Technical Guides on Use of Reference Areas and Technical Standards For Evaluating Surface Mine Revegetation in OSM Regions I and II

Prepared for
The Office of Surface Mining
U.S. Department of the Interior
Knoxville, Tennessee 37902

by

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Norris, Tennessee 37828

This report was prepared by the Tennessee Valley Authority and has been reviewed by the Office of Surface Mining Reclamation and Enforcement regional offices in Knoxville, Tennessee, and Charleston, West Virginia Approval does not signify that the contents necessarily reflect the views and policies of the Office of Surface Mining Reclamation and Enforcement or the Tennessee Valley Authority.

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TVA/ONR/LFR-81/12

TECHNICAL GUIDES ON USE OF REFERENCE AREAS AND TECHNICAL STANDARDS FOR EVALUATING SURFACE MINE VEGETATION IN OSM REGIONS I AND II

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OSM J5701442/TV-54055A

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Office of Surface Mining Reclamation and Enforcement
Region II Office
Knoxville, Tennessee 37902
1981

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ABSTRACT

This handbook, Technical Guides on Use of Reference Areas and Technical Standards for Evaluating Surface Mine Revegetation in OSM Regions I and II, was prepared to assist mine operators and regulatory authorities in evaluating success of reclamation vegetation in the Appalachian coalfields. Neither the interim nor the permanent regulations specified methods for evaluating revegetation success but left the decision to OSM and the States. The availability of published standards will provide for uniform measurement of revegetation success and permit the use of technical standards instead of reference areas in assessing ground cover and productivity.

Section 1 is devoted to pastureland and other agronomic and horticultural crops, postmining land uses for which the use of both the reference area and technical standards approaches to productivity are suitable.

Section 2 deals with considerations relative to the use of reference areas in evaluating reclamation for forestry, wildlife management, and watershed protection and suggests technical standards be adopted as the regulatory approach.

Section 3 describes a system for evaluating revegetation where the postmining land use is forestry and where standards (woody plants per acre and ground cover percentage) are fixed by regulation.

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ACKNOWLEDGMENTS

Acknowledgment is due the many individuals and organizations that assisted in the development of this handbook. Valuable consultation and advice were provided by an ad hoc working group assembled to develop procedures for using reference areas and technical standard methods in evaluating adequacy of postmining revegetation. The working group included the following:

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procedures outlined in section 1 are largely the products of this working group.

The authors also wish to express their thanks to those who helped on specialized phases of shaping and completing section 1 of the handbook These men are: Richard I. Barnhisel, University of Kentucky; Henry A Fribourg, The University of Tennessee; J Nick Jones, Jr., USDA Scientific and Education Administration; and Willis G. Vogel, U.S. Forest Service, Northeastern Forest Experiment Station.

Special thanks are due the Bureau of Land Management Eastern States office, the Virginia Division of Mined Land Reclamation, OSM Regional Offices I and IV and Headquarters Office staff, the Soil Conservation Service State offices in Alabama, Kentucky, and Tennessee, which provided critica review of the draft final report.

The support of this project by OSM Region II, Knoxville, Tennessee, and the help provided by Gary B. Tucker, Technical Project Officer, and Larry G. Springate are gratefully acknowledged

SECTION 1

PLANNING AND EVALUATING AGRICULTURAL LAND USES ON SURFACE-MINED AREAS

by

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To develop land use and evaluation procedures for surface-mined areas in Regions I and II, an ad hoc working group was formed (see Acknowledgments) to draw on the insight and experience of a number of scientists and professionals. A principal focus of the group sessions was the development of procedures for application of reference area and the technical standard methods of evaluating revegetation. Early in its deliberation, the group decided that the use of reference areas was not generally practical for evaluating postmining lands devoted to forestry, wildlife management, and other nonagricultural uses in Regions I and II. The problems of using reference areas in evaluating these land uses are discussed in section 2 of this handbook. Revegetation performance standards for forestry and wildlife management have already been published in the regulations (sections 816.116 and 816.117). Therefore, this section is devoted to forage and other agronomic and horticultural crops postmining land uses for which the use of both the reference area and the technical standard approaches to productivity evaluation is suitable.

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Introduction

Federal surface mining regulations published under the authority of the Surface Mining Control and Reclamation Act of 1977 (PL 95-87) provide for a variety of postmining land uses. These regulations further authorize changes in postmining land use if they lead to "higher and better uses" (section 816.133). In the eastern coalfields, lands mined under PL 95-87 regulations frequently will be suitable for agricultural uses, sometimes as a consequence of land-form and site quality changes related to mining Section 816.116 of the rules generally provides for evaluating these uses in terms of ground cover and productivity on the basis of "reference areas" or through the use of technical guidance procedures. This section outlines procedures with which the mine operator and landowner can plan and manage agricultural land uses through the period prior to bond release, including methods for using the reference area and technical standards approaches to evaluation. It is restricted to consideration of: 1) mined lands in Office of Surface Mining, Regions I and II and (2) agricultural uses that do not come under rules covering prime farmlands as defined in the regulations.

While agricultural use of mined land is increasing with the advent of better mining and reclamation techniques and more effective regulations, the only land use employed to any extent has been pastureland. In OSM Regions I and II, production of row crops, small grains, and horticultural crops on surface-mined areas is still largely in experimental or pilot-scale stages. However, experience with pastureland is more extensive, and postmining sites suitable for these land uses are frequently encountered in the Appalachia coalfields. Moreover, the economics of postmining forage production are good, given the fact that cost of land clearing and forming and the establishment of forage vegetation are borne by the coal resource. In short, pastureland will probably constitute a major postmining land use in the near future

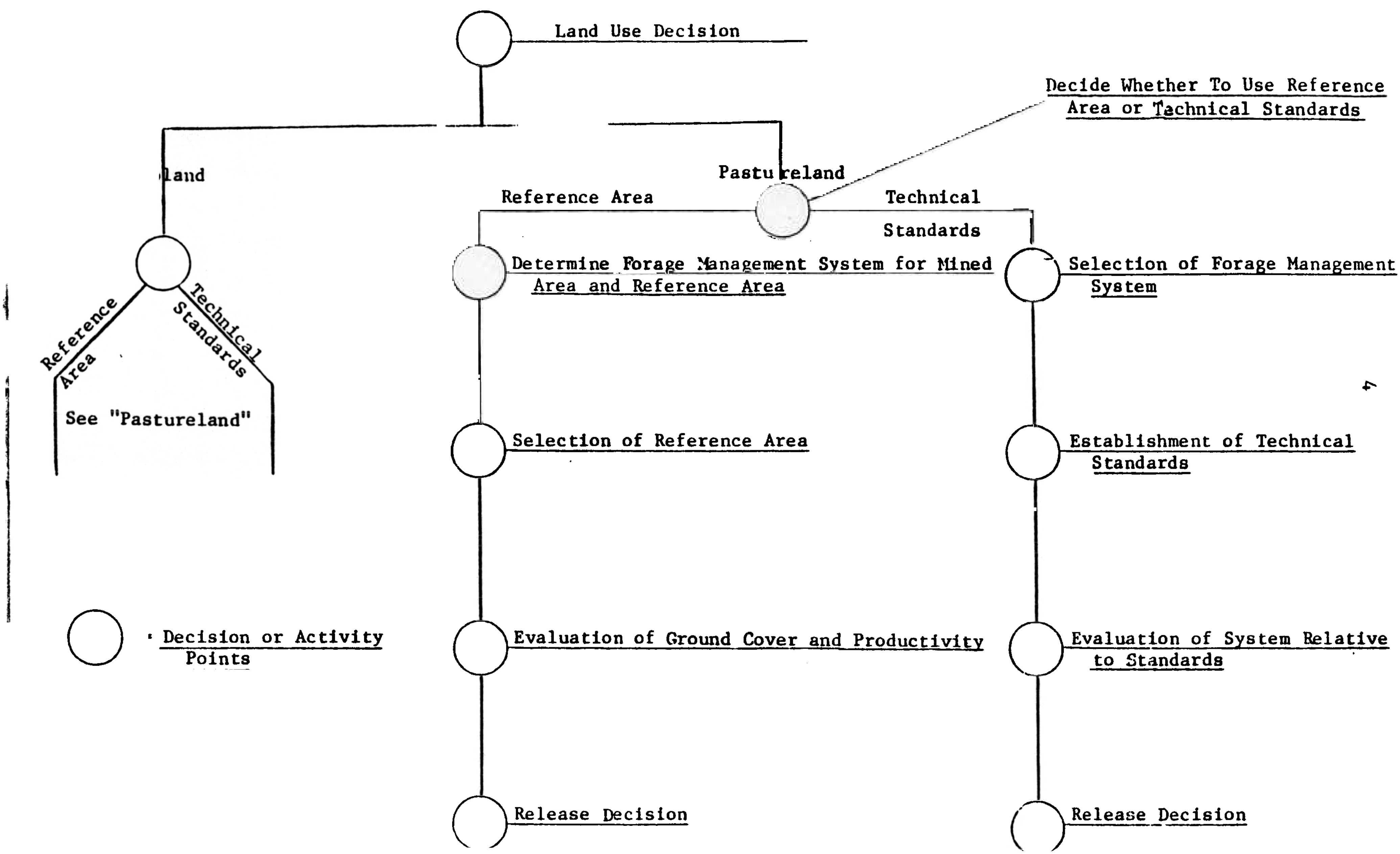
The regulated process of converting forest land to agricultural uses in the course of surface mining consists of a series of land use decisions made by the mine operator, landowner, and regulatory agency. This process begins with a decision to pursue one of several land use options determined by resource evaluation and ends with the regulatory decision approving reclamation for bond release. The sequence of decisions is outlined in figure 1.1.

Among the most important decisions made by the mine operator is one on evaluation procedures, i.e., "reference area" versus "technical standards." The "reference area" approach to evaluation involves comparing crop production and environmental protection on the reclaimed site with that on a similarly managed undisturbed site nearby that serves as a reference area or standard. Regulations require that mined land be at least 90 percent as productive as the reference area. While relatively expensive to use, the reference area approach automatically accounts for year-to-year differences in production due to weather The "technical standards" method of evaluation consists of comparing production on the reclaimed area with an accepted production standard (i.e., performance standard). Though simpler in application than the reference area method, lack of good production data local to the mined area will present some problems and require judgment evaluations.

The Postmining Land Use Decision: Forest, Pasture, or Row Crops

The decision on a postmining land use is documented in the reclamation plan required under section 780.23 of the regulations, which require "a detailed

Figure 1.1. Decision system for planning, managing, and evaluating postmining agricultural uses.



description of the proposed use." If the selected use involves a change in land use, the requirements of section 816.133 must additionally be met. In brief, requirements in these sections of the regulations are aimed at ensuring that the postmining land is capable of the proposed use and that realistic management arrangements have been made for that use. A landowner's decision should integrate his or her land management objectives and capabilities, the potential land capability after mining and land forming, and the regulatory constraints contained in part 816 of the regulations. It will usually require professional assistance, which the large owner-operator may wish to obtain from either an inhouse staff person or a consultant The small landowner should use the consultative services of the several public agencies that can assist him or her in this decision: the U.S Soil Conservation Service, the U.S. Agricultural Stabilization and Conservation Service, the State Agricultural Extension Service as represented by the County Agricultural Extension agent or representatives from land grant universities, the regulatory authority (i.e., the State reclamation agency), and the State forestry agency. Some landowners may use private consultants, who in turn may contact these agencies All public agencies have access to technical data and testing services that support their knowledge of local land capabilities and opportunities. In working with these agencies on this initial decision, the mine operator and landowner establish relationships through which other management and evaluation decisions can be assisted later. In the final analysis, the land use decision incorporates a unique blend of considerations that is specific to a certain land use and for which on-the-ground advice is necessary.

Pastureland as a Postmining Land Use

Forage crops are grasses and legumes that are harvested by grazing animals (pasture) or as hay or ensilage. Within the context of mined-land reclamation discussed in this guide, forage refers to the exclusive use of land for pasture and/or hay. Forage systems described generally by Brown an Baylor (1974) for the Northeast and Chamblee and Spooner (1974) for the uppe South are applicable to the Appalachian coalfield area. Cool-season grasses and legumes are predominant species in these forage systems, which are a maj component of agricultural land uses in the region. This successful regional experience with forage mainly for erosion control has led to its relatively extensive use on mined lands in some parts of Appalachia. There is a good body of literature on mined land forage systems based on both experimental results and practical experience (Bennett 1975, Powell and Barnhisel 1977, Powell et al. 1980, Bradshaw and Chadwick 1980, Sutton 1979, Fribourg et al 1981). Local Soil Conservation Service and Agricultural Extension Service agents usually have extensive experience with forage systems. In short there are good opportunities for pastureland as a postmining land use.

Making the Forage Decision

Making a decision to adopt pastureland as a postmining land use anc designing the resulting forage systems are very closely related and may be done in one process. Key considerations are final land conformation, mineso characteristics, and site-specific economics. Their evaluation will require consultation involving the operator, landowner, and forage specialist.
is a major determining factor, and 25 percent (15°) slope has been suggested as the maximum for improved pasture. If hay is to be the major crop, slopes less than 20 percent will be required. Development of suitable slopes must be planned into the postextraction land-forming process. Provisions in

sections 816.101 and 816.102 allow considerable latitude, on approval of the regulatory authority, in shaping land. Minesoil characteristics and their relationship to forage systems are so variable that an onsite examination and subsequent chemical and physical analysis of overburden and/or final minesoils may be required to make a sound decision This examination should be assisted by county Soil Survey Reports and agents of the Soil Conservation Service and the State Agricultural Extension Service. These agents will also be able to furnish data and advice on the management implications and economics of forage systems under local conditions. Transportation, management costs, and land management attitudes of local residents in the remote areas commonly being mined may be of special importance in a decision whether or not to use a forage system.

Designing a Forage System

Species Mixtures--Once a decision has been made to adopt forage as a postmining land use, a forage system suited to the area must be planned, including species selection and management procedures. Considerable operational experience with many different species has now been obtained on minesoils. The examples of forage mixtures listed in table 1.1 generally been used successfully on surface-mined lands in Appalachia The mixtures should contain from three to five species to satisfy requirements for diversity, they should include at least one permanent grass and one permanent legume. Lists of grasses and legumes with optimum pH ranges as commonly used in reclamation are included in appendixes A.1 and A.2

Table 1.1. Examples of mixtures used successfully on minesoils in Appalachia.*

Mixture 1: Primarily for pasture, but can be used for hay.

