Soil Survey and Its Use in Alaska

by

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TABLE OF CONTENTS

PREFACE

Soils have been surveyed in various parts of Alaska to meet resource-development needs since territorial days. These surveys have been conducted and published by the National Cooperative Soil Survey since 1952 and are a joint effort of the United States Department of Agriculture Soil Conservation Service and the Alaska Agricultural Experiment Station. Initially, government agencies were the major users of such soil surveys because land ownership was controlled almost entirely by government agencies. However, the demand for soils and geographic information increased substantially as population increased and urban areas grew following the discovery of oil on the Kenai Peninsula during the 1950s and on the North Slope in the late 1960s. Interest also heightened when the state gained title to a large portion of land following statehood in 1959. The National Cooperative Soil Survey (NCSS) published many soil surveys for areas of intensive land use or potential land development. These soil surveys often are underutilized or misused.

This publication, "Soil Survey and Its Use in Alaska," was developed over three years based on my field reviews of NCSS activities in Alaska as well as on my discussions with users of soil surveys regarding questions and problems arising from using the reports. In this publication, soil surveys and their use in Alaska are reviewed and discussed.

While land-use planners and land managers are my primary intended audience, the information contained herein should also be useful to soil scientists, extension agents, conservationists, students of natural-resources management, and other interested persons.

Many people have contributed ideas and concepts for this publication. I am especially grateful to the following for technical reviews and encouragement during the development of this publication: Dr. R.G. Cline, Soil Correlator, U.S. Forest Service, Missoula, Montana; Mr. J. Moore, Assistant State Soil Scientist, USDA-SCS, Anchorage, Alaska; Dr. J.D. McKendrick, Associate Professor of Agronomy, Agricultural and Forestry Experiment Station, University of Alaska-Fairbanks; and D. Witte and T. Cox, former SCS soil scientists, now private consultants.

INTRODUCTION

What is Soil?

Soil is the collection of natural bodies which occupies those portions of the earth's surface which support plants and have certain properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time (Soil Survey Staff 1962). Soil surveying is an applied science which includes identifying and mapping these soils over the landscape and scientifically interpreting their land-use potentials.

Early Works

Soil survey has 70 years of history in Alaska. In 1914, Bennett and Rice conducted a reconnaissance soil survey covering about 31,000 square miles. This survey was done at the request of and in cooperation with the Alaska Railway Commission. The purpose was to present information on crops, surface configuration, climate, soils, transportation, markets, mining, and settlements as elements affecting potential agriculture for the region. Areas of major concern were: Cook Inlet-Susitna, Copper River Basin, and Yukon-Tanana. The authors predicted agricultural feasibility for Alaska based on the agricultural success in Siberia where similar environmental conditions prevail. In their report, soils were classified into series or groups of soil types. The Knik Series, a Matanuska Valley soil, was first recognized at that time. Chemical and mechanical analyses of Alaska soils were performed on samples collected during this survey. This was a good example of the early cooperative soil survey; the Bureau of Soils executed the survey; the Alaska Engineering Commission paid expenses; and the Alaska Agricultural Experiment Station experimented with crop production.

In 1949, Kellogg and Nygard (1951) investigated agricultural capabilities of fifteen geographic units in the state and described their soils and respective management problems. Individual soils were identified to the series level but described in associations. This report, ''Exploratory Study of the Principal Soil Groups of Alaska,'' served as the predecessor of the first comprehensive investigation of Alaskan soils. In this survey, the state was divided into twelve physiographic provinces, a general soils map of the state was compiled, and major areas having agricultural potential were identified. Soil information included both mechanical and chemical analyses. The Great Soil Groups classification system from the 1983 USDA Yearbook was used in this survey.

Both of those surveys, though their soil classification systems are now outdated, still provide valuable information and a review of agricultural development in Alaska.

Current Status

There were no detailed soil surveys in Alaska until 1939-40 when the Matanuska Valley was surveyed (Rockie 1946). With the establishment of the Alaska State Office of the Soil Conservation Service (SCS) in 1948, soil surveys done in cooperation with the Alaska Agricultural Experiment Station became an important part of SCS operations in Alaska. Subsequent detailed soil surveys included portions of the interior and south-central regions. In spite of these activities, soil information was not sufficient to provide the basis for wise and efficient land-use planning throughout the state. Only a timely small-scale, general soil survey could meet these needs. The ''Exploratory Soil Survey of Alaska'' was initiated in 1967 to meet those demands. The survey was completed by Rieger, Schoephorster, and Furbush in 1973 and was published in 1979. It is a good example of a statewide exploratory survey. The field work was done at a scale of 1:500,000 and published at a scale of 1:1,000,000 which is approximately equivalent to 1 inch: 16 miles. There were fifteen major land-resource areas recognized and characterized by their unique pattern of topography, climate, vegetation, and soils. Soils within each landscape segment were described and classified. Relationships among soils, the native vegetation, and landforms were noted; and the proportion of each major soil in each area was estimated. Each map unit in this survey is an association of soils arranged in a consistent pattern. Soils were identified by phases at their respective subgroup levels according to Soil Taxonomy (Soil Survey Staff 1975). This survey is useful in general land use planning and as a guide to identifying the most desirable areas for specific uses. It functions as a basis for determining areas where more detailed soil surveys are needed to give adequate information for planning and management.

In a recently published introductory soils textbook (Donahue et al. 1983), it was stated that "remote and wild areas (as in most of Alaska today) usually have only an exploratory soil survey made for most of the land." Actually, besides the "Exploratory Soil Survey of Alaska," there have been more than twelve detailed soil surveys published since 1956 (table 1). Detailed soil surveys issued by the National Cooperative Soil Survey (NCSS) in which the SCS has leadership include the following areas: Fairbanks (Rieger et al. 1963), Goldstream-Nenana (Furbush and Schoephorster 1977), Homer-Ninilchik (Hinton 1971), Kenai-Kasilof (Rieger et al. 1962), Matanuska Valley (Schoephorster 1968), Salcha-Big Delta (Schoephorster 1973), Susitna Valley (Schoephorster and Hinton 1973), and Totchaket (Furbush et al. 1980). The total acreage is 3,129,919 acres. There are two areas, Haines (McCloskey, personal communication[1]) and Yentna (Olszewski, personal communication[2]), where field work has been completed, and publications are due in the near future, covering an additional 3,615,520 acres. The Copper River Basin Survey Area (Clark 1983) comprises some 598,880 acres, with field work scheduled for completion at the end of 1984. Preliminary field work for the Kantishna Area started in the summer of 1983. The

Table 1. Status of National Cooperative Soil Survey (NCSS) in Alaska (Dec. 1984).

