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EVALUATION OF AREAS FOR OFF-ROAD RECREATIONAL MOTORCYCLE USE. V-ETC(U)
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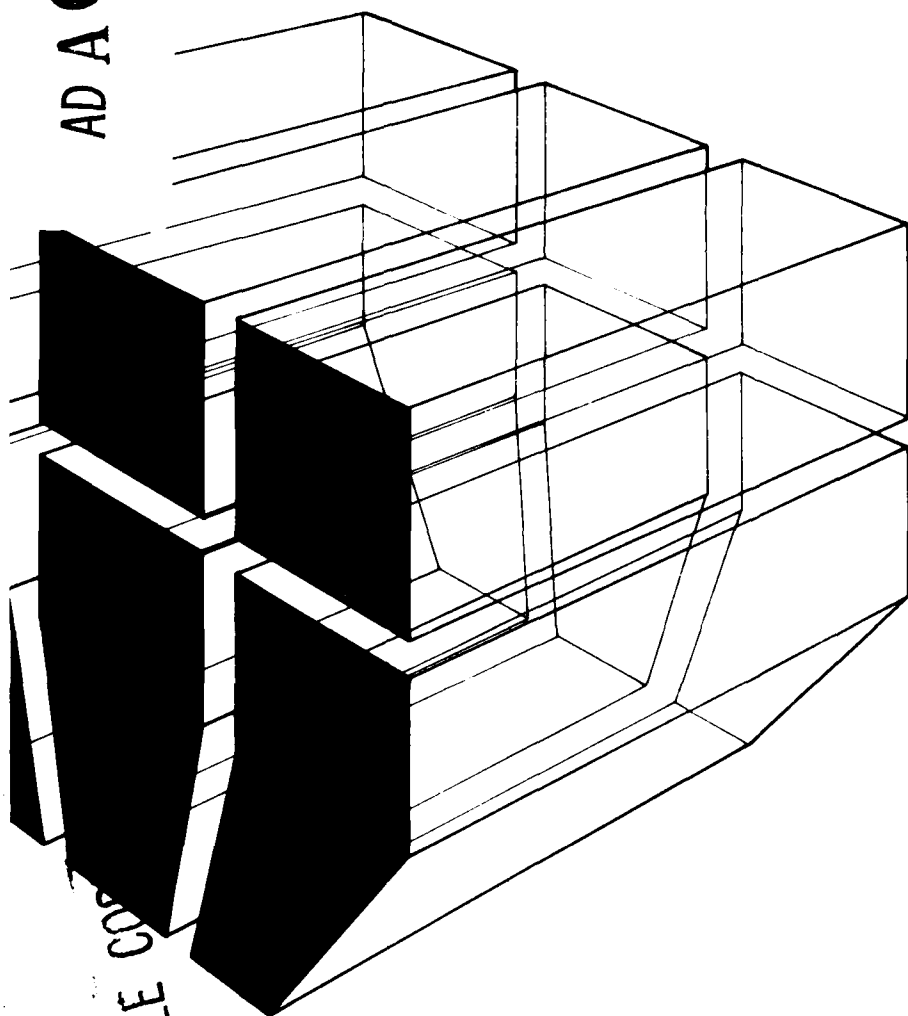


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TECHNICAL REPORT N-86
November 1980
Guidelines for Natural Resources Management
and Land Use Compatibility

EVALUATION OF AREAS FOR OFF-ROAD
RECREATIONAL MOTORCYCLE USE
VOLUME II: ALTERNATE SOIL
SUITABILITY DETERMINATION METHODS

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by
R. M. Lacey
H. E. Balbach

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Volume I of this report described how to evaluate the soil suitability of areas for off-road recreational motorcycle (trailbike) use on land under the jur- isdiction of the Department of the Army. This soil evaluation method relied on the availability of a recent, detailed soil survey. Since such surveys are not always available, Volume II describes alternative methods of evaluating the sui- tability of soils for trailbike use.		

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Volume II illustrates and describes seven alternative soil evaluation methods. Each method is defined as more or less useful in terms of its reliability and the ease and speed by which its results may be obtained. Included are descriptions of simple ways to conduct the field and laboratory soil analyses required when using alternative soil evaluation methods.

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FOREWORD

This investigation was performed for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task B, "Land Use Planning"; Work Unit 024, "Guidelines for Natural Resources Management and Land Use Compatibility." The applicable QCR is 3.01.001. The OCE Technical Monitor was Mr. Donald Bandel, DAEN-MPO-B.

The work was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (CERL). Dr. E. W. Novak was Acting Chief of CERL-EN.

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EVALUATION OF AREAS FOR OFF-ROAD RECREATIONAL MOTORCYCLE USE VOLUME II: ALTERNATE SOIL SUITABILITY DETERMINATION METHODS

1 INTRODUCTION

Background

Over the past decade there has been a rapid increase in the production, sale, and use of off-road recreational vehicles (ORRVs). These vehicles include snowmobiles, dune buggies, trailbikes, all-terrain vehicles, swamp buggies, four-wheel drive trucks, and many more. Their widespread use prompted President Nixon to issue Executive Order 11644 in 1972 and President Carter to issue Executive Order 11989 in 1977.¹ These orders require that public lands in the custody of the Federal government be evaluated for potential use by ORRVs. They establish policies and procedures to insure that ORRV use on public lands is controlled and directed so as to protect natural resources, promote the safety of all users, and minimize conflicts among various land uses.

In response to these Presidential orders, Army Regulation (AR) 210-9 was issued in 1975, and revised 1 July 1978.² This AR charges Army personnel with determining the suitability of installation lands for ORRV use. To help in this task, researchers at the U.S. Army Construction Engineering Research Laboratory (CERL) developed a method to evaluate land areas for off-road recreational motorcycle (trailbike) use. Guidance for conducting this evaluation is in Volume I.³ The principal components of the evaluation method described in Volume I are:

1. An examination of existing land use to determine areas which are incompatible with trailbike use.
2. The establishment of noise buffer zones around noise-sensitive land uses.
3. The establishment of potential candidate areas for ORRV use.
4. An evaluation of the soil suitability of candidate areas.
5. An examination of other environmental factors which would restrict ORRV use in a candidate area.
6. Site selection and trail development of candidate areas found to be acceptable for trailbike use.

One of the major elements of this evaluation is the determination of soil suitability; procedures used to determine soil suitability range from simple to highly complex. Although the mechanics of the soil suitability determination method described in Volume I are reliable and easy to do, it uses sophisticated information; its success depends on the availability of reliable soil survey information.

While many Army installations have detailed soil survey information, many do not. Therefore, the methods and soil analysis techniques presented in this report represent acceptable alternatives to the soil suitability determination method described in Volume I. These alternatives are intended to be as nontechnical as possible so that they may be used by persons who may be familiar with soils and their characteristics, but who are not necessarily professional soil scientists. This was done primarily because most installations do not have professional soil scientists on staff and/or may not be able to obtain the services of such a professional.

¹ U.S. President (Richard Nixon), 1972, Executive Order 11644, "Use of Off-Road Vehicles on the Public Lands," *Federal Register*, Vol. 37, No. 178, 28778-8, signed U.S. President (Jimmy Carter), 1977, Executive Order 11989, "Off-Road Vehicles on Public Lands," *Federal Register*, Vol. 42, No. 109, 20926-6.

² *Army Regulation (AR) 210-9, "Off-Road Vehicle Use,"* Army Regulation (AR) 210-9 (Department of the Army, 1 July 1978), R. E. L. 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1-1514, 1-1515, 1-1516, 1-1517, 1-1518, 1-1519, 1-1520, 1-1521, 1-1522, 1-1523, 1-1524, 1-1525, 1-1526, 1-1527, 1-1528, 1-1529, 1-1530, 1-1531, 1-1532, 1-1533, 1-1534, 1-1535, 1-1536, 1-1537, 1-1538, 1-1539

Many of these alternative methods and techniques have been adapted from standard field and laboratory soils examination methods. However, standard methods are often highly technical and expensive. Therefore, some of the more intricate and time-consuming steps of the standard methods have been simplified or modified. The adaptations have been field tested and reviewed for technical accuracy. While the adaptations affect the absolute accuracy of some methods, results will be reliable enough to identify areas which may or may not be acceptable for trailbike use.

Objective

The objective of this study is to provide information for evaluating soil suitability for motorcycle use. This volume identifies seven alternative methods.

Approach

A literature search was conducted to gather data on available soil survey and testing methods. In addition, professional soil scientists with the U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS), the University of Illinois, and other organizations were consulted.

Soil survey and testing methods considered adaptable to the soil suitability evaluation requirements developed for trailbike-use areas (Volume I) were field tested to determine the ease and speed with which they could be used. During the tests, seven distinct scenarios (in terms of data availability and the use of survey and testing methods) were identified. The survey and testing methods which were most applicable to each scenario were combined to create seven alternative evaluation methods. The survey and testing methods were then modified to make them (1) as nontechnical as possible and (2) maintain their reliability as tools for each of the seven evaluation methods.

Scope

The methods described in this report are specifically oriented toward evaluating soil suitability for recreational trailbike use. Competitive events are not considered, nor is the use of other types of ORRVs or tactical vehicles.

Mode of Technology Transfer

Information and techniques contained in this report will be incorporated into an Army Technical Manual which will provide guidance for evaluating areas for trailbikes, snowmobiles, four-wheel drive vehicles, and competitive events.

2 ALTERNATIVE METHODS

Approach

A simple way to determine and document soil suitability is to develop a soil limitations map.⁴ Soil limitations ratings are used to develop these maps. Limitations ratings define the degree of limitation which a soil has for a particular use, i.e., slight, moderate, or severe. For example, a particular soil in an area being considered for trailbike use might be rated as having severe limitations because it has many large stones in its surface layer.

The following are definitions of slight, moderate, and severe limitations.

1. **Slight** is the rating given to soils and areas where soils have properties acceptable for trailbike use. The degree of limitation is minor and environmental damage is expected to be below average. Good performance and low maintenance can be expected.

2. **Moderate** is the rating given to soils and areas where soils have properties moderately acceptable for trailbike use. This degree of limitation can be overcome or modified by special planning, design, or trail maintenance. Some soils rated *moderate* require treatment such as artificial drainage, control for runoff to reduce erosion, or some modification of certain features through manipulation of the soil, e.g., removal of large stones.

3. **Severe** is the rating given to soils and areas where soils have one or more properties that are unacceptable for trailbike use, such as steep slopes, high organic matter, flooding, a seasonal high water table, or a high erodibility factor. This degree of limitation generally requires major soil reclamation, special design, or intensive maintenance. Some of these soils can be improved by reducing or removing the soil feature that limits use; however, in most situations, it is difficult and costly to alter the soil or to design the trail so as to compensate for a severe degree of limitation.

Special soil interpretations are required to rate soils for a particular use. Accordingly, CERL researchers have cooperated with the staff of the SCS Soil Survey Interpretations Division in the development of a guide for rating soil limitations for trailbike trails (Table 1); this table can be used to rate every soil series in the United States which has been identified by the SCS. If the resource manager evaluating an area has a recent soil survey, complete with series maps, he or she can directly use these limitations ratings to develop the limitations map. However, limitations ratings can only be directly applied if there is a recent, detailed survey available.

Since the rating guide is the essential tool for determining soil suitability, the seven methods described in this report identify alternative ways to apply it. Each method represents an identifiable scenario in terms of (1) combinations of soil survey availability, (2) the extent to which the assistance of a soil scientist is available, and (3) dependence on original field survey techniques. Each alternative is evaluated for its reliability and the ease and speed with which it can be used by Army field personnel.

Elements of the Alternative Methods

The alternative methods to determine soil suitability for trailbike use are shown in the flow chart in Figure 1. A discussion of each block or element in the flow chart and diagrams illustrating each alternative method and its use are given below.

Choose Candidate Area

Candidate areas for trailbike use should be selected as described in Volume I; generally, two or more areas are chosen after all incompatible and noise-sensitive land uses and noise buffer zones have been eliminated from consideration.⁵ If possible, candidate areas should range in size from 100 to 250 acres (40 to 100 hectares), as portions of these areas will probably be eliminated from consideration for

⁴ L. J. Bartelli, et al (Editors), *Soil Surveys and Land Use Planning* (Soil Science Society of America and American Society of Agronomy, 1966)

⁵ Also see *Evaluation of Areas for Off-Road Recreational Motorcycle Use*, ETN 80-9 (Department of the Army, Office of the Chief of Engineers, 4 March 1980)

Table 1
Guide for Rating Soil Limitations for
Trailbike Use

Property	Limits			Restrictive Feature
	Slight	Moderate	Severe	
1. USDA Texture	---	---	ICE	Permafrost
2. Fraction > 3 in. (wt %) (surface layer)*	<10	10 - 25	>25	Large stones
3. Depth to high water table, ft (m)	>2 (0.6) ---	1-2 (0.3-0.6) ---	0-1 (0-0.3)	Wetness Ponding
4. Erosion factor (K) x % slope	<2	2 - 4	>4	Erodes easily
5. USDA Texture (surface layer)	---	---	SC,SIC,C	Too clayey
6. USDA Texture (surface layer)	---	LCOS,VFS	COS,S,FS	Too sandy
7. Unified (surface layer)	---	---	OL,OH,PT	Excess humus
8. Slope (%)	0 - 25	25 - 40	>40	Slope
9. Coarse fragments (wt %) (surface layer)	<40	40 - 65	>65	Small stones
10. USDA Texture (surface layer)	---	SIL,SI VFSL,L	---	Dusty
11. Flooding	NONE,RARE OCCASSIONAL	FREQUENT	---	Floods
12. Other ⁺	---	---	---	Fragile

* Soils in UST, TOR, ARID, BOR, or XER suborders, great groups, or subgroups rate one class better.

** 100 minus the percent passing No. 10 sieve.

⁺ If the soil is easily damaged by use or disturbance, rate as "Severe-Fragile."

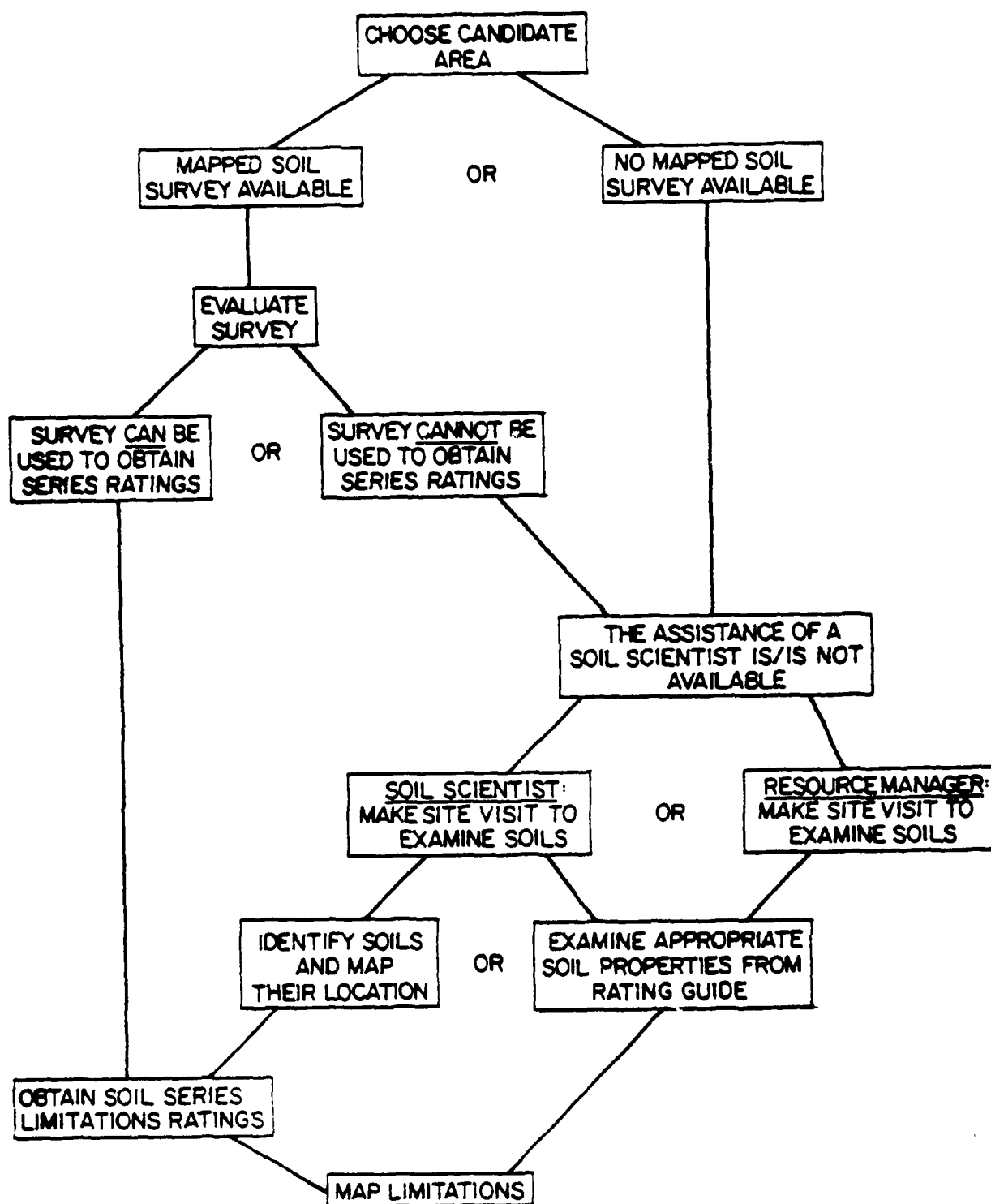


Figure 1. Alternative methods of determining soil suitability -- flow chart.

use because of soil limitations. Depending on user demand and type of terrain, a final trailbike-use area will range in size from 20 to 250 acres (8 to 100 hectares).

Mapped Soil Survey Available

If a candidate area has a mapped soil survey that is available to the user, the pathways on the left-hand side of Figure 1 are followed.

No Mapped Soil Survey Available

If no mapped soil survey of a candidate area is available, the pathways on the right side of Figure 1 are followed.

