Alabama Surface Mining Commission

TECHNICAL MANUAL #1

Approved Statistical Analysis and Sampling Techniques for Determining
Revegetation Success on Surface Mine Lands in Alabama

November, 1990

(enhanced for website July 2016)

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INTRODUCTION

The procedures or methods contained in this manual are those which the ASMC will accept for demonstrating revegetation success for bond release. These are the **only** methods approved by the Office of Surface Mining for the State of Alabama.

Certain portions of this manual contain excerpts from the "Technical Guides on Use of Reference Areas and Technical Standards for Evaluating Surface Mine Revegetation in OSM Region I and II" published by the Office of Surface Mining Reclamation and Enforcement. These excerpts are reprinted with the permission of OSMRE. We also wish to acknowledge the contributions of Dr. Sam Lyle in developing the guidelines for sampling ground cover and tree stocking.

CHAPTER 1

Applications of the Point Frequency Method of Estimating
Soil Vegetative Cover

There are several reasons for wanting to know the amount of soil area covered by vegetation. It is assumed in this paper that the reason is to know how well the soil is being protected from erosion by the vegetation growing on the soil. Some of the other reasons could be the vegetation yield for a crop, the amount of cover for game animals, or the estimation of biomass for fuel production.

In mine reclamation, vegetative cover is necessary for the initial stabilization of the soil material to prevent soil erosion and sediment pollution. It is a well-known fact that the vegetative cover on a soil prevents rain drops from dislodging particles of soil. This dislodging of soil particles is the beginning of soil erosion, and if it can be prevented there is little chance of erosion. Of course, this same vegetative cover will also slow the downhill movement of water and the slower the movement of water, the less soil carried by the water.

It is permissible to measure any organic matter (living or dead) that is produced by the plants growing on a reclaimed mine. No material applied by man or other animal should be considered. The dead plant material lying on the soil surface, or protruding above the soil surface will prevent soil erosion as well as and living material. However, it must be kept in mind that the dead material must be continually produced by perennial living plants. Applied mulch or annual plants do not give lasting protection

unless the annual plants are reseeding or the mulch is applied yearly and cannot be considered as ground cover.

There are many methods of measuring soil cover, but most of the methods have been found to be inaccurate and their results hard to reproduce. One method that is considered accurate and reproducible is the point-frequency method. This is the method used by the Office of Surface Mining and by the Alabama Surface Mining Commission. Three ways to apply the point-frequency method will be described. The preselected random-point application is the only one that can be legitimately analyzed by statistical methods and should be most accepted in a court-of-law. The field selected random-point application is probably not quite as accurate as the preselected random-point but it is quick and reasonably accurate if bias is avoided. The field selected random-point application allows unintentional bias to occur and this can destroy accuracy. The systematic point-frequency application is practically always as accurate and reproducible as the preselected application and it is much easier to apply.

1. Preselected Point Application of the Point-Frequency Method

The first step is to locate 100 points at random on the area to be measured. An aerial photograph or map is needed for this procedure. A north-south line and an east-west line are located outside the area to be measured (Figure 1). The starting point for these lines can be located by measuring direction and distance from two known points such as the road

intersection and shop shown in illustration. The N-S and E-W lines are graduated in some unit of measure that can be used to locate points in the field. Now, use a table of random numbers, computer program or page numbers from a book to select random numbers for the N-S and E-W lines. Use these numbers to locate 100 points on the map (Figure 1). One hundred points are used because this is the least number that allows reasonable limits of confidence when the results are analyzed statistically. One hundred points will give the same confidence limits, regardless of area size. Next, use a protractor or any other method to determine the direction to be walked from one point to the next. Measure the distance between points in the direction that you intend to walk. Measure distances and directions in a pattern that will be most convenient for the field work. The directions and distances do not have to be extremely accurate since the purpose of this scheme is to assure unbiased randomness.

The field work starts at this point. Go to the starting point on the area to be measured and use a compass to locate the direction to the first sampling point, go to the point and, without looking, extend your arm to one side and push the sight tube into the ground. Distance can be measured by pacing or any other convenient method. Look through the tube and align the two cross-hairs with a point on the ground. If the point on the ground or any point between the cross-hairs and ground shows vegetation, a +1% is recorded. If no vegetation is seen on the line created by the cross-hairs, a -1% is recorded. Now, go to the point and continue the procedure until all 100 points have been measured. The number of + points is the percent of cover on the area if 100 points are measured.

The A.S.M.C. regulations require 80 percent cover for certain postmining land uses. The measurements that you make are only an estimate

of the amount of cover on the area. In order to be fair about the estimate, a statistical procedure is used to tell the percent cover estimated that is close enough to the allowable percent cover to be accepted.