Survey area	Publication year	Acreage	Order of survey	Field map scale	Published scale
Kenai-Kasilof	1962	238,248	2	1:21,120	1:31,680
Fairbanks	1963	254,571	2	1:12,670	1:31,680
Matanuska Valley	1968	449,300	2	1:15,840	1:20,000
Homer-Ninilchik	1971	271,300	2	1:21,120	1:31,680
Salcha-Big Delta	1973	308,960	2	1:21,120	1:31,680
Susitna Valley	1973	701,500	2	1:15,840-1:21,120	1:31,680
Nenana-Goldstream	1977	326,250	2	1:21,120-1:24,370	1:31,680
Totchachet	1980	579,790	2	1:20,000	
Subtotal, Order 2, surveyed acreage		3,129,919[1]			
Yentna	[2]	3,300,000	3	1:24,000	1:31,680
Haines	[2]	315,520	3	1:24,000	
Copper River	[2]	598,880	3	1:24,000	
Subtotal, Order 3, surveyed acreage		4,214,400			
Subtotal, Orders 2 and 3, surveyed acreage		7,344,319			
NE Kodiak Island	1960	310,407	4	1:120,000	1:63,360
Seward Peninsula	[2]	21,590,000	4	1:125,000	1:125,000
Subtotal, Order 4, surveyed acreage		21,900,407			
Total NCSS Survey Area[3]		29,244,726			

[1] Published
[2] Field work completed or scheduled to be completed
[3] *Exploratory Soil Survey* covers the whole state.

This 1949 photograph shows a SCS soil survey crew working in the Kenai-Kasilof area. Tents are still used today for soil surveys in roadless and remote areas. (*Soil Conservation Service photo*)

Soil scientists from the Soil Conservation Service and the Agricultural and Forestry Experiment Station examine the field texture of a Cryorthod mapped north of Yenlo mountain during a field review of the Yentna Soil Survey Project.

[1] *McClosky, J., Soil Scientist, USDA-SCS, Anchorage, Alaska.*
[2] *Olszewski, K., Soil Scientist, USDA-SCS, Anchorage, Alaska.*

NCSS also published a reconnaissance soil survey of northeastern Kodiak Island (Rieger and Wunderlich 1960) of 310,407 acres. Field work for the "Seward Peninsula Reindeer Range Soil Survey," which covers 21,590,000 acres, was completed in 1983 (Van Patten, personal communication[3]).

Besides those NCSS projects, the SCS in Alaska also conducted and published many special-purpose surveys, totaling 3,517,130 acres as of 1984. These surveys are being used for such specific purposes as urban planning, highway corridors, and moose range. The detailed soil surveys in Alaska were published at a scale of 1:31,680 except for the Matanuska Valley Soil Survey which was at a scale of 1:20,000. Less-detailed soil surveys were usually at a scale of 1:63,360 or larger. A map scale of 1:31,680 was used for the remote soil surveys.

The total acreage of National Cooperative Soil Survey in Alaska at the Order 2 and 3 levels (detailed surveys), either published or with field work completed by 1984, is 7,119,440 acres and, at the Order 4 level (reconnaissance surveys), 21,900,407 acres (table 1). The U.S. Forest Service also conducted soil resource inventory reports for lands under that Federal agency's jurisdiction. The total soil acreage surveyed by the U.S. Forest Service in Alaska by 1984 was 16 million acres, among which 10.2 million acres are in the Tongass National Forest with the remainder in the Chugach National Forest. Besides government agencies, there are also private consulting firms conducting soil surveys on some areas for specific purposes, such as the soil survey for Cape Yakataga designed for timber inventory (Cox, personal communication[4]).

National Cooperative Soil Survey

The National Cooperative Soil Survey (NCSS) was organized in 1952 to coordinate and simplify the great amount of soil survey information. It is coordinated by the Soil Conservation Service of the United States Department of Agriculture (USDA). In most states, the state land-grant institutions (state universities) serve as the statewide cooperating agency. In Alaska, the Agricultural and Forestry Experiment Station of the School of Agriculture and Land Resources Management, University of Alaska-Fairbanks, represents the state's interests.

[3] *Van Patten, D., Soil Scientist, USDA-SCS, Anchorage, Alaska.*

[4] *Cox, T., Consultant, Arctic Geo. Resource Associates, Palmer, Alaska.*

The U.S. Forest Service, Bureau of Land Management, Fish and Wildlife Service, and other Federal agencies may cooperate closely in survey areas within their respective jurisdictions. All soil surveys in which the SCS participates are done cooperatively with Federal and state agencies, such as the U.S. Forest Service, Alaska State Department of Natural Resources, Department of Fish and Game, local conservation districts, and Alaska Native corporations.

The SCS also cooperates with some municipalities, Alaska Native corporations, and other agencies and private industries to survey soils to meet local needs for community planning and development. However, these surveys are not correlated nor is their publication anticipated under the NCSS schedule due to the size and isolation of the surveyed areas. Normally these surveys will be printed only as a special report with a limited number of copies. An example is the soil survey entitled "Soil and Range Sites of the Umnak-Unalaska Area" (Preston and Fibich 1978). With increased interest or expanded survey activity adjacent to some of these survey areas, these surveys may be correlated and incorporated into the NCSS program.

Cooperative arrangements relating to soil-survey activities may be initiated by the SCS or concerned agencies. These cooperative arrangements are delineated in the memorandum of understanding as specified in Chapter 3, "Preparing for Mapping," *Soil Survey Manual*, revised (Soil Conservation Service 1981). This document is an agreement between the SCS and the principal cooperators, and it describes the basis of their collaboration in general terms. Specific commitments and obligations are defined in a separate memorandum of understanding for each survey area.