Evaluate Survey

Although current SCS soil classification is based on the *Comprehensive Soil Survey System*, the concepts behind soil classification, identification, and interpretation have remained basically the same since 1950; since 1957, information in detailed SCS surveys has been very consistent.⁶ Detailed surveys done after 1950 are generally still in print and are available from state SCS offices. For these reasons, post-1950 SCS surveys are defined as *recent* soil surveys and are, in most cases, considered readily applicable for use with the methods outlined in Volume I of this report.* SCS soil surveys done before 1950 and surveys done at any time by other agencies may or may not be readily applicable. The following criteria can be used to determine if surveys are usable:

1. The survey includes a map on which the soils' boundaries are indicated.
2. The survey is a detailed survey; therefore, the mapping units are soil series names and/or series names and phases, e.g., Smolan silt loam, 1 to 4 percent slopes; or Smolan silty clay loam, 4 to 8 percent slopes, eroded.

The following criteria can be used to determine if the surveys are not usable:

1. The survey was done according to soil associations. A soil association is a group of defined and named soil types occurring together in an individual and characteristic pattern over a geographic area. Because soils included in associations are of varying properties, it is difficult to evaluate the actual soil suitability of an area, since the spatial distribution of each soil is not easily determined.
2. The survey does not include a map of the location of the soils, or the scale of the mapping is not useful, e.g., an entire state, or a scale of 1:500,000.
3. The survey identifies soils by texture name, engineering property, or other characteristic with no indication of the series or association names.
4. The survey uses soil names which do not correspond to existing SCS series names.
5. The survey is no longer reliable because of earthmoving operations in the area.

The best test of a survey is to attempt to obtain soil series limitations ratings for the soils identified in it (see p 14).

Survey Can Be Used to Obtain Series Ratings

If the evaluation of an area's existing soil survey reveals that it can be used to obtain series limitations ratings, the left-hand pathway in Figure 1 is used.

⁶ Soil Survey Staff, *Soil Classification -- A Comprehensive System -- 7th Approximation* (USDA, August 1960), and Nyle C. Brady, *The Nature and Properties of Soils*, 8th Ed. (MacMillan Publishing Co., Inc., 1974), p 318.

* An explanation of how to apply these methods to the selection and evaluation of trailbike-use areas is given in Volume I of this report.

Survey Cannot Be Used to Obtain Series Ratings

If the evaluation of an area's existing soil survey reveals that the survey cannot be used to obtain series limitations ratings, the right-hand pathways in Figure 1 are used. These pathways represent essentially the same approaches recommended if there is no mapped soil survey of the area. However, even though a survey cannot be used to directly obtain series ratings, it may be used as a source of information when making field examinations.

The Assistance of a Soil Scientist Is/Is Not Available.

A memorandum of understanding established between the Department of Defense and the USDA authorizes execution of cooperative agreements in the attainment of mutual conservation objectives.⁷ Many Army installations and activities have also established cooperative agreements with the state or local offices of the USDA SCS. In most other instances, local SCS offices will provide short-term assistance without an established cooperative agreement. If soil limitations ratings cannot be obtained by using an existing soil survey, or if there is no survey for the area, the user should ask an SCS or other professional soil scientist for help. (The state or local SCS office may be able to recommend one or more local consulting soil scientists.)

Soil Scientist: Make Site Visit to Examine Soils

If assistance from SCS personnel (or other soil scientist) is available, the soil scientist should visit each alternative site and examine the soils.

Resource Manager: Make Site Visit to Examine Soils

If cooperation and/or assistance from the SCS cannot be obtained, and other professional scientists are unavailable, the installation natural resource manager, agronomist, or other official must make the site visit. Chapter 3 lists simple survey techniques which the resource manager can use to examine an area's soils.

Identify Soils and Map Their Location

An experienced soil scientist can survey up to 250 to 500 acres per day (100 to 200 hectares per day). Generally, if an installation has an effective cooperative agreement with the SCS, a 1 to 2 day visit by an experienced soil scientist for the purpose of identifying and mapping soils should cost little or nothing. A site visit of more than 2 days, or a survey of a significant amount of acreage, can generally be obtained on a 50 percent shared-cost basis. If a site visit by SCS personnel (or a private consultant) can be organized, it is best to have the soil scientist identify and map the location of soils by soil series names and phase. The identification and mapping techniques should be the same as those used in a detailed county survey.

Examine Appropriate Soil Properties From the Rating Guide

If SCS or other professional assistance is limited because of budgetary and/or manpower constraints and a detailed soil survey of alternative areas cannot be performed, the SCS soil scientist (or private consultant) should be asked to examine the soils on the basis of Table 1. As noted earlier, Table 1 was developed by a cooperative effort between CERL and the SCS. The SCS has developed similar guides for other uses, e.g., playgrounds and septic tank absorption fields. The interpretation of soil suitability for these other uses is normal procedure as part of the National Cooperative Soil Survey being conducted by the SCS. Since its development, the guide in Table 1 has been included in the National Soils Handbook with the other guides. As a result, state or local SCS offices should be familiar with the guide and should be able to assess soil suitability for trailbike use fairly quickly.

Using Table 1, the soil scientist can examine the most important soil properties, identify the restrictive features which may limit trailbike use, and determine the degree of limitation for that use. He or she should then prepare a map of the area which will illustrate those portions of the area with slight, moderate, and/or severe limitations. This map need not be elaborate; a simple hand sketch (which can be easily reproduced) is sufficient. The soil scientist should supplement this map by indicating why

⁷ *Natural Resources - Land, Forest, and Wildlife Management*, AR 420-74 (Department of the Army, 1 July 1977), p 2-1

each portion of the area was rated slight, moderate, or severe. When determining this rating, the highest degree of limitation should apply. For example, if a soil occurs on 0 to 10 percent slopes in an area where the water table is greater than 2 ft (0.61 m) deep and is a silty clay (SIC), it should be rated as having severe limitations because it is "too clayey." It is rated severe even though it has only slight limitations for wetness and slope (Table 1).

If professional assistance is not available, the installation resource manager and/or agronomist who makes the site visit will need to examine several of the soil properties indicated in Table 1, i.e., soil texture, slope, erodibility, depth to high water table, presence of large and small stones, and frequency of flooding. These soil properties can be examined and mapped using simple survey and analysis techniques (Chapter 3).

Obtain Soil Series Limitations Ratings

Soil limitations ratings may be obtained from either of two sources; state or local SCS offices or the major command (MACOM) natural resource offices of the Training and Doctrine Command (TRADOC) and Forces Command (FORSCOM) and the Natural Resources Section of the Installation and Services Activity (I&SA) of the Materiel Development and Readiness Command (DARCOM).

SCS Offices. Since the rating guide in Table 1 has been included in the National Soils Handbook, SCS field personnel will be familiar with it and may have already rated local soils for potential trailbike use. To obtain ratings from the state or local SCS offices, it will be necessary to prepare a list of each soil series or phase found in candidate-use areas. This is done by examining the published survey(s) which cover the areas, if available, and/or the soils map which is prepared in the field by an experienced soil scientist. This list and all other appropriate material is then taken to the nearest state or local SCS office and appropriate assistance is requested.

MACOM Offices. As noted earlier, every soil in the U.S. which has been identified by the SCS has been rated for its suitability for trailbike use. These limitations ratings are available from the MACOM natural resources offices of TRADOC and FORSCOM and the Natural Resources Section of the I&SA, DARCOM.* To obtain these ratings from these offices, it will again be necessary to prepare a list of each soil series or phase found in the candidate-use areas. Once this list is prepared, a request for the soil limitations ratings for each soil on this list is then forwarded to the appropriate MACOM office. (Appendix A gives a sample of user instructions which will accompany soil limitations ratings obtained from the MACOM offices.)

Map Limitations

The final step in evaluating soil suitability is to prepare a soil limitations map. To do this, a soil base map should be prepared. This map should illustrate the location of every soil series or series phase which is found in a candidate area. This base map can be made by reproducing the soil map found in the soil survey, if available. Otherwise, the field maps prepared by the cooperating soil scientist or the resource manager should be reproduced. A detailed explanation of map preparation and interpretation is given in Chapter 4.

Relative Usefulness of Each Alternative Method

Each of the seven alternative methods is considered more or less useful than the other methods. This usefulness is relative and is defined in terms of the *reliability* of the soil survey and/or field map, and the ease and speed with which each method can be accomplished. Also considered is the cost of each method. The amount of effort and accuracy which the resource manager and/or soil scientist applies to each method determines its absolute utility.

Figures 2 through 8 illustrate each method. Table 2 briefly describes each method's positive and negative aspects. Method 1 is considered the most usable and is discussed in depth in Volume 1 of this

* About 13,000 soils have been identified by the SCS. Soil property data for each of these soils is stored in files on computer tape. Using the trailbike rating criteria, and with the help of the SCS and the Statistical Laboratory at Iowa State University, CERL has accessed these files and developed the ratings. Paper copies of the limitations ratings are voluminous. Therefore a limited distribution to only the MACOM natural resource offices was appropriate.

Table 2

**Positive and Negative Aspects of Alternative Methods for
Evaluating Soil Suitability for Recreational Trailbike Use**

Alternative Method	Positive Aspects	Negative Aspects
No. 1	• Availability of mapped survey provides usable background information on soil properties. • Uses most recent published data. • Requires little or no additional field work. • Generally does not require that funds be spent for a consultant. • Accomplished fairly rapidly • Requires little or no technical effort to prepare limitations map • Use of detailed data results in very reliable limitations map	• Evaluation of available survey will require some expertise/experience in working with soils. • Depends on the usefulness and reliability of existing survey
No. 2	• Availability of mapped survey provides usable background information on soil properties • Input of professional soil scientist yields very reliable data • Uses recent detailed field data • Requires little or no technical effort to prepare limitations map • Use of detailed data results in very reliable limitations map	• Evaluation of available survey will require some expertise/experience in working with soils. • Since existing survey cannot be used directly - varying degrees of field effort are required • Requires preparation of agreement or contract with a soil scientist • May require that funds be spent for consultant • Preparation of detailed field survey may require substantive consultant effort and time
No. 3	• Input of a professional soil scientist yields very reliable data	• Lack of existing mapped survey requires the development of soil maps without the

Table 2 (Cont'd)

Alternative Method	Positive Aspects	Negative Aspects
No. 3	• Uses, recent detailed field data • Requires little or no technical effort to prepare limitations map • Use of detailed data results in very reliable limitations map	• Lack of valuable background information • Lack of existing mapped survey increases the amount of field effort required • Requires preparation of agreement or contract with a soil scientist • May require that funds be spent for consultant • Preparation of detailed field survey may require substantive consultant time and effort
No. 4	• Availability of mapped survey provides usable background information on soil properties • Input of a professional soil scientist yields very reliable data • Since consultant is not required to prepare a detailed survey, field effort and time is reduced.	• Evaluation of available survey will require some expertise/experience in working with soils • Since existing survey cannot be used directly varying degrees of field effort are required • Requires preparation of agreement or contract with a soil scientist • May require that funds be spent for consultant • Use of a nondetailed survey reduces the reliability of the limitations map
No. 5	• Input of professional soil scientist yields very reliable data • Since consultant is not required to prepare a detailed survey.	• Lack of existing mapped survey requires the development of soil maps without the aid of valuable background information

Table 2 (Cont'd)

Alternative Method	Positive Aspects	Negative Aspects
No. 5	field effort and time is reduced.	• Lack of existing mapped survey increases the amount of field effort required. • Requires preparation of agreement or contract with a soil scientist. • May require that funds be spent for consultant • Use of a nondetailed survey reduces the reliability of the limitations map.
No. 6	• Availability of mapped survey provides usable background information on soil properties. • Does not require preparation of agreement or contract with a soil scientist • Generally does not require that funds be spent for consultant.	• Evaluation of available survey will require some expertise/ experience in working with soils. • Since existing survey cannot be used directly, varying degrees of field effort are required. • Lack of input from a professional soil scientist decreases reliability of survey data. • Requires a significant amount of in-house time and effort. • Soils information and survey may not be extremely reliable • Use of a nondetailed survey reduces the reliability of the limitations map
No. 7	• Does not require preparation of agreement or contract with a soil scientist. • Generally does not require that funds be spent for consultant	• Lack of existing mapped survey requires the development of soil maps without the aid of valuable background information • Lack of existing mapped survey increases the amount of field effort required

Table 2 (Cont'd)

Alternative Method	Positive Aspects	Negative Aspects
No. 7		• Lack of input from professional soil scientist decreases reliability of survey data • Requires a significant amount of in-house time and effort • Soils information and survey may not be extremely reliable • Use of a nondetailed survey reduces the reliability of the limitations map

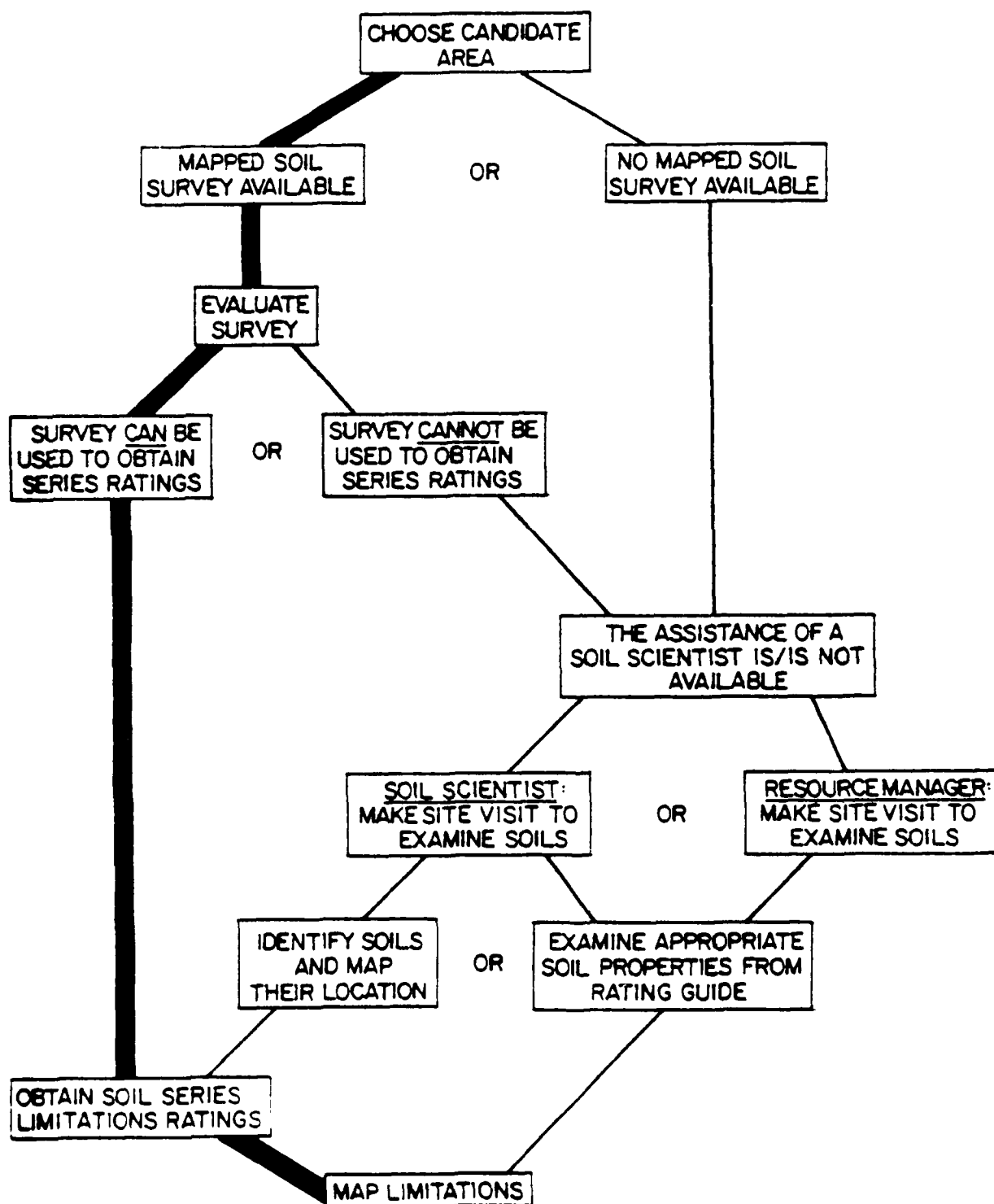


Figure 2. Method I.

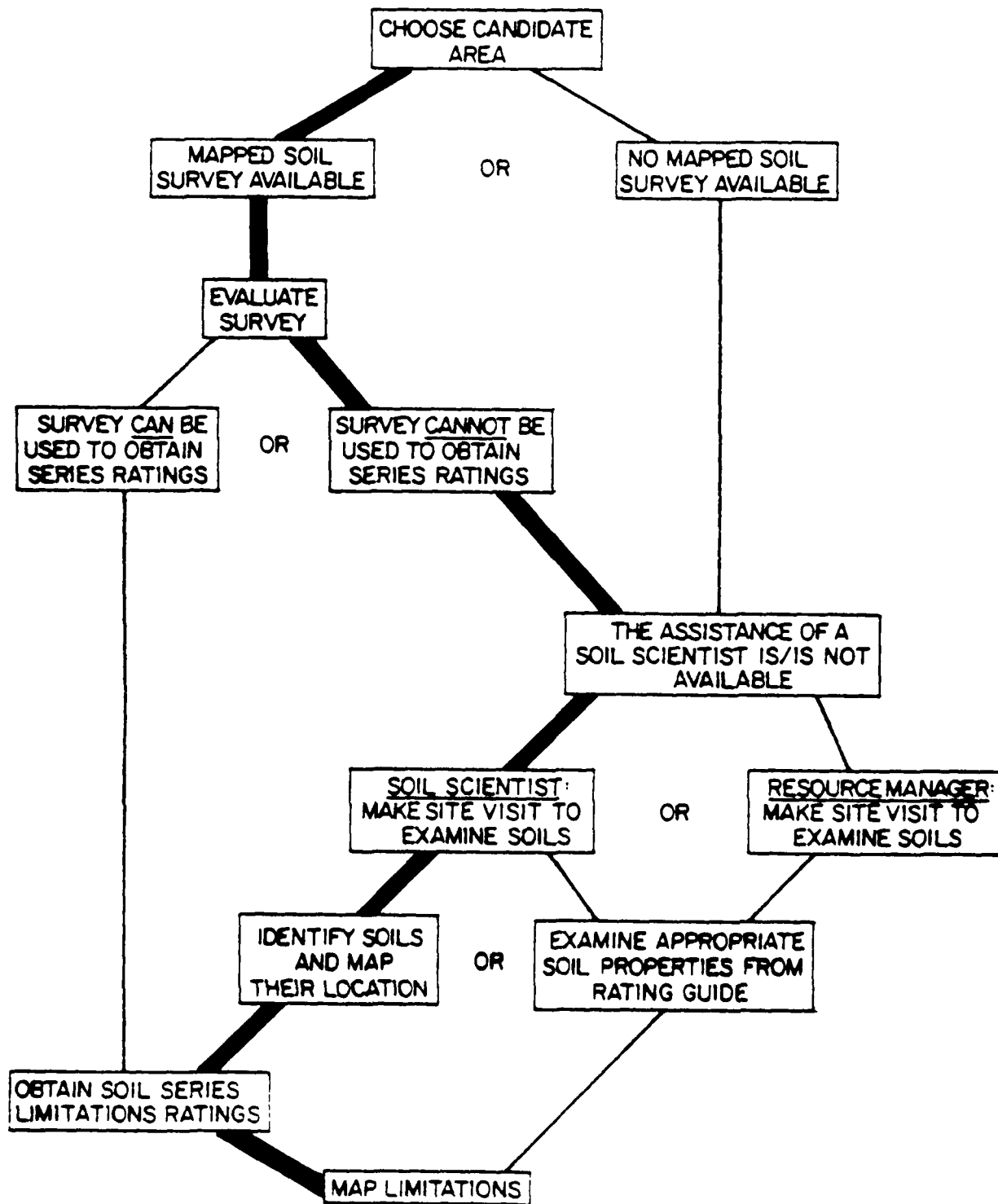


Figure 3. Method 2.