The procedure for this calculation is as follows:

$$S_{\bar{x}} = \sqrt{\frac{pg}{n}} = \sqrt{\frac{80 \times 20}{100}} = \sqrt{16} = \pm 4\%$$

$S_{\bar{x}}$ = standard error of estimate of mean

p = percent soil cover needed (80 in this example)

q = n − p (n can be any number but 100 points is considered practical

n = number of points read

$$C.\,I. = \bar{x} \pm \left[t_{\alpha,df} \times S_{\bar{x}}\right] = 80 \pm [1.64485 \times 4] = 80 \pm 6.57$$

$$80 + 6.57 = 86.57 \text{ and } 80 - 6.57 = 73.43$$

C. I. = confidence interval

$\bar{x}$ = percent soil cover required by regulatory agency

t = value taken from table 1 (α and df are used to locate t in table 1)

α = 100 − % statistical confidence allowed by regulatory agency

df = degrees of freedom (number of points sampled − 1)(100 − 1 = 99 d. f.)

Therefore the confidence interval is 73 to 87. This means that if 73 or more of the 100 points are vegetated, the soil cover requirement is satisfied.
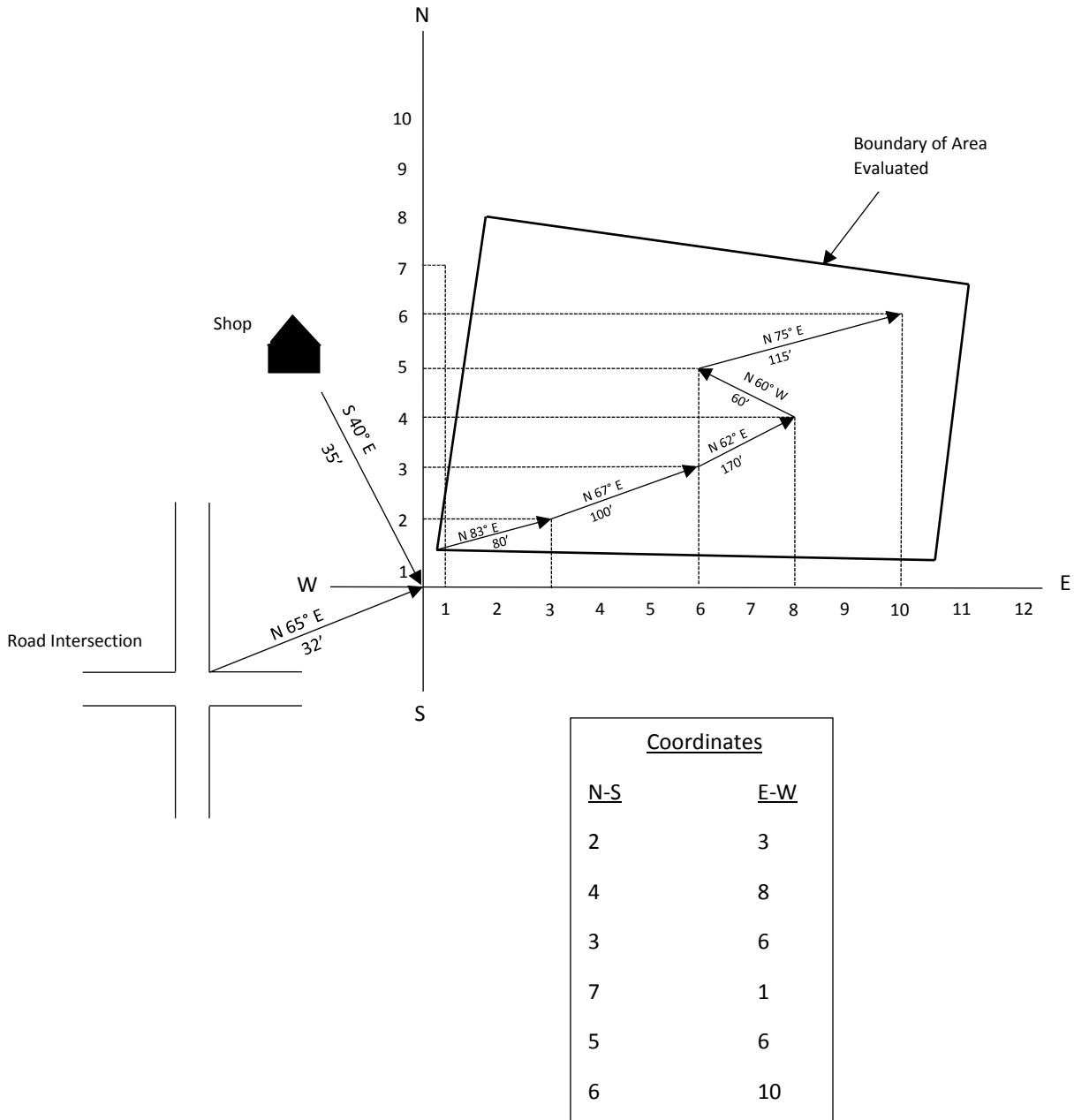
FIGURE 1. Locating Points for Point-Frequency Method.