Species	lb seed/acre
Kentucky 31 tall fescue	25
Ladino clover	3
or birdsfoot trefoil	7
Red clover	4
Annual lespedeza	15
Annual ryegrass	5

Mixture 2: Primarily for hay, but can be used for pasture.

Species	lb seed/acre
Orchardgrass and/or Kentucky 31 tall fescue	20
Red clover	10
Ladino clover	2
Annual lespedeza	15
Annual ryegrass	5

Mixture 3: For pasture

Species	lb seed/acre
Kentucky 31 tall fescue	25
Sericea lespedeza	20
or birdsfoot trefoil	8
Annual ryegrass	5
Redtop	3

Mixture 4: High quality hay mixture

Species	lb seed/acre
Alfalfa	20
or red clover	10
Orchardgrass	10
Oats	56

*Specific locations in Appalachia have different requirements for species and seeding rates to ensure high probability of successful establishment and survival. Check and use local recommendations whenever available.

One of the universal characteristics of forage mixtures for mined lands is inclusion of one or more legumes that will serve as nitrogen fixers on the usually nitrogen-deficient minesoils However, minesoil characteristics, desired forage products (pasture or hay), elevation, topography, and latitude will vary with each permit area, and this variation requires that each forage mixture be a unique product of site-specific planning. The planned mixture should be documented in the permit application.

Management--Management procedures to be described in the permit application should include plans for seeding (timing and rate), fertilization (in establishment and maintenance), harvesting, livestock (if area is to be grazed), and possibly renovation. All of these components of management are covered in detail by State Agricultural Experiment Station handbooks on forage production which are well known to Soil Conservation Service and Agricultural Extension Service personnel who are familiar with application. There are, however, some aspects of forage management that require special consideration on minesoils. The first of these is the problem of nutritional relationships on new minesoils, which is still under active investigation by research organizations. While blanket recommendations are not possible, special onsite attention must be given to adjustment of pH and to nitrogen and phosphorus relationships. Provisions for periodic plant and soil analyses and interpretation should be made in the management plan. The other special concern is for harvesting methods, which will encourage rapid establishment for productive plant communities and encourage maintenance of appropriate species mixtures. A conservative nonintensive grazing schedule during the first five years will be a key element of pasture management and maintenance, and should provide for exclusion of livestock for the initial one to three years after seeding depending on ground cover and sod development.

Evaluation--After planning a forage management system, the mine operator must decide upon an appropriate evaluation method upon which bond release will be based. As noted earlier, he or she may adopt either the "reference area" or "technical standards" approach. In the Eastern coal-fields, ground cover and productivity must meet objectives set under either system for the last two consecutive years of the five-year responsibility period (section 816.116). Under forage systems, there are several general advantages and disadvantages worthy of brief review in each approach.

reference area method is usually administratively more cumbersome and expensive than the technical standards procedure. An appropriate area of at least 10 acres if animals are to be grazed, or 1 acre if the product is hay, must be under operator control by ownership, lease, or cooperative agreement for at least a two-year period and managed under the system selected for the mined area. While the technical standards method may be less expensive to establish and use, there may be instances where it is difficult to define and set standards for a given crop at a specific location that are acceptable to the operator and regulatory agency. Consultation with the local Soil Conservation Service and/or Agricultural Extension Service will help in deciding between using technical standards and reference areas. Review of the following standard procedures for using the two techniques should also be helpful

Establishing and Using a Reference Area

reference area (minimum 1 acre for hay, 10 acres for pasture) should be as close to the mined area as possible (preferably within a radius of 20 miles) and should be in the same physiographic area as the minesite. Its soil and ecological characteristics should be as close to those of the mined area as possible. The operator may wish to arrange for several reference areas, the average production from which may be used as the performance standard. Designation of a reference area must include the legal arrangements for its use, and this designation must be included in the permit application (sections 780.18, 783.22). The same management practices must be followed on the reference area and the mined area during the two-year evaluation period. These will include the same species mix and fertilization and harvesting regimes.

During the two-year evaluation period, the mine operator is responsible for collecting ground cover and production data from the two areas, which may be used as supporting data for his or her application for bond release. In instances where the regulatory agency determines by visual evaluation that the ground cover and productivity of a reclaimed area unquestionably exceed that of the reference area, the supporting evaluation data may not be required 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

When the hay crop is to be harvested, evaluation will consist of comparing total harvests from the reference area with those of the mined area for the required two years. Records required for the bond release application would include total acreage of reclaimed area, the number of tons or bales (or other standard units) harvested from it, and the same data from the reference area. The yield of the reclaimed area computed in standard units per acre must equal the yield obtained from the reference area. Also, ground cover must equal that of the reference area, except when the reclaimed area is 40 acres or less and the operator opts to use the standard; then 70 percen cover is required for five full consecutive years. Percentage cover can be estimated by using the technique described by Rennie and Farmer in section 3 of this handbook or by other approved standard methods.

In cases where the forage produced is not harvested, the productivit must be evaluated by sampling the percentage cover and forage yields on the two areas. 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 weigh 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 harvest. The total weight of the clippings will be immediately determined and a small (1/2- 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:

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

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. weight per acre of material from the reclaimed area must be equal to that on the reference area. 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 (section 816.116(b)(3)). Such a procedure is presented in appendixes A.3 A.4. Percentage ground cover must equal that of the reference area, or be least 70 percent for areas of 40 acres or less.

If the forage is harvested by the grazing of livestock, productiv can be evaluated in terms of <u>grazing capacity</u>, the maximum stocking rate possible without inducing damage to vegetation or related resources. Stock 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 an 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 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 grazed on the entire reference are and the entire mined area. The minimum grazing capacity for the reference area, as determined by agricultural specialists and approved by the regulator agency, must be specified in the reclamation plan. For bond release, grazing capacity for the reclaimed area must be 90 percent of the reference area for two consecutive years. Percentage ground cover of the reclaimed area must be equal to that of the reference area, or at least 70 percent if the reclaimed area is 40 acres or less and the standard is opted by the operator. 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 and reference areas. 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.

Technical Standards

Use of this evaluation approach will include setting a productivity standard acceptable to the regulatory authority, documenting it in the permit application, and then comparing production on the reclaimed area with the standard for two years. During this period ground cover is required to be at least 90 percent, except for areas 40 acres or less where 70 percent ground cover is required after five full consecutive years.

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. Recent county Soil Survey Reports published by the Soil Conservation Service contain expected yields for forage and other crops by soil type, and State crop reporting services publish average yields per acre by county (examples in appendixes A.5 and A.6). Unpublished data from the State Agricultural Experiment Stations often are available to agents. If a technical standard acceptable to the regulatory agency cannot be determined, the reference area method must be used.

Techniques for determining yield to meet a technical standard will be identical with those described for the reference area approach. If total harvests are made or the reclaimed area is grazed, total yield per acre or Animal Unit Months will be compared with the standard. Productivity of the reclaimed area must be at least 90 percent of the technical 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 A.3

Cropland as a Postmining Land Use

In contrast to pastureland as a postmining land use, production of row crops is still largely in the experimental stage in the Appalachian coalfields. 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 landowners with an 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 noted by Jones et al. (1979), "organic matter and pH are of prime importance in the development 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 considerations 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, (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 are entirely appropriate if the proper climatic conditions exist and plans provide for an adequate ground cover.

Evaluation

Evaluation procedures using either the reference area or technical standards approach will follow the basic outline described above for forage systems. The reference area for row crops should be at least 1 acre in size, located on a site as similar as possible to the reclaimed site in terms of potential productivity and preferably within 20 miles of it. The management level will be that proper for the region and site conditions and will be the same for reference area and reclaimed mine. The comparison will be based on records of total harvest for two consecutive years. The reclaimed area must produce at least 90 percent of the yield of the reference area.

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 the last two years of the responsibility period

The technical standards 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) These 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 of this standard with total harvest records for the last two years of the five-year period of responsibility. Productivity of the reclaimed area must be at least 90 percent of 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

SECTION 2

CONSIDERATIONS IN USE OF REFERENCE AREAS IN EVALUATING SURFACE MINE RECLAMATION FOR FOREST AND WILDLIFE USE IN REGIONS I AND II

by

Robert E. Farmer, Jr., and Thomas G. Zarger

Revegetation standards outlined under sections 816.116 and 816.117 of the permanent regulations under PL 95-87 allow two approaches to evaluating revegetation success on surface mines being returned to plant communities for uses such as forestry, wildlife management, and watershed protection: (1) meeting technical standards published in the regulations, i.e., percentage cover and woody plants per acre and (2) successful comparison of the revegetated area with an undisturbed adjacent plant community that would serve as a reference area or standard.

Adoption of the reference area approach would be aimed at assuring that reclaimed areas were returned to an equal or better plant community than existed on the mined area. In principle this is a good approach to reclamation and may be the best practical procedure in some areas of the country. In the eastern deciduous forest biome, its use presents some technical problems. The purposes of this analysis are: (1) to review the reference area approach as defined by specific rules in sections 816.116 and 816.117, (2) to outline the techniques required for its use, (3) to consider its practicality relative to the fixed standards approach (816.116(d)), and (4) to set the general priority of developing the techniques necessary for its use.

The Ecological Nature of Typical Reference Area Plant Communities in Regions I and II and Their Relationship to the Concept

The vast majority of lands being disturbed by surface mining in the Appalachian coalfields are occupied by mixed hardwood and pine-hardwood forest communities. With the exception of relatively small areas in secondary stages of succession due to disturbance or intensive forest management of conifers, this forest is in late stages of succession. The predominant species (over 50 percent) in these successional stages are oaks (Quercus) and hickories (Carya); genera such as Liriodendron, Fraxinus, Acer, Prunus, Betula, Ulmus, and Pinus are individually usually minor components. Yellow-poplar (Liriodendron tulipifera) is occasionally a dominant species in communities subjected to recent harvest.

These mixed hardwood communities develop on disturbed sites over a period of several decades or more. Some of their major species components, oaks and hickories, typically develop in the understory and gradually assume dominance when intolerant species in a secondary stage of succession die or are harvested. Moreover, the typical oak-hickory forest has an understory component of herbaceous and shrub species, which is also a product of succession.

In forest practice, hickories are almost never planted; the oaks have proven difficult to plant, and support of artificial regeneration research with them has been very limited. Practically nothing is known about the artificial regeneration of understory plants in the mixed hardwood forest. On the other hand, several species found abundantly in secondary stages of succession have been planted and seeded in forest practice (e.g., yellow-poplar and pines). Thus when choosing to use an undisturbed reference area as a revegetation standard, a mine operator will usually find a 30- to 50-year-old mixed hardwood stand in which oak and hickory are predominant species. At present there is only a very limited supply of oak and hickory planting stock, and often no sources for many of the understory plants that are an important part of the forest community.

Land Use Alternatives and Their Requirements Under the Reference Area Approach

In the event the mine operator reclaiming to a forest or wildlife plant community chooses to use the reference area approach, he or she will adhere to standards outlined in figure 2.1 for the two alternative postmining land uses: (1) commercial forest land (816.117(b)) and (2) wildlife management, recreation, shelter belts, or forest uses other than commercial forest land (816.117(c)).

The two key points of inspection are at the beginning of the five-year period of responsibility and at the end of this period when an inspection is made upon which bond release is based. It is useful to analyze the requirements under these two postmining land uses following a strict interpretation of the regulations in sections 816.116 and 816.117

First, if the land is to return to commercial forest, the reference area approach is used only to evaluate the cover since woody plant requirements are fixed in section 816.117(b)(1) and (2). Ground cover is defined (816.116(d)(3)) as the combined aerial parts of vegetation and the litter that is produced naturally onsite. The ground cover on the revegetated area must satisfy 816.116(b)(3)(iv), which requires 70 percent of the ground cover of the reference area (with a confidence level of 90 percent). Cover on an undisturbed reference area will be dramatically different in dimension and composition from cover on a reclaimed area. However, since

Figure 2.1. Schedule of revegetation and vegetation inventory requirements under PL 95-87 for two postmining land uses.

Postmining Land Use

"Commercial forest land" (816.117(b))

Begin five-year responsibility period

- 450 trees and shrubs per acre, 75 percent of which are commercial tree species. No confidence level required for estimate. 816.117(b) (1) and (2)
- Ground cover - 70 percent of reference area. Confidence level of 90 percent required for estimate. 816.116(b)(3)(iv)

End five-year responsibility period

- Same requirements for cover and woody plants as above.

"Wildlife management, recreation, shelter belts, or forest uses other than commercial forest land (816.117(c))

Begin five-year responsibility period

- Inventory of trees, half shrubs, and shrubs on reference area to contain but not be limited to:
  (1) "site quality"
  (2) "stand size"
  (3) "stand condition"
  (4) "site and species relations"
  (5) "appropriate forest land utilization considerations" 816.117(c)(1)
- Stocking of live woody plants equal to 90 percent of that on reference area. Must be of same "life form" as those on reference area. No confidence level required for estimate. 816.117(c)(2)
- Ground cover - "approximate" that on reference area 816.117(c)(2)

End of five-year responsibility period

- Woody plants - "90 percent of the stocking of live woody plants of the same life form of the approved reference area with 80 percent statistical confidence. 816.117(c)(3)(i)
- Ground cover - "70 percent of that on reference area with 90 percent statistical confidence." 816.116(b)(3)(iv)
- "Species diversity, seasonal variety, and regenerative capacity . . . shall be evaluated on the basis of the results that could reasonably be expected using the revegetation methods described in the mining and reclamation plan." 816.117(c)(3)(ii)

cover on a reference area in the Appalachian coalfields will commonly be 100 percent, the standard 70 percent cover for a reclaimed area will usually apply. The cover (816.116(b)(3)(iv)) must be deemed adequate to control erosion. Thus the regulatory authority may set another standard. In the Appalachian region of high rainfall and steep slopes, requiring an 80 percent cover of trees and shrubs and a 90 percent herbaceous ground cover (both within a 90 percent confidence level) is not unreasonable. Whatever the situation, an operator opting for the reference area approach with commercial forest as a reclamation goal will in actuality be following technical standards, but with the additional cost of establishing and surveying a reference area.