The memorandum of understanding clearly states the reason (purposes) for making the soil survey, what the work will entail, how it will be done, the scale to be used in the field and for publication, publication plans, interpretations, schedule, and who is responsible for the various aspects of operations. The memorandum is completed when signed by authorized representatives of each cooperating agency, and it should be completed before field work commences.

Soil surveys are utility oriented, therefore the survey can be executed in a variety of ways depending on the users' needs. It is most important to specify clearly the purposes of the survey in the memorandum. Soil scientists can design a soil survey properly only if the land use is known and interpretation objectives are specifically stated. Thus, a memorandum of understanding is the cornerstone for quality control of the soil survey.

HOW SOIL SURVEYS ARE MADE

Soil scientists make a survey to learn what kinds of soils are in an area, where they are located, how they can be used, and how they respond to management practices. Traditionally, soil scientists travel in standard vehicles using existing road systems for stopovers, observation, and short-distance transecting and traversing. Transecting is a way of systematically recording the location and number of inspections necessary to determine the kind, proportion, and pattern of soil and nonsoil components of each delineation. Traverses differ from transects in that no separate record or field notes are required other than a simple circle drawn on the field sheet to indicate where a soil inspection has been made by auger or shovel (Cline 1984). In Alaska, the available road systems are limited. Therefore, the soil-survey parties in Alaska depend heavily upon helicopter support for access and transecting. Using helicopters allows the survey party to cover a larger area and to observe the landforms, vegetation, drainage patterns, and other surface features more closely. In roadless regions, this is a time-saving and cost-effective technique for making soil surveys.

A soil-survey party can consist of two to three crews, each containing a soil scientist and a biotechnician who study the geology, climate, landscape and terrain characteristics, vegetation, and any existing soils information for the area in order to get a general perspective. Then they examine aerial photographs by stereo-viewing to delineate various geomorphic units. Generally, images from NASA satellites and photos from reconnaissance aircraft are enlarged to the appropriate scale and used for base maps. Infrared color photos are used to separate unique vegetation communities and soil-moisture regimes. The survey crews travel by helicopter to selected sites and examine areas on the ground using transects and traverses across selected landscapes. Soil types and map-unit boundaries are identified by examining representative sites on the ground and correlating on-the-ground findings with previous air-photo signatures. The aerial photographs show vegetation, relief, natural drainage, landforms, and other details that aid in locating boundaries accurately. A compass is used to maintain transect bearings as the crews struggle through dense spruce forest, willow patches, thick alder, muskeg, or tundra. They generally carry firearms while in remote sites to protect themselves from bears. However the ''biggest'' enemy is often an army of mosquitoes.

Since it is not cost effective for a soil scientist and biotechnician to examine every acre in most survey areas in Alaska, they have to depend on the data collected along the transect line to predict the soil type and unit boundary on the landscape. Along transects, the soil scientists and biotechnicians observe and record the steepness, azimuth, length, and shape of slopes; size and speed of streams; kinds of native vegetation or crops; fire history; kinds of rock; relative positions of different soil units on the landscape; and many other soil details such as pH, depth, color, structure, field texture, con-

Soil survey crews depend on helicopters for accessibility in roadless and remote areas. Muskegs and river beaches are often used for drop-off and pick-up points where the crew starts or finishes a transect.

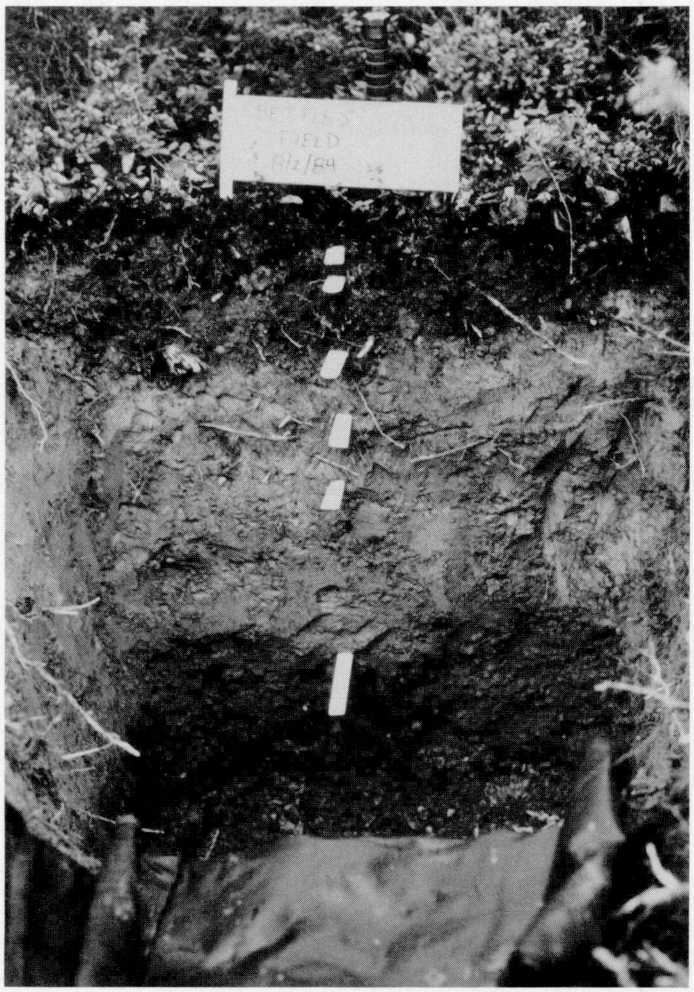
sistency, rooting depth, and density. Distances between transect lines vary from one-half mile to over a mile, depending on the complexity of the landforms or soil-distribution patterns, in accordance with the intensity of the survey. Detailed soil surveys involving the examination of every acre can be done if such detail and level of confidence are justified.

The soil scientists usually dig many holes to expose soil profiles. Tile spades, shovels, augers, or probes are used. Power ice augers are used for frozen soils. A profile is the sequence of natural layers, or horizons, in a soil; it extends from the surface down into the parent material, which has been changed very little either by leaching or by the action of plant roots. The soil scientists record the characteristics of soil profiles and compare those profiles with others in nearby areas and more distant in places. They classify and name the soils in accordance with nationwide, uniform, soil-correlation procedures.

