defined in the baseline study. Through a process of overlaying or clipping a topsoil polygon coverage with other polygon coverages, detailed reports are created to describe, for example, the extent (acres) of each soil type and the quantity (yards) within a proposed permit boundary.

This application can be used to develop reports which summarize the projected total amount of topsoil available for salvage within the disturbance limits of the mine plan, for use in determining an average salvage and reclamation replacement depth. Additional analyses can be performed to define area and volume by individual disturbance year, for mass balance tables in the mine plan section.

(2) Baseline Vegetation Surveys

GIS applications are used to store, illustrate and analyze specific vegetation information (vegetation types) according to geographical boundaries and parameters defined in the baseline study. Through the same processes described for topsoil surveys, detailed reports can be created to describe the extent (acres) of each vegetation type within a defined polygon (permit boundary, disturbance area, or study area).

The DBMS is also utilized to store raw baseline vegetation data from surveys, provide printed reports of selected criteria, and provide a statistical baseline for comparison of pre- to post-mining vegetation data at the time of bond release.

(3) Legal Description and Ownership

Regulatory requirements call for the legal description of all lands within and surrounding a permit area. Through GIS applications, specific legal or ownership data are associated with known tracts of land, and spatial

relationships can be established to determine the exact acreage of a permit area, by legal identification (ID) (section, township, range), or ownership (surface or mineral) by owner, address or legal ID.

(4) Wildlife

Both CAD and GIS systems can be applied to the protection of wildlife resources. Electronic data are used to accurately map and define the extent of important wildlife habitats within and adjacent to mining operations. Habitats such as wetlands, big game ranges, game bird breeding areas and raptor nest locations are documented electronically so they can be referenced to mining activities for appropriate mitigation actions.

(5) Reservoir Designs

Through the use of CAD/GIS topographic maps (five foot contours) for the mining area, reservoir sites are selected, construction contours drawn and merged with existing topography, and stage volume tables are created using CAD routines. Design information including existing topography with reservoir design contours can be placed on an exhibit with stage volume tables, cross sections, plan view, and associated water level annotation.

(6) Overburden Suitability

Surface mining operations can use maps developed through CAD/GIS applications to determine overburden suitability. These maps show suitability of overburden (by individual suitability parameter) according to the criteria described in each mine site's approved permit. These same data can then be provided to the state regulatory agency in electronic format.

(7) Hydrology

Hydrologic data, including surface flow, static water levels for wells, and geochemistry data can be stored in the DBMS. Data can be directly loaded through a custom window application or batch loaded from a file provided by contract laboratories. Use of the DBMS allows for production of reports with user defined parameters, statistical analysis for selected data, creation of graphs to monitor trends, and electronic transfer of data to regulatory agencies for compilation into larger database applications.

(8) Revegetation/Reclamation

All aspects of an EDM system can be used in the storage, tracking, analysis and reporting of revegetation/reclamation activities. GIS applications can be used to define reclaimed areas (area ID, extents, seed mixture, year of topsoiling, year of seeding...). Through the various attributes assigned to individual areas, detailed reports and maps can be created based on user defined variables.

The DBMS can be used to store interim monitoring vegetation data collected for each area. This information can be entered through a custom windowing application or batch loaded from files prepared by vegetation contractors. Various outputs are available through the vegetation DBMS system which

include: cover, production, and density reports (raw data and summaries); plant species summary by area (which describes species observed, first year observed and number of years observed); and statistical summary reports for data collection parameters (standard deviation, actual sample size, computed adequate size, computed Z value, and confidence level achieved).

Reclamation exhibits illustrating backfill and reclamation progression can be prepared in CAD along with associated backfill mass balance tables. WP is utilized to textually describe each action associated with the reclamation plan along with tabular illustrations of each mine site's seed mixtures. Through application of the EDM, practically all portions of the Reclamation Plan can be provided to the regulatory agency in electronic format.

(9) Textual Information

WP software is used for all textual material included in permit documents. This software should be compatible with that used by the regulatory agency reviewing the document. Examples include text changes made in bold type to better define changes, and pages submitted with consistent pagination and revision dates.

d. Summary

An EDM system as described above can provide a powerful tool for use in complying with State and Federal regulatory requirements. Considerable cost and manpower savings can be realized, along with increased technical knowledge and analytical capabilities, consistency of information, and enhanced transfer of complex scientific data.

G. REFERENCES

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