If the operator decides to return the land to wildlife management, recreation, etc., the reference area will actually be used. Information from some portions of the required reference area inventory (site quality, stand condition, etc. (816.117(c)(1)), has no apparent bearing upon release from bond. At the end of the five-year responsibility period, stocking of woody plants must be 90 percent of that of the reference area with an 80 percent confidence level. Ground cover must satisfy section 816(b)(3)(iv), which requires it to be 70 percent of reference area, with a 90 percent confidence level. If an old growth forest is used for a reference area, it is possible that it will have fewer trees per acre than required for an adequately stocked young stand on a reclaimed site. Rationally the regulatory authority should recognize the need and require additional trees and shrubs In setting such requirements, the regulatory authority would rely on stocking and ground cover parameters different from the reference area

The evaluation of species diversity, seasonal variety, and regeneration capacity (816.117(c)(3)(ii)) is referenced to the mining plan, not the reference area. No mention of a species compositional requirement for the reclaimed area relative to the reference area is made anywhere in the regulations. In short, clarification of these several points would essentially consist of writing further (and rather difficult to use) regulations on the use of reference areas, not simply outlining survey and comparison methods

Conclusion

This review suggests that comparison of reclaimed sites with reference areas using regulations in sections 816.116 and 816.117 will be (1) complex (procedures vary with land use and examination time), (2) unnecessarily expensive (requiring data unused in the needed comparison), (3) lacking in techniques needed for a valid comparison of the two communities, and (4) presently unrealistic because of a lack of techniques for establishing late successional forest communities on surface-mined areas. Stocking rate numbers based on locally acceptable forest practice and effective ground cover to control erosion would be more realistic Technical standards like those described in section 816.116(d) for permit areas 40 acres or less in size therefore appear to be the most effective regulatory approach in the Appalachian coalfields. For these reasons, it would appear undesirable to invest public monies in developing guidelines for use of forest and wildlife reference areas at the present time.

However, in adopting technical standards, operators should guard against the tendency to revegetate with single-tree species marginally appropriate to geographic and site conditions. This could lead to poorly stocked stands and delay bond release. While, in the final analysis, regulations in sections 816.116 and 816.117 do little to promote species diversity of highly productive natural plant communities, it is clear that this was their goal. Moreover, the regulations as stated certainly provide no barriers to using more creative revegetation systems, the adoption of which should be promoted at the planning stage of mining.

SECTION 3

AN INVENTORY SYSTEM FOR EVALUATING REVEGETATION OF RECLAIMED SURFACE MINES TO FOREST RESOURCE CONSERVATION STANDARDS

by

John C. Rennie* and Robert E. Farmer, Jr.

The Surface Mining Control and Reclamation Act of 1977 (PL 95-87) requires mining firms to meet published standards for revegetation as a prerequisite for bond release. Under the permanent regulatory program, standards for forest tree and shrub stocking are 450 woody plants per acre and an acceptable ground cover (section 816.117(b)). For permit areas under 40 acres in size planted with a mixture of herbaceous and woody plants, standards are 400 woody plants per acre (600 stems per acre on slopes of more than 20°) and 70 percent ground cover (section 816.116(d)). Evaluation is at the time of establishment and again five years after establishment of adequate stocking and ground cover. It is impractical and unnecessary to count all the stems on a permit area to determine whether these standards are met. Counting stems and evaluating vegetative cover on a properly selected sample of the area will give the needed information. However, at present, there are no published or generally recognized standard procedures for determining whether a mining permit area meets these regulatory standards. An objective method of estimating and documenting ground cover and woody plant stocking is a key element of mining and reclamation control since bond release is directly dependent on revegetation success.

This section describes a practical, reliable survey method for use by mine operators and inspectors. The procedures particularly apply

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in situations where the adequacy of reclamation vegetation is in doubt. Examples of calculations to determine adequate woody plant stocking and ground cover are for revegetation criteria of 450 woody stems per acre (600 woody stems per acre on steep slopes) and 70 percent ground cover. Except for the 70 percent ground cover requirement on permit areas 40 acres or less in size (section 816.116(d)), all mention of ground cover relates to reference areas. In substituting technical standards, a more realistic ground cover percentage to assure adequate erosion control in high rainfall areas of Regions I and II is 80 percent where tree, shrub, and herbaceous cover is used, and 90 percent if only herbaceous cover is used. Procedures and computations can be developed for these levels or others as described in appendix B.2. Modifications of sampling procedures for different levels of woody plant stocking are described in appendix B.3.

Sampling Considerations

General

A vegetation sampling system must meet several criteria to be both valid and practical. First, it must provide estimates of ground cover and stems per acre at the prescribed level of statistical confidence, in this case 90 percent (sections 816.116 and 816.117). A sampling system designed at this confidence level will, because of chance, indicate on an average of 1 out of 10 times that an area is inadequately vegetated when in fact the vegetation is adequate. On the other hand, it may also indicate that vegetation does meet standards when in fact it does not. The probability of the latter type of sampling error varies with sample size, i.e, number of samples: the larger the sample size, the less chance of such an error. To obtain an adequate estimate, a certain number of samples must be taken via a system that will be unbiased in the selection of the samples. The techniques described below have built-in procedures for assuring that enough samples are taken and that they are as unbiased as practically possible. Second, the sampling method should allow for an assessment of the distribution of vegetation on the permit area when some portions meet regulatory standards and others require further revegetation. This capability is important since there are provisions (section 807.12) for partial release of bond if revegetation is partially completed. Finally, the whole process of designing, using, and evaluating a sampling system for a given permit area should be simple, easy to use, inexpensive, contain a minimum of bias, and be adapted to the vegetation being inventoried. Cook and Bonham (1977) discuss a variety of measurement procedures and sampling techniques to assess vegetation on mined areas

Ground Cover

Ground cover consists of the living vegetation and litter naturally produced onsite on any unit of land surface. In the context of surface mine reclamation, it is an important measure of erosion control. For the purposes of estimating the revegetation success via the method described below, ground cover will be defined as the percentage of the land covered by vegetation. This includes shrubs, trees, and litter in addition to grasses and herbaceous plants

Cover can be estimated from plots or transects. If plots are used, an appropriately sized area (usually either square or round) is superimposed on the ground and an estimate of percentage cover is made either ocularly or by some system of subplot sampling. A transect is a line along which vegetation is estimated. In cover estimation, it may be a stick with marks or pins at regular intervals that is laid on the ground. The number of pins or marks contacting vegetation is then counted and recorded. The percentage ground cover is the number of pins or marks contacting vegetation divided by the total number of pins or marks. This stick transect method has been adopted for the sampling system below because it is objective and simple in application

Woody Plant Stocking

Woody plant stocking is most conveniently estimated from plots. If these plots are small enough (e.g., 1/1000 of an acre) simply recording the presence or absence of living stems on them will give an estimate of the number of stems per acre and their distribution. Stems may be recorded by species so that an estimate of community composition can be obtained. Larger and more expensive plots (1/10 to 1/20 of an acre) are required if more detailed information on community structure and productivity is required but such information goals are usually beyond the scope of vegetative surveys to evaluate revegetation success. Therefore, the sampling system described here uses milacre (1/1000 of an acre) plots that can be conveniently combined with a short line transect for simultaneously evaluating woody plant stocking and ground cover

Plot and Transect Location

Ideally plots and transects should be located randomly on each portion of the permit area to be evaluated, i.e., each potential plot has an equal chance of being selected. This would, however, entail physically identifying each potential plot (i.e., 1,000 per acre) and assigning it a number and then randomly picking the required number of plots to give the proper sampling intensity; such an approach is complex and often impractical. Therefore, most surveys of the sort needed to evaluate stocking and cover reduce bias in selecting plots by establishing a systematic sampling design which begins at a single, randomly located spot, usually on the boundary of the area to be evaluated. A systematic sampling design is one with a fixed distance between plots. The design described below is aimed at assuring adequate sampling of an area with a minimum number of plots.

Description of Sampling Procedures

Equipment

A stick 3.72 feet long to measure the milacre plot radius having 20 marks or pins spaced at 2 inches.

A 50-foot or longer tape (optional to lay out grid of sample points or to check pacing.

A compass to orient grid.

A clipboard to hold tally sheet.

A pocket calculator (optional) to do calculations

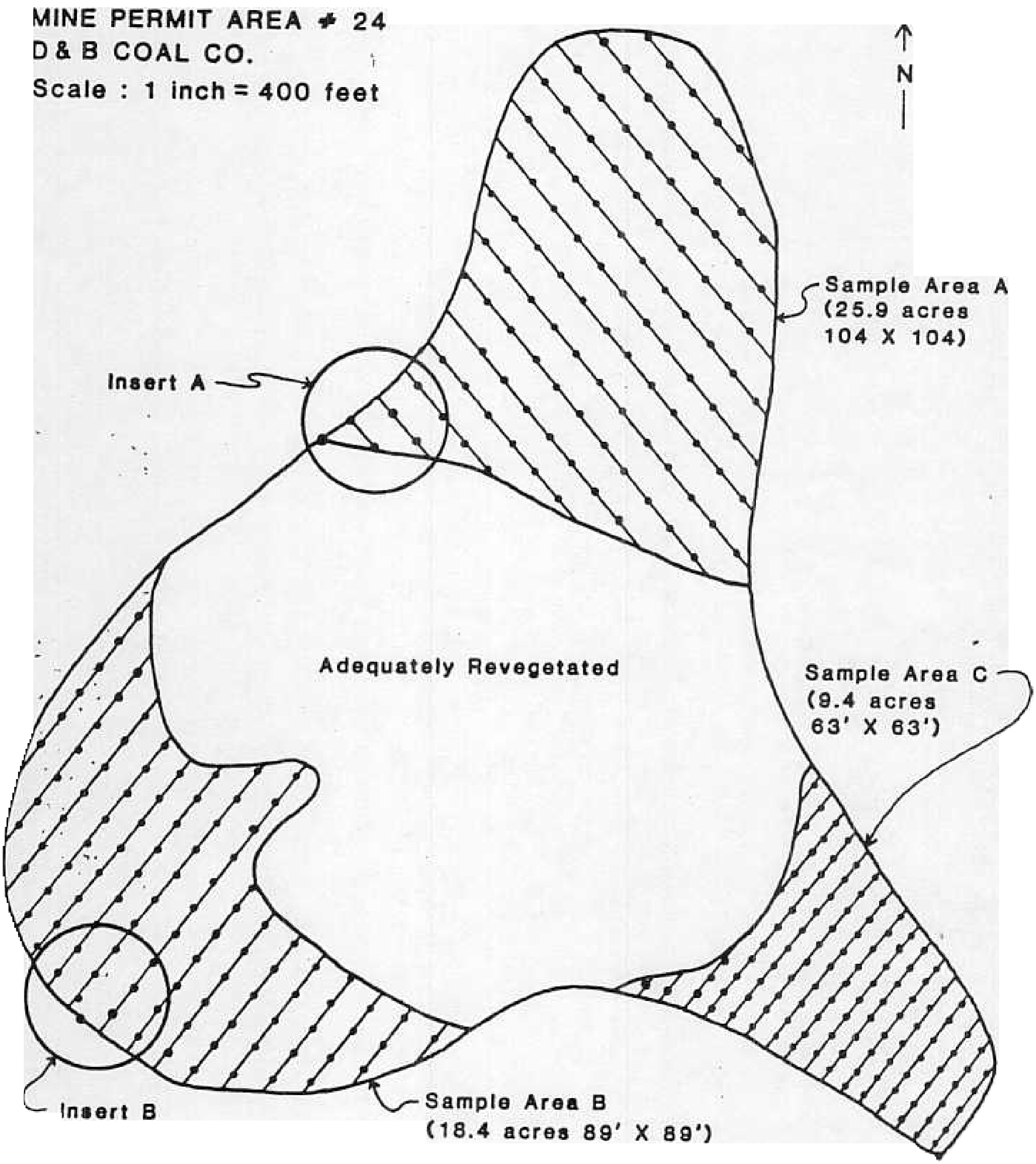
A plumb bob with a 5-foot string (for steep slopes)

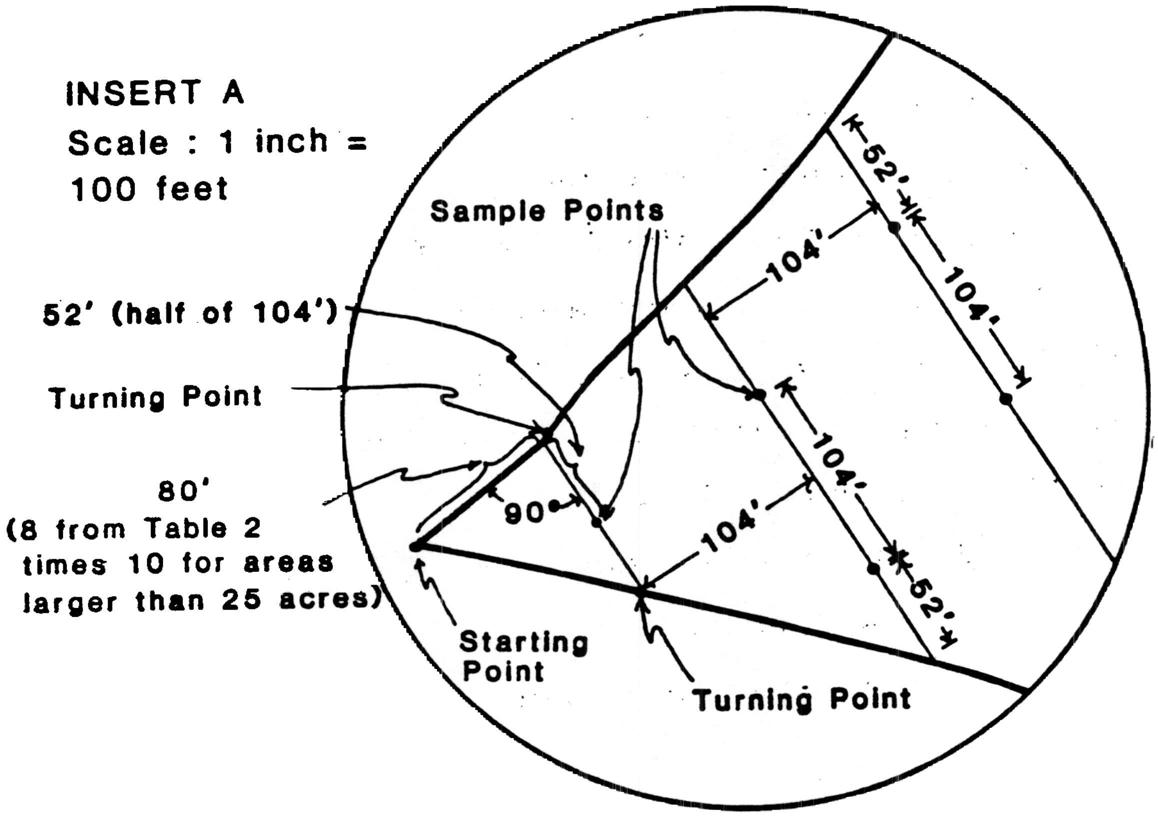
Abney level or Suunto clinometer (optional for steep slopes)