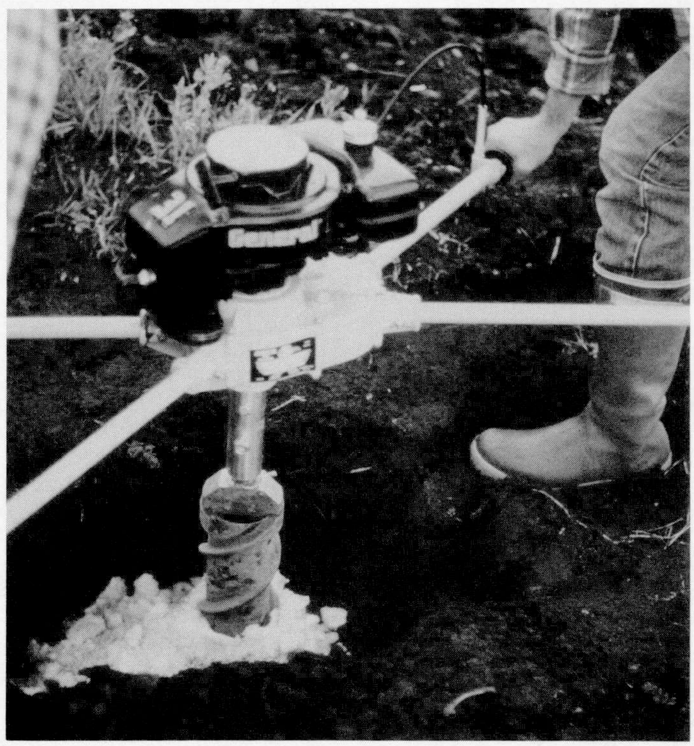
Soil correlation is the process of maintaining consistency in naming and classifying soils and of the units delineated on maps as specified in the chapter ''Maintaining standards in soil survey'' of the revised *Soil Survey Manual* published by the Soil Conservation Service in 1981. In the correlation process, field and laboratory data are examined for similarities and differences in terms of management interpretations between soils at different places. The soil-correlation process includes quality control and mapping decisions carried out by the survey party throughout each survey. Following this process, the soil survey is considered *correlated*, otherwise it is considered *uncorrelated*.

While a soil survey is in progress, samples of key soils are taken for laboratory determinations and for engineering tests. Vegetation is sampled to determine range forage production. Trees are core sampled to measure forest productivity. Data on yields of crops under defined practices are assembled, if available, from farm records and from experimental plots on the same kind of soil. Crop-production data are sometimes unavailable, as many survey areas have never been farmed. In this case, crop production is estimated and/or extrapolated from similar soils in other areas.

The completed soil survey includes soil and map unit descriptions, maps, laboratory data, and utility interpretations combined and organized into a report. These reports are then used by planners, farmers, range and forestry managers, engineers, conservationists, developers and builders, property buyers, recreationists, mining industries, and others for a variety of planning and management purposes.



This view of an exposed soil profile shows horizons marked for description and sampling. This pit was excavated for site specification of a soil climate study near Bettles. The rooting depth is limited to the top 5 inches due to high bulk density of the soil.



An ice auger is used to sample frozen soils. An ice wedge from a Histic Pergelic Cryaquept (a permafrost soil) near Silver Lake, Copper River Basin is shown here.

HOW SOILS ARE CLASSIFIED AND NAMED

Soil Classification

All soils in the United States and soils in many other countries have been classified according to Soil Taxonomy (Soil Survey Staff 1975). Such classification systems are contrived by man to organize knowledge. They are not, themselves, truths that can be discovered. Soil classification is the technique by which soils can be segregated into categories that are useful for understanding their genesis, properties, and responses to use. Soil Taxonomy is one system of classification that is concerned primarily with relationships among soils and the factors responsible for their character. Soil Taxonomy is a hierarchical system with six categories:

- Orders
  - Suborders
    - Great Groups
      - Subgroups
        - Families
          - Series

Each category is designed to be useful for a given purpose at an appropriate level of detail or generalization. Soil Taxonomy has been developed to serve the purpose of soil surveys so that characteristics of soil can be translated into maps for land use and management. Soil Taxonomy is also necessary to facilitate data transfers. The properties selected as criteria for classification at levels from order to subgroup are largely those that result from soil-forming processes influenced by the environment. They are defined in terms of either recognizable or easily measured soil characteristics.

The *order* is the most general category in Soil Taxonomy. Currently there are ten orders. There is one new soil order proposed and under review. Five of the ten orders are represented in Alaska (Rieger et al. 1979, Smith 1978). The orders are differentiated by the presence or absence of diagnostic horizons or features that are characteristic of the kinds and intensities of soil-forming processes and contrasting climates. The subdivision of the order is the suborder.