TABLE 1. Values of t for α and degrees of freedom (d.f.)

Degrees of freedom (d.f.)	α											
	90	80	70	60	50	40	30	20	10	5	2	1
1	.158	.325	.510	.727	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.657
2	.142	.289	.445	.617	.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925
3	.137	.277	.424	.584	.765	.978	1.250	1.638	2.353	3.182	4.451	5.841
4	.134	.271	.414	.569	.741	.941	1.190	1.533	2.132	2.776	3.747	4.604
5	.132	.267	.408	.559	.727	.920	1.150	1.476	2.015	2.571	3.365	4.032
6	.131	.265	.404	.553	.718	.906	1.134	1.440	1.943	2.447	3.143	3.707
7	.130	.263	.402	.549	.711	.896	1.119	1.435	1.895	2.365	2.998	3.499
8	.130	.261	.399	.546	.706	.889	1.108	1.397	1.860	2.306	2.896	3.355
9	.129	.260	.398	.543	.703	.883	1.100	1.383	1.833	2.262	2.821	3.250
10	.129	.260	.397	.542	.700	.879	1.093	1.372	1.812	2.228	2.761	3.169
11	.129	.259	.396	.540	.697	.876	1.088	1.363	1.796	2.201	2.718	3.106
12	.128	.259	.395	.539	.695	.873	1.083	1.356	1.782	2.179	2.681	3.055
13	.128	.258	.394	.538	.694	.870	1.079	1.350	1.771	2.160	2.650	3.012
14	.128	.258	.393	.537	.692	.868	1.076	1.345	1.761	2.145	2.624	2.977
15	.128	.258	.393	.536	.691	.866	1.074	1.341	1.753	2.131	2.602	2.947
16	.128	.257	.392	.535	.690	.865	1.071	1.337	1.746	2.120	2.583	2.921
17	.128	.257	.392	.534	.689	.863	1.069	1.333	1.740	2.110	2.567	2.898
18	.127	.257	.392	.534	.688	.862	1.067	1.330	1.734	2.101	2.552	2.878
19	.127	.257	.391	.533	.688	.861	1.066	1.328	1.729	2.093	2.539	2.861
20	.127	.257	.391	.533	.687	.860	1.064	1.325	1.725	2.086	2.528	2.845
21	.127	.257	.391	.532	.686	.859	1.063	1.323	1.721	2.080	2.518	2.831
22	.127	.256	.390	.532	.686	.858	1.061	1.321	1.717	2.074	2.508	2.819
23	.127	.256	.390	.532	.685	.858	1.060	1.319	1.714	2.069	2.500	2.807
24	.127	.256	.390	.531	.685	.857	1.059	1.318	1.711	2.034	2.492	2.797
25	.127	.256	.390	.531	.684	.856	1.058	1.316	1.708	2.060	2.485	2.787
26	.127	.256	.390	.531	.684	.856	1.058	1.315	1.706	2.056	2.479	2.779
27	.127	.256	.389	.531	.684	.855	1.057	1.314	1.703	2.052	2.473	2.771
28	.127	.256	.389	.530	.683	.855	1.056	1.313	1.701	2.048	2.467	2.763
29	.127	.256	.389	.530	.683	.854	1.055	1.311	1.699	2.045	2.462	2.756
30	.127	.256	.389	.530	.683	.854	1.055	1.310	1.697	2.042	2.457	2.750
infinity	.12566	.25335	.38532	.52440	.67449	.84162	1.03643	1.28155	1.64485	1.95996	2.32635	2.57583

Degrees of freedom = number of points sampled -1. (100 points – 1) = 99 d.f.

Infinity in our case is any number over 30.

2. Field Selected Point Application of the Point-Frequency Method

This application can give results as accurate as the preselected point application if the operator is careful to eliminate bias from his work. In the field selected point application, the operator wanders at random over the area to be measured (Figure 2). It is suggested that the operator use a predetermined distance between sample points. This will eliminate some bias. The route of travel should cut across topographical features and any other features that appear to differ in growth or kind of vegetation. Use of the sight tube is the same as previously described. It is also reasonable to measure 100 points but this is not absolutely necessary. However, it is probably not wise to measure less than 50 points.