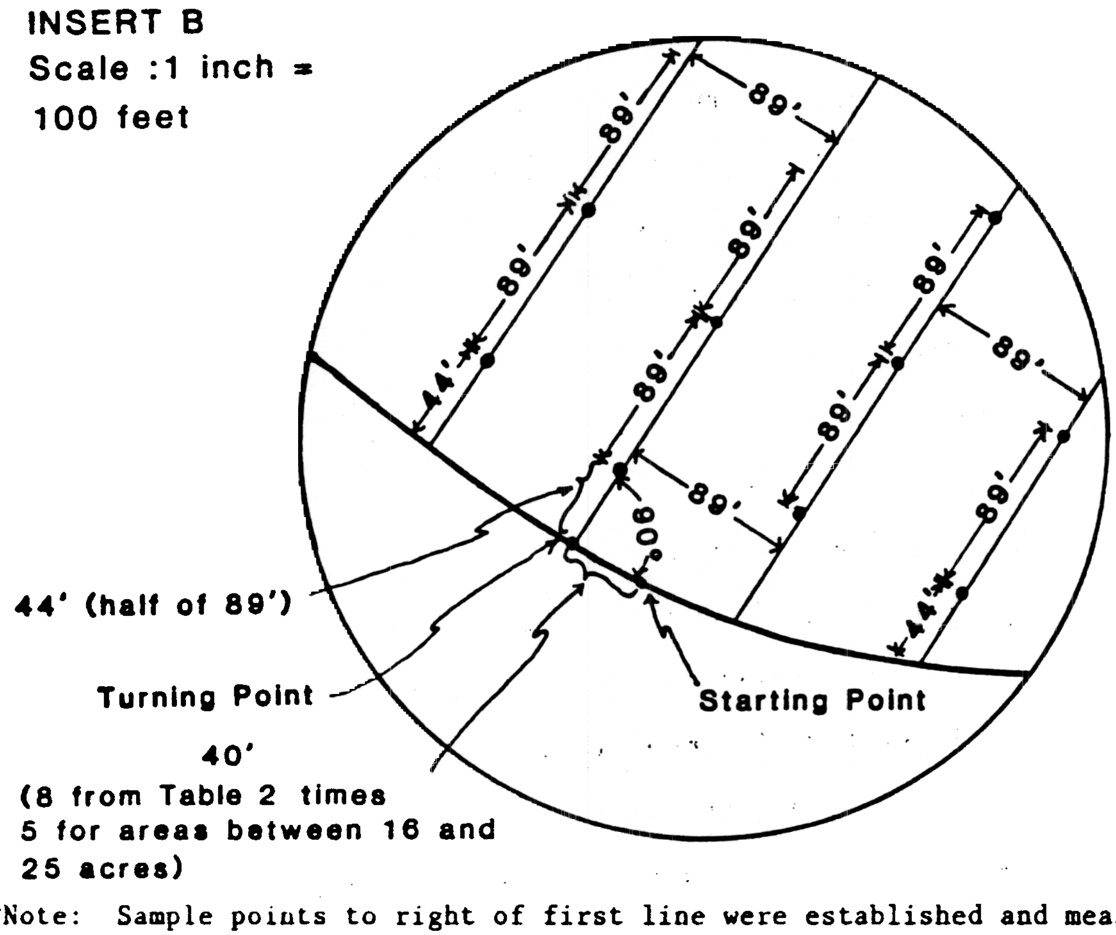
Classification and Mapping

An accurate large-scale map of the revegetated surface mine should be used to delineate areas of similar vegetation and to lay out sampling points in those areas to be sampled. Figure 3.1 is a sample map of a revegetated surface mine and will be referred to throughout the discussion on sample plot location. The revegetated surface mine may be divided into vegetatively similar areas. The acreage of rock areas and permanent road and surface water drainage ways should not be considered since stocking of these areas is not required. The regulatory agency or consultants for the operator will classify areas as adequately vegetated, inadequately vegetated, or questionable. An area is adequately vegetated if an informal visual examination reveals it unquestionably meets the revegetation criteria of 450 woody stems per acre (600 woody stems per acre on steep slopes) and

Figure 3.1. Sample map of revegetated strip mine with areas of homogeneous vegetation delineated and portions of sample point grids located in areas to be sampled.







*Note: Sample points to right of first line were established and measured after first line; then sample points to left were established with the first line to the left located from the turning point on the

70 percent ground cover. Similarly, an area is inadequately vegetated if it obviously does not meet these criteria. Areas of questionable revegetation are those on which a decision about one of the other two categories cannot be made by informal visual examination and thus require formal sampling for classification. The sampling procedures should also be used to train new staff in vegetation classification and occasionally to check areas previously classified as adequate or inadequate.

On the map, the boundaries of each area are carefully sketched and the appropriate class is recorded for each. Areas should not consist of less than five acres. Also, irregular boundaries should be avoided, if possible

Location of Sampling Points

Approximately 100 sample points will be used in each area sample size has been selected to ensure the adequate sample needed in highly variable areas. It also avoids the cumbersome procedures of taking a preliminary sample to determine variability and thus sample size, followed by a main sample to assess vegetative stocking and ground cover. The statistical evaluation of various sample sizes is presented in appendix B.1. Techniques for modifying the sampling procedures are given in appendix B.2 for ground cover and in appendix B.3 for woody plant stocking

Spacing of the sample points will vary with the size of the to be sampled. First, determine the spacing of sample points for each area classified as questionable or for the whole surface mine if it is not subdivided (figure 3.1). To start, determine the acreage of each area excluding rock areas and permanent road and surface water drainage ways either by observation on the ground or from the sketched boundaries on the map. Next, refer to table 3.1 or figures 3.2 or 3.3 for the plot spacing to be used on each area. On the map, record the acreage and plot spacing for each area.

Table 3.1. Spacing needed to locate 100 sampling points in tracts of various areas.

Area (acres)	Spacing (ft by ft)
1	21 by 21
	30 by 30
3	36 by 36
4	42 by 42
5	47 by 47
6	51 by 51
7	55 by 55
8	59 by 59
9	63 by 63
10	66 by 66
12	72 by 72
14	78 by 78
16	83 by 83
18	89 by 89
20	93 by 93
25	104 by 104
30	114 by 114
35	123 by 123
40	132 by 132
45	140 by 140
50	148 by 148
60	162 by 162
70	175 by 175
80	187 by 187
90	198 by 198
100	209 by 209
125	233 by 233
150	256 by 256
175	276 by 276
200	295 by 295

$$\text{Spacing} = \sqrt{\frac{\text{Area} \times 43560}{100}}$$

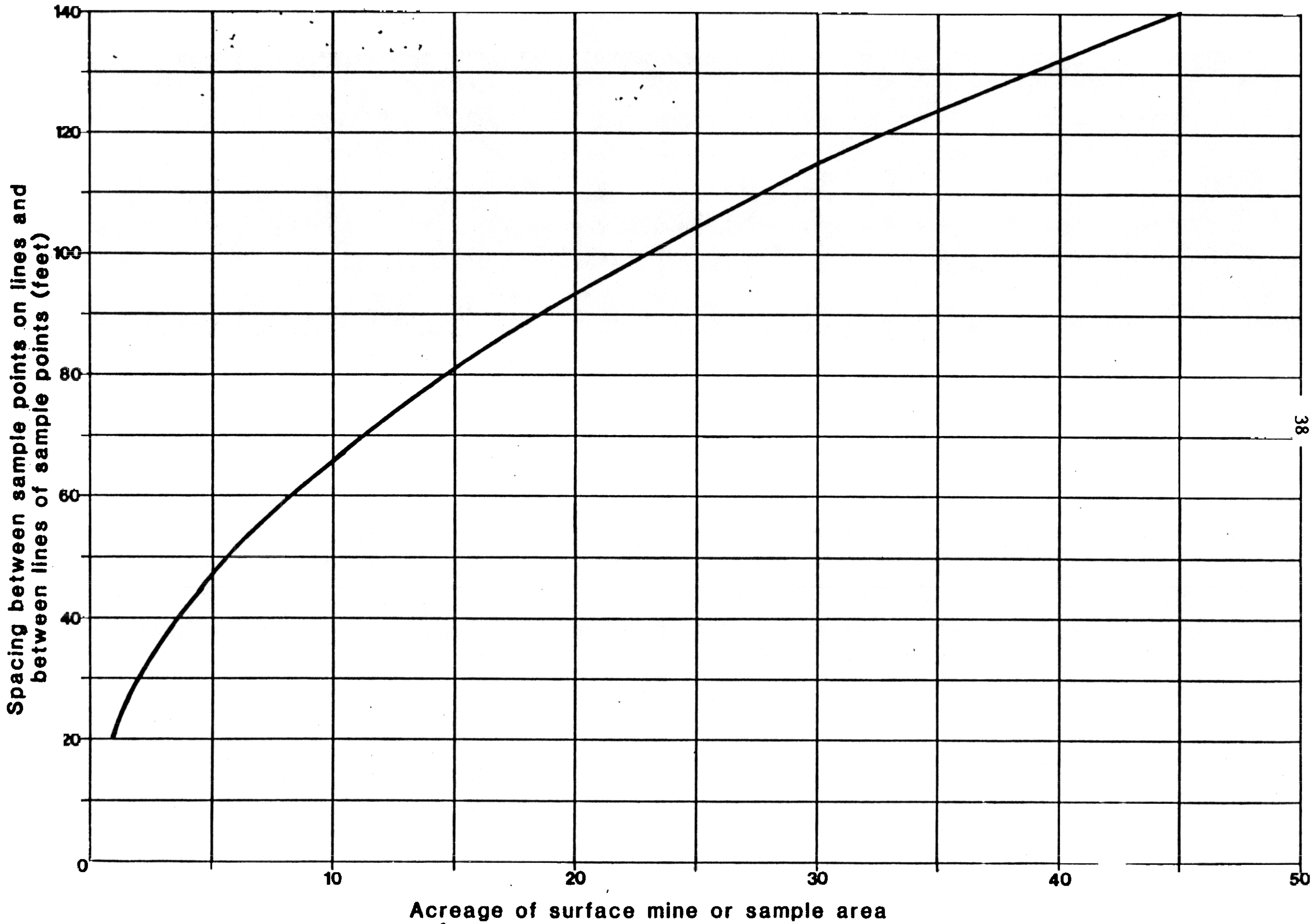


Figure 3.2. Plot spacing required to locate 100 sample points on areas up to 45 acres

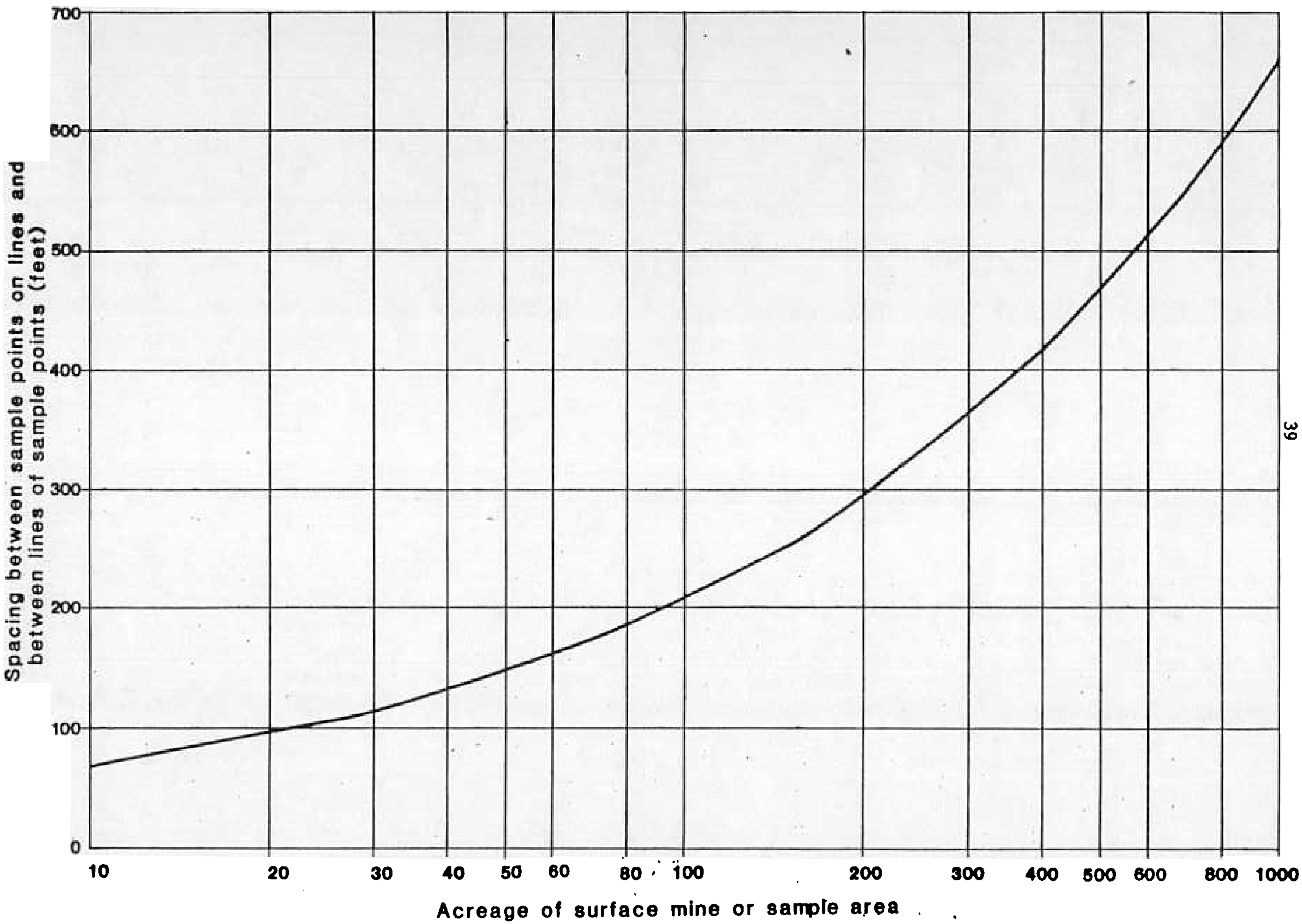


Figure 3. Plot spacing required to locate 100 sample points on areas from 10 to 1,000 acres.