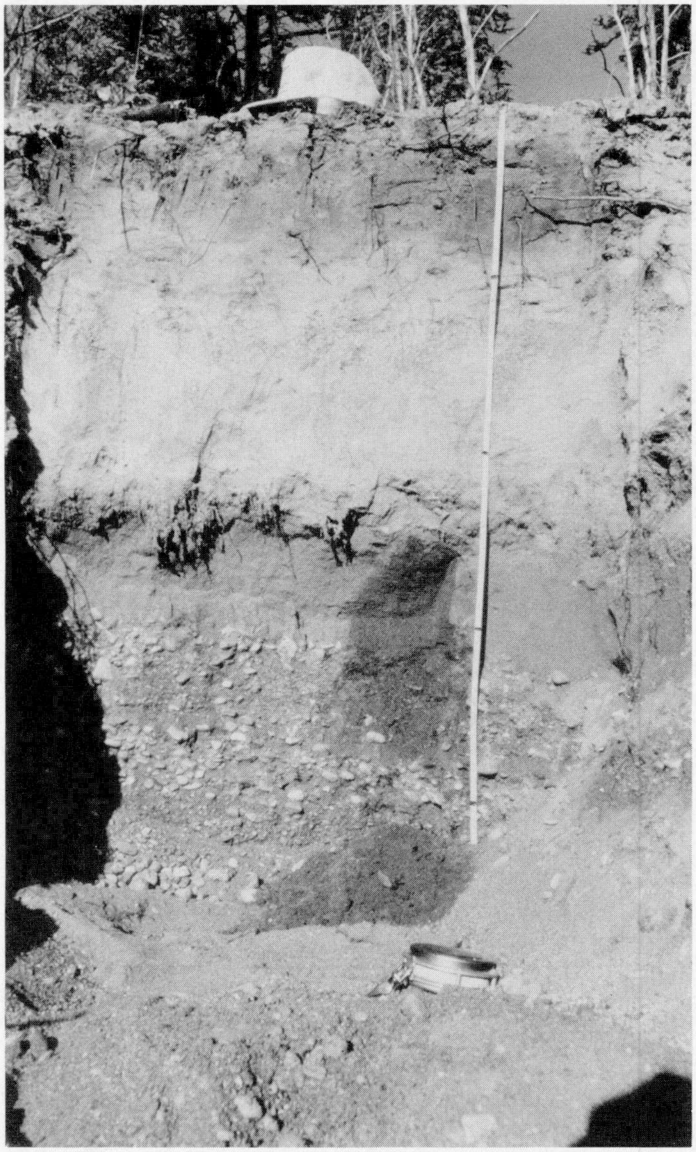
Suborders within soil orders are differentiated as to soil properties and horizons resulting from differences in soil moisture, soil temperature, and other specific genetic features. There are forty-four suborders currently recognized, and about twelve are represented in Alaska.

Great soil groups are a subdivision of suborders. The great groups are distinguished on the basis of soil horizons and soil morphological features. There are 187 great groups identified in the U.S. and more than seventeen represented in Alaska. Each great soil group is divided into three kinds of subgroups: *typic, intergrade,* and *extragrade. Typic* means the common ones of that category, *intergrade* means it is going to or coming from other categories, and *extragrade* means exceptional features. There are 990 subgroups identified in the U.S., of which approximately 74 are represented in Alaska.

Soil *families* are separated within subgroups based on soil properties important to the growth of plants or response of soils when used for engineering purposes. There are about 5,603 familes identifed in the U.S., more than 100 of which are in Alaska.

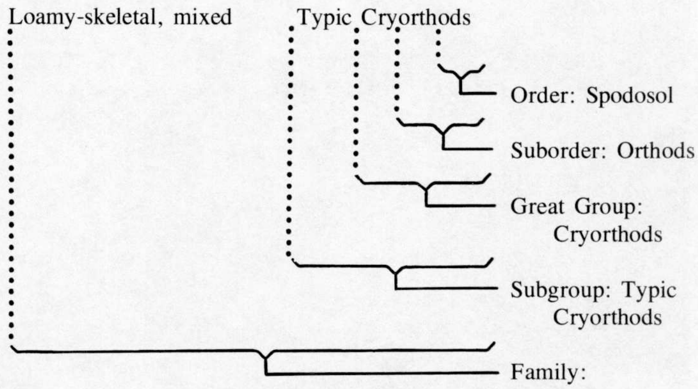
As the categories go from higher to lower levels, the information becomes more specific and the interpretations are more detailed. All levels are practical and useful in soil mapping. From order to subgroup level, Latin and Greek are used to designate the formative elements, as required by most taxonomy or nomenclature systems, such as those used in the plant, animal, and medical sciences. At the family and series level, English terms are used. Soil family is the lowest level of this heirarchy, and *soil series* are like individual members of the family. Soil series are differentiated on the basis of observable and mappable soil characteristics, such as color, fineness of soil particles, the size and shape of the soil clod, behavior under various moisture conditions, thickness, pH, and number and arrangement of horizons in the soil body (Soil Survey Staff 1962).

Features used to separate series are also important to land use and management. Each soil series is named for a town or other geographic feature near the place where a soil of that series was first observed and mapped. Kenai, Knik, and Nenana, for example, are the names of three soil series mapped in the Kenai Peninsula, Matanuska Valley, and the Interior, respectively. Sometimes the name is simply coined. All the soils in the U.S. correlated with the same series name are essentially alike in those characteristics that affect their behavior in the natural undisturbed landscape and how they will react under similar management and use. Currently, there are more than 13,500 series defined and named in the U.S. In Alaska, there are more than 200 correlated series defined and named in the published surveys and reviewed field works. These numbers are expected to increase greatly as the statewide soil-survey program progresses. The number of other categories, especially at family, subgroup, and great group levels, will increase with new surveys.



This profile of Gulkana silt loam, mapped in the Copper River area, shows 2.5 feet of wind blown silty material (loess) overlain alluvial sand and gravel. Note the concentration of root mat at the base of the loess layer where the contrast texture (with sandy layer below) creates a moisture interface which restricts root extension into the sandy layer.

The classification of the Homestead Series, a soil which occurs extensively in the Mat-Su Valley, is used below to demonstrate the Soil Taxonomy classification system:



This means the Homestead Series belongs to the family of Loamy-skeletal, mixed, Typic Cryorthods. The Homestead Series is a Spodosol. Spodosols are leached soils of the conifer forest zone. Leaching normally results in an accumulation of organic carbon, together with iron and aluminum, in one of the subsurface horizons. This usually occurs in the upper part of the profile. This horizon usually has strong brown and yellowish-brown color. The suborder Orthod indicates it is a common Spodosol. The great group Cryorthod indicates this soil is developed under a cryic (cold) temperature regime where the mean annual soil temperature at 20 inches is 0 to 8 °C. (32 to 47 °F). The family name indicates that this soil, at a depth of 10 to 40 inches, has over 35 per cent coarse fragments ($>$ 2 mm) by volume, less than 35 per cent clay in the remaining fine earth ($<$ 2 mm) portion, and mixed mineralogy.

The classifcation of the Homestead series is conceptual. The Homestead Series is a taxonomic unit which is used for communication among soil scientists, technology transfers, and understanding the relationships and differences regarding other soils. However, soil series are not used in mapping.