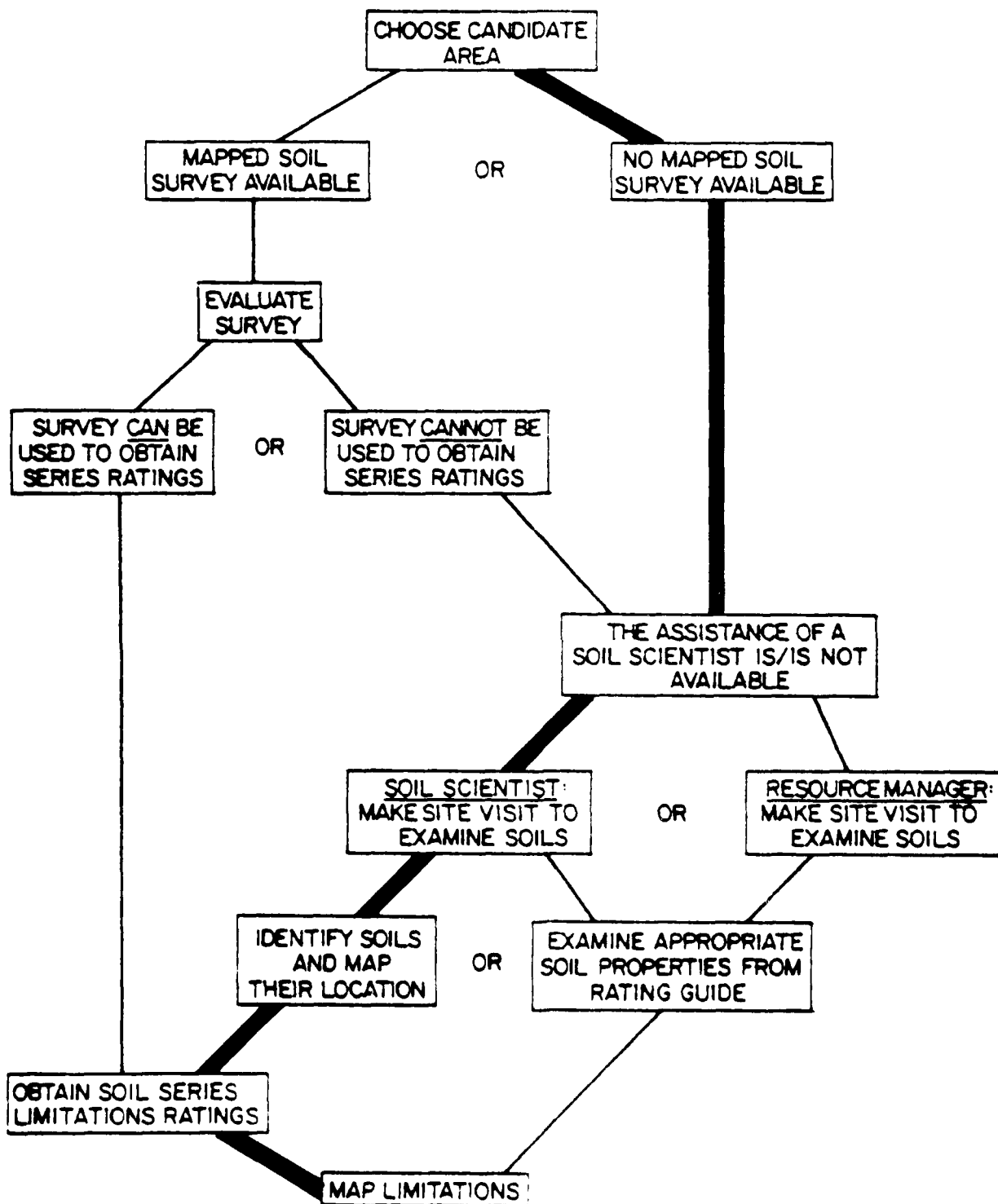


Figure 4. Method 3.

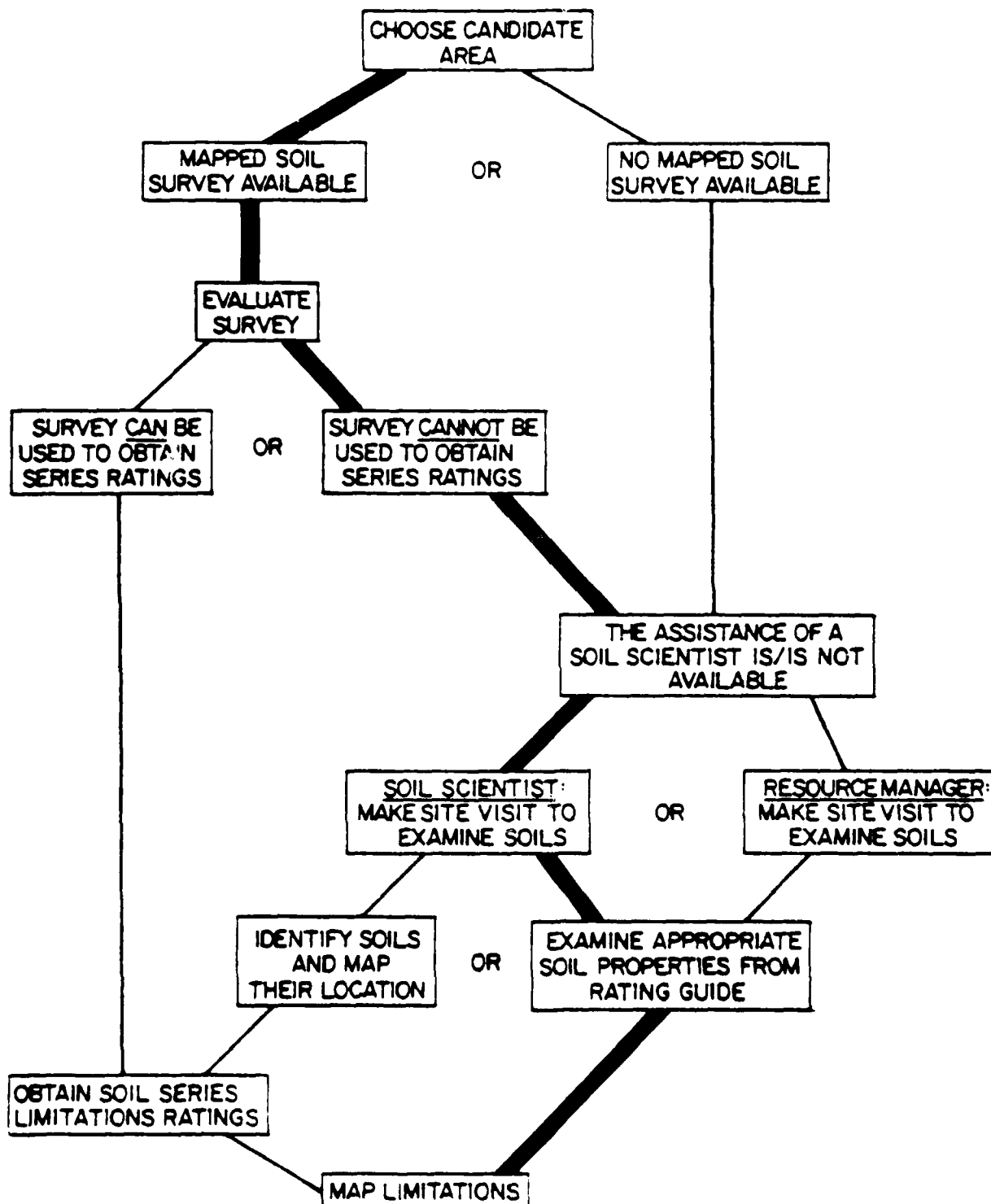


Figure 5. Method 4.

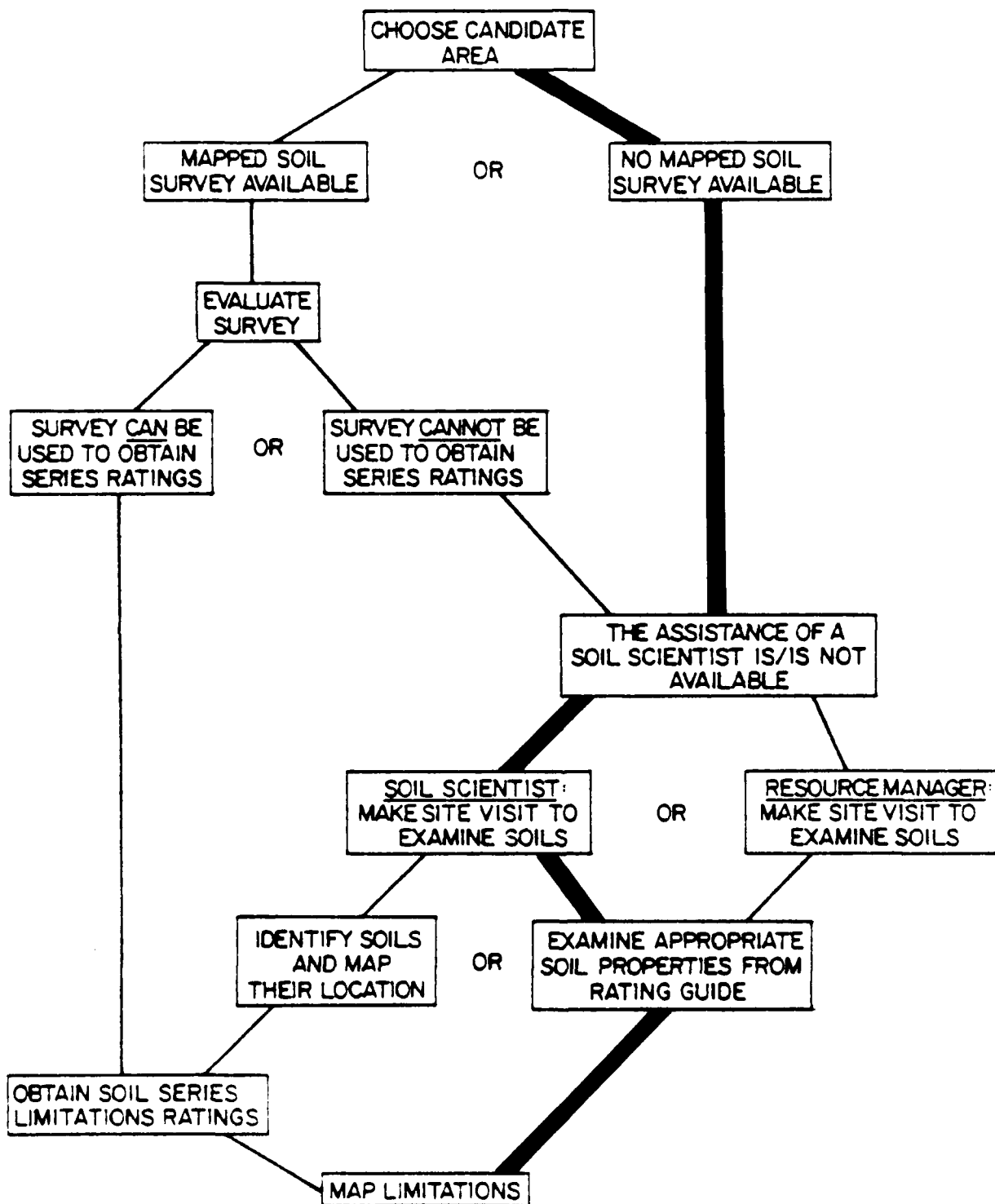


Figure 6. Method 5.

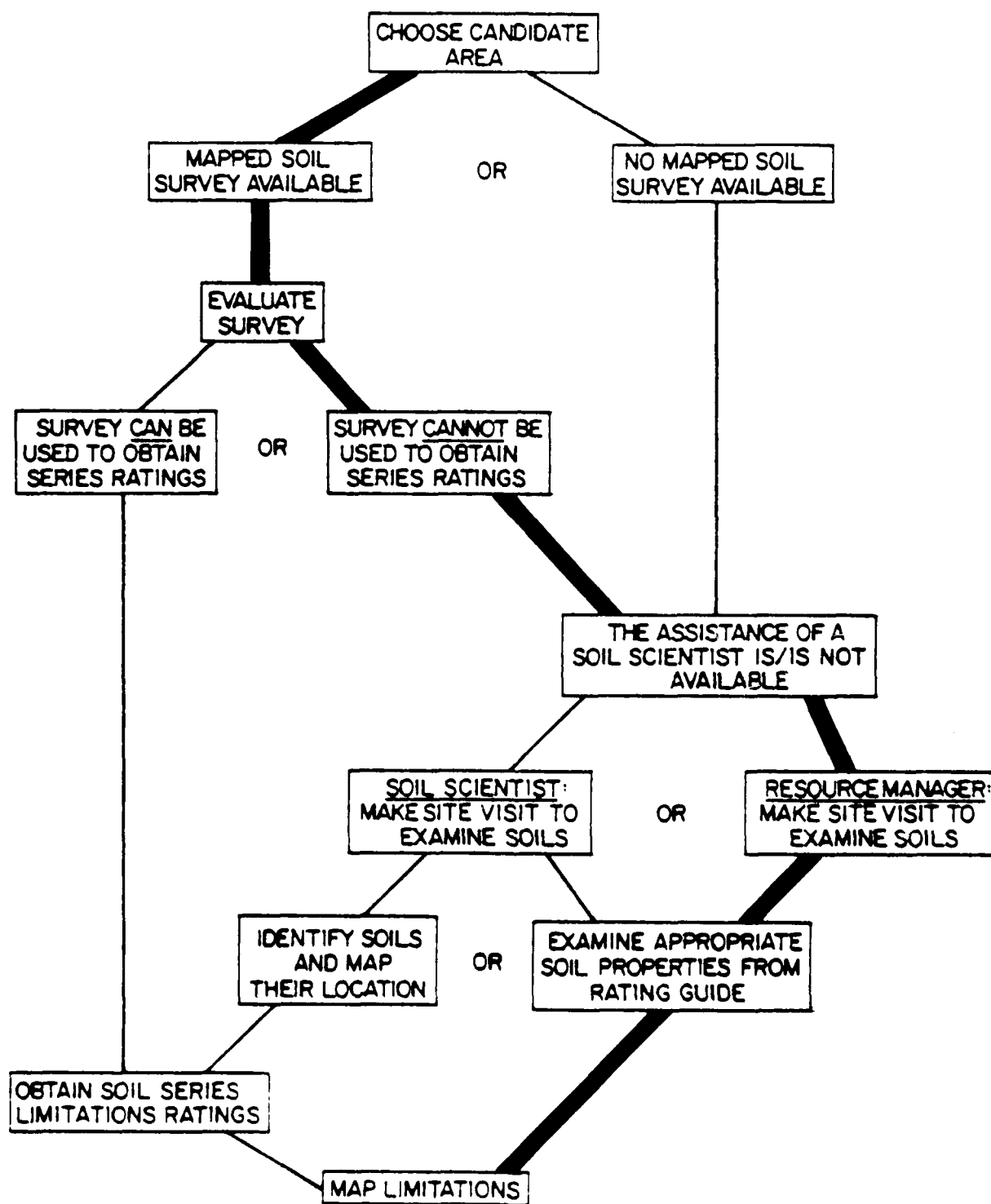


Figure 7. Method 6.