Randomly locate the first sample point from a starting point on the boundary of the area. If the area has a corner in the boundary, use it as the starting point. Otherwise, any point on the boundary can be selected To get a random distance, get a random digit by entering table 3.2 in the proper row and column for the current date (consider "0" to be "10"); for areas less than 4 acres use this number directly; for areas between 4 acres 16 acres multiply it by 2; for areas between 16 acres and 25 acres, multiply it by 5; for areas between 25 acres and 100 acres, multiply it by 10; for areas larger than 100 acres, multiply by 20. From your starting point, measure or pace along the boundary the distance you calculated from the random digit to a turning point. Now with the compass, turn 90° from the boundary toward the area being sampled and proceed in the new direction half the distance from table 3.1. This is your first sample point (figure 3.1). Refer to "Plot and Line Sampling Methods" on page 13 for a description of the measurements to take at this and subsequent sample points

After taking the measurements, use the spacing recorded on your map to locate subsequent sample points. Locate the next sample point by continuing on the same compass bearing you used to get from the boundary to the first point; the distance from the first point to the second point is distance you determined from table 3.1. Continue along this compass bearing locating sample points at this distance from the previous one and taking measurements at each until you reach the boundary opposite that from which you started. If you have an irregularly shaped tract, mark this point to return to later and complete sampling the second side of your first line of plots (figure 3.1); for regularly shaped tracts where you paralleled a boundary, you have only one side to sample.

Now use your compass and turn 90°; proceed the distance determined from table 3.1 to the next line of sample points; turn 90° again back into

Table 3.2 Random digits to use in locating first sample point. Determine random digit by locating column for month and last digit of year of current date, and row for current date of month.

Year	0 or 5	1 or 6	2 or 7	3 or 8	4 or 9
Month	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND
Date of Month					
1	927580968305	412103315828	207808466848	615667405572	901391749910
2	788888461870	610052218296	150104552213	231396388767	589927064691
3	383401968422	795459220913	816675893466	580978561904	801445267178
4	268729477167	861390465302	119567718460	570073469467	482025579733
5	810534951745	757961082770	705859701411	566160932936	911072487398
6	070390634466	236994783233	798401907774	612441088337	882904613692
7	371237299607	835910986466	215248878907	040294755658	050518153964
8	228220583458	762691295638	535970827485	218247858170	590852110165
9	846194642593	145873178028	898237304473	315967965792	138916623903
10	584525302781	218768705866	138057660969	087624888098	310228294995
11	668516017775	634990186905	205768618917	978856137629	373994631003
12	974877529640	879836620865	431367732774	897380683273	924353511268
13	357180395050	978601761580	848180582662	408081612366	349498600140
14	122137528810	407669900020	129167601991	166140991475	339851223103
15	616011536728	814444318018	539348234566	167165484110	335710131420
16	553680373998	044196920966	605584877721	381372401280	496802138320
17	709379732419	272657918265	374568047385	047296764536	167620749990
18	088945348392	411153794473	795580808719	441212939049	699767205463
19	743928377767	900935330739	382098094244	627922142122	900912280204
20	556532617257	112003492574	016866964168	747910742521	139934960188
21	057087894726	379465151827	400075014724	191150013918	994657753119
22	661027474167	187864327655	946771962963	942173914292	589971998420
23	819332161853	747866620475	147437515706	565200648937	585255449318
24	666242776145	943418076334	129301737183	597420908863	096286230545
25	407869760385	747923272293	758636924156	040404035834	109588703573
26	958017134280	147815941080	755597470573	103099877978	137997804449
27	038489696184	447314737971	478208141532	714011835185	909338753615
28	252976113349	061799975701	444962919083	486066915437	614571618406
29	679009205175	595551329096	542627837392	969290855371	297669647614
30	054982128101	141031000866	413662864768	120673825138	818636570339
31	376312826366	532074009307	923562915512	535076492686	241763142394

the area; you should now be heading along a line parallel to that just completed (figure 3.1). Your first sample point will be located half the distance determined in table 3.1 from the boundary; subsequent sample points will be spaced as on the first line. At end of the second line, proceed as you did at the end of the first. Continue the process until you have completed the area. If your area is irregular, return to the point you marked on the boundary at the end of the first line and complete the other part of the area.

Plot and Line Sampling Methods

At each sample point that is not located on a rock area or in a permanent road or surface water drainage way, you will make two observations and record them in the appropriate part of a form like that in figure 3.4. Use a separate tally form for each area you sample. First, using the sample point as the center make a milacre acre plot with the 3.72-foot stick. This plot is stocked if there is one or more live woody plants (woody shrubs, trees, and vines) in it: tally the plot as stocked by putting an X over the smallest unmarked number in the upper portion of the tally form. If there are no live woody plants, circle the smallest unmarked number

Ground cover is estimated by setting the stick at right angles to the line of travel between sample points with the center of the stick over the sample point as close to the ground as possible. There are now 10 marks or pins on each side of the sample point. Determine how many of the 20 marks or pins are directly over or under live vegetation; in column 2 of the tally

Figure 3.4 Tally Form for Strip Mine Revegetation Sample (use one form for each area sampled).

SAMPLE AREA:_____________________________ DATE:______________________ BY:

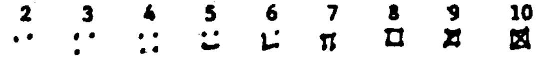
A. WOODY PLANT STOCKING: For each plot with one or more live tree, woody shrub, or woody vine, mark lowest unmarked number with an X; otherwise, circle lowest unmarked number:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162
163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180

B. GROUND COVER: Tally each line transect in the row corresponding to the number of marks or pins out of 20 that intersect vegetation.

Dot-dash tally method

1 2 3 4 5 6 7 8 9 10



Column 1 No. of Pins or Marks out of 20 Vegetated	Column 2 Tally for Sample Points	Column 3 Number of Sample Points Tallied	Column 4	Column 5 C3xC4	Column 6	Column 7 C3xC6
0			0		0	
1			1		1	
2			2		4	
3			3		9	
4			4		16	
5			5		25	
6			6		36	
7			7		49	
8			8		64	
9			9		81	
10			10		100	
11			11		121	
12			12		144	
13			13		169	
14			14		196	
15			15		225	
16			16		256	
17			17		289	
18			18		324	
19			19		361	
20			20		400	
	Total ΣC3=		ΣC5=		ΣC7=	

sheet, record one sample point in the row corresponding to the number of marks or pins which intersected live vegetation.

Modifications for Steep Slopes

Some modifications of the inventory's system will be required for areas with steep slopes (more than 20°). These include classification of areas for visual examination, determination of acreage, orientation of lines of sample points, pacing or taping up or down a slope, construction of milacre plots, and layout of the line transects. These modifications are necessary because all distances are measured horizontally, and all acreages of plots and areas are defined after the border has been projected vertically onto a level surface

When classifying each homogeneous area as you map the boundaries, you will need to examine the area more thoroughly. On steep slopes, particularly when you are looking downhill, you get a biased impression of the vegetation; more thorough visual examination will reduce such bias. Determination of acreage on steep slopes should be based on the boundaries you have drawn on your map, since the map represents the area on a horizontal surface. Estimation of acreage from field observations of steep areas will usually be more than the actual acreage; overestimates of acreage result in a shortage of sample plots and a loss of precision

Lines of sample points should be located to follow the contour as closely as possible to reduce the physical exertion of the sampler. When going between lines of sample points, it will be necessary to go straight uphill or downhill. Pacing on steep slopes without considerable experience is difficult and inaccurate. Thus, to go between lines of sample points, you should measure the distance with a tape. One way to do this with two people is to measure the distance in short, horizontal segments (figure 3.5); a plumb bob is used to

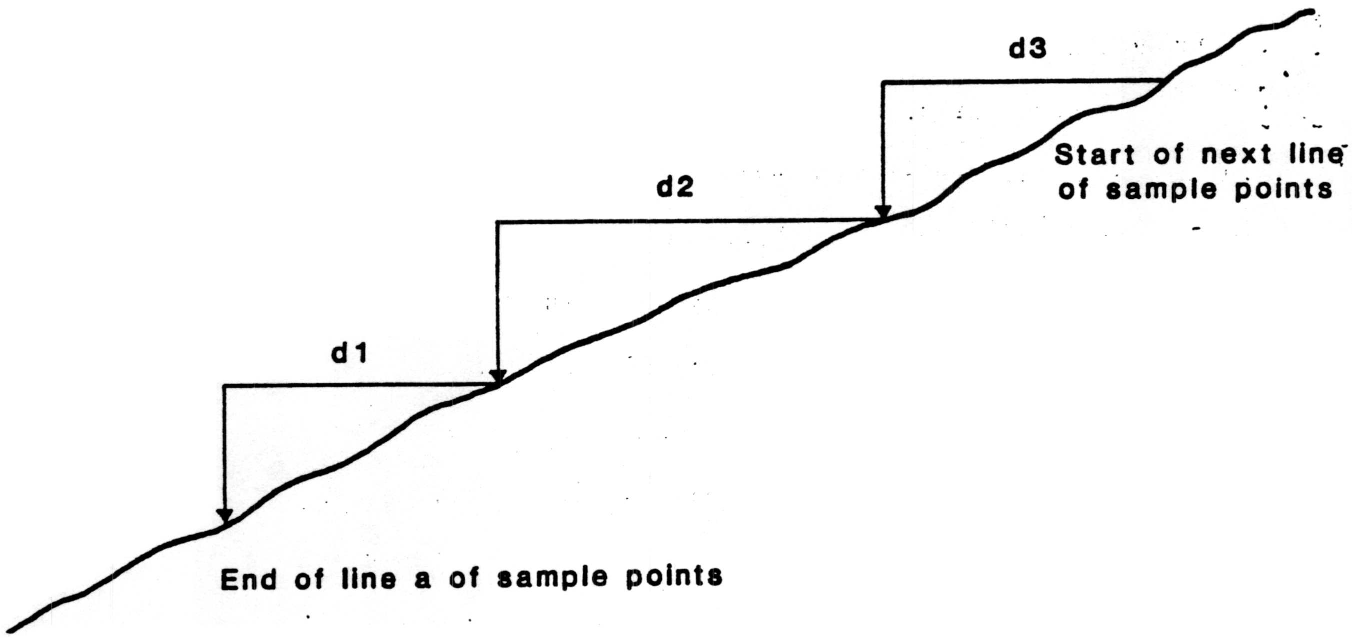


Figure 3.5: Example of measuring between end of one line of sample points and start of next line on a steep slope. (Distances d_1, d_2, and d_3 are horizontal measured directly with the tape horizontal and a plumb bob used to align the downhill end of the tape. The sum of the three distances (d_1, d_2, and d_3) equals the distances between lines of sample points.)

align the downhill end of the tape with the starting point of the line segment. An alternate way to determine the distance is to measure the slope between the line of sample points and the start of the next line, determine the appropriate correction factor from table 3.3, and multiply the desired horizontal distance between lines of sample points by this correction factor to get the appropriate distance along the slope. Now, measure up or down the hill the distance you have calculated; this will put you at about the same point you would have been if you had measured the distance as shown in figure 3.5

Construction of milacre plots on steep slopes is simplified by using a plumb bob. If there is one woody plant that is obviously in this plot, there is no need to use special methods. Where the woody plant is near the edge, below the center, suspend the plumb bob from the end of the stick to establish the edge, and determine if the plant is in or out; for the half of the plot uphill from the plot center, use the plumb bob to accurately locate one end of the stick over the sampling point while you turn the other end to define the upper edge of the plot. To lay out the line transect on steep slopes, rather than holding the stick horizontal, it can be laid on the contour for checking vegetation under each of the 20 points.

Calculations and Decisions

After you have completed all the areas to be sampled, use one copy of the calculation form (figures 3.6 or 3.7) to do the calculations for each area sampled. This form has directions and spaces to record data for the two types of samples. Completion of the form indicates whether or not an area has adequate woody plant stocking and adequate vegetative cover. Completed sample tally and calculation forms are found in figures 3.8 and 3.9

Table 3.3. Correction factors to calculate distances along various slopes that correspond to desired horizontal distances. (For example, to go a horizontal distance of 63 feet on a slope of 53 percent, you would measure a distance of 71 feet (1.13 x 63) along the slope.)

Limits of slope percentage	Correction factor	Limits of slope percentage	Correction factor	Limits of slope percentage	Correction factor
		55.8		80.7	
	1.01		1.15		1.29
		57.8		82.3	
	1.02		1.16		1.30
		59.8		83.9	
	1.03		1.17		1.31
26.7		61.7		85.4	
	1.04		1.18		1.32
		63.6		86.9	
	1.05		1.19		1.33
		65.4		88.4	
	1.06		1.20		1.34
		67.2		89.9	
	1.07		1.21		1.35
		69.0		91.4	
	1.08		1.22		1.36
		70.8		92.9	
	1.09		1.23		1.37
		72.5		94.3	
	1.10		1.24		1.38
		74.2		95.8	
	1.11		1.25		1.39
49.3		75.8		97.2	
	1.12		1.26		1.40
51.5		77.5		98.7	
	1.13		1.27		1.41
		79.1		100.1	
	1.14		1.28		1.42
55.8		80.7		101.5	

Correction factor for steeper slopes is:

$$\sqrt{1 + (\text{Slope percentage}/100)^2}$$

From: Space, J. C. 3-P Forest Inventory: Design, Procedures Data Processing. USDA Forest Service, State and Private Forestry - Southeastern Area, Atlanta.

Figure 3.6. Calculation form for strip mine revegetation sample on moderate slopes (Use one form for each area sampled.)

SAMPLE AREA: ___ ___________________ __ DATE: _____ _____ _________ BY: _____

A. WOODY PLANT STOCKING SAMPLE

1. Count number of stocked plots (X) and record below.
2. Count number of unstocked plots (0) and also record.
3. Sum 1 and 2 to get total number of plots.

No. of stocked plots: Line 1

No. of unstocked plots: Line 2

Total no of plots: Line 3=1 + 2

Line 4

4. Locate the range (Column 1) that includes the number of plots you took (Line 3) and record the minimum number of stocked plots needed for adequate stocking from Column 2 on Line 4

Column 1 No. of Sample Plots Observed	Column 2 Minimum No. of Sample Plots Stocked for Adequate Stocking	Column 1	
50- 54	18	115-119	45
55- 59	20	120-124	47
60- 64	22	125-129	49
65- 69	24	130-134	51
70- 74	26	135-139	53
75- 79	28	140-144	56
80- 84	30	145-149	58
85- 89	32	150-154	60
90- 94	35	155-159	62
95- 99	37	160-164	64
100-104	39	165-169	66
105-109	41	170-174	68
110-114	43	175-179	70

5. Is Line 1 equal to or larger than Line 4?
   __ Yes: The area has adequate woody plant stocking.
   __ No: The area lacks adequate woody plant stocking.