Soils of the same series, family, and subgroup can differ somewhat in texture of the surface horizon and in slope, stoniness, drainage, depth to permafrost, or some other characteristic that either affects or reflects the use of that soil by man. On the basis of such differences, a soil series (or higher taxonomic category) is divided into *soil phases*. Soil phase is utility oriented, reflecting the objective of mapping. For example, *Homestead silt loam, rolling*, is one phase of Homestead series which has a silt loam surface texture and occurs on 7 to 12 per cent slopes. Another example is *Tanana silt loam, thawed*, which is a thawed phase of the Tanana Series. Normally this series has permafrost within 14 inches of the surface. Tanana thawed is used after clearing or natural fire, when the permafrost recedes to more than 40 inches due to the loss of the insulating layers of mosses and organic litters. In practice, a phase unit is more a function of the map-unit definition and design than a division of a conceptual taxonomic idea.

Skookum Valley and tidal marshes near the mouth of Placer River near Portage. Descriptive names are used as map unit names for miscellaneous land types such as glaciers, talus slope, rock outcrops, riverwash, marshes and beaches.

Map Units

When soil scientists delineate an area on a soil map, the areas are called *map units*. A single area on a soil map bounded by a continuous line is called a *map delineation*. The map unit is named after the major soil or soils in that unit along with soils of a minor extent. When a map unit consists primarily of one kind of soil or includes soils in other taxa considered similar for survey objectives, the map unit is called a *consociation*. For example, *Nenana silt loam, rolling,* is a consociation map unit.

When a map unit consists of two or three dominant kinds of soil that occur naturally in a consistent pattern, it is called an *association*. For example, the Fairbanks-Ester association, steep to very steep, is a map unit which contains two major soil types, mapped on high ridges east of Fairbanks. The Fairbanks silt loams are on south-facing slopes, and Ester silt loams are on north-facing slopes. The two soils occur next to each other in a regular pattern and are not separated in the delineation on the map. Generally the Fairbanks silt loams make up more than 75 per cent of this association, and the Ester silt loams make up about 15 to 25 per cent. Included in this map unit are some Gilmore silt loams and Goldstream silt loams.

A map unit in which two or three different soils are so intricately mixed that it is impractical to show them separately on the map is called a *complex*. Soil complex is named for the major kinds of soil in it, for example, Killey-Moose River Complex. This complex contains primarily Killey and Moose River Series but also includes other soils of minor extent.

On most soil maps, areas are shown that are so rocky, shallow, disturbed, or frequently worked by wind and water that they do not support vegetation and can scarcely be called soils at all. These areas are depicted on soil maps, but they are given descriptive names, such as rock outcrops, riverwash, beaches, and glaciers. These mapping units are referred to as *miscellaneous land types*.

THE USE OF SOIL SURVEY

Soil: A Valuable Resource

Soil is considered one of the natural, nonrenewable resources needed for sustaining food and fiber production to meet human needs. At the same time, soil has also been used for supporting buildings and roads and as a recipient of waste. Uses of soils for all such purposes intensifies as population increases. Not until after World War II did the people in this country discover that there *is* a limit to our supply of land, especially land suitable for urban development. In recent years, we found that the pride of America — agriculture — is threatened by a rapidly diminishing landbase (Little 1979). Alaska is a new state, and much of it is yet to be developed, but it has already faced growing pains associated with changing land use. A brief summary of the use of soil surveys in other parts of the country and this state may shed some light on the approach to better use and management of a most precious nonrenewable resource: soil.

General Resource Planning

For a very large area like an entire country or a state like Alaska, a general soils map is used for broad land-use planning. The ''Exploratory Soil Survey of Alaska'' (Rieger et al. 1979) is an example of this. It gives general information about potentials and limitations of specific physiographic areas. Further, it identifies 20 million acres of land as having agricultural potential, 18 million acres of grassland with grazing potential, and 40 million acres of forest land with commercial value. Information contained in this publication has helped to guide those engaged in planning development of the state's resources. It is also used as a guide to the most desirable areas for a variety of specific purposes, such as agricultural projects in different parts of the state. Following this guide, more detailed soil surveys are to be designed for the implementation stage of the projects and field work. The map units used for this level of planning are mostly phases of soil subgroups or great groups and, in some cases, suborders.

Regional Land-Use or Watershed Planning

Regional land-use or watershed management usually involves more than one kind of soil map. First, a general soils map is used for an overall broad-stroke study of available soil resources in the early planning stages. Then a detailed soil map is needed for careful study of individual soils. The detailed soil map is essential in considering limitations, restrictions, and hazards as well as suitability of the soils for specified uses. The ''Tanana Basin Area Plan'' is based on both detailed and general soil maps (Todd 1983) and the study entitled ''Agricultural Practices and Water Quality Effects'' (Rummel 1982) is based on more general soil maps. The U.S. Forest Service uses Soil Resource Inventory (SRI) for watershed management planning. The soil components of units used in general soil maps are identified as phases of subgroups because less detail is required. In the detailed soil maps, they are phases of consociations, associations, or complexes of soil series.

Community Planning

Community, urban, or city planning usually require more than one kind of soils map. A general soils map offers the planner a ''birds-eye view'' of the area of interest. Then a detailed soil survey of medium intensity is needed for establishment of zoning, ordinances, flood control, public sanitary sewer, and parks. Basic soils information contributes to all phases of land-use planning. The general soils map for these purposes consists of map units of phases of association or complexes of soil series. The detailed soil map consists of map units of phases of series. The general purpose NCSS publications in Alaska are useful for community planning. The scales of these groups of maps range from 1:20,000 to 1:31,680.

A soil survey report can be used for selecting land for development. The map unit description indicates the high flood hazard in this area in southeast Palmer. (*Soil Conservation Service photo*)

The ''Anchorage Area Soil Survey'' (SCS 1979), ''Soils of the Juneau Area, Alaska'' (Schoephorster and Furbush 1974), both uncorrelated, and many remote surveys are examples of soil surveys especially designed for such purposes.

When land use in community planning narrows to such small acreages as subdivisions, trailers parks, and individual lots, high-intensity detailed soil survey or on-site studies and verification of detailed soil maps are sometimes needed.

Agricultural Development

In the United States, people involved in farming have for many years learned to use soil surveys for land selection and for learning how various soils on a specific tract of land might respond to management for crops, grasses, vegetables, and trees. This wise use and management of soils is basic to farm efficiency.