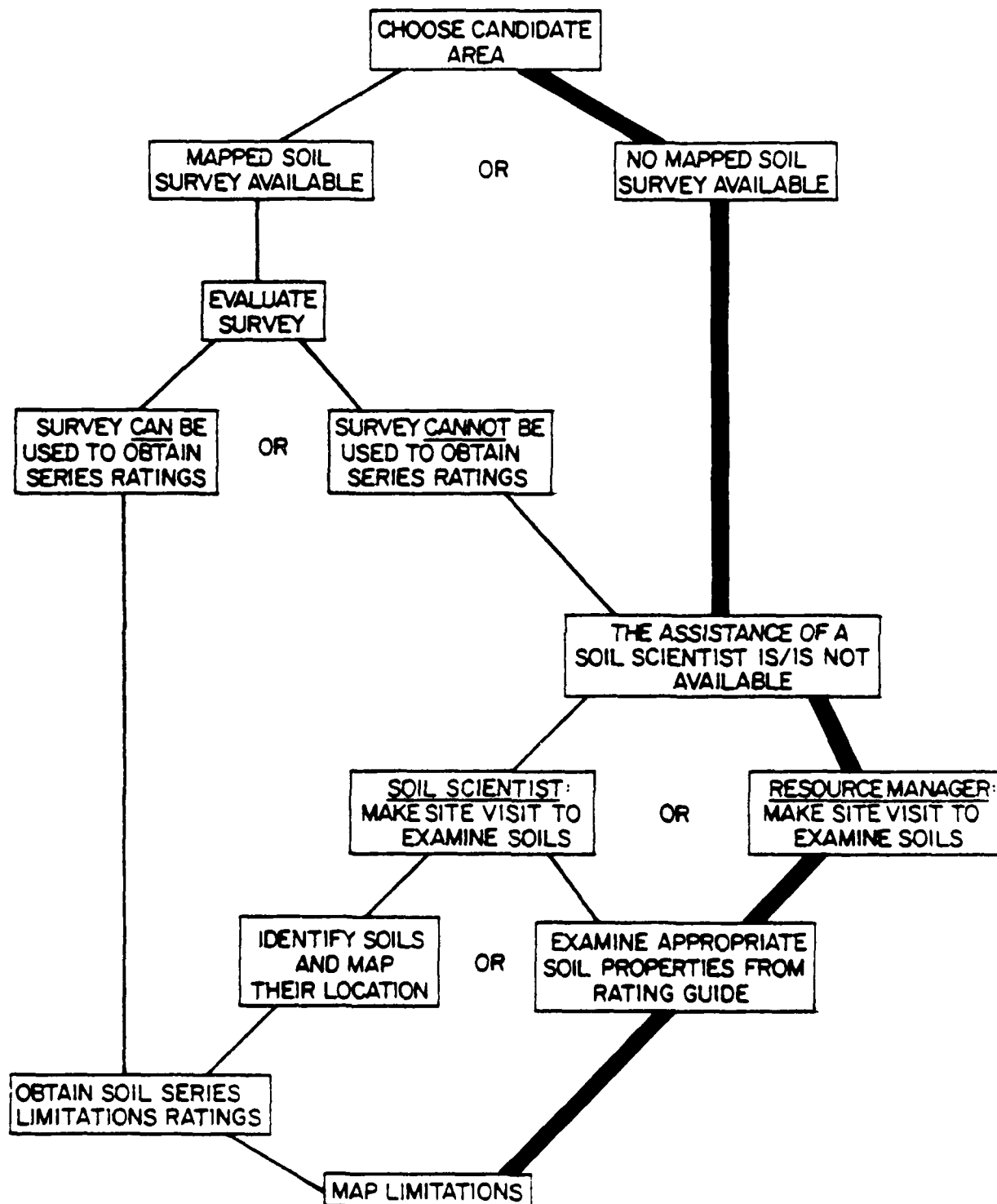


Figure 8. Method 7.

report. Method 2 is considered the next most usable, etc. Method 7 is considered the least usable and reliable; Method 7 also requires the greatest effort.

When the installation resource manager begins to evaluate an area's suitability for trailbike use, he or she should first examine the positive and negative aspects of each method. Then, based on this examination, the availability of a usable soil survey, and the extent to which the cooperation of a professional soil scientist can be obtained, the most usable and reliable method should be selected.

To use any of the seven alternative methods, the resource manager simply follows the flow chart elements and element discussions in the order in which they apply to each method. The heavier lines on Figures 2 through 8 indicate the appropriate pathways for each method.

3 FIELD TECHNIQUES FOR EXAMINING SOIL PROPERTIES

General

This chapter describes simple techniques which can be used to conduct a soil survey and identify soil properties. These techniques are intended to be used for determining soil suitability for trailbike use. Therefore, discussion is limited to those soil properties which can easily be examined and are necessary to determine suitability for this particular use. (However, the techniques can be used to evaluate soil suitability for other uses if an applicable limitations rating guide is available.)

The resource manager who uses these techniques should always allow that the results obtained are approximations. In the absence of any other data or technical/professional assistance, these techniques provide more reliable information than could be obtained from a cursory examination.

These techniques are used with Methods 6 and 7. If it becomes necessary to use them, the resource manager should reduce the candidate-use area acreage to a size which can more easily be examined, e.g., 100 to 150 acres (40 to 60 hectares).

Preparing the Soil Survey Map

Before examining the soil properties of a candidate area, it is necessary to prepare a soil base map. This can be done in either of two ways, depending on survey data availability. One way is to examine any existing soil survey of the area and, through interpretation, prepare the necessary base map. The other is to prepare an original field survey map.

Interpreting an Existing Survey

Even if an area's existing survey is not detailed enough to allow the resource manager to use Method 1, the information in the survey can still be used to prepare the soil base map. If the survey includes a map which delineates soil boundaries, the map itself should be reproduced and used as the base map. Whenever possible, soil boundaries should be drawn on a topographic map. Special care should be taken to draw the boundaries so that the original scale of the soil map corresponds to the scale of the topographic map.

An existing survey which contains written soil descriptions is extremely useful. In many cases, these descriptions will identify one or more of the properties which determine a soil's limitation for trailbike use (Table 1). Special note should be made of the property characteristics included in the soil descriptions. If the existing survey contains soil descriptions but no map, the resource manager will need to prepare a field map based on (1) a site visit and (2) any appropriate information found in the survey's soil descriptions.

Most of the existing, nondetailed surveys which are available will be general soils surveys which include general soils maps. A general soils map is prepared using soil associations as the mapping unit. Soil associations are groups of soil series which occur in individual and characteristic patterns. Association names are a combination of the soil series names. For example, the Susquehanna-Sumter-Houston Association is found in and around Fort Polk, LA and the three major soil series which make up the association are the Susquehanna, Sumter, and Houston series.

The following example describes how to interpret the information on a general soils map; this information can then be used to develop a more detailed map. This interpretation method uses the association descriptions (which generally accompany the general soils map) and a topographic map. (Note that many of the concepts described below may be applied to interpreting other surveys.)

The following hypothetical association description is written in much the same manner as most association descriptions:

HILL-CLIFF-STREAM ASSOCIATION

This is an area of very gently sloping to moderately steep clayey and silty clay soils in the northern part of the county. These soils are well drained and typify the upper reaches of small intermittent streams. The Hill soils are found on moderately sloping hillsides and make up about 60 percent of the association. They have a fine clay loam surface with a clayey subsoil. Cliff soils are found on moderately steep side slopes and make up about 15 percent of the association. They have a very fine clay loam surface and a fine clay loam subsoil. The Stream soils make up 15 percent of the association. They are found along stream beds and are very gently sloping. They have a fine silty clay loam surface and a silty clay loam subsurface. Minor soils make up the remaining 10 percent of the association.

This hypothetical association is mapped with two other associations on the association map shown in Figure 9. Figure 9 also includes a topographic map of the same area. Considering the description -- especially the locational factors of each soil and the association and topographic maps for the hypothetical area -- a relatively accurate series interpretation map can be produced by:

1. Examining each association description. The association descriptions generally indicate the percentage of each major soil in the association and their locations relative to slope.
2. Using the information from the association description and examining the elevation contours on the topographic map to interpolate between the contour lines and identify the location of each major soil in terms of slope and spatial area.
3. Drawing the soil boundaries of each soil association on the topographic map. Any difference in the scale of the general soils map and the topographic map should be taken into consideration.

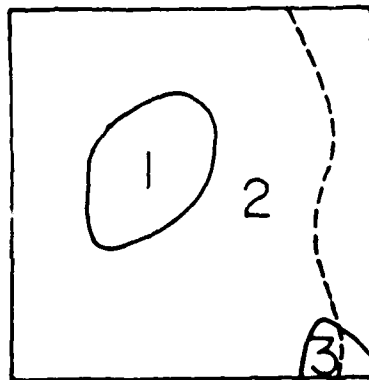
In the series interpretation map in Figure 9, the boundaries for the hypothetical Hill soils have been tentatively located on the moderately sloping hillsides (as defined by the elevation contours). Since the Hill soils make up 60 percent of the association, they are drawn to contain about 60 percent of the spatial area of the map. The remaining 40 percent of the spatial area of the map has been divided about evenly between the Cliff and Stream soils, since they are the remaining major soils and each make up about 15 percent of the association. The boundaries for the moderately steep-sloped Cliff soils have been located where the slopes are steeper (as defined by the close contour lines). The Stream soils have been located along the stream where there is a gentle slope (as defined by widely spaced contour lines).

If done carefully, this interpretation will enable the resource manager to directly apply the soil limitations ratings. Since association names are composed of the series names of each major soil in the association, the resource manager can obtain the limitations ratings for each major soil in the association and then prepare the limitations map (Chapter 4).

As a general rule of thumb, if one soil makes up 80 percent or more of an association, the entire association can be considered to have the soil properties of that one soil. Therefore, the resource manager can logically assume that the limitations of that one soil can be applied to the entire association. However, if another major soil has severe limitations, its location within the association should be noted. For example, the Cliff soils of the hypothetical association are located on moderately steep side slopes. If the Cliff soils were determined to have severe limitations, it would be best to avoid the steep side slopes of the candidate area, or at least design trails which would traverse side slopes as little as possible.

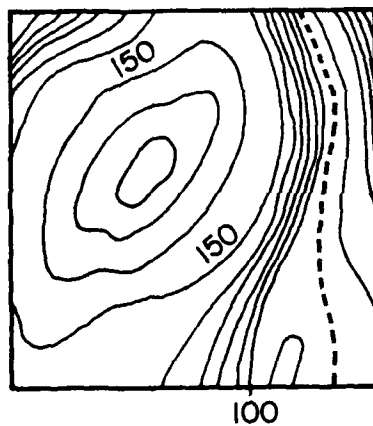
The type of detailed interpretation described above is not recommended unless the person doing the interpolation is adept at determining slope, interpreting a topographic map, and is somewhat familiar with soils and the terms used in association descriptions.

ASSOCIATION MAP

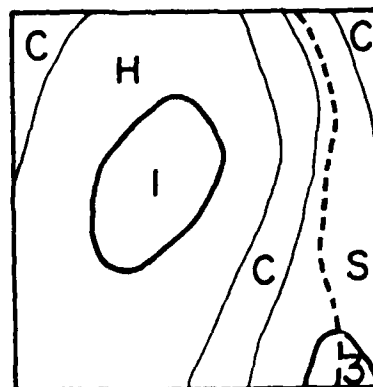


Symbol 2 represents the
Hill - Cliff - Stream
Association

TOPOGRAPHIC MAP



SERIES INTERPOLATION



H- Hill
C- Cliff
S- Stream
1- Association not
examined
3- Association not
examined

Figure 9. Association map interpolation technique

Mapping Soil Boundaries During a Field Survey

If it is necessary for the resource manager to use Method 6 or 7 (Chapter 2), a great deal of effort will be spent in preparing and correcting the soil map. Much time will be spent examining soil properties at many different test sites; such examinations are critical to the accurate definition of soil boundaries.

Since definitive procedures for preparing a field survey map are only acquired through experience, this discussion is limited to describing the basic observations which are used to initially delineate soil boundaries. The primary consideration while making these observations is the natural landscape; based on a visual survey of differences in the natural landscape, the resource manager can tentatively draw boundaries on either a topographic map or an aerial photograph of the area.*

The first and most obvious of the considerations which define differences in the natural landscape and associated soil characteristics are slope and vegetation. Slope is generally expressed in terms of a percentage -- the difference in elevation in feet for each 100 ft (30 m) horizontally. For example, a rise of 75 ft (23 m) in elevation over 100 ft (30 m) of horizontal distance is a 75 percent slope. Changes in soil type and characteristics generally correspond to changes in slope. In areas with relatively steep slopes, the resource manager should delineate on a topographic map and/or aerial photograph those places where slope changes considerably; e.g., the bottom of a hill which spreads out into an area of much gentler slopes, or the top of a bluff line which spreads out into gentler slopes towards the crest of a hill. In areas where the landscape varies less, smaller changes in slope should be identified.

Changes in the type and density of the vegetative ground cover may also indicate differences in soil properties. This is especially true where the ground has not been cultivated; in these areas, definite changes in the type of ground cover indicate changes in the chemical characteristics of the soils. In many instances, changes in vegetative cover also correspond to changes in slope.

Obvious changes in soil texture and stoniness should be marked on the field map as well as obvious changes in the color of the soil. These observable changes define differences in the spatial distribution of soil characteristics. In many instances, changes in these observable surface features will correspond to (or are an extension of) changes in slope. For example, an area at the bottom of a relatively steep slope may have a very gentle slope before it flattens out -- the area with the gentle slope will often also exhibit a significant difference in the color of the soil material.

After the resource manager has identified these changes in the natural landscape and drawn lines which indicate tentative soil boundaries on a working base map (preferably an aerial photo), he or she can begin to identify the soil properties which may restrict trailbike use. If the soil base map was prepared from an existing survey map, an examination of the appropriate soil properties should be made at two or three test sites within each soil's boundary. If the resource manager prepared the working base map from field observations, several test sites should be chosen; two or three sites should be located in the central portion of each bounded area and at least five should be located along the area's boundaries. Test sites along boundaries will give specific information on soil properties so boundaries can be adjusted to be more accurate.

Examining Soil Properties

Various field and laboratory techniques can be used to examine the soil properties listed in Table 1 (the soil limitations rating guide). This section describes one or more such techniques for each soil property; some are technical and will require the purchase of testing equipment, others are very simple and will only require time and effort. It is left to the resource manager to decide which technique he or she will use. However, to obtain the most reliable results, the more technical techniques should be used.

Each technique's description will refer to one or more of the 12 restrictive features listed in Table 1. Since there is considerable interrelationship among the properties which are examined to

* For examples of a detailed soil survey and survey maps, the reader should obtain a recent SCS survey for a county or area near his or her location. Additional information and soil survey techniques can be found in the *Soil Survey Manual*, U.S. Department of Agriculture Handbook No. 18, prepared by the Soil Survey Staff and issued August 1951; this manual is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

determine these restrictive features, they are not discussed in the order they appear in Table 1. The description of each technique is accompanied by an explanation of how to interpret the results in terms of trailbike-use suitability.

USDA Texture

Soils are composed of mixtures of various-sized particles. These particles are classified by size into gravel, sand, silt, and clay. Gravel may range from 2.0 to 76.2 mm. Sand grains feel gritty and can be seen easily (0.05 to 2.0 mm). Silt particles can be seen with a microscope and look and feel much like flour (0.002 to 0.05 mm). Clay particles are so fine (less than 0.002 mm) that they can only be seen with a very sophisticated microscope. A soil's texture is determined by the relative percentage of each particle size it contains. If a soil contains considerable quantities of at least two sizes of particles, it is known as loam. Table 3 lists the various terms and abbreviations the USDA gives to various soil textures.

An examination of USDA soil textures will help determine if a soil has limiting properties because it is a "permafrost," "too clayey," "too sandy," or "too dusty" (restrictive features 1, 5, 6, and 11 in Table 1). Two techniques for doing this are:

Texture by Hydrometer Technique. The hydrometer technique for determining soil texture is based on a mechanical analysis of the settling rates (in water) of soil particles of varying sizes. The hydrometer technique is fairly precise. However, if this technique is used, the resource manager will need to obtain several items of equipment. Fortunately, the majority of the items are relatively inexpensive. They are:

1. A soil hydrometer, calibrated at 20°C, graduated in grams per liter with a range of 0 to 50 (approximate cost: \$14).
2. A sedimentation cylinder, 64 mm in diameter and 460 mm in height. The cylinder should be marked for a volume of 1000 ml (approximate cost: \$20). In most cases, the resource manager will want to test several soil samples in a day. This means he or she will have to obtain several sedimentation cylinders.
3. A balance, sensitive to 0.1 g.

The sedimentation cylinder and the balance may be available from the laboratory of the installation's water or sewage treatment plant. If they are not available and cannot be purchased, a Corps of Engineers District office can be asked to help perform the procedures.

The hydrometer technique, as presented here, has been simplified considerably. However, if each measurement taken throughout the technique is as accurate as possible, the results will be reliable. Further information and a more technical explanation of this technique is given in Appendix V of EM 1110-2-1906.⁸ The simplified technique is as follows:

Step 1. Oven dry at least 200 g of the sample soil at 220°F (105°C) for at least 8 hours. (This can be done in a domestic oven.)

Step 2. Weigh out 50 g of oven dry soil and place it into a clean container which will hold at least 600 ml.

Step 3. Fill the container to within 5 cm (50 mm) of the top with distilled water. Add 10 ml (8 g) of sodium hexametaphosphate (trade name: Calgon).

Step 4. Allow the soil sample to soak for 15 minutes.

Step 5. Disperse (mix) the contents of the container until the soil particles are suspended in the liquid. This can be done using a paint mixer or a kitchen blender (3 to 5 minutes mixing time).

Step 6. Immediately pour and wash the mixture into the sedimentation cylinder and fill the cylinder to the 1-l. mark with distilled water.

⁸ *Laboratory Soils Testing*, Engineer Manual (EM) 1110-2-1906 (Department of the Army, Office of the Chief of Engineers, 30 November 1970)

Table 3
Abbreviations Used for Various Soil Textures*

Texture	Abbreviation	Texture	Abbreviation
Coarse sand	COS	Very fine sandy loam	VFSL
Sand	S	Loam	L
Fine sand	FS	Silt loam	SIL
Very fine sand	VFS	Silt	SI
Loamy coarse sand	LCOS	Sandy clay loam	SCL
Loamy sand	LS	Clay loam	CL
Loamy fine sand	LFS	Silty clay loam	SICL
Loamy very fine sand	LVFS	Sandy clay	SC
Coarse sandy loam	COSL	Silty clay	SIC
Sandy loam	SL	Clay	C
Fine sandy loam	FSL	--	--

*Source: USDA, Soil Conservation Service, Form SCS-SOILS-5, Soil Survey Interpretations Instructions

Step 7. Tightly cover the end of the cylinder with one hand. Shake the contents vigorously while turning the cylinder upside down and back several times. (Make sure that all soil particles are suspended in the solution and do not stick to the bottom of the cylinder.)

Step 8. Place the cylinder on a table (note the time) and quickly but gently place the hydrometer into the mixture. Record the reading of the hydrometer at the end of exactly 10 seconds and at the end of 40 seconds. The hydrometer is read at the point where the stem breaks the surface of liquid mixture at the top of the cylinder. If there is too much foam to accurately read the hydrometer, add a few drops of isoamyl alcohol or touch the foam with a piece of hand soap before taking the 10-second reading. (Ten seconds is a very short period of time, but the reading obtained if the steps are practiced a few times and done carefully will be sufficient for further calculations and should yield fairly accurate data.)

Step 9. Remove the hydrometer at the end of the final 40-second reading and wipe it clean. (Wipe the hydrometer clean with a soft cloth each time it is removed from the mixture.)

Step 10. Repeat Steps 7, 8, and 9 to check the results. Record the average for the 10- and the 40-second readings.

Step 11. At the end of 2 hours, again place the hydrometer into the cylinder for another reading. (The contents of the cylinder should not be disturbed between the 40-second and 2-hour measurement periods.)