B. GROUND COVER SAMPLE

1. On tally form, count the number of plots tallied in Column 2 for each row and record in Column 3.

2. For each row on tally form, multiply the number in Column 3 by the number in Column 4 and record in Column 5.

3. For each row on tally form, multiply the number in Column 3 by the number in Column 6 and record in Column 7.

4. Total Columns 3, 5, and 7; record each sum at the bottom of the column and below:

   $\Sigma C3 =$ $\qquad$ $\Sigma C5 =$ $\qquad$ $\Sigma C7 =$

5. Calculate the mean: $\bar{X} = \Sigma C5/\Sigma C3 =$

6. Calculate the correction factor: $cf = \Sigma C5 \times \Sigma C5/\Sigma C3 =$

7. Calculate the sum of squares: $SS = \Sigma C7 - cf =$

8. Calculate the degrees of freedom: $df = \Sigma C3 -$

9. Calculate the variance: $V = SS/df =$

10. Calculate the standard error: $s.e. = \sqrt{V/\Sigma C3} =$

11. Circle the appropriate t value: if $\Sigma C3$ is 60 or less, $t = 1.303$;
    if $\Sigma C3$ is between 60 and 120, $t = 1.296$;
    if $\Sigma C3$ is more than 120, $t = 1.289$.

12. Calculate the upper bound on the confidence limit: $[\bar{X} + (t \times s.e)] =$ ___

13. Is the results of step 12 equal to 14.0 or more?
    Yes: The area has adequate ground cover.
    No: The area lacks adequate ground cover

Figure 3.7. Calculation form for strip mine revegetation sample on steep slopes. (Use one form for each area sampled.)

SAMPLE AREA: ____________________ DATE: ____________________ BY: ____________

A. WOODY PLANT STOCKING SAMPLE

Count number of stocked plots (X) and record below.

2 Count number of unstocked plots (0) and also record.

3 Sum 1 and 2 to get total number of plots.

No. of stocked plots: ___ Line 1

No. of unstocked plots: ___ Line 2

Total no of plots: ___ Line 3=1 + 2

Line 4

4. Locate the range (Column 1) that includes the number of plots you took (Line 3) and record the minimum number of stocked plots needed for adequate stocking from Column 2 on Line 4

Column 1 No. of Sample Plots Observed	Column 2 Minimum No. of Sample Plots Stocked for Adequate Stocking	Column 1 No. of Sample Plots Observed	Column 2 Minimum No. of Sample Plots Stocked for Adequate Stocking
50- 54	25	115-119	62
55- 59	28	120-124	65
60- 64	31	125-129	68
65- 69	34	130-134	71
70- 74	37	135-139	74
75- 79	39	140-144	76
80- 84	42	145-149	79
85- 89	45	150-154	82
90- 94	48	155-159	85
95- 99	51	160-164	88
100-104	53	165-169	91
105-109	56	170-174	94
110-114	59	175-179	96

5. Is Line 1 equal to or larger than Line 4?
___ Yes: The area has adequate woody plant stocking.
___ No: The area lacks adequate woody plant stocking.

B. GROUND COVER SAMPLE

On tally form, count the number of plots tallied in Column 2 for each row and record in Column 3.

2 For each row on tally form, multiply the number in Column 3 by the number in Column 4 and record in Column 5.

3. For each row on tally form, multiply the number in Column 3 by the number in Column 6 and record in Column 7.

Total Columns 3, 5, and 7; record each sum at the bottom of the column and below:

$\Sigma C3 =$ $\Sigma C5 =$ $\Sigma C7 =$

5 Calculate the mean: $\bar{X} = \Sigma C5/\Sigma C3 =$ ________.

6 Calculate the correction factor: $cf = \Sigma C5 \times \Sigma C5/\Sigma C3 =$

Calculate the sum of squares: $SS = \Sigma C7 - cf =$

8. Calculate the degrees of freedom: $df = \Sigma C3 - 1 =$

9 Calculate the variance: $V = SS/df =$

10. Calculate the standard error: $s.e. = \sqrt{V/\Sigma C3} =$

11. Circle the appropriate t value: if $\Sigma C3$ is 60 or less, $t = 1.303$;
if $\Sigma C3$ is between 60 and 120, $t = 1.296$;
if $\Sigma C3$ is more than 120, $t = 1.289$.

12. Calculate the upper bound on the confidence limit: $[\bar{X} + (t \times s.e)] =$ ___

13. Is the results of step 12 equal to 14.0 or more?
______ Yes: The area has adequate ground cover.
______ No: The area lacks adequate ground cover.

Figure 3.8 Sample of Completed Tally Form for Strip Mine Revegetation Sample for one sample area.

SAMPLE AREA: Mine Permit Area #24, Sample Area A DATE: August 8 1980 BY: JCR

A. WOODY PLANT STOCKING: For each plot with one or more live tree, woody shrub, or woody vine, mark lowest unmarked number with an X; otherwise, circle lowest unmarked number:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126
127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162
163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180

B. GROUND COVER: Tally each line transect in the row corresponding to the number of marks or pins out of 20 that intersect live vegetation.

Dot-dash tally method

2 3 4 5 6 7 8 9 10

Column 1 No. of Pins or Marks out of 20 Vegetated	Column 2 Tally for Sample Points	Column 3 Number of Sample Points Tallied	Column 4	Column 5 C3xC4	Column 6	Column 7 C3xC6
0	:	2	0	0	0	0
1	:.	3	1	3	1	3
2	.	1	2	2	4	4
3	::	4	3	12	9	36
4		7	4	28	16	112
5		3	5	15	25	75
6		7	6	42	36	252
7		9	7	63	49	441
8		3	8	24	64	192
9		5	9	45	81	405
10		9	10	90	100	900
11		7	11	77	121	847
12		6	12	72	144	864
13		9	13	117	169	1521
14		13	14	182	196	2548
15		7	15	105	225	1575
16		3	16	48	256	768
17		6	17	102	289	1734
18		3	18	54	324	972
19		3	19	57	361	1083
20	..	2	20	40	400	800
	Total ΣC3=	112	ΣC5=	1178	ΣC7=	15132

Figure 3.9 Sample of Completed Calculation Form for Strip Mine Revegetation Sample for one sample area.

SAMPLE AREA: Mine Permit Area #24, Sample Area A DATE: August 8, 1980 BY: JCR

A. WOODY PLANT STOCKING SAMPLE

1. Count number of stocked plots (X) and record below.
2. Count number of unstocked plots (0) and also record.
3. Sum 1 and 2 to get total number of plots.

No. of stocked plots: 71 Line 1

No. of unstocked plots: 41 Line 2

Total no of plots: 112 Line 3=1 + 2

43 Line 4

4. Locate the range (Column 1) that includes the number of plots you took (Line 3) and record the minimum number of stocked plots needed for adequate stocking from Column 2 on Line 4

Column 1 No. of Sample Plots Observed	Column 2 Minimum No. of Sample Plots Stocked for Adequate Stocking	Column 1 No. of Sample Plots Observed	Column 2 Minimum No. of Sample Plots Stocked for Adequate Stocking
50- 54	18	115-119	45
55- 59	20	120-124	47
60- 64	22	125-129	49
65- 69	24	130-134	51
70- 74	26	135-139	53
75- 79	28	140-144	56
80- 84	30	145-149	58
85- 89	32	150-154	60
90- 94	35	155-159	62
95- 99	37	160-164	64
100-104	39	165-169	66
105-109	41	170-174	68
110-114	43	175-179	70

Is Line 1 equal to or larger than Line 4?

✓ Yes: The area has adequate woody plant stocking.

___ No: The area lacks adequate woody plant stocking

B. GROUND COVER SAMPLE

1. On tally form, count the number of plots tallied in Column 2 for each row and record in Column 3.

2. For each row on tally form, multiply the number in Column 3 by the number in Column 4 and record in Column 5.

3. For each row on tally form, multiply the number in Column 3 by the number in Column 6 and record in Column 7.

4. Total Columns 3, 5, and 7; record each sum at the bottom of the column and below:

$\Sigma C3$ = 112 $\Sigma C5$ = 1178 $\Sigma C7$ = 15132

5. Calculate the mean: $\bar{X} = \Sigma C5/\Sigma C3$ = 10.52.

6. Calculate the correction factor: $cf = \Sigma C5 \times \Sigma C5/\Sigma C3$ = 12390.04

7. Calculate the sum of squares: $SS = \Sigma C7 - cf$ = 2741.96.

8. Calculate the degrees of freedom: $df = \Sigma C3 - 1$ = 111.

9. Calculate the variance: $V = SS/df$ = 24.70.

10. Calculate the standard error: $s.e. = \sqrt{V/\Sigma C3}$ = 0.47.

11. Circle the appropriate t value: if $\Sigma C3$ is 60 or less, $t = 1.303$;
if $\Sigma C3$ is between 60 and 120, $t = 1.296$; (circled)
if $\Sigma C3$ is more than 120, $t = 1.289$.

12. Calculate the upper bound on the confidence limit: $[\bar{X} + (t \times s.e)]$ = 11.13

13. Is the results of step 12 equal to 14.0 or more?

___ Yes: The area has adequate ground cover.

✓ No: The area lacks adequate ground cover.

Example of Classification, Mapping, and Sample Plot Location

For this example, a revegetated strip mine of about 100 acres was selected (figure 3.1). This mine had four distinct areas of homogeneous vegetation: based on visual inspection, the central portion had adequate stocking of woody plants and adequate ground cover; the areas on each of the three arms appeared to be well vegetated, but it was not obvious that they the criteria set forth in the regulations. Therefore, the boundaries were sketched on the map and the central portion noted as "Unquestionably Revegetated"; the three arms were labeled as "Sample Area A, B, and C." The boundaries were regular, in general, except for "Sample Area B," which included a small section of questionable stocking protruding into the central portion of the mine.

The acreage of each of the three sample areas was estimated and recorded on the map. Referring to table 3.1, the spacing needed for each area to be sampled was determined based on each acreage; these were also noted on the map. Starting points were selected for each area: for Sample Area A, it was the southwest corner (in insert A); for Sample Area B, a point along edge was selected (in insert B) because of the shape of the sample area in two corners; the southeast corner was used for Sample Area C. Random distances from each starting point were calculated by multiplying the random digit from table 3.2, eight in this case, by a factor based on the acreage of each sample area. For Sample Area A, being larger than 25 acres, 8 was multiplied by a factor of 10 to get a distance of 80 feet from the starting point to the turning point (see large-scale version of insert A). For Sample Area B, 8 was multiplied by 5; for Sample Area C, 8 was multiplied by 2.

After locating the first turning point from the starting point on Sample Area A, a compass was used to turn 90° into the sample area from the between the starting point and the turning point. Based on the acreage of Sample Area A (25 acres being the largest area in table 3.1 less than 25.9 acres), the spacing was 104 feet by 104 feet The first sample point located half this distance (52 feet) from the turning point. A milacre plot and line transect of 20 points was taken here.

After recording the data at the first sample point, the sampler continued on the same compass bearing used to get from the turning point to the first sample point. Before going the required 104 feet to the next sample point, the border of the area was encountered. Here, the sampler turned and proceeded 104 feet to the next line of sample points. To get to the boundary of the tract, the sampler again turned 90° and proceeded to the boundary. From this point, the first sample point on the second line was located 52 feet and the next sample point 104 feet.

Sample point location and data collection for Sample Area A continued with each new line being located 104 feet from the previous line of sample points, then the first sample point located 52 feet from the edge of the Sample Area, and subsequent sample points 104 feet from the previous point. This resulted in a grid of 112 sample points regularly spaced over Sample Area A with one circular milacre plot and one 20-point line transect located at each sample point.

Sample point location on Sample Area C was similar to that used on Sample Area A except that a spacing of 63 feet by 63 feet was necessary to locate a sufficient number of sample points. Because of the shape of Sample Area B and the location of the starting point, it was necessary to return to the first turning point and establish sample points in the northwest portion of the sample area after sampling the southeast portion. Either end of the first line of sample points could have been used as a base for next line northwest; the end on the mine boundary was used because of convenience

Example of Calculations To Determine Adequate Woody Plant Stocking and Ground Cover

Figure 3.8 is a completed copy of the tally form presented in figure 3.4. At the top, information identifying the area sampled was entered. In part A, one number was marked with an X for each plot having at least one woody plant and another number circled when a plot lacked woody vegetation. In part B, each line transect was tallied with a dot or a dash in column 2 and the row corresponding to the number of pins or marks out of 20 intersecting line vegetation.

After locating and evaluating the 112 sampling points for woody plants and ground cover, the calculations were performed (figure 3.9). For woody plant stocking, the number of X's and O's were counted and entered on the appropriate line. The sum of these two numbers must equal the total number of sample points, 112 in this example. This number of plots was in the range 110-114, so 43, the minimum number of stocked plots for adequate stocking, was entered on line 4. Since the actual number of stocked plots--71 on line 1--was more than the minimum required, Sample Area A had adequate woody plant stocking.

Next, the number of line transects was counted and recorded by row, that is, for each possible number of pins or marks intersecting live vegetation. These were recorded in the appropriate rows in column 3. Next columns 5 and 7 were calculated, and columns 3, 5, and 7 summed and recorded at the bottom of the respective column and in the appropriate spaces in step 4 on the Calculation Form. The sum of column 3 must equal the number of sample points for the sample area, again 112 in this example. Steps 5 to 12 were completed, and in step 13, the decision on whether or not there was adequate ground cover was made; in this example, there was not adequate ground cover, since the value calculated in step 12 was less than 14.

REFERENCES

Acheson, J. D. 1974. Quality Control and Industrial Statistics. Fourth Edition. Richard D. Irwin and Co., Homewood, Illinois.

Bennett, O. L. 1975. Forage production and quality from disturbed land areas. Proc. West Virginia Chapter and West Virginia Grassland Council pp. 19-35. Soil Sci. Soc. of Am., Blackwater Falls State Pk., West Virginia. West Virginia Univ. Press, Morgantown.

Bradshaw, A. D. and M. J. Chadwick. 1980. The restoration of land. Univ. of California Press, Berkeley. 317 pp.