As mentioned above, general soil surveys have been used successfully to identify land having agricultural potential in Alaska. Based on those surveys, locations of interest were identified and more-detailed soil surveys were conducted. Subsequently, agricultural projects were designed. An example is the Nenana-Totchaket area (Agricultural Action Council 1983). Detailed soil surveys are effectively used to outline project areas and formulate conservation plans for individual tracts following development (DNR 1982).

Such agricultural projects become possible with the state ownership of land after statehood in 1959. The Federal Government transferred public land to the state and boroughs which have in turn transferred land to private ownership through land disposals. Examples are the Delta and Pt. MacKenzie agricultural projects by the state and agricultural land and homestead parcels by the Matanuska Susitna Borough (1982). Lands for disposal are selected based on land capability classifications in detailed soil surveys.

As agriculture in this country is threatened by a diminishing land base due to the competition for prime farmland from other uses, many states have established farmland preservation programs (Steiner and Teilacker 1979). The land capability classification system is used as a scientific basis for those programs. In Alaska, parcels conveyed in an agricultural land disposal carry agricultural rights only.

Soil surveys are also used in range management to help ranchers formulate grazing plans and protect range productivity. The soil surveys for the Seward Peninsula and Kodiak Island were specifically designed for rangeland management objectives.

The relationships between soils and forest productivity have long been studied (Gessel 1949) and used in forest land assessment (Storie and Weir 1942, Storie and Wieslander 1948). In recent years, many projects have been devoted to utilizing soil surveys to map forest productivity and operability and to formulate management alternatives (Gilkeson 1981). The most noted is the Private Forest Land Grading program (PFLG) in Washington State (Forest Land Grading Staff 1978, 1981) in which the Departments of Revenue and Natural Resources became members of the NCSS and entered cooperative agreements with SCS, U.S. Forest Service, Washington State University, and private lumber industry to survey soil to provide the basic information required for forest land grading. There are many private industries also using soil surveys for forest management, such as Weyerhaeuser Company (Webster and Steinbrenner 1974), and the Internation Paper Company (Haines and Haines 1980). In Alaska, the ''Haines Area Soil

Barley is now harvested on Volkmar silt loam in the Delta II Agricultural Project area where the project layout was based on Delta-Salcha Soil Survey Report.

An aerial view of the Industrial Park (lower left), south of Palmer, and portions of the Matanuska Valley. The soils here, formed in deep loess deposits, are very productive, but urban development is competing with agriculture for a limited land base.

Survey'' (McCloskey, personal communication[5]) Cape Yakataga (Cox, personal communication[6]) and the soil survey program of U.S. Forest Service, Alaska Region, are specifically designed for forest land management purposes.

By using soil classification and survey information, the Alaska Agricultural and Forestry Experiment Station is testing the fertility status and response to fertilizer according to taxonomic groups. Results from such studies will help the Alaska Cooperative Extension Service interpret soil test results and recommend fertilizer rates according to the soils on various farms.

Engineering Interpretation

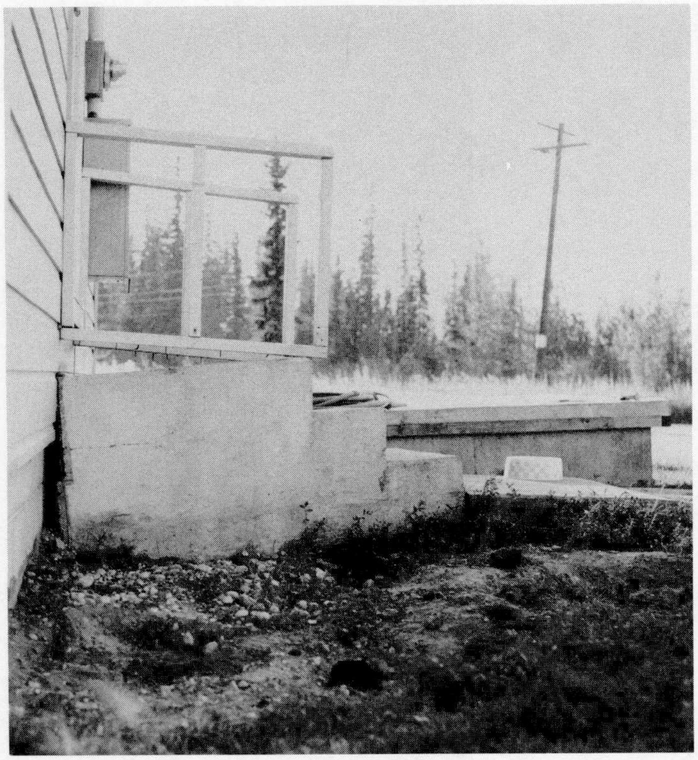
Soil Taxonomy classification provides a systematic approach to identification and description of soils for engineering purposes. Each taxonomic level carries different levels of engineering significance, but the most pragmatic and descriptive is the family level. Soil families were specifically designed to identify soil properties significant to engineering purposes (Soil Survey Staff 1975). Higher categories are substantially less definitive because of the incorporation of properties much less directly tied to engineering interpretation.

Engineers seek to determine the strength, stability, compressibility, permeability, and corrosivity of soils based on soil and map unit properties such as particle size, mineralogy, pH, temperature, depth, slope, aspect, bulk density, consistency, and structure. Engineers are not only concerned about those properties, but also about their variability. Soil family groups and series are based on restricted ranges in those properties.

In NCSS reports, the engineering data and interpretations are given in tables which are based on ranges of physical and chemical properties. These interpretative tables are generally limited to individual soil components (taxonomic units) and not map units. However, map unit criteria rather than taxonomic units have been used to develop engineering interpretations in the NCSS report designed for the U.S. Forest Service, Northern Region (Cline 1981). Such an approach should be encouraged in Alaska. The engineering interpretation of soil survey is essential to most land use categories.