The hydrometer readings indicate the weight of the soil particles which remain in suspension at the time of each reading. Based on Stokes' law relating the terminal velocity of a sphere falling freely through a fluid to the diameter of the sphere, the large-size sand particles will fall out of suspension first, followed by silt, then clay. At the 40-second reading, all sand particles greater than 0.05 mm will have fallen out of suspension. Therefore, the 40-second hydrometer reading indicates the weight of the silt and clay which has remained in suspension. At the 2-hour reading, only the clay particles will have remained in suspension. By calculating the weight of the particles which have fallen from suspension after each reading, the percent of sand, silt, and clay which the soil contains is determined. Knowing this, the texture of the sample can be established. (The 10-second reading is used to determine the soil erodibility [K] factor and is discussed beginning on p 44).

Table 4 describes the procedure for determining the percent of sand, silt, and clay. It can be reproduced and used as a work sheet.

To determine a soil's textural classification from the percentages of particle size, the USDA textural triangle (Figure 10) is used. To use the textural triangle locate (along the appropriate sides of the triangle) the percentages of sand, silt, and clay which were found in the sample. From those points, the lines which divide the triangle are followed to the point where all three lines intersect. For percent sand, the lines which proceed up and to the left are followed. For percent silt, the lines which proceed down and to the left are followed. For clay, lines which proceed to the right (straight across the triangle) are followed.

The heavier lines on the triangle bound areas for which soil texture classes have been named. The point where the lines extending from the sides of the triangle intersect determines the sample soil's textural classification. For example, if the intersection point falls within the area which is classified as clay, the sample soil is a clay.

As listed in Table 1, if the soil is found to fall in the textural classes sandy clay, silty clay, or clay, then it has severe limitations for trailbike use because it is "too clayey" (refer to Table 3 for textural abbreviations). If the soil is found to be a sand, then it also has severe limitations because it is "too sandy" (note that the textural triangle does not divide the sands into coarse sand, fine sand, or very fine sand; therefore, all of these textures should be considered to have severe restrictions). If the soil is a loamy sand, then it has moderate limitations because it is "too sandy" (the triangle does not define the differences in a loamy coarse sand, loamy sand, loamy fine sand, or loamy very fine sand). If the soil is found to be a sandy loam, loam, silt loam, or silt, it is "too dusty." If the soil is a sandy clay loam, clay loam, or silty clay loam, it has only slight limitations for trailbike use. Accordingly, by determining the texture of each sample soil, the resource manager establishes the soil's degree of limitation for restrictive features 5, 6, and 10 in Table 1.

Table 4

Data Sheet for Soil Texture Identification

Sample from test site	_____
1. The oven dry weight (g) of the soil sample	_____
2. The 10-second reading on the hydrometer (g)	_____
3. The 40-second reading on the hydrometer (g)	_____
4. The 2-hour reading on the hydrometer (g)	_____
* 5. Corrected 10-second reading	_____
* 6. Corrected 40-second reading	_____
* 7. Corrected 2-hour reading	_____
8. Grams of sand (after 40 seconds the sand has settled; weight is determined by subtracting the remaining grams of silt and clay [line 6] from the total weight of the soil originally (line 1))	_____
9. Percent sand in the sample ((line 8 divided by line 1) multiplied by 100)	_____
10. Percent clay in the sample ((line 7 divided by line 1) multiplied by 100)	_____
11. Percent silt in the sample (find silt by subtracting the sum of percent sand [line 9] and the percent clay [line 10] from 100)	_____

* Note that the addition of Calgon as a dispersing agent will add to the weight of the material held in suspension. The hydrometer reading should be corrected accordingly. If the resource manager used 10 ml of Calgon for each test (or 10 ml of Calgon for approximately 1000 ml of distilled water), the correction factor should be 8 g/l. Therefore 8 g should be subtracted from each hydrometer reading to obtain the corrected reading. If some other dispersing agent or ratio of Calgon in distilled water solution was used, then the correction should be determined by taking a hydrometer reading when the cylinder is filled to the 1000 ml mark with only the dispersing solution and no soil material.

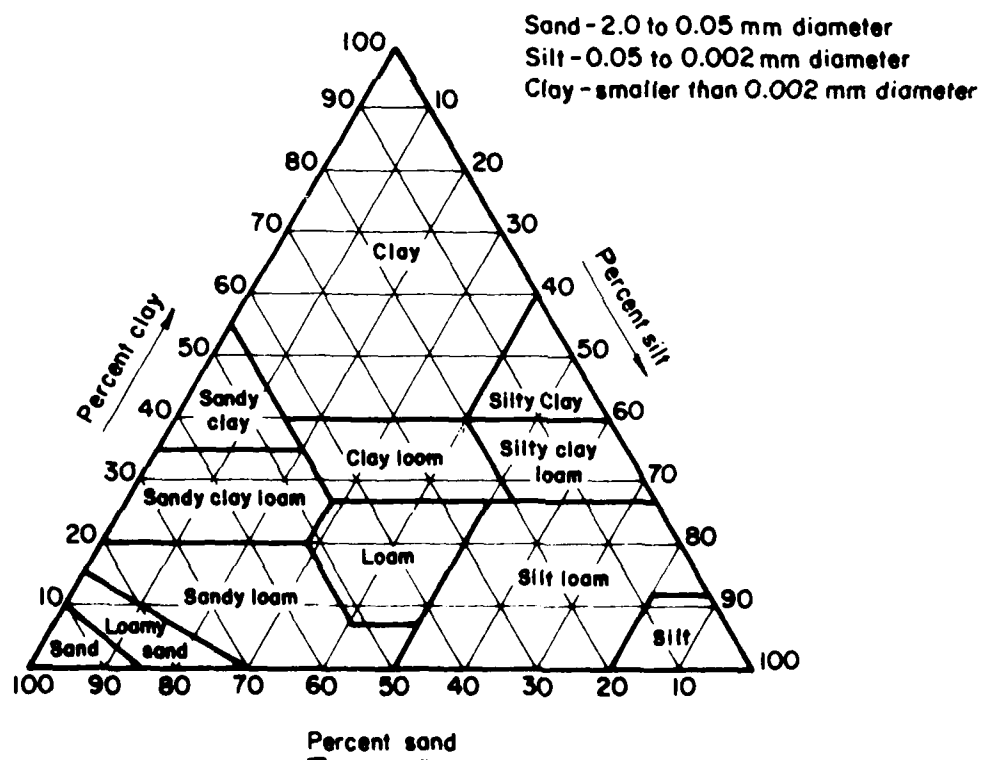


Figure 10. USDA textural classification triangle.

The restrictive feature permafrost (feature 1 in Table 1) is also defined by the property USDA texture, but it is determined in a different way. If a soil is permanently frozen at a depth of closer than 3 feet (0.9 m) from the surface, then it has severe limitations because it is a permafrost soil. This limitation can only be determined by experience. The local SCS office or a professional soil scientist should be able to provide the resource manager with this information. Soils which exhibit permafrost characteristics are found in Alaska, and in a few isolated locations in the higher elevations of the Rocky Mountains.

Texture by Feel Technique. Various ways of determining texture by feel have been developed. They are very similar in that they require the examiner to squeeze and manipulate a moistened soil sample. The following describes a technique which is simple and fairly rapid, and with practice can be used to quite accurately determine soil texture.* The technique should be done several times for each test sample in order to obtain the best estimate of soil texture. Figure 11 is the simplified textural triangle that is used with this technique.

Step 1. Moisten a sample of soil in the palm of the hand until it can be worked into a small ball the size of a nickel or quarter (add only a very small amount of water at a time). If a ball cannot be formed and the sample feels very gritty, it is probably a coarse or fine sand.

Step 2. If a ball forms, hold it between the thumb and forefinger and gradually press the thumb forward, pushing the soil into a ribbon. Work the thumb back and press forward several times until the soil ribbon breaks. If a strong ribbon forms (greater than 25 mm) the soil contains a large amount of a clay and its textural class is located in the upper part of the triangle on Figure 11. If a ribbon forms, but breaks into pieces 19 to 25 mm long, the soil is probably a clay loam and is located in the central portion of the textural triangle. If a weak ribbon (less than 19 mm) or no ribbon forms, the soil is located in the lower part of the textural triangle.

Step 3. Excessively moisten (in the palm of the hand) the same sample used in the ribbon test. Rub the soil sample (with a fair amount of pressure) with the index finger. If it feels gritty, the soil contains a large amount of sand and its textural class is located on the left side of the textural triangle. If it feels very smooth and talc-like, it contains a considerable amount of silt and its textural class is located on the right side of the triangle.

Step 4. By combining the results of Steps 2 and 3, the texture of the soil sample can be established. For example, if the soil sample formed a moderate ribbon and felt smooth and talc-like, the soil is probably a silty clay loam (Figure 11).

Once a soil's texture has been determined by the Texture by Feel technique, its limitations for trailbike use can be established. If the soil is a sandy clay, clay, or silty clay, it has severe limitations because it is "too clayey." If the soil is a sand (no ball was formed), it has severe limitations because it is "too sandy." If the sample soil was a sandy loam, loam, or silt loam, it has moderate limitations because it may become "too dusty." If the soil is a sandy clay loam, clay loam, or silty clay loam, it has slight limitations and is acceptable for trailbike use.

Stoniness

Stoniness refers to the percent of gravel, cobbles, and stones found on the surface layer of the soil. As noted earlier, gravel ranges in size from 2.0 to 76.2 mm. Cobbles range from 76.2 to 254 mm. Stones are rock fragments larger than 254 mm.

An examination of the weight percent of rock fragments found on the surface of a soil will help determine if that soil has limiting properties caused by large or small stones (restrictive features 2 and 9 in Table 1). The presence of stones in a trailbike-use area is considered a restriction, since travel over stony surfaces is generally unsafe for the rider. Large stones may cause the rider to lose control and small stones may result in poor traction on climbs and turns and/or may be thrown at trailing riders by spinning tires. Three techniques to determine the weight percentage of large and small rock fragments are described below.

*This method was adapted in part from W. L. Binwart and E. J. Husset, *Expedition Techniques* (Stipes Publishing Co., 1960) and through cooperation with Dr. E. Husset, Astronomy Department, University of Illinois.

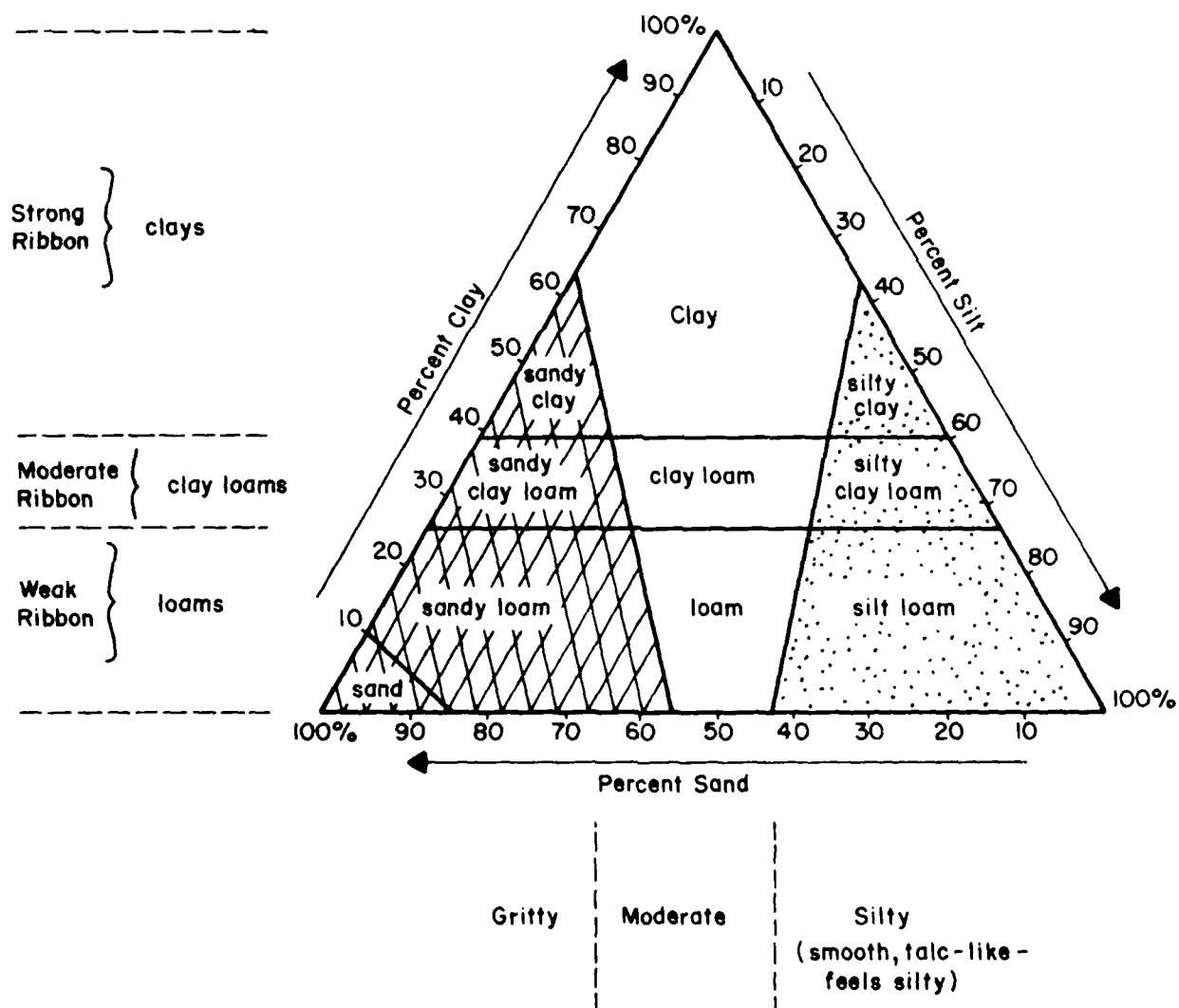


Figure 11. Simplified textural triangle.

Visual Technique. The visual technique uses estimating charts and a considerable amount of visual perception. Figure 12 gives charts for estimating the proportion of rock fragments on the surface layer. These charts are to be used in the field.

Each chart represents what the soil surface might look like if it were covered with a certain percent of rock fragments. The rock fragments are represented by black squares; and fine-textured soil material (less than 2 mm) is represented by white space between the black squares. Each quarter of any one chart represents the same percent of rock fragments as the entire chart. To illustrate this, the chart which represents 15 percent coverage by rock fragments is divided into quarters. Each quarter of the chart (as well as the entire chart) illustrates 15 percent coverage by rock fragments.

The estimating charts and visual technique are used as follows:

Step 1. Compare the coverage in black on the charts to the actual rock coverage on the ground to estimate the percent of surface coverage of rock fragments. This is more effectively done if an area on the ground is marked off, this area should be at least 1 m².

Step 2. Determine which chart or quarter-chart most closely corresponds to the number and size of rock fragments seen on the ground. This determination should be done for two different sizes of rock fragments—once for only those rock fragments greater 76.2 mm in diameter and/or length (cobbles and stones), and once for all rock fragments greater than 2 mm in diameter, i.e., all visible rock fragments (gravel, cobbles, and stones). The two estimates are necessary to determine limitations for both large and small stones.

Step 3. Convert the estimated percent of surface coverage of the large rock fragments to percent by weight using Figure 13. Enter the graph on the horizontal axis labeled "Percent of Estimated Rock Fragments (stones, cobbles and/or gravel) by Surface Coverage". On this axis, locate the percent surface coverage of rock fragments greater than 76.2 mm (large rock fragments) as estimated from the charts. Then, move vertically toward the top of the graph until intersecting the curve labeled "0% by volume stones and cobbles (> 3 in.)." Next, move horizontally to the left until intersecting the axis labeled "Percent of Rock Fragments by Weight." The value of this intersection point is the percent by weight of the large stones in the soil's surface layer.

Step 4. Determine the percent by weight for small stones (restrictive feature 9) by entering the graph from the horizontal axis at the point which represents the estimated percent surface coverage of all rock fragments. Then, move vertically upward until intersecting the curve which represents the percent of surface coverage by large rock fragments. Next, move horizontally to the left until intersecting the left-hand axis. The value at this intersection is the percent by weight of small stones (coarse fragments ranging from 2.0 to 76.2 mm) in the soil's surface layer.

If this technique results in a percent by weight of large rock fragments greater than 25, the sample soil has severe limitations for trailbike use because of "large stones." If the percent by weight is 10 to 25, the soil has moderate limitations. If the percent by weight is less than 10, the soil has slight limitations due to "large stones." If the value of the percent by weight of small rock fragments is greater than 65, the sample soil has severe limitations for trailbike use because of "small stones." If the percent by weight of small stones is from 40 to 65, the soil has moderate limitations. If the percent value is less than 40, the soil has slight limitations for trailbike use.

Sampling Technique. The visual technique to determine limitations caused by stoniness is considered fairly accurate. However, if it is desirable to more accurately determine the limitations, the resource manager should use the sampling technique. With this technique, the examiner marks off an area on the ground. This area should be at least 1 m², the larger the area which is marked off, the more accurate the sample will be.