It would be difficult to measure exactly 100 points without putting too many or too few points near the end of the random traverse. Try to apply your point sampling as evenly as possible and accept the number of points that results. As an example, say that 88 points are sampled and 63 points were vegetated. To calculate the percent of vegetative cover, divide 63 by 88 and multiply the quotient by 100 to obtain the percent of soil surface covered by vegetation.

$$63 \div 88 = 0.7159$$

$$0.7159 \times 100 = 71.59\% \text{ cover}$$

It is not mathematically correct to apply statistical analyses to data collected in a non-random procedure.
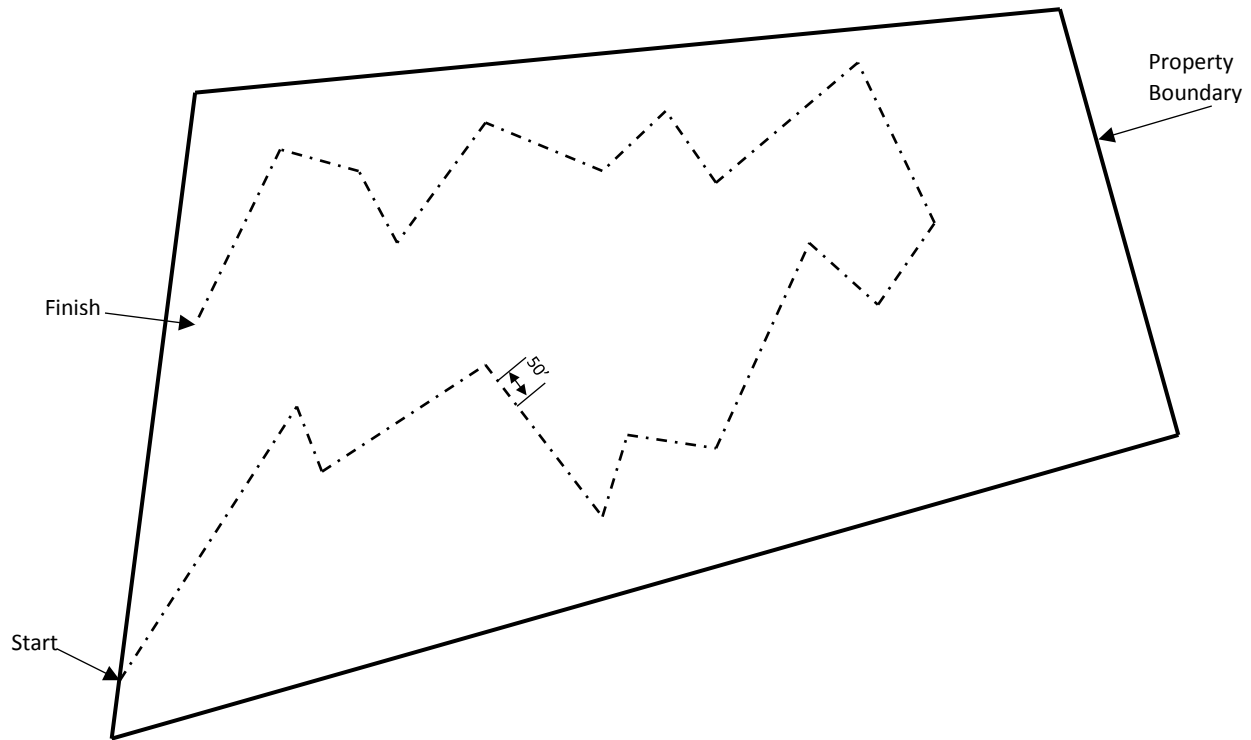
Property
Boundary

Finish

50'

Start

FIGURE 2. Field Selected Point Application of Point Frequency Method.

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3. Systematic Point Selected Application of the Point-Frequency Method

In this application a systematic procedure is used to locate sample points (Figure 3). Again, it is wise to use 100 points but fewer points as low as 50 can be used with reasonable accuracy. This application will remove all operator bias but it can be biased unintentionally if plantings such as trees are in lines with set spacings between lines and between trees within lines. It would be possible for systematic sampling to give either an unreasonably high reading or unreasonably low reading, depending on whether the sampling lines coincided with the planting lines or missed the planting lines. Problems such as this must be avoided in systematic sampling.

To use this application, the distance between lines must be chosen and the distance between sample points on the line must be chosen. It is obvious that a small area will require shorter distances than larger areas to obtain a given number of sample points and distribute them evenly over the area. Figure 3 shows an example of the systematic application. In this example the lines are running east and west, but direction doesn't matter so long as the lines cut across to topography. This is done to assure an adequate sample of the variations in plant growth caused by topographic position.