Brown, C. S. and S. E. Baylor. 1974. Hay and pasture seedings for the Northeast. In Forages, ed. M. E. Heath, D. S. Metcalfe, and R. F. Barnes. Iowa State Univ. Press, Ames. pp. 437-448.

Chamblee, D. S. and A. E. Spooner. 1974. Hay and pasture seedings for the humid South. In Forages, ed. M. E. Health, D. S. Metcalfe, and R. F. Barnes. Iowa State Univ. Press, Ames. pp. 460-475.

Cochran, W. G. 1977. Sampling Techniques. Third Edition. Wiley, York. 428 pp.

Cook, C. W. and C. D. Bonham. 1977. Techniques for vegetation measurements and analysis for a pre- and post-mining inventory. Colorado State University Range Science Department. Science Series No. 28. Fort Collins, Colorado. 94 pp.

Dawkins, H. C. 1968. Statforms: formats for elementary statistical calculation. Paper No. 41. Commonwealth Forestry Institute, Univ. of Oxford.

Fribourg, H. A., C. H. Jent, S. Maher, J. D. Burns, and J. H. Paugh. 1981. Guide to revegetation of surface coal-mined areas in Tennessee. Institute of Agriculture, Univ. of Tennessee. SP 248.

Hodges, J. L., Jr., and E. L. Lehmann. 1964. Basic Concepts of Probability and Statistics. Holden-Day, San Francisco. 375 pp.

Jones, Jr., J. N., W. H. Armiger, and O. L. Bennett. 1979. Specialty crops--an alternate land use on surface mine spoil. Proc. Int. Hill Lands Symp. Morgantown, West Virginia. pp. 560-564.

Powell, J. L. and R. I. Barnhisel. 1977. Reclaiming surface-mined in west Kentucky. Mining Congress J (Dec). pp. 29-35.

Powell, J. L., R. I. Barnhisel and G. W. Akin. 1980. Reclamation of surface-mined coal spoils in western Kentucky. Agronomy J. 72:597-600.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. Seventh Edition. The Iowa State University Press, Ames. 593 pp.

Sutton, P. 1979. Reclamation alternatives for disturbed lands and their application in humid regions. In Planning the Uses and Management of Land, ed. M. T. Beatty, G. W. Peterssen, and L. D. Swindale. No. 21 in the agronomy series. Am. Soc. of Agron., Crop Sci. Soc. of Am., Soil Sci. Soc. of Am. pp. 853-874.

't Mannetje, L (ed.). 1978. Measurement of grassland vegetation and animal production. Bull. 52, Commonwealth Bureau of Pastures and Field Crops. Commonwealth Agricultural Bureaux, Slough, United Kingdom. 260 pp.

USDA Soil Conservation Service. 1981. Soil survey of White and Van Buren Counties, Tennessee. U.S. Government Printing Office: 1981-226-006/51. 86 pp.

U.S. Environmental Protection Agency. 1976. Erosion and sediment control, surface mining in the eastern U.S., EPA Technol. Transf. Sem. Publ., Vol. 1, EPA-625/3-76-006.

APPENDIXES

Appendix A

Supplemental Information on Revegetation for Agricultural Land Uses

APPENDIX A.1

Commonly Used Grasses for Revegetation of Disturbed Lands*

Name	pH range†	Remarks‡
Perennials:		
Bermudagrass (w)[§]	4.5-7.5	Does best at pH of 5.5 and above. Grows best on well-drained soils.
Bluegrass, Kentucky (c)[¶]	5.5-7.0	Shallow root; best adapted to well-drained soils of limestone origin; productivity may be low.
Bluestem, big (w)	5.0-7.5	Strong, deep rooted, and short underground stems; bunch grass.
Bluestem, little (w)	6.0-8.0	Dense root systems; grows in a clump and more drought tolerant than big bluestem; bunch grass.
Bromegrass, smooth (c)	5.5-8.0	Tall, sod forming, drought and heat tolerant.
Canarygrass, reed (c)	5.0-7.5	Excellent for wet areas, ditches, waterways, gullies. Can emerge through 6 to 8 inches of sediment.
Deertongue (w)	3.8-5.0	Very acid tolerant; drought resistant. Adapted to low fertility soils.
Fescue, tall (c)	5.0-8.0	Does well on acid and wet soils of sandstone and shale origin. Drought resistant. Ideal for lining drainage channels; good pasture grass.
Lovegrass, weeping (w)	4.5-8.0	Grows well on infertile soils. Short-lived; bunch grass.
Oatgrass, tall (c)	5.0-7.5	Short-lived bunchgrass, matures early in the spring. Good on sandy and shallow shale sites. Drought resistant.
Orchardgrass (c)	5.0-7.5	Tall-growing bunchgrass. Good fertilizer response. More summer growth than timothy or bromegrass. Excellent pasture grass.
Redtop (c)	4.0-7.5	Tolerant of wide range of soil fertility, pH, and moisture conditions.
Ryegrass, perennial (c)	5.5-7.5	Short-lived bunchgrass. Longer lived than weeping lovegrass or tall oatgrass.
Switchgrass (w)	5.0-7.5	Withstands eroded, acid, and low-fertility soils. Blackwell variety most often used. Drainageways and terrace outlets.
Timothy (c)	4.5-8.0	Stands are maintained perennially by vegetative reproduction. Shallow, fibrous root system. Usually sown in a mixture with alfalfa and clover.
Annuals:		
Barley (c)	5.5-7.8	Provides winter cover.
Millet, foxtail (w)	4.5-7.0	Requires warm weather during the growing season.

APPENDIX A.1

(Continued)

Name	pH range†	Remarks‡
(c)	5.5-7.0	Bunch forming. Winter cover. Requires nitrogen for good growth.
winter (c	5.5-7.5	Winter hardy. Survives on coarse, sandy spoil. Temporary cover.
Ryegrass, annual (c)	5.5-7.5	Excellent for temporary cover. Can be established under dry and unfavorable conditions.
Sudangrass (w)	5.5-7.5	Good for temporary cover. Drought tolerant. Cannot withstand cool, wet soils; rapid growth.
Wheat, winter (c)	5.0-7.0	Requires nutrients. Poor growth in sandy and poorly drained soils. Use for temporary cover; winter hardy.

*Adapted from U.S. Environmental Protection Agency, 1976.

†Optimum growth occurs within these ranges.

‡Because of space limitations, information under Remarks is often incomplete and might lead the reader to unwarranted conclusions. Reference to State agricultural bulletins or standard tests and consultation with extension personnel are recommended for additional information.

warm season species, grows mostly during late spring and summer.

cool season species, grows mostly during the spring and fall.

APPENDIX A.2

Commonly Used Legumes for Revegetation of Disturbed Lands*

Name	pH range†	Remarks‡
Perennials:		
Alfalfa (c)§	6.5-7.5	Requires high fertility and good drainage.
Clover, Alsike (c)	5.0-7.5	Good for seeps and other wet areas.
Clover, white (c)	6.0-7.0	Stand thickness decreases after several years.
Crown vetch (c)	5.5-7.5	Excellent for erosion control. Drought tolerant. Winter hardy.
Flatpea (w)¶	5.0-6.0	Seed is toxic to grazing animals. Good cover.
Lespedeza, Sericea (w)	5.0-7.0	Woody, drought tolerant. Seed should be scarified.
Trefoil, birdsfoot (c)	5.0-7.5	Survives at low pH; persistent; high quality forage.
Biennials:		
Clover, red (c)	6.0-7.0	Should be seeded in early spring.
Sweetclover, white (c)	6.0-8.0	Tall growing. Poor grazing.
Sweetclover, yellow (c)	6.0-8.0	Tall growing. Can be established better than white sweetclover in dry conditions Poor grazing.
Annuals:		
Lespedeza, common (w)	5.0-6.0	Low-growing wildlife feed. Acid tolerant.
Lespedeza, Korean (w)	5.0-7.0	Less tolerant of acid soils than common lespedeza.
Vetch; hairy (c)	5.0-7.5	Adapted to sandy soils as well as heavier ones. Used most often as a winter cover crop.

*Adapted from U.S. Environmental Protection Agency, 1976.

†Optimum growth occurs within these ranges.

‡Because of space limitations, information under Remarks is often incomplete and might lead the leader to unwarranted conclusions. Reference to State agricultural bulletins or standard texts and consultation with extension personnel are recommended for additional information.

§(c) = cool season species, grows mostly during the spring and fall.

¶(w) = warm season species, grows mostly during late spring and summer

APPENDIX A.3

Comparison of Production on a Mined Area with Production on a Reference Area or with a Performance Standard

The use of sampling to compare production requires knowledge of some simple statistical methods, which can be obtained from standard texts. The procedure recommended for the above comparison is the t-test, which is outlined on the following form developed by the Commonwealth Forestry Institute (Dawkins 1968). An example of comparing production on a mined area with that on a reference area is provided which uses the 90 percent level of probability required by sections 816.116 and 816.117 of the regulations.

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

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

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.

APPENDIX A.4

t-Test of the Difference Between the Means of Two Small Samples, Using a Common Variance*

Example: Comparison of hay production on mined land and reference area

Observations of the two samples: a	b	Nature of the observations
11, 5, 9, 8, 10	9, 6, 9, 9, 13	a. kg/plot of hay, mined
11, 10, 8, 11, 8 9, 8	6, 5, 6, 10, 7	b. kg/plot of hay, reference area (reduced to 90%)

Statistical Procedure

1.	Number of observations,	na = 12	nb = 10
2.	Sums, Σ,	Σa = 108	Σb = 80
3.	Means, Σ/n,	$\bar{a}$ = 9.0	$\bar{b}$ = 8.0
4.	Difference between means,	$\bar{a}$ $\bar{b}$ = 1.0	= Diff.
5.	Sum of squared observations,	$\Sigma(a^2)$ = 1006	$\Sigma(b^2)$
6.	Correction factor, $(\Sigma)^2/n$,	$(\Sigma a)^2/na$ = 972	$(\Sigma b)^2/nb$
7.	'Sum of squares':	SSa = 34	SSb = 54
8.	Degrees of freedom, n-1,	d.f.a = 11	d.f.b = 9
9.	Variance, SS/d.f.,	Va = 3.09	Vb = 6.0

10. Variance ratio = greater V/lesser V = 6.0 / 3.09 = 1.94

11. Tabulated F at P.025 for d.f. of greater V over d.f. of lesser V is 3.1. Continue with t-test unless the variance ratio greatly exceeds tabulated F. (In latter case, variances are heterogeneous and t-test is unreliabl

12. Common Variance $= \frac{(SSa + SSb)}{(d.f.a + d.f.b.)} = \frac{(34 + 54)}{(11 + 9)} = 4.4$ = V.com

13. Standard error of difference $= \sqrt{\frac{V.com}{na} + \frac{V.com}{nb}} = \sqrt{\frac{4.4}{12} + \frac{4.4}{10}} = 0.898$ = SEd

14. t-ratio $= \frac{Diff}{SEd,} = \frac{1.0}{0.898} = 1.1$

APPENDIX A.4

(Continued)

15. Student's t at P0.1 for degrees of freedom (d.f.a + d.f.b) is 1.72. If this exceeds the calculated t-ratio then the means are not significantly different at the 90% probability level.

16. Confidence limits at 90% probability for the difference $\bar{a}-\bar{b}$, are given by:

17. Student's t x SEd = 1.72 x 0.898 = 1.54 = CL

18. i.e.
(upper limit:Diff+CL = 2.5)
(Diff = 1.0) 90% confidence range.
(lower limit:Diff-CL = <0)

---

*Adapted from Dawkins, 1968.

APPENDIX A.5

Example of Crop Yield Information Available in Soil Survey Reports*

(Yields in column A are those obtained under common management; those in column B are to be expected under a high level of management. Absence of yield indicates crop is not suited to the soil or is not commonly grown in it.)

Soil series and mapping units	Corn A	Corn B	Wheat A	Wheat B	Alfalfa A	Alfalfa B	Soybeans A	Soybeans B	Pasture A	Pasture B
	Bu	Bu	Bu	Bu	Tons	Tons	Tons	Tons	Cow-acre-days	Cow-acre-days†
Allen:										
AeC	48	75	34	51	2.1	3.3	23	35	135	195
AeD	46	68	30	46	2.1	3.1	-	-	135	180
AeE	-	-	-	-	-	-	-	-	125	170
AnD3	32	50	24	36	1.7	2.4	-	-	90	150
Atkins: At	35	50				-	22	30	80	135
Bewleyville:										
BeB	58	92	36	54	2.3	3.4	27	40	115	195
BeC	55	85	34	52	2.2	3.3	21	36	115	195
Bodine: BdF				-					55	90
Bonair: Bn	42	68		-			20	33	105	180
Bouldin: BoF			-			-				
Christian:										
ChC2	42	60	32	47	2.0	2.9	17	21	120	165
ChD2	40	55	30	44	1.9	2.6	-	-	110	165
CnC2	40	56	32	44	2.0	2.5	16	20	125	165
CnD2	32	52	28	41	1.8	2.4	-	-	105	150
CnE2	-	-	-	-	-	-	-	-	95	135
CsD3	-	-	20	33	1.4	1.9	-	-	75	110
Curtistown: CuB	75	115	38	54	2.6	3.8	28	43	150	225

*Adapted from USDA Soil Conservation Service, 1981.

†Cow-acre-days is a term used to express the grazing capacity of pasture. It is the number of animal units (one cow, one steer, one horse, one mule, five sheep, or seven hogs) carried per acre multiplied by the number of days the pasture is grazed during a single grazing season without injury to the sod. For example, an acre of pasture that provides 30 days of grazing for two cows has a grazing capacity of 60 cow-acre-days.