Once this sampling plot has been established, all surface rock fragments greater than 2.0 mm are collected. Each rock fragment is measured. The radius of each round fragment is determined; and used as input into the equation to determine the area of a circle; πr^2 or 3.14 x the radius squared. For example, a rock fragment with a radius of 25 mm will represent a surface area coverage of 20 cm². The sum of the area values will indicate the approximate surface area of the sample plot which is covered by round fragments. If the rock fragments are rectangular, the surface area covered by those fragments are the sum of the area values of each rock fragment. For example, two rock fragments which are each approximately 50 mm wide and 130 mm long cover a total area of 130 cm². Two values for surface

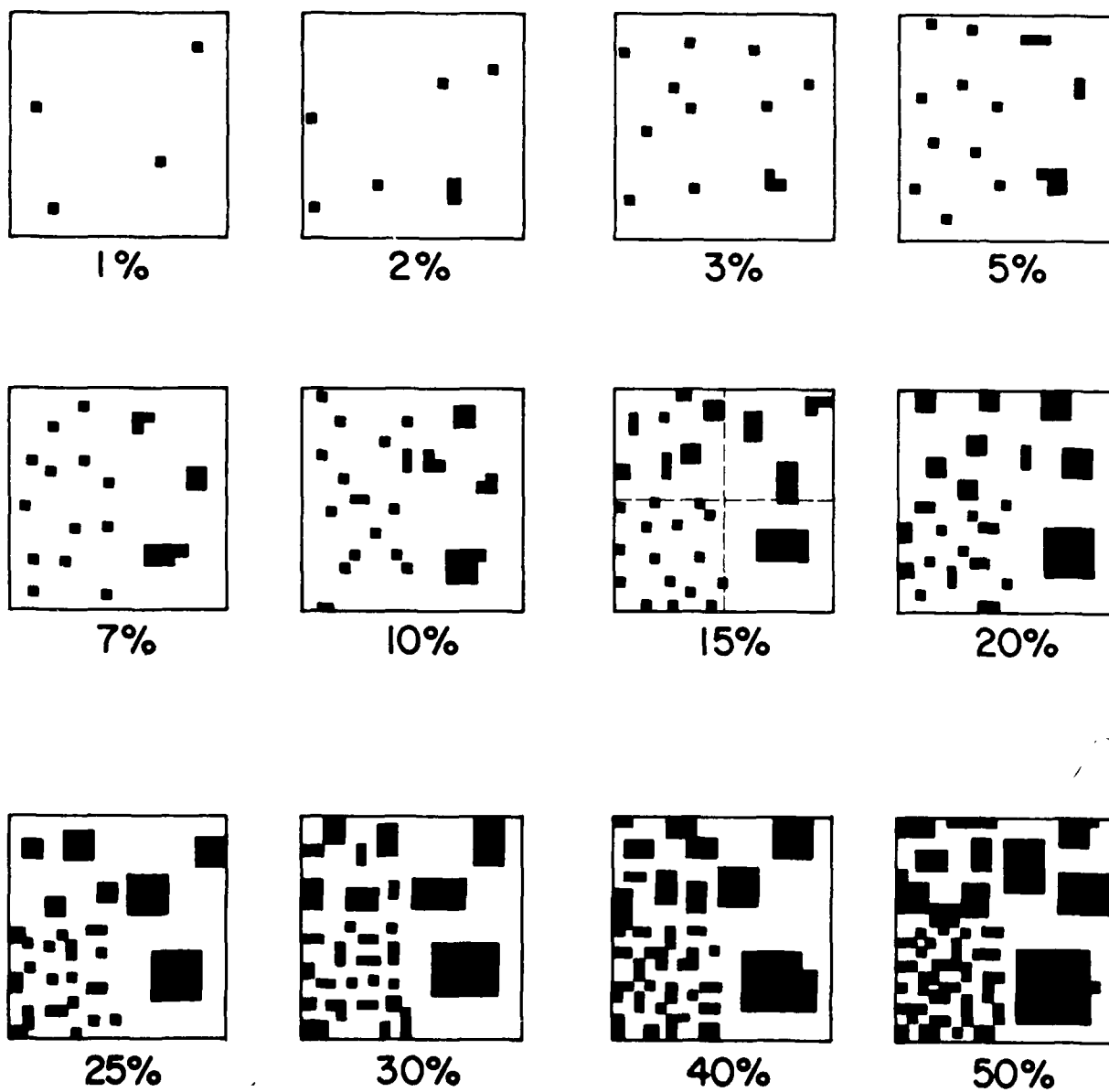


Figure 12. Charts for estimating proportions of rock fragments.

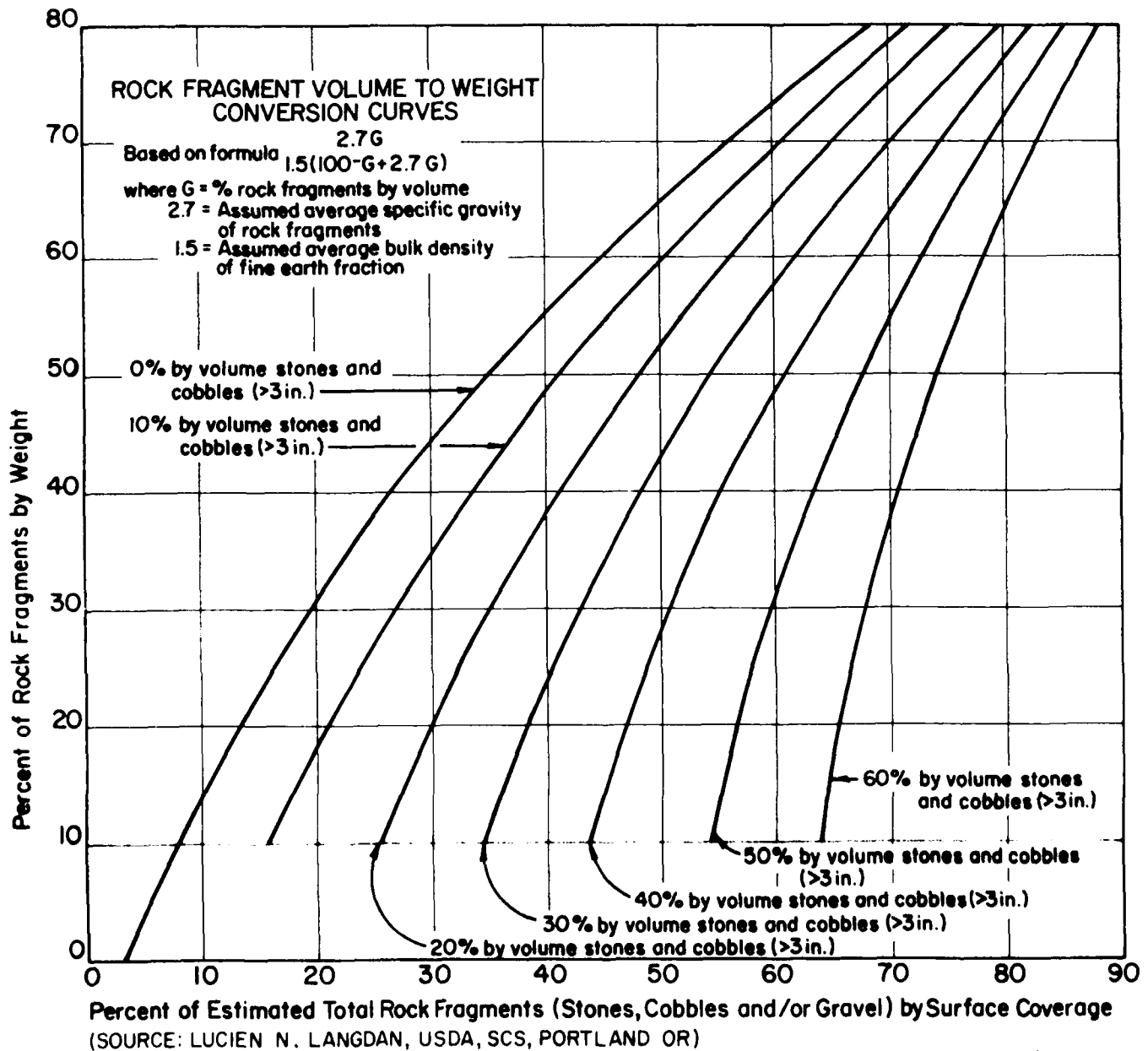


Figure 13. Graph for converting percentage of rock fragment surface coverage to percent by weight.

area coverage should be computed: one for rock fragments greater than 76.2 mm in diameter or length (large stones), and one for all fragments with a diameter or one side greater than 2.0 mm.

The percent of surface coverage of both large and small rock fragments is established by determining the percent of the total sample area which is covered by rock fragments of the different sizes. For example, a 1 m² area which is covered by 0.2 m² of rock fragments with a diameter or one side greater than 76.2 mm is considered to have a 20 percent coverage of large rock fragments.

To determine limitations for trailbike use, the percent surface coverage of rock fragments is again converted to percent by weight using the graph in Figure 13. If the sample plot contains 20 percent surface coverage of larger stones, the graph is entered on the horizontal axis at the 20 percent point. The next steps for using the graph, as described in the visual technique, are then completed for each rock fragment size. The degree of limitation for both large and small stones is then determined.

Point-Count Technique. A third technique which is considered very accurate is a point-count technique. It also requires the examiner to mark off a sample plot of at least 1 m²; again, the larger the sample plot, the more accurate the estimate of the percent surface coverage of stones. The sample plot should be as representative of the surface as possible; it should not contain any particularly large stones or unusual concentrations of stones or bare spots.

Once the sample plot has been established, a grid is constructed over it. The grid can be wire mesh or netting or it can be a simple system of nails or stakes and string. A point count of approximately 100 points yields fairly accurate results and should be the minimum number of points counted. However, the more points counted, the more accurate the results. If the sample plot is 1 m², the grid should have lines that are a maximum of 100 mm apart; this gives 121 possible points or grid intersections, including 81 inside and 40 peripheral intersections.

To estimate the weight percent of large and small stones using this technique, steps are completed as follows:

Step 1. Place or construct the grid so that it covers the sample plot.

Step 2. Count the number of grid intersections which are located directly above a stone. This count should be done twice: once for intersections directly above stones with one dimension greater than 76.2 mm (large stones), and once for intersections directly above all stones with one dimension greater than 2.0 mm. Intersection points on the periphery of the grid are counted only if the number of inside intersection points is less than 100. For best results the grid should include at least 100 inside intersection points.

Step 3. Divide the number of intersection points counted by the total number of intersection points and multiply by 100. This is done for both counts: large stones (greater than 76.2 mm in length or width) and all stones. The figure used for the total number of intersection points includes points on the periphery of the grid only if they were used to make the point-count of stones. The figures derived from the calculations represent the percent surface coverage of stones.

Step 4. Find the weight percent of large and small stones found in the sample plot by using Figure 13 as described in the visual and sampling techniques.

Once the weight percent of large and small stones in the sample plot is determined, the soil's degree of limitation due to stoniness is identified from Table 1.

Slope

Slope is the term used to describe the incline or steepness of the land. It is defined as the change in elevation over horizontal distance, or the amount of rise over run. A rise of 60 ft (18.3 m) in elevation over distance of 100 ft (30 m) represents a 60 percent slope. By determining the percent slope of the land on which a soil is located, the resource manager can determine if a soil has limiting properties because of "slope" (restrictive feature 8 in Table 1). Two techniques for doing this are described below.

Instrument Technique. Soil slope is usually measured in the field with a hand level. An instrument commonly used is the Abney hand level. This instrument is easy to use; the percent slope is determined directly from the instrument reading. Abney hand levels are relatively inexpensive and may be available from the Facilities Engineer Office.

To use the Abney hand level, stand at the lowest point on the slope which is being measured (Figure 14). Look through the level at a surface feature (generally a tree or shrub) on the top of the slope being measured. If the distance from the bottom to the top of the slope is short, sight in on the surface feature at a point which would be about head-high if standing next to it. The percent slope of the land is then read directly from the level.

If slope of the ground on which a soil is located is greater than 40 percent, the soil has severe limitations for trailbike use because of excess "slope." If the slope is between 25 and 40 percent, the soil has moderate limitations. If the slope is less than 25 percent, the soil has slight limitations for trailbike use.

Topographic Technique. If an Abney hand level or similar instrument for measuring slope is not available, the resource manager can determine percent slope from a topographic map. Topographic maps have contour lines drawn on them which illustrate changes in elevation.

To determine the percent slope of a given area on a topographic map, the resource manager must determine the change in elevation over a particular distance on the map. For example, suppose that the resource manager wishes to find the percent slope of a small area on a map drawn to a scale of 1:24,000. The area on the map contains nine contour lines in a distance of 1 in. (25.4 mm). If the contour interval is 20 ft (6 m), the elevation changes by 160 ft (49 m) within the eight contour intervals (8 x 20) along the 1 in. (25.4 mm) distance. (Note that it must be determined that the slope of the area does not go up and then down. This is done by precisely determining the elevation represented by each contour line.) Since the scale of the topographic map is 1:24,000 (1 in. = 2400 in. or 1 in. = 2000 ft (610 m)), the elevation changes 160 ft (49 m) in a distance of 2000 ft (610 m), or 8 ft (2.5 m) in a distance of 100 ft (30 m). Therefore, the area has an 8 percent slope. (Note that the scale of topographic maps can vary considerably.)

Once the slope of the soil being examined has been found, its degree of limitation is determined from the ranges given in Table 1.

Depth to High Water Table

If the resource manager knows the depth to the high water table, he or she will be able to determine the degree of limitation caused by wetness or ponding (restrictive feature 3 in Table 1). The depth of the high water table can be determined in two ways:

Records. Most installations have records of any earthwork or excavation which may have been done on the installation. These records will generally include an engineering study if the earthwork was done to prepare a construction site. In most cases, these studies include a record of the depth to the water table. Any studies available for candidate trailbike areas are valuable sources of water table information. Other sources for this information are well drilling logs, area farmers, and local soil scientists.

If the depth to the high water table is less than or equal to 1 ft (0.3 m), then the soil has severe limitations for trailbike use because of "wetness." Obviously, if there is standing water (ponding) in the area for much of the year, the soil has severe limitations. If the depth is somewhere between 1 to 2 ft (0.3 to 0.6 m), then the soil has moderate limitations for trailbike use. If the depth to the high water table is greater than 2 ft (0.6 m), then the soil has slight limitations due to "wetness."

Field Technique. If no records of the depth to the high water table exist, the resource manager can determine the depth at each test site by digging a post hole. These holes should be at least 2-1/2 ft (0.76 m) deep and dug during the wet season of the year (when the water table is at its highest).

The depth to the high water table is then determined by measuring the distance from the top of the water which fills the post holes to the surface of the ground. If (after a day) a particular hole fills with water to within 1 ft (0.3 m) of the surface, the immediate area has a high water table and severe limitations for trailbike use. If the hole fills with water to between 1 to 2 ft (0.3 to 0.6 m) of the surface, then the soil has moderate limitations. If the water level in the hole stays at a point more than 2 ft (0.6 m) below the surface (or the hole does not fill up with water at all), the soil has slight limitations for trailbike use.

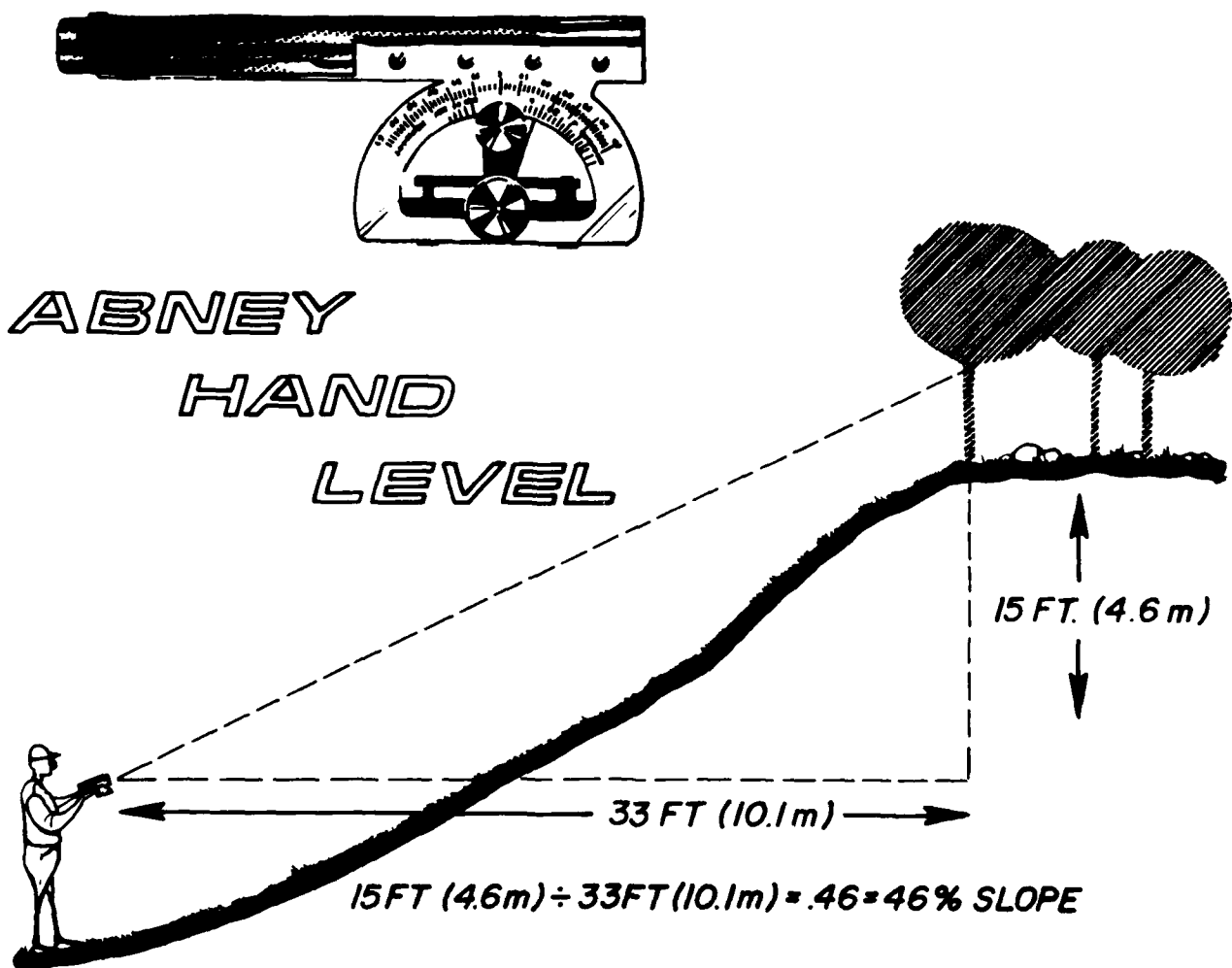


Figure 14. Diagram illustrates hand level method for determining slope.

Unified Soil Texture

A soil's unified soil texture is the most difficult soil property to establish. There are no readily applicable and easy field methods for the installation resource manager to use. However, since the most important textural property which requires identification is the presence of excess organic material or humus (restrictive feature 7 in Table 1), it is important for the resource manager to be familiar with the characteristics of highly organic soils.

In the unified classification system, OL is the abbreviation used to identify organic silts and organic silty clays of low plasticity. (Plasticity refers to a soil's capability of being molded or deformed by relatively moderate pressure.) The symbol OH identifies organic silts and clays of medium to high plasticity. PT is used to identify peat and other highly organic soils. All soils with these classifications will have severe limitations for trailbike use because they contain a significant amount of organic material.