When this application is used, the number of sample points may vary from the intended 100 or any other intended number. If this happens, the percent of soil covered by vegetation can still be calculated with ease. Assume that 76 sample points were measured and 56 of the points had vegetation showing. To calculate the percent of vegetation cover, divide 56 by 76 and multiply the quotient by 100.

$$56 \div 76 = 0.7368$$

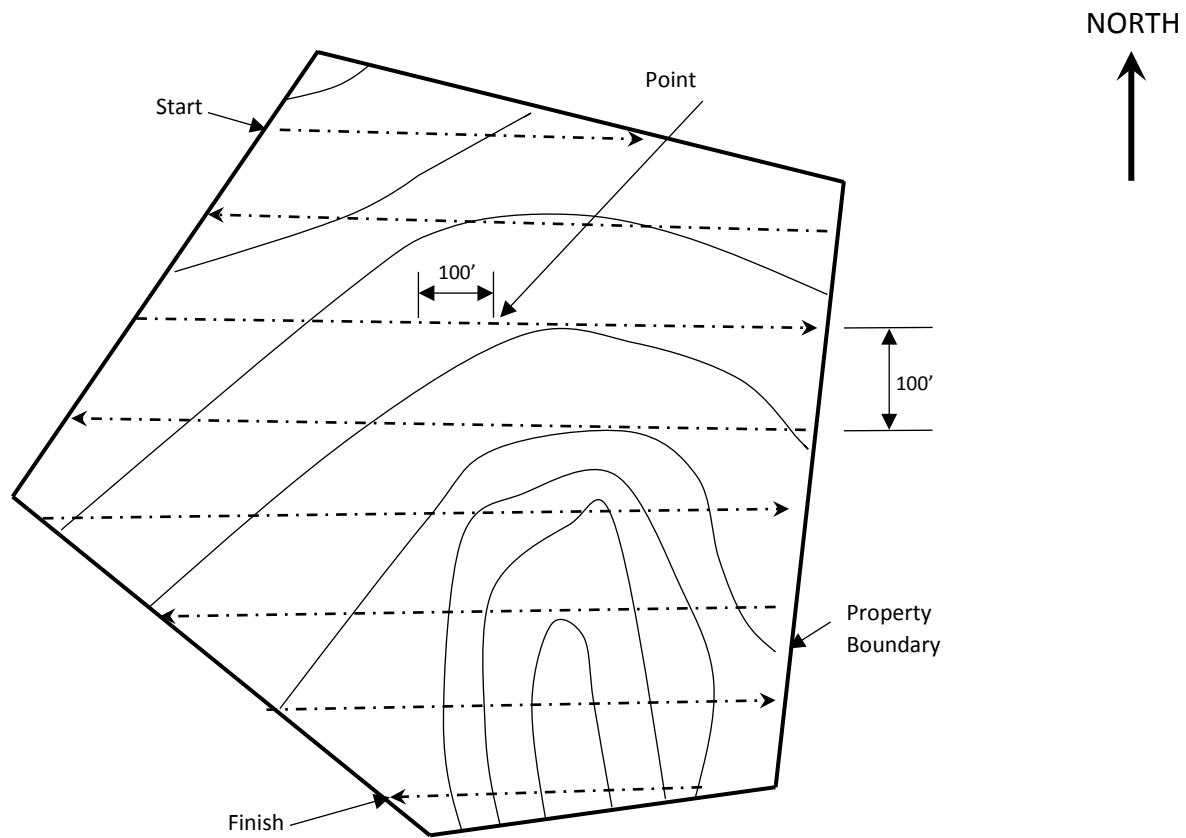$$0.7368 \times 100 = 73.68\% \text{ cover}$$

FIGURE 3. Systematic Application of Point Frequency Method.

CHAPTER 2

Procedure for Estimating Number of Tree Seedlings Per Acre

Any of the applications of the point frequency method for estimating vegetative cover can also be used to estimate number of tree seedlings per acre. The procedure would be the same as for vegetative cover estimation up to the point when the sight tube is pushed into the soil. After the vegetative cover reading has been taken the sight tube could be used as a center point for a circular plot with a radius of 11.78 feet. This circular plot will have an area of 0.01 acre. To measure a tree plot simply note the number of main stems of tree seedlings that occur within the 0.01 acre plot. At the end of the measuring procedure, the total number of tree stems is divided by the area in acres on which tree stems were counted. As an example, assume that 86 sample points are measured and 386 seedlings are counted.

$$86 \times 0.01 = 0.86 \text{ acres sampled}$$
$$386 \text{ seedlings} \div 0.86 = 448.8 \text{ seedlings/acre}$$

This will provide an estimate of the number of seedlings on the area. However, there is no way to statistically analyze the estimate unless the preselected point application has been used.

If the preselected point application is used and a confidence interval is needed, use the following method. Assume that the reclaimed mine to be examined is 40 acres in size and 100 plots of 0.01 acre size are measured.

Also, assume that the total number of points available for sampling was 3624. This is the total number of points on the map where X and Y lines intersect.