APPENDIX A.6

Examples of Yield Data from State Crop Reporting Services

Alabama

Average Crop Yields by County, 1977-1978

County	Corn	Soybeans	Wheat	Hay
Bibb	26	22	26	2
Blount	37	24	34	2
Cherokee	34	23	28	2
Choctaw	31	25	17	2
Cullman	27	24	31	2
DeKalb	36	23	29	2
Etowah	40	25	36	1
Fayette	30	21	29	2
Franklin	35	21	26	1
Jackson	35	22	27	1
Jefferson	23	24	33	2
Marion	36	22	24	2
Marshall	43	20	24	2
Morgan	35	19	25	2
Shelby	22	21	33	1
St. Clair	36	21	27	2
Tuscaloosa	19	20	27	2
Walker	21	26	28	2
Winston	30	19	29	2

APPENDIX A.6

Kentucky

Average Crop Yields by County, 1977-1978

County	Corn	Soybeans	Wheat	Alfalfa hay	All other hay
	Bu	Bu	Bu	Tons	Tons
Bell	80	-	-	-	2
Boyd	85	-	-	-	2
Breathitt	90	-	-	-	2
Butler	89	30	33	-	2
Caldwell	81	30	30	3	2
Carter	80	-	-	-	2
Christian	82	31	39	3	2
Clay	83	-	-	-	2
Clinton	85	30	-	-	1
Crittenden	80	27	31	2	2
Daviess	101	32	32	3	2
Edmonson	76	30	-	3	2
Elliott	80	-	-	-	2
Estill	91	-	-	-	1
Floyd	79	-	-	-	1
Grayson	80	30	27	3	2
Greenup	83	32	-	3	2
Hancock	90	30	29	-	2
Harlan	75	-	-	-	1
Henderson	92	31	39	3	2
Hopkins	86	27	32	-	2
Jackson	80	-	-	-	2
Johnson	84	-	-	-	2
Knott	82	-	-	-	1
Knox	73	-	-	-	1
Laurel	84	-	-	-	1
Lawrence	82	-	-	-	1
Lee	82	-	-	-	2
Leslie	70				
Letcher	85	-	-	-	-
Magoffin	75	-	-	-	2
Martin	75	-	-	-	-
McCreary	78	-	-	-	1
McLean	101	34	36	-	2
Menifee	80	-	-	-	2
Morgan	88	-	-	-	2
Muhlenberg	83	28	29	-	1
Ohio	90	30	30	-	2
Owsley	78	-	-	-	2
Perry	75	-	-	-	-

APPENDIX A.6

Kentucky

(Continued)

County	Corn	Soybeans	Wheat	Alfalfa hay	All other hay
	Bu	Bu	Bu	Tons	Tons
Pike	85	-	-	-	2
Pulaski	93	33	34	3	2
Rockcastle	98	33	-	3	2
Union	96	34	37	4	1
Warren	89	32	33	3	2
Wayne	101	34	31	-	2
Webster	93	30	35	3	1
Whitley	73	-	-	-	1
Wolfe	92	-	-	-	1

Tennessee

Average Crop Yields by County, 1977-1978

County	Corn	Soybeans	Wheat
	Bu	Bu	Bu
Anderson	62	23	33
Bledsoe	54	23	29
Campbell	70	25	28
Claiborne	68	23	30
Cumberland	71	27	29
Grundy	69	22	29
Hamilton	51	24	36
Marion	51	22	28
Morgan	73	29	29
Overton	80	23	33
Putnam	71	27	30
Rhea	50	21	33
Scott	74	-	30
Sequatchie	53	26	27
Van Buren	61	25	27

APPENDIX A.6

Pennsylvania

Average Crop Yields by County, 1977-1978

County	Corn silage	Corn grain	Wheat	Alfalfa	Other hay
	[illegible]	Bu	Bu	Tons	T
Allegheny	15	94	32	2	1
Armstrong	15	94	30	3	2
Beaver	15	92	37	3	2
Bedford	15	94	31	3	2
Blair	16	95	36	3	2
Bradford	14	91	38	2	2
Butler	16	94	33	3	2
Cambria	14	88	29	2	2
Carbon	14	91	26	3	2
Centre	16	95	33	3	2
Clarion	16	95	26	3	2
Clearfield	14	86	28	2	1
Clinton	16	95	31	2	1
Columbia	15	93	30	3	2
Dauphin	13	98	31	3	2
Elk	15	74	34	3	2
Fayette	13	96	33	2	2
Fulton	13	94	25	2	1
Greene	16	96	30	3	2
Huntington	15	95	30	3	1
Indiana	15	90	29	2	2
Jefferson	15	97	26	2	2
Lackawana	11	80	29	2	2
Lawrence	15	96	32	3	2
Luzerne	15	90	29	2	1
Lycoming	14	98	30	3	2
Mercer	15	93	34	3	2
Northumberland	17	93	30	2	2
Schuylkill	15	87	34	3	1
Somerset	16	94	31	3	2
Sullivan	14	86	32	2	1
Tioga	14	92	28	2	2
Venango	20	94	28	2	2
Washington	17	95	32	2	2
Westmoreland	16	96	35	3	2

APPENDIX A.6

West Virginia

Average Crop Yields by County, 1977-1978

County	Wheat	Corn
Barbour	-	82
Boone	-	73
Braxton	-	80
Brooke	-	82
Cabell	-	70
Fayette	-	65
Gilmer	-	69
Grant	29	78
Greenbrier	34	84
Harrison	-	77
Kanawha	-	75
Lewis	-	74
Lincoln	-	74
Marion	-	73
Marshall	30	67
Mason	34	83
Mercer	35	68
Mineral	33	72
Monongalia	-	69
Nicholas	31	72
Ohio	34	79
Preston	32	81
Putnam	33	72
Raleigh	-	78
Randolph	35	85
Summers	32	79
Taylor	-	75
Tucker	32	82
Upshur	-	79
Wayne	-	73

APPENDIX A.6

Virginia

Average Crop Yields by County, 1977-1978

County	Wheat	Corn
	Bu	Bu
Buchanan	-	79
Dickenson	-	85
Lee	33	87
Russell	31	84
Scott	32	84
Tazewell	32	79
Wise	-	87

Appendix B

Supplemental Information on an Inventory System for Evaluating Revegetation

APPENDIX B.1

Statistical Bases for Critical Levels

Hypothesis

The null hypothesis and alternative hypothesis for woody plant stocking and vegetative cover are given below:

Woody plant stocking	Vegetative cover
H_o: $\rho = .45$	H_o: μ (%)
H_a: $\rho < .45$	H_a: μ (%) $< 70\%$

Where ρ is estimated by p, the proportion of milacre plots stocked with one woody stem or more; and μ (percentage) is estimated by the percentage of the marks or pins out of 20 that have vegetative cover.

The critical values (number of plots with one or more wood stem, and average number of plots out of 20 with vegetative cover) are the smallest means possible to have with the upper end of the 90 percent confidence intervals including the specified value of the population (450 woody plants per acre and 70 percent stocking of vegetative cover)

Sample sizes and error levels

This procedure will correctly identify adequately vegetated areas 9 out of 10 times in the long run. However, 1 time out of 10, the sampling procedure will indicate an area is inadequately vegetated, when in fact, the area is adequately vegetated. This is Type I error, which occurs 10 percent of the time, a level determined by the specification of a 90 percent confidence level by the Regulations.

Inadequately vegetated areas are also subject to either correct or incorrect classification. Correct classification (an inadequately vegetated area being designated as such) should have a high probability of occurring while misclassification (occurrence of Type II error) should have a low probability. The probability of Type II error is determined by (1) the probability selected for Type I error, (2) the sample size, and (3) the true population value. The relation of these variables is summarized with operating characteristic curves (Acheson 1974).

From the operating characteristic curves for determining woody plant stocking, the following table was developed which presents values of actual stocking resulting in Type II error equal 10 percent for various sample sizes.

Sample size (n)	Actual stocking (trees per acre) resulting in Type II error of 10% for given sample size
50	265
100	315
150	340
200	350

The presence or absence designation used for woody plants results in a binominal distribution. The binominal distribution has the attractive feature of variance (npq) being specified when the mean is specified (np) (Hodges and Lehmann 1964). This is not the case with the normal distribution, which was used to describe the distribution of the number of marks or pins per sample with vegetative cover. Two standard deviations (σ) were assumed: 9 and 3 based on the near-worst case and a more moderate case.

The following table presents the actual percentage of cover which results in Type II error being 10 percent for combinations of three sample sizes and two standard deviations.

Sample (h)	Standard deviation (σ)	Actual vegetative cover (%) resulting in Type II error of 10% for given sample size
50	3	64.5
100		66.5
200		67.5
50	9	53.5
100		58.0
200		61.0

Sample size

Based on these two tables and their underlying operating characteristic curves, desired sample size was selected to be 100. This was based on the large gain in stocking and cover which had Type II error being 10 percent when the sample size was increased from 50 to 100 but smaller gain for increased sample sizes beyond 100.

Appendix B.2

Modification of Ground Cover Sampling Procedures to Other Levels of Ground Cover or Other Confidence Levels or Both

The procedure for ground cover sampling described in the handbook is designed to test for 70 percent cover at the 90 percent confidence level. Other percentages of ground cover can be tested by first calculating the average number of points vegetated out of 20 that this new percentage of cover would result in; i.e., 80 percent would be 16 out of 20, 90 percent, 18 out of 20. Then this number is substituted for 14.0 in step 13, Part B, figure 3.6 and figure 3.7 of the inventory system description.

New confidence levels are obtained by substituting values from a table of Student's t-distribution for those in step 11 of the figures mentioned above. The values must be for a one-tailed test, which is also called a test with sign considered. The three values are for 40 degrees of freedom, 60 degrees of freedom, and 120 degrees of freedom, respectively.

Appendix B.3

Modification of Woody Plant Stocking Sampling Procedures to Other Levels of Stocking or Other Confidence Levels or Both

The procedure [1] for evaluating woody plant stocking described in the handbook tests for 450 stems per acre on moderate slopes and 600 stems per acre on steep slopes. The confidence level is 90 percent. The minimum numb of stocked plots for various total numbers of plots is the lowest number of plots out of the total that results in an upper confidence limit larger than the desired number of stems per acre divided by 1,000. The confidence interval is that associated with a binomial distribution (Cochran 1977).

For different levels of desired stocking or different confidence levels, new critical values can be obtained by using the computer program presented in appendix B.4. The input for this program consists of the values for Student's-t for 40, 60, and 120 degrees of freedom at the desired confidence level, and the desired number of woody stems per acre. The value for Student's-t are for a one-tailed test. These four values are entered on one card following the program deck with each having five-card columns. An example for 450 stems per acre at the 90 percent confidence level is include with the program

Appendix B.4

Program to Calculate Minimum Number of Stocked Plots

```
THIS  PROGRAM CALCULATES THE MINIMUM NUMBER OF PLOTS NEEDED WITH
AT LEAST ONE WOODY STEM TO HAVE A SPECIFIED LEVEL OF STOCKING.
THE RANGE FOR THE TOTAL NUMBER OF PLOTS EXAMINED IS FROM 50 TO 200.
THE MINIMUM NUMBER OF PLOTS IS ONE MORE THAN THAT WHICH RESULTS IN
THE UPPER CONFIDENCE LIMIT BEING LESS THAN THE DESIRED LEVEL OF
STOCKING EXPRESSED AS A PROPORTION OF 1000.
THE INPUT IS ONE CARD WITH VALUES OF STUDENT'S T FOR 40 DF, 60 DF,
AND 120 DF IN CARD COLUMNS 1-6, 7-12, AND 13-18. IN CARD COLUMNS
19-23, INSERT THE DESIRED NUMBER OF TREES PER ACRE. THIS CARD
FOLLOWS THE  //GO.SYSIN DD * CARD
READ(5,1) T40,T60,T120,STOCK
FORMAT(3F6.4,F5.0)
STKPER=STOCK/1000.
WRITE(6,5) STOCK
FORMAT('1 TOTAL NUMBER OF PLOTS   MINIMUM NUMBER OF STOCKED PLOTS
1 TO HAVE',F5.0,'STEMS PER ACRE')
DO 2 NUMPLT=50,200,5
UPLIM1=1.000
PLTNUM=DFLOAT(NUMPLT)
T=T40
IF(NUMPLT.GE.60)T=T60
IF(NUMPLT.GE.120)T=T120
STKPLT=AINT((PLTNUM*STKPER)+1.)
P=STKPLT/PLTNUM
STDDEV=((P)*(1-P)/(PLTNUM-1.))**.5
UPLIM2=P+((T*STDDEV)+(0.5/PLTNUM))
IF(UPLIM1.GE.STKPER.AND.UPLIM2.LT.STKPER)GO TO 3
STKPLT=STKPLT-1.
IF(STKPLT.LE.0)GO TO 7
UPLIM1=UPLIM2
GO TO 6
CRSTPL=(PLTNUM*P)+1.0
NMPTP4=NUMPLT+4
WRITE(6,4)NUMPLT,NMPTP4,CRSTPL
FORMAT(' ',I8,'-',I8,3X,F10.0)
GO TO 2
WRITE(6,8)
FORMAT(' NUMBER OF STOCKED PLOTS LESS THAN ZERO')
CONTINUE
STOP
END
```

(See program example on next page)

Appendix B.4

(Continued)

Program Example for Stocking at 450 Stems per Acre

TOTAL NUMBER OF PLOTS	MINIMUM NUMBER OF STOCKED PLOTS
50 - 54	18
55 - 59	20
60 - 64	22
65 - 69	24
70 - 74	26
75 - 79	28
80 - 84	30
85 - 89	32
90 - 94	35
95 - 99	37
100 - 104	39
105 - 109	41
110 - 114	43
115 - 119	45
120 - 124	47
125 - 129	49
130 - 134	51
135 - 139	53
140 - 144	56
145 - 149	58
150 - 154	60
155 - 159	62
160 - 164	64
165 - 169	66
170 - 174	68
175 - 179	70
180 - 184	73
185 - 189	75
190 - 194	77
195 - 199	79
200 - 204	81

GLOSSARY

Cropland means land used for production of row crops, small grain crops, nursery crops, orchard crops, and other similar specialty crops.

Grazing capacity means the maximum stocking rate possible at which livestock can graze without inducing damage to vegetation or related resources.

Half-shrubs are perennial plants with a woody base whose annually produced stems die back each year.

Pastureland means land used primarily for long-term production of forage plants for livestock consumption either by grazing or as hay or ensilage.

Prime farmland means land having the potential for the production of food, feed, forage, fiber, and oilseed crops and possessing soil qualities, growing season, and moisture supply needed to produce sustained high yields of a variety of crops economically when treated and managed according to modern farming methods utilizing minimal amounts of energy and resource inputs relative to output and having minimal environmental impact. The land must also have historically been used for cropland.

Reference area means a land unit maintained under appropriate management for the purpose of measuring vegetation ground cover, productivity, and plants species diversity produced naturally or by crop production methods approved by the regulatory authority.

Shrubland means land used primarily for growing woody, multistem perennial plants unsuited for commercial forests and utilized mainly by wildlife.

Stocking rate means the actual number of animals on a specific area at a specific time, expressed in animal unit months or animal unit days.

Technical standard means a productivity or percentage ground cover level that must be attained for a reclaimed area to be equivalent to unmined areas for specific plant type, land uses, and growth situations