Organic soils are formed under moist, warm conditions such as those which exist in marshes, bogs, and swamps. The organic material contained in these soils is actually the decayed remains of plants. Organic soils are generally very dark brown or intensely black; they have a very high water-holding capacity and are generally moist to the touch. When dry, organic soils appear to be very light weight because they have low bulk densities. If, during the field examination of the soils of a candidate trailbike area, the resource manager finds an area in which the soils are expected to have been formed under swamp-like conditions, he or she should consider these soils to have severe limitations for trailbike use.*

Erodibility

A soil's susceptibility to erosion is a very important factor in determining its suitability for trailbike use. Susceptibility to erosion is determined by multiplying the soil's erodibility factor (K), by the percent slope of the soil (restrictive feature 4 in Table 1). To do this, the resource manager will need to establish a value for K.

Nomograph Technique. The nomograph technique gives a relatively accurate approximation of the possible range of K values for a soil. However, before the nomograph technique can be used, the resource manager must have determined the sample soil's texture by the hydrometer technique (p 31).

Figure 15 provides the nomograph which should be used to approximate the K value. This nomograph was adapted from Wischmeier's soil erodibility nomograph for farmland and construction sites.⁹

As noted earlier, sand grains range from 0.05 to 2.0 mm in size, and silt particles range from 0.002 to 0.05 mm. To use the erodibility nomograph, the percent of very fine sand (0.05 to 0.1 mm) in a sample soil is combined with the percent silt. Therefore, percent sand becomes the percentage of particles ranging from 0.1 to 2.0 mm in size. The hydrometer technique described on pp 31 to 33 requires the resource manager to take a reading 10 seconds after suspending the sample soil in solution and placing the sedimentation cylinder on a table. This 10-second reading is used to adjust the percent sand and percent silt figures to the needed percent sand (0.1 to 2.0 mm) and percent silt plus very fine sand (0.002 to 0.1 mm). The percentages are determined by substituting the corrected 10-second reading (line 5) for the corrected 40-second reading (line 6) in the calculation for line 8 in Table 4. The calculations for the remaining lines in Table 4 are then completed using the new results for line 8.

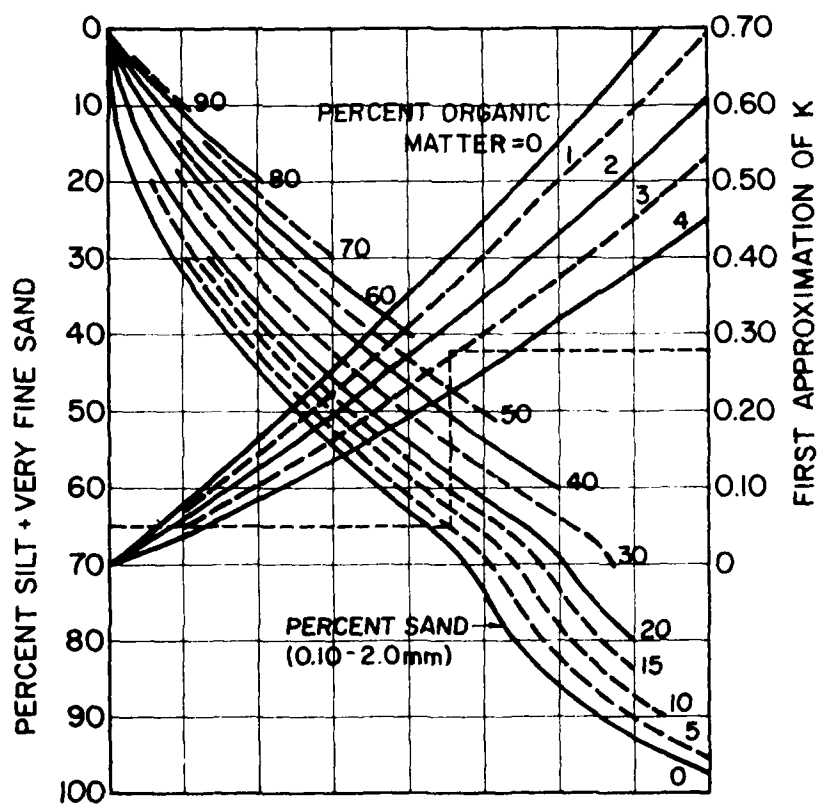
After the percentages of silt plus very fine sand and sand in a sample soil are determined, the nomograph is used as follows:

Step 1. Enter the nomograph on the left-hand side at that point which represents the percent silt plus very fine sand (0.002 to 0.1 mm) in the sample soil.

Step 2. Move horizontally to the right until intersecting the curve which represents the percent sand (0.1 to 2.0 mm) in the sample.

* Tropical soils, especially the soils of Hawaii, deserve special consideration. Many of them are highly organic soils and have other distinct characteristics which would make them unacceptable for trailbike use. As a result, all tropical soils must be examined by a professional soil scientist to determine their limitations for trailbike use.

⁹ W. H. Wischmeier, C. B. Johnson, and B. V. Cross, "A Soil Erodibility Nomograph for Farmland and Construction Sites," *Journal of Soil and Water Conservation*, Vol 26, No. 5 (September-October 1971), pp 189-193.



(adapted from W. H. Wischmeier, C. B. Johnson, and B. C. Cross,
 "A Soil Erodibility Nomograph for Farmland and Construction
 Sites," *Journal of Soil and Water Conservation*, Vol 26,
 No. 5 [September-October 1971])

Figure 15. Nomograph for approximating the erosion factor (K) of soils.

Step 3. Move vertically up and/or down until intersecting the two lines which represent 0 and 4 percent of organic material.

Step 4. Move right from the points where the 0 and 4 percent organic material curves were intersected to the right-hand side of the nomograph. The values of these two intersections represent the range of possible K values for the soil.

This technique only describes how to arrive at an *approximation* of K. The *range* for the value of K reflects possible differences in organic material. If the resource manager wishes to identify a smaller range for the value of K, he or she should consider the characteristics of organic soils discussed on p 44. If he or she feels that the sample soil does indeed contain a significant amount of organic material, the range of the approximation of K can be shortened somewhat toward the lower value. The same type of logic will apply if the resource manager feels that there is little or no organic material in the soil sample. In this case, the range is shortened somewhat toward the higher value.

The Textural Classification Technique. If the resource manager has determined the soil texture by feel, the erodibility nomograph cannot be used to obtain a range for the value of K. In this case, a range for the value of the erosion factor is obtained from Table 5. Table 5 is used as follows:

Step 1. Find the appropriate line which identifies the textural classification of the sample soil.

Step 2. Move to the right and locate the line which represents the range of K values for a soil of that particular texture.

Step 3. Read the range of the K values from the top of the table.

Once a range for the value of K has been determined by either the nomograph or textural classification technique, the degree of limitation caused by erodibility is determined by (1) multiplying the lowest value of K for the sample soil by the percent slope on which the soil is located, (2) multiplying the highest K value by the percent slope. If the product of either multiplication is greater than 4, the soil has severe limitations for trailbike use because it "erodes easily." If the value of both products is 2 through 4, the soil has moderate limitations. If the value of both products is less than 2, the soil has slight limitations.

Flooding

The degree of soil limitation caused by flooding (restrictive feature 11 in Table 1) can only be determined by examining any historical records of flooding in the area or by consulting installation personnel or local residents who may be familiar with the area's flooding history. If there is a history of frequent flooding (more often than once in 2 years), the soils which become inundated have moderate restrictions for trailbike use due to "floods." If flooding does not occur, occurs rarely (unlikely but possible under abnormal conditions), or occurs occasionally (less often than once in 2 years), the soils have slight limitations.

Susceptibility to Very Severe Damage

The final examination of a sample soil requires a determination of its susceptibility to very severe damage (restrictive feature 12 in Table 1). This determination is primarily based on individual judgment. In most cases, a soil which is susceptible to very severe damage will have been rated as having severe limitations for one or more of the other soil properties. However, if for any reason, the resource manager feels that a soil is fragile and would be very severely damaged by trailbike use, he or she should rate it as having severe limitations for the use until it has been examined by a professional soil scientist.

Table 5

Guide for K-Factor Determination by Textural Classification*

Soil Texture	K Factor Range**											
	0.10	0.15	0.17	0.20	0.24	0.28	0.32	0.37	0.43	0.49	0.55	0.64
COS	X		X									
S		X						X				
FS		X	X									
VFS		X			X							
LCOS		X						X				
LS		X						X				
LFS			X		X							
LVFS				X		X						
COSL		X						X				
SL				X				X				
FSL				X				X				
VFSL						X			X			
L					X				X			
SIL						X				X		
SI						X					X	
SCL					X				X			
CL					X					X		
SICL						X					X	
SC					X				X			
SIC					X				X			
C					X			X				

* This table was developed from a combination of sources, including *K and T Factors of Soil Series Mapped in the Northeast Region* (USDA-SCS, Upper Darby, PA, June 1970); *Guidelines for K Values* (USDA-SCS, Lincoln, NE); W. H. Wischmeier, C. B. Johnson, and B. V. Cross, "A Soil Erodibility Nomograph for Farmland and Construction Sites," *Journal of Soil and Water Conservation*, Vol 26, No. 5 (September-October 1971); and an examination of the published values of K for 100 soils from various parts of the country.

** The range of the value of K for a particular soil texture can be adjusted with the following considerations: (1) high organic material puts a soil in the lower values of the range of K, (2) considerable numbers of coarse fragments puts a soil in the lower values of the range of K, and (3) slow permeability puts a soil in the higher values of the range K.

4 HOW TO PREPARE THE SOIL LIMITATIONS MAP

General

This chapter describes how to prepare and interpret the soil limitations map, which helps document site suitability as it relates to soils. This map can also be used to help determine if a candidate area can or should be opened to trailbike use.

How to Prepare the Base Map

Before the limitations map can be prepared, the resource manager will need to prepare a base map. This done by reproducing the soil survey or field maps of the candidate areas. If there is a useable published survey available (alternative Method 1), the appropriate maps in the survey are reproduced. If a field survey was undertaken by a professional soil scientist (alternative Methods 2, 3, 4, and 5), the maps prepared by the scientist are reproduced. If the resource manager used an existing soil survey map to produce a field survey map (alternative Method 6), the soil boundaries of the existing survey should be reproduced. If the soil survey map was an association map and series boundaries were interpolated, these interpolated boundaries should be reproduced on the base map. If the resource manager prepared a field survey map during a visual survey of the candidate area (alternative Method 7), the visual survey map should be reproduced.

It is essential that any soil boundaries which were adjusted as a result of the examination of soil properties be reproduced with the appropriate adjustments. Figure 16 is an example of the detail necessary in the base map.

In most cases, if the base map is copied exactly from a soil survey or field maps, it will not correspond to scale with the other maps which are used to examine other environmental parameters during the total trailbike-area evaluation procedure (Volume 1). If it is desirable to make this map correspond to scale with the other maps, the resource manager can ask the installation's Master Planning Office to help adjust the base map's scale.

How to Prepare the Limitations Map

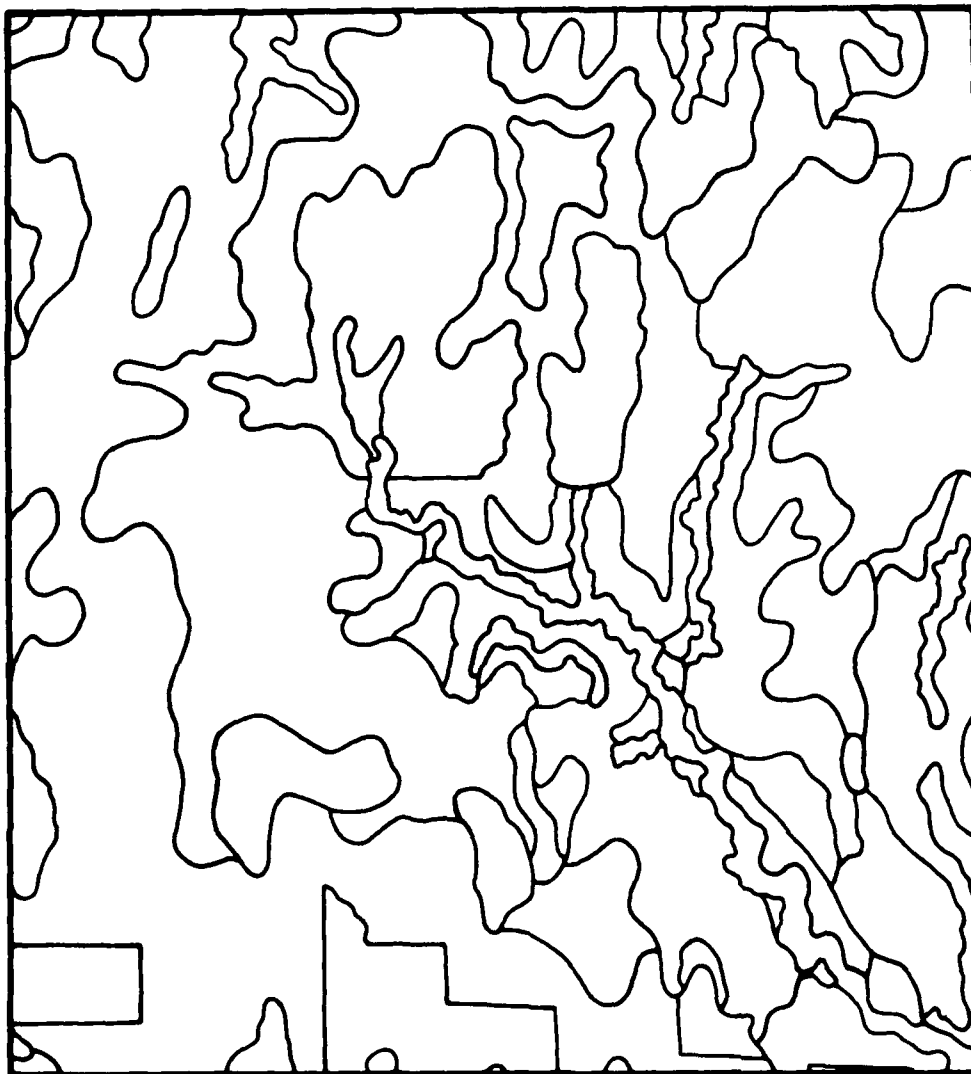
To prepare the limitations map it will be necessary to identify the degree of limitation for trailbike use of each soil series or phase on the base map. If alternative soil suitability Methods 1, 2, or 3 in Chapter 2 are used, the limitations ratings are available as described on p If alternative Methods 4 or 5 are used, limitations should have been identified by the professional soil scientist responsible for the field survey. If alternative Methods 6 or 7 are used, the resource manager identifies the limitations from data obtained using the field and laboratory analysis techniques (Chapter 3).

To identify the degree of limitation from the analyses data, the combined properties and limitations of each soil or soil phase are examined on a "worst case" basis. Each soil is then given an overall rating. For example, if a soil has slight restrictions for every soil property which was examined, except that it has greater than 65 percent by weight small stones (a severe limitation), the soil is rated as having severe limitations.

For each soil, the restrictive feature(s) which gives it the worst case limitation should be recorded. For the example soil above, the following would be recorded:

1. The soil's name, phase, and/or textural classification
2. Its location and/or map symbol on the base map
3. The degree of limitation (i.e., severe)
4. The restrictive feature which caused the rating (i.e., small stones).

If a soil has two properties which give it a severe limitation, both restrictive features should be recorded. This allows the resource manager to document the reason(s) why a soil was given a certain degree of limitation. These records should be kept for *all* soils, even those with only slight restrictions.



(Source: Soil Survey of Riley County and Part of Geary County, Kansas — Sheet Number 24, USDA—Soil Conservation Service, Washington, D.C., June 1975)
Scale 1:24,000 ↑ N

Figure 16. Example soils base map.

To prepare the limitations map, the soils displayed on the base map are colored red or yellow within their respective boundaries. Soils or areas which have moderate limitations should be colored yellow; soils or areas with severe limitations should be colored red; soils or areas with slight limitations remain uncolored (or colored green). Figure 17 is a sample limitations map.

How to Interpret the Limitations Map

Since the soil limitations map is color-coded according to the degree of limitation which the soil or area exhibits, the resource manager and/or decision-maker can readily determine the suitability of candidate areas. Those areas left uncolored (or colored green) have slight limitations and are acceptable for trailbike use as far as soils are concerned. Those areas colored yellow have moderate limitations. By consulting the soil limitations records and/or field notes, the resource manager should be able to identify the restrictive feature which gave each soil or area the moderate limitation. Soils or areas with moderate limitations may be acceptable for use if proper planning, design, and management procedures are used to designate trails, control erosion, and/or mitigate the restrictive feature.