18 plots had 5 seedlings each = 90
41 plots had 4 seedlings each = 164
38 plots had 3 seedlings each = 114
 3 plots had 2 seedlings each =   6
374 total seedlings for 100 plots

$$S^2 = \frac{\sum_{i=1}^{n} y_i^2 - \frac{(\sum_{i=1}^{n} y_i)^2}{n}}{(n-1)}$$

$$S^2 = \frac{(5^2)(18) + (4^2)(41) + (3^2)(38) + (2^2)(3) - \frac{374^2}{100}}{99}$$

$$S^2 = 0.6186$$

$$S_{\bar{x}} = \sqrt{\frac{S^2}{n}\left(1 - \frac{n}{N}\right)}$$

$$S_{\bar{x}} = \sqrt{\frac{0.6186}{100}\left(1 - \frac{100}{3624}\right)} = 0.0775 \text{ seedlings}/0.01 \text{ acre plot}$$

$$(100)(0.0775) = 7.75 \text{ seedlings/acre}$$

Assume that the level of confidence allowed by the regulatory agency is 90%.

This will result in an α of 10% (100% - 90% = 10%).

$$C.I. = (total\ number\ of\ seedlings\ counted) \pm \left(t_{\alpha, d.f.} \times S_{\bar{x}}\right)$$

$$C.I. = 374 \pm (1.6448)(7.75)$$

$$= 374 \pm 12.76\ seedlings\ per\ acre$$

Range = 387 – 361

In this case, it is not likely that the true number of seedlings per acre has been missed by more than 2 seedlings.   If the desired number of seedlings per acre was 450, this reclaimed area does not comply with regulations.

In the above example there was not a large range of number of seedlings per acre. Therefore, the standard error of the mean was small and the confidence interval was small.   The following example has a wider variation in seedlings per plot and the confidence interval becomes wider.

$$
\begin{array}{l}
4\ plots\ had\ 10\ seedlings\ each = \quad 40 \\
14\ plots\ had\ \ 8\ seedlings\ each = 112 \\
41\ plots\ had\ \ 4\ seedlings\ each = 164 \\
36\ plots\ had\ \ 3\ seedlings\ each = 108 \\
2\ plots\ had\ \ 2\ seedlings\ each = \quad 4 \\
3\ plots\ had\ \ 4\ seedlings\ each = \quad \underline{12}
\end{array}
$$

440 total number of seedlings found on 100 plots

$$S^2 = \frac{\sum_{i=1}^{n} y_i^2 - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n}}{(n-1)}$$

$$S^2 = \frac{(10^2)(4) + (8^2)(14) + (4^2)(41) + (3^2)(36) + (2^2)(2) + (0^2)(3) - \frac{440^2}{100}}{99}$$

$$S^2 = \frac{348}{99} = 3.52$$

$$S_{\bar{x}} = \sqrt{\frac{s^2}{n}\left(1 - \frac{n}{N}\right)} = \sqrt{\frac{3.52}{100}\left(1 - \frac{100}{3624}\right)} = 0.185 \text{ seedlings/0.01 acre plot}$$

$(100)(0.1850) = 18.50$ seedlings per acre

$C.I. = (\text{total number of seedlings counted} \pm \left(t_{\alpha, d.f.} \times S_{\bar{x}}\right)$

$\qquad = 440 \pm (1.6448)(18.50)$

$\qquad = 440 \pm 30.43$

Range $= 470 - 410$

This time the confidence interval or range overlaps the accepted number of seedlings per acre (450) and the reclaimed mine passes regulations.

$S^2 =$ estimate of the variace of individual values for number of seedlings
   on each plot

$$\sum_{i=1}^{n} y_i^2 = \text{sum of squares of number of seedlings found on each plot}$$

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$$\sum_{i=1}^{n} y_i = \text{total number of seedlings found on all plots}$$

n = number of plots

$S_{\bar{x}}$ = standard error of mean

N = total number of plots that could be obtained on the mine. This number is obtained by noting all the possible points available for choosing on the map.

$C.I.= confidence\ interval$

$t_{\alpha,d.f.}$ =value found in Table one. (α and d.f. are used to locate t in

Table one) (α is 100% - 90% = 10%,

d.f. is 100 sample points – 1 = 99)

α = 100 - % statistical confidence allowed by regulatory agency

(100 – 90 = 10)

d.f. = degrees of freedom (number of plots – 1)

CHAPTER 3

Methods for Estimating or Determining Productivity

Forage Production/Pasture and Grazingland

In the permit review process, a productivity standard acceptable to the regulatory authority will be selected and documented. Production on the reclaimed area is compared with the standard for two years. During this period productivity is required to equal the success standard using a 90% statistical confidence interval.

The established standard (i.e., yield per acre) will be specifically applicable to the mined area and will be a product of consultation among the regulatory authority, the mine operator, and appropriate specialists (e.g., agents of the Soil Conservation Service or the State Agricultural Extension Service). The level of management will be equivalent to that on which the standards (or target yields) are based. To the degree possible, it will be based on published yield information for the county and/or soil mapping units. County Soil Survey Reports and Field Office Technical Guides published by the Soil Conservation Service also contain expected yields for forage and other crops by soil type, and State crop reporting services publish average yields per acre by county.

During the two-year evaluation period, the mine operator is respon- sible for production data from the reclaimed area, which will be used as supporting data for his or her application for bond release. Evaluation methods that may be used are determined by the actual use of the forage on

the mined area. Three major use categories are considered: (1) mechanized harvest of the total hay crop, (2) forage produced and not harvested--may be designated as hay or pasture in the reclamation plan, and (3) harvest of forage by the grazing of livestock.

If total harvests are made or the reclaimed area is grazed, total yield per acre of Animal Unit Months will be compared with the standard. Productivity of the reclaimed area must be equal to success standard approved in the reclamation plan. When vegetation is sampled to evaluate yield, comparison with the standards will involve slightly different statistical procedures, which are described in appendix 1.

When the hay crop is to be harvested, evaluation will consist of comparing total harvests from the mined area to the success standard for the required two years. Records required for the bond release application would include total acreage of reclaimed area and the number of tons or bales (or other standard units) harvested from it. The yield of the reclaimed area computed in standard units per acre must be equal the success standard.

In cases where the forage produced is not harvested, the productivity must be evaluated by sampling forage yields on the reclaimed area. Ovendry weight per acre of aboveground plant material will be the measure of productivity. There are many accepted procedures for determining this weight ('t Mannetje 1978). The following productivity measurement method is proposed as a standard one. The operator may select another from the extensive literature upon approval of the regulatory authority. Ovendry

weight will be estimated from the harvest of plants from milacre (1/1000 acre) strip-plots with a dimension of 1.5 feet by 29 feet. Sampling intensity will depend upon the size of the area to be evaluated as follows:

Areas Sampled (acres)	Sampling Intensity (percentage)	Number plots/acre
1-5	0.5	5
6-10	0.4	4
11-20	0.3	3
21-40	0.2	2
41+	0.1	1

Plots are to be established on parallel lines that are 100 feet apart and oriented in cardinal directions. Distance between plots will be as follows for the several sampling intensities.

Number Plots/acre	Distance between lines (ft)	Distance between plots on lines (ft)
5	100	80
4	100	100
3	100	132
2	100	198
1	100	395

The initial plot will be established 29 feet in a cardinal direction from a randomly located point on the boundary.

In each 1.5- by 29-foot plot, all aboveground plant material will be harvested to a 2- to 3- inch stubble during the final month of the growing season. A power mower with an 18-inch blade and collector bag is a suitable harvesting device. All rocks and debris will be removed before weighing the harvest. The total weight of the clippings will be immediately determined, and a small (½- to 2-pound) subsample of the material will be taken for determination of ovendry weight by drying at 150° F for 24 hours. The total ovendry weight of the sample will be computed using the following equation:

$$\begin{array}{l}\text{total ovendry weight} \\ \text{from milacre plot}\end{array} = \frac{(\text{total fresh weight}) \times (\text{sample dry weight})}{(\text{sample fresh weight})}$$

Ovendry sample weight of all plots will be averaged and the result multiplied by 1,000 to obtain pounds per acre of ovendry plant material. The weight per acre of material from the reclaimed area must be equal to that of success standard. Since this comparison is based on a sample rather than total harvest, a statistical procedure must be used to determine whether the comparison meets the standard of 90 percent probability set in the regulations. Such a procedure is presented in appendix 1. Percentage ground cover must equal that of the success standard.

If the forage is harvested by the grazing of livestock, productivity can be evaluated in terms of grazing capacity, the maximum stocking rate possible without inducing damage to vegetation or related resources.

Stocking rate is the actual number of animals on a specific area at a specific time, usually expressed in Animal Unit Months (A.U.M.) per acre. The standard animal unit is a 1,000-pound adult animal. Animal units are adjusted for different size and types of animals--e.g., a mature bull, 1.25 A.U.; a cow yearling, 0.6 A.U.; a horse (not supplemented), 1.2-1.7 A.U.; and a sheep (ewe), 0.2 A.U. Thus a 1-acre pasture with a grazing capacity of four A.U.M. per acre will maintain four 1,000 pound animals for a one-month period, or one animal for four months. The data required for the bond release application will include a complete record by month of animal units grazing on the entire mined area. The minimum grazing capacity for the success standard, as determined by agricultural specialists and approved by the regulatory agency, must be specified in the reclamation plan. For bond release, grazing capacity for the reclaimed area must equal the success standard for two consecutive years. Periodic inspections of animal use may be made by the regulatory agency. While there are other more precise methods of evaluating animal production (e.g., see 't Mannetje 1978 or local State agricultural experiment station), they all require expensive animal handling procedures and measurements. The grazing capacity method has been selected because of its relative simplicity.