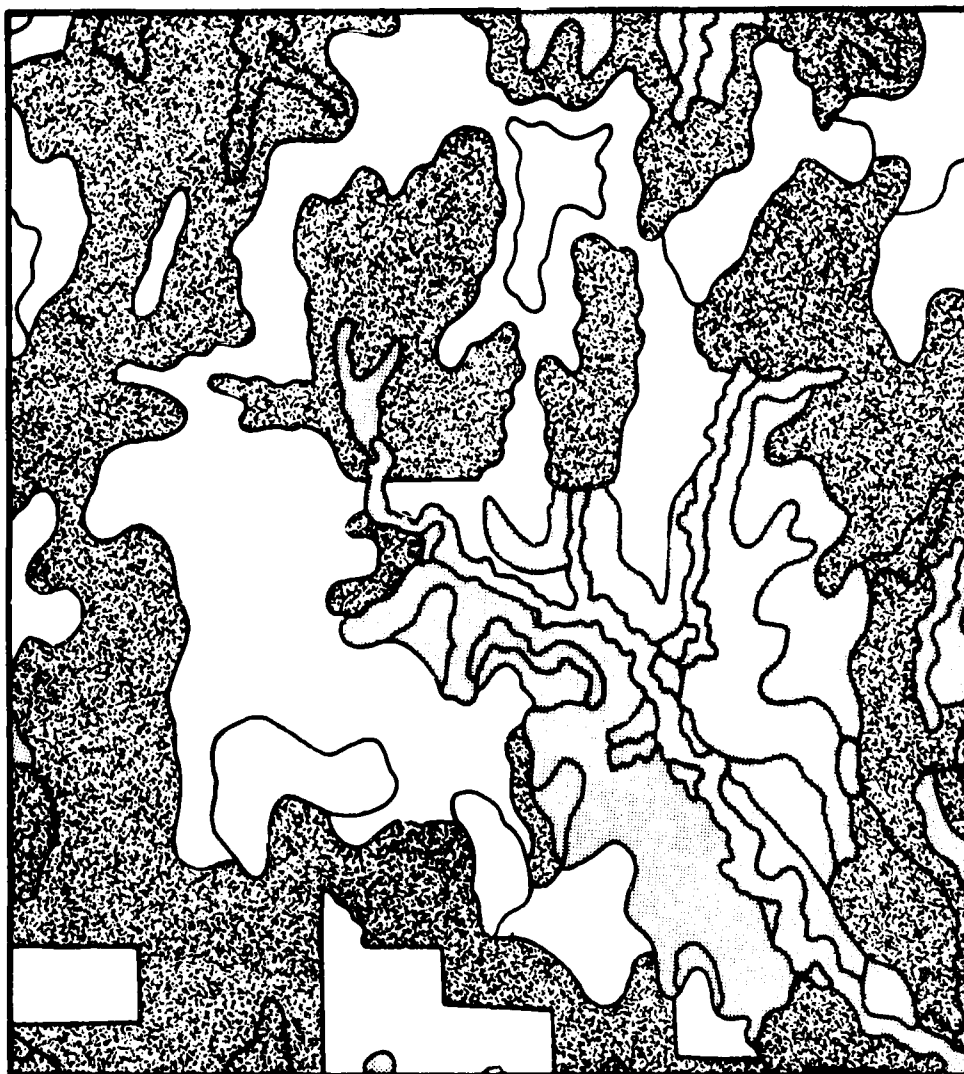
Those soils with severe limitations may also be developed as trailbike-use areas if the restrictive feature can be mitigated. This, however, depends on the type of restricting soil property and trail design and management. Army Technical Manual 5-630 provides guidance on techniques and procedures which can be used for erosion control and soil management.¹⁰

Many of the soils on most installations will have moderate or severe limitations. In many cases, these soils will be the ones which have properties which are desired by trailbike users, e.g., steep slopes. Therefore, it is likely that the resource manager will have to make certain tradeoffs between user desires and absolute environmental protection. This means that some soils with moderate and severe restrictions will often be included in the trailbike-use area.

Table 1 was developed with this tradeoff in mind. The restrictive features are listed in order of the relative severity of their restrictions. Therefore, "permafrost," "large stones," "wetness," "ponding," and "erodes easily" represent the most severe restrictive features. The features listed at the bottom of Table 1 are less severe, with the exception of "fragile soils." (No soils identified as fragile should be included in a trailbike-use area.) If soils with moderate and severe restrictions are opened to trailbike use as a tradeoff with user desires, the soils which have restrictive features which appear at the bottom of Table 1 should receive first consideration.

Having examined the soils of candidate use areas in the manner described in this report, the resource manager or decision-maker has complete documentation of the suitability of the soil in each area. Before deciding if an area can be opened to trailbike use, he or she should examine the other environmental factors as described in Volume I of this report. After completing the procedures described in Volume I, the decision of whether or not to open an area to trailbike use can be made. If an area is to be opened, the resource manager should follow the trail development guides given in Volume I of this report.

¹⁰ *Repairs and Utilities: Ground Maintenance and Land Management*, Army Technical Manual (TM) 5-630 (Department of the Army, 4 December 1967).



Scale 1:2400

N ↑

LEGEND



Slight soil limitations



Moderate soil limitations



Severe soil limitations

Figure 17. Example soil limitations map.

5 CONCLUSIONS

The alternate soil evaluation methods given in Chapter 2 and Figures 2 through 8 are immediately applicable to Army military activities. These methods (and other information provided in Volume I) can be used any time there is a need to investigate or establish a trailbike-use area; the information obtained through the use of these methods should be applied in all environmental assessments of trailbike use.

To use these methods in the most effective way, the resource manager and/or person doing the evaluation should attempt to use the easiest and most reliable one, as defined by his or her particular situation. In all cases, it is first recommended that efforts be undertaken to obtain the cooperation and/or opinion of a professional soil scientist. This effort is especially necessary if there is any question as to the suitability of a particular soil. Also, most soils have different properties at different depths and many behave and/or react differently under changing conditions, e.g., rainfall or freezing. An experienced soil scientist can help identify those soils which might be adversely affected by changing conditions. He or she can also provide valuable advice concerning mitigation procedures.

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Army Matls. and Mechanics Res. Ctr.
Corpus Christi Army Depot
Harry Diamond Laboratories
Dugway Proving Ground
Jefferson Proving Ground
Fort Monmouth
Letterkenny Army Depot
Natick Research and Dev. Ctr.
New Cumberland Army Depot
Pueblo Army Depot
Red River Army Depot
Redstone Arsenal
Rock Island Arsenal
Savanna Army Depot
Sharpe Army Depot
Seneca Army Depot
Tobyhanna Army Depot
Tooele Army Depot
Watervliet Arsenal
Yuma Proving Ground
White Sands Missile Range

FORSCOM

FORSCOM Engr. ATTN: AFEN-FE/Tachmart (10)

ATTN: Facilities Engineers
Fort Buchanan
Fort Bragg
Fort Campbell
Fort Carson
Fort Devens
Fort Drum
Fort Hood
Fort Indiantown Gap
Fort Irwin
Fort Sam Houston
Fort Lewis
Fort McCoy
Fort McPherson
Fort George G. Meade
Fort Ord
Fort Polk
Fort Richardson
Fort Riley
Presidio of San Francisco
Fort Sheridan
Fort Stewart
Fort Wainwright
Vancouver Bks.

TRADOC

HQ, TRADOC, ATTN: ATEN-FE-MR (14)

ATTN: Facilities Engineer
Fort Belvoir
Fort Benning
Fort Bliss
Carlisle Barracks
Fort Chaffee
Fort Dix
Fort Eustis
Fort Gordon
Fort Hamilton
Fort Benjamin Harrison
Fort Jackson
Fort Knox
Fort Leavenworth
Fort Lee
Fort McClellan
Fort Monroe
Fort Rucker
Fort Sill
Fort Leonard Wood

INSCOM - Ch. Instl. Div.

ATTN: Facilities Engineer
Vint Hill Farms Station
Arlington Hall Station

WESTCOM

ATTN: Facilities Engineer
Fort Shafter

MDW

ATTN: Facilities Engineer
Cameron Station
Fort Lesley J. McNair
Fort Myer

HSC

HQ USAHSC, ATTN: HSLO-F
ATTN: Facilities Engineer
Fitzsimons Army Medical Center
Walter Reed Army Medical Center

USACC

ATTN: Facilities Engineer
Fort Huachuca
Fort Ritchie

MTMC

HQ, ATTN: MTMC-SA
ATTN: Facilities Engineer
Oakland Army Base
Bayonne MCT
Sunny Point MCT

US Military Academy

ATTN: Facilities Engineer
ATTN: Dept of Geography & Computer Science

USAES, Fort Belvoir, VA

ATTN: ATZA-DTE-EM
ATTN: ATZA-DTE-SU
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Chief Inst. Div., I&SA, Rock Island.

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TARCOM, Fac. Div.
TECOM, ATTN: DRSTE-LG-F
TSARCOM, ATTN: STSAS-F
NARAD COM, ATTN: DRONA-F
AMMRC, ATTN: DRXMR-WF

HQ, XVIII Airborne Corps and
Fl. Bragg
ATTN: AFZA-FE-EE

HQ, 7th Army Training Command
ATTN: AETTG-DEH (5)

HQ USAREUR and 7th Army
DDCS/Engineer
ATTN: AEAFN-EH (4)

V Corps
ATTN: AETVDEH (5)

VII Corps
ATTN: AETSDEH (5)

21st Support Command
ATTN: AEREH (5)

US Army Berlin
ATTN: AEBA-EN (2)

US Army Southern European Task Force
ATTN: AESE-ENG (5)

US Army Installation Support Activity
Europe
ATTN: AEUES-RP

8th USA, Korea

ATTN: I&AF
Dir. for Engr Act (8)
All, Yongsan Area
All, 2D Inf Div
All, Area II Spt Det
All, 1st Humphreys
All, Pusan
All, Taegu

DLA ATTN: DLA-WI

USA Japan (USARJ)
Ch, FE Div, AJEN-FE
Fac Engr (Honshu)
Fac Engr (Okinawa)

ROK/US Combined Forces Command
ATTN: EUSA-HHC-CFC/Engr

416th Engineer Command
ATTN: Facilities Engineering

Norton AFB
ATTN: AFCE-MX/DEE

ENR Team Distribution

Chief of Engineers
ATTN: DAEN-MPD-B
ATTN: DAEN-CW2-R (3)
ATTN: DAEN-CWR-R (2)
ATTN: DAEN-MPE-1
ATTN: DAEN-MPE-7 (10)
ATTN: DAEN-MPP (2)
ATTN: DAEN-RDL

US Military Academy
ATTN: Dept of Mechanics
ATTN: Library
West Point, NY 10996

Learning Resources Center
US Army Engineer School
ATTN: ATSEN-DT-LD (2)
ATTN: Archives Section/Bldg 270
ATTN: Kingman Bldg, Library
ATTN: Canadian Liaison Officer (2)
Ft. Belvoir, VA 22060

US Army Combined Arms Combat
Development Activity
ATTN: ATZLCA-SA
Ft. Leavenworth, KS 66027

Assistant Chief of Engineers
ATTN: DAEN-ZCE (10)
WASH DC 20310

The Army Library (ANRAL-R)
ATTN: Army Studies Section
WASH DC 20310

Ft. Monroe, VA 23651
ATTN: ATEN-ADCSN (3)
ATTN: ATEN-FE-NR (4)

USA ARRADCOM
ATTN: Fac Engr/Env Ofc
Dover, NJ 07801

Each US Army Engr Dist
ATTN: Regulatory Functions
ATTN: Military Planning Section*
*Kansas City, Omaha, Baltimore,
New York, Norfolk, Alaska,
Mobile, Savannah, Los Angeles
Sacramento, Fort Worth

US Army Engr Dist, Chicago
ATTN: Chief, NCCPE-PES

US Army Engr Div, North Central
ATTN: Chief, Engr Div
Chicago, IL 60605

US Army Engr Div, New England
ATTN: Regulatory Functions
Waltham, MA 02154

Indicated Fac. listed in DA PAM 210-1
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7th US Army
ATTN: AETM-HRD-EHD

Director, USA-WES
ATTN: WES-EA
ATTN: Library
Vicksburg, MS 39181

Ft. Sam Houston, TX 78234
ATTN: HQ, HSCM-R

Env Mgmt Committee
Army Logistics Mgmt Center
ATTN: DRXMC-MR-1 (5)
Ft. Lee, VA 23801

HQ Defense Logistics Agency
ATTN: DLA-OSC (3)
ATTN: DLA-WS (2)
Alexandria, VA 22314

193d Inf BDE (C2)
ATTN: AFZU-FE-E (3)
Miami, FL 34004

Ft. Buchanan, PR 00934
ATTN: Facility Engr/Env Office

Institute for Water Resources
Kingman Building
ATTN: J. Cella Priscoll
Ft. Belvoir, VA 22060

Ft. Richardson, AR 99505
ATTN: Facility Engr/Env Office

Schofield Barracks, HI 96857
ATTN: Facility Engr/Env Office

Ft. Wainwright, AK 99703
ATTN: Facility Engr/Env Office

Ft. Shafter, HI 96558
ATTN: Facility Engr/Env Office

Ft. Greely
ATTN: Facility Engr/Env Office

US Army Engr Command, Europe
APO New York, NY 09403

US Army HQ FORSCOM
ATTN: AFEN-EC (4)
Ft. McPherson, GA 30330

Aberdeen Proving Ground
ATTN: STEAP-PE-E (2)
Aberdeen Proving Ground, MD 21005

Armament Materiel Readiness Command
ATTN: DRASAR-ISE
Rock Island, IL 61201

Armament R&D Command
ATTN: DRDAR-LCM-S
Dover, NJ 07801

Aviation R&D Command
ATTN: DRDAV-EQP
St. Louis, MO 63166

Depot System Command
ATTN: DRSDS-S
Chambersburg, PA 17201

Electronic Proving Ground
ATTN: STEEP-LS-S
Ft. Huachuca, AZ 85613

Communications and Electronics
Materiel Readiness Command
ATTN: DRSEL-PL-ST
Ft. Monmouth, NJ 07703

Electronics R&D Command
ATTN: DELHD-FA
Adelphi, MD 20783

Installations and Services Activities
ATTN: DRCIS-RI
Rock Island, IL 61201

Missile Materiel Readiness Command
ATTN: DRSMI-KL
Redstone Arsenal, AL 35809

Missile R&D Command
ATTN: DRDMI-MS
Redstone Arsenal, AL 35809

Mobility Equipment R&D Command
ATTN: DRDME-U
Ft. Belvoir, VA 22060

Tank-Automotive Materiel Readiness
Command
ATTN: DRSTA-SP
Warren, MI 48090

Tank-Automotive R&D Command
ATTN: DRDTA-J
Warren, MI 48090

Test and Evaluation Command
ATTN: DRSTE-PP-E
Aberdeen Proving Ground, MD 21005

HQ DARCOM
ATTN: DRCIS-A (2)
Alexandria, VA 22333

Troop Support and Aviation Materiel
Readiness Command
ATTN: DRST-LE
St. Louis, MO 63120

Bugway Proving Ground
ATTN: STEOP-PP
ATTN: STEOP-MT-L-E (2)

Chief, Civil Engr. Research Div.
Air Force Weapons Lab
ATTN: DE
Kirtland AFB, NM 87117

Tyndall AFB, FL 32403
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ATTN: AFESC/ECA
ATTN: AFESC/TS*

HQ USAF/LEEVE
WASH DC 20330

Chief, Naval Operations
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WASH DC 20360

US Naval Academy
Political Science Dept
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ATTN: Prof Cochran
Annapolis, MD 21402

Transportation Research Board
National Research Council (3)
WASH DC 20418

Office of Mgmt Svc, MS 110-FAA
WASH DC 20553

Jefferson Proving Ground
ATTN: STEJP-LD-N
Madison, IN 47250

Anniston Army Depot
ATTN: SDSAN-DS-FE
Anniston, AL 36201

Red River Army Depot
ATTN: SDSRR-S
Texarkana, TX 75501

Tooele Army Depot
ATTN: SDSTE-FW
ATTN: SDSTE-NA
ATTN: SDSPU-A
ATTN: SDSTE-UM
ATTN: SDSTE-SE
Tooele, UT 84074

Holston Army Ammunition Plant
ATTN: SARHO-EN
Kingsport, TN 37662

Indiana Army Ammunition Plant
ATTN: SARIO-EN
Charlestown, IN 47111

Iowa Army Ammunition Plant
ATTN: SARIO-EN
Middletown, IA 52638

Kansas Army Ammunition Plant
ATTN: SARKA-FE
Parsons, KS 67357

Milan Army Ammunition Plant
ATTN: SARMI-EN
Milan, TN 38358

Sharpe Army Depot
ATTN: SDSSH-ASF
Lathrop, CA 95331

Sierra Army Depot
ATTN: SDSSI-FE
Hertling, CA 96113

ENP

Tobyhanna Army Depot
ATTN: SDSTO-AF
Tobyhanna, PA 18466

Rocky Mountain Arsenal
ATTN: SARMM-F
Commerce City, CO 80022

Lake City Army Ammunition Plant
ATTN: SARLC-D-F
Independence, MO 64056

Volunteer Army Ammunition Plant
ATTN: SARVO-D
Chattanooga, TN 34701

Watervliet Arsenal
ATTN: SARWV-FEE
Watervliet, NY 12189

Savanna Army Depot Activity
ATTN: SDSLE-A
Savanna, IL 61074

Pine Bluff Arsenal
ATTN: SARPB-ETD
Pine Bluff, AR 71611

Yuma Proving Ground
ATTN: STEYP-PL
Yuma, AZ 85444

Chemical Systems Laboratory
ATTN: JPDAR-CLT-E
Edgewood Area
Aberdeen Proving Ground, MD 21010

Lone Star Army Ammunition Plant
ATTN: SARLS-EN
Texarkana, TX 75501

Longhorn Army Ammunition Plant
ATTN: SARLO-D
Marshall, TX 75670

Louisiana Army Ammunition Plant
ATTN: SARLA-S
Shreveport, LA 71130

Radford Army Ammunition Plant
ATTN: SARRA-IE
Radford, VA 24141

Sacramento Army Depot
ATTN: SDSA-SDF
Sacramento, CA 95813

US Army Operational Test and
Evaluation Agency
ATTN: CSTE-PHO
ATTN: CSTE-POP
Falls Church, VA 22041

US Army Medical Bioengineering Res.
and Development Laboratory
ATTN: Env. Protection and Res. Div.
Ft. Detrick
Frederick, MD 21701

Dept of Transportation Library
Acquisitions Section (SR) TAD-491.1
WASH DC 20590

Library of Congress
Exchange and Gift Div
ATTN: Federal Documents Section (2)
WASH DC 20540

Institute of Defense Analysis
Arlington, VA 22202

Veterans Administration
Environmental Planning Div (088C)
WASH DC 20420

USA Intelligence and Security Command
ATTN: IALOG-IF
Arlington, VA 22212

Environmental Protection Agency (EPA)
ATTN: International Env Referral Cntr
ATTN: Office of Environmental Review
WASH DC 20460

Defense Logistics Agency
Defense Property Disposal Service
ATTN: DPDS-OP
Battle Creek, MI 49016

Patrick AFB, FL 32925
ATTN: XRQ

McClellan AFB, CA 95652
ATTN: APG/OE

Chief, Construction and Maintenance
Standards Branch, AAS-580
Federal Aviation Administration
WASH DC 20591

Installation and Services Activities
ATTN: ORCIS-RI-IB (10)
Rock Island, IL 61201

Lacey, Robert M

Evaluation of areas for off-road recreational motorcycle use : vol. II alternate soil suitability determination methods / by R. M. Lacey, H. E. Balbach. -- Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from NTIS, 1980.

52 p. ; 27 cm. (Technical report ; N-86, vol. 2)

1. Motor vehicles--recreational use. 2. Motorcycles. 3. Soils. I. Balbach, Harold E. II. Title. III. Series: U.S. Army Construction Engineering Research Laboratory. Technical report ; N-86, vol. 2.

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