Methods of measuring productivity of grazing lands without involving animal units could be carried out by installing fenced or caged livestock exclosures on the reference and reclaimed sites. Forage samples would be collected outside the exclosures before initiation of grazing, and at the end of the grazing season samples would be collected within the exclosures. Values for growth and utilization of the grazed areas can be computed from the forage samples to provide for comparison of the reclaimed to the

success standard.   Exclosure methods for evaluating grazing lands would be relatively site specific in design and application and likely would require special instruction and guidance from an agricultural extension forage specialist to achieve reliable results.

Cropland

In contrast to pastureland as a postmining land use, production of row crops is still largely in the experimental stage in the Appalachian coal-fields.   In western Virginia, Jones et al. (1979) have shown that vegetable crops can be grown on a minesoil that has been in tall fescue and sericea lespedeza for five years.   Some work in progress in western Kentucky, Illinois, Missouri, Iowa, and other States suggests that row crops may be grown successfully on reclaimed area mines.   However, current information on nonprime farmland suggests that, at present, most operators or land-owners with agricultural land use in mind should opt to obtain bond release under forage production and then consider a transition to row crops later.

The relationship of final land conformation to crop management is even more important than for forage, and producing a minesoil of potentially good tilth must be planned into the mining operation. As notes by Jones et al. (1979), "organic matter and pH are of prime importance in the develop-ment and utilization of minesoils."   For crop production, soil acidity is critical, and a soil pH of 5.5 is the generally accepted minimum for row

crops. This further suggests the desirability of a forage cover crop for several years immediately after mining, since it will both provide the necessary cover and ameliorate key soil characteristics.

Designing a Crop System

With above consideration in mind, the mine operator and landowner interested in crop production must include in the permit application what will amount to a farm plan. This plan, which should be based on consultation with local Soil Conservation Service and Agricultural Extension Service agents, will include: (1) provisions for appropriate land forming and soil handling during the mining operation, and (2) plans for a rotation of species mixtures, which will prevent erosion and prepare the site for the major species or groups of species to be produced, and (3) a soil amendment plan including provisions for periodic evaluation of soil potential and problems.

While species mixtures and their sequence of use must necessarily be fitted to the individual site, some general recommendations can be made. These might include the use of no-till systems that would progress from a cover crop, including annual or biennial legumes, to wheat, and then to a row crop such as soybeans. The key features of such a system are the use of grasses and legumes to provide some organic matter and no tillage to reduce erosion. Ultimately a rotation of legume forage with row crops may be appropriate. A crop such as corn with high nitrogen and water requirements would probably not be appropriate in the early years. Orchard horticultural crops are entirely appropriate if the proper climatic conditions exist and plans provide for an adequate ground cover.

<u>Evaluation</u>

Evaluation procedures using the success standards will follow the basic outline described for forage systems. The management level will be that proper for the region and site conditions. The comparison will be based on records of total harvest for two consecutive years. The productivity of the reclaimed area must equal the success standards.

Since orchards will not be productive during the five-year responsibility period, the use of reference areas for them is not appropriate. Orchard evaluation will be based on ground cover requirements and appropriate stocking and approved management (as recommended by State Horticultural Extension agent) of live trees for at least two years of the responsibility period.

The success standard for cropland will be set through consultation of the mine operator, landowner, regulatory authority and appropriate specialists, using available productivity information and must be approved by the regulatory agency. The basic data on expected individual crop productivity by county and/or soil mapping unit are published by State crop reporting services and in county Soil Survey Reports (examples in appendixes A.5 and A.6) and SCS Field Office Technical Guides. These data are familiar to all district soil conservationists and agricultural extension agents. The productivity standard resulting from this consultation will be placed in the permit application. The bond release decision will be based upon comparison to this standard with total harvest records for the last two years of the five-year period of responsibility. Productivity of the

reclaimed area must equal this standard.   Also, ground cover requirements for orchards must be met unless an exception has been authorized.   The regulatory authority will supplement the productivity reports with on-the-ground inspections.

APPENDIX 1

Comparison of Production on a Mined Area

with a Success Standard

The use of sampling to compare production requires knowledge of some simple statistical methods, which can be obtained from standard t-tests. The procedure recommended for the comparison is the t-test.

If the average of samples from a mined area is compared with a fixed standard, the following form of the t-test is used:

$$t = \frac{(sample\ mean) - (0.9 \times production\ standard)}{standard\ error\ of\ sample\ mean}$$

For the sample mean to meet the standard, the computed "t" value must be greater than the tabulated "t" value for the 0.1 level of probability and the degrees of freedom in the sample.

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