[5] *McCloskey, J., Soil Scientist, USDA-SCS, Anchorage, Alaska.*

[6] *Cox, T., Consultant, Arctic Geo. Resource Associates, Palmer, Alaska.*



The back steps of the Soil Conservation Service building in Fairbanks are settling due to permafrost melting over a 3-year period. (*Soil Conservation Service photo*)

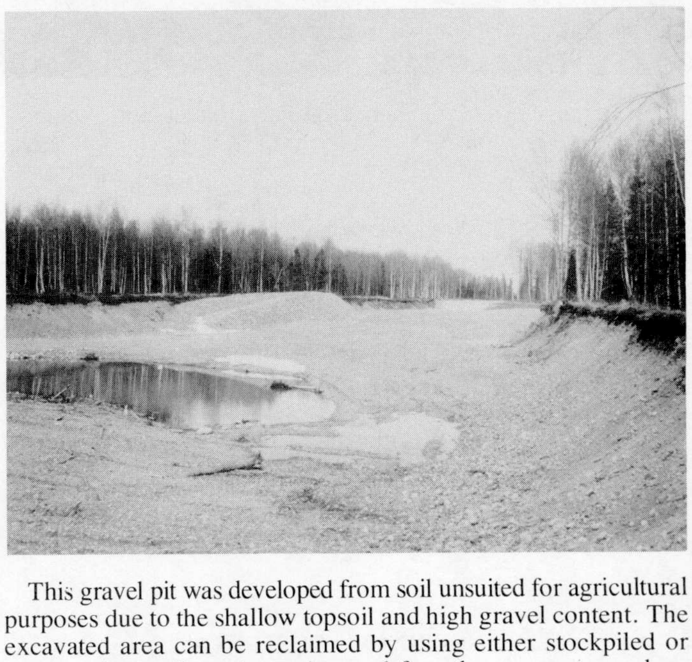
Recreation and Wildlife Management

Soil surveys have been used for recreation purposes such as siting camps, trails, ski resorts, and play grounds (Vink 1975). Soil survey offers information on the relationships between vegetation types and wildlife habitat. The "Report of Reconnaisance Soil Survey, Kenai National Moose Range" is wildlife-management oriented (Rieger 1963).

The SCS is noted for its effort to recognize class VIII soils suitable only for wildlife and natural conservation (Vink 1975), because it was through such identification that agricultural interests recognized that certain lands would be better used for purposes other than economic production.

Other Potential Uses in Alaska

There are many examples demonstrating the value of a modern soil survey to appraisers in assessing land values or land grades (Gilbert 1980, Olsen 1982, Forest Land Grading Staff 1978). Soil survey reports contain information on special landforms and soil horizons which can be chronologically related (Olsen 1981), therefore they have been used in natural feature preservation and archeological examinations.



This gravel pit was developed from soil unsuited for agricultural purposes due to the shallow topsoil and high gravel content. The excavated area can be reclaimed by using either stockpiled or borrowed topsoil, or it can be used for other purposes such as a sanitary land fill site or a building site. (*Soil Conservation Service photo*)

Environmental Protection

Soil is one of the most important elements in the ecosystem, therefore, soils information is essential in environmental protection or ecosystem studies. A soil survey is required for permit issuance for hydroelectric projects, surface mining and exploration, pipeline construction, and other operations involving the disturbance and removal of soil and native vegetation. In those operations, detailed soil surveys are used for sedimentation and erosion control, topsoil stockpiling and recovery, and reclamation and rehabilitation of disturbed sites (Ping and Kaija 1985).

Alaska has abundant coal and mineral reserves. With increasing demand for energy and strategic minerals, exploration and subsequent mining are expected to increase. Soil maps at 1" = 400' scale correlated according to NCSS standards are required in permit applications. An example is the "Soils Baseline Studies Report, Diamond Chulitna Project" (southcentral Alaska) (ERT 1984). This does not necessarily mean the SCS has to do the soil survey, but that agency may be required to participate in field reviews and correlation.

PROBLEMS AND QUESTIONS ABOUT SOIL SURVEYS

Map Scale and Order of Survey

It is commonly heard in conversations between map users and soil surveyors that "we want an Order 2 soil survey . . ." or "this is an Order 3 survey," or "the scale of this survey is 2 inches to the mile . . . ." Then what is the *order of surveys*? Is an Order 2 survey really needed all of the time?

When the soil scientists talk about the scale of a survey, they generally refer to more than just the scale of the published map. They are referring to the precision and detail with which the survey was made. Generally, the larger the scale, the more detail can be mapped. The smaller the scale, the less detail can be shown. Several factors must be considered in selecting a map scale. In general, the selection of map scale depends upon the intricacy of soil patterns in relation to the expected intensity of land use. The term *order of survey* is used to convey this meaning and is used as a reference of map intensity. The relationship between order of survey and scale of mapping is shown in Table 2.

Order 1 is the highest intensity, with the most detailed procedures resulting in the most precise map. The soils in each delineation have to be identified by transecting, and soil boundaries are observed throughout their length. More general surveys (Order 2 and Order 3) are supported by fewer direct observations to identify delineations and more use of air-photo interpretation to plot boundaries. Still, Order 1 through Order 3, are called *detailed soil survey* with different intensities (high, medium, and low). Order 4 soil survey is a reconnaissance survey. Order 5 is the lowest intensity with the least-detailed procedures, giving a generalized map. Maps from all orders of survey can be equally accurate because their soils and map units are described with differing degrees of precision appropriate to their intensity (Mapping System Working Group 1981).

Occasionally, different areas within the same survey area (project) are mapped at different intensities. This is because some areas of intensive land use need more detail compared to other areas. Sometimes it is because of inaccessibility. It is common to find small areas mapped at an intensity equivalent to Order 3 or even Order 4 in an Order 2 survey. By the same token, one may find areas of Order 4 intensity in an Order 3 survey, and even small areas of Order 2 intensity due to special concerns. More detail is generally needed for urban and cropland use, and less detail is needed for range and forest management. Even less detail is required for areas of low intensity use such as muskegs, tundra, and very steep or rocky landscapes. A need has been voiced by some survey users concerning map inclusions in Alaskan agricultural project parcels. An overall soil survey suits the purpose of planning an agriculture project, but more detail is needed at the project development stage. Therefore some have suggested the need for a high-intensity survey at the scale of 1:15,000 to 1:10,000 in agricultural project areas.

Two approaches may be appropriate to meet this need in future surveys in Alaska. One is to have an Order 3 survey first, then an Order 2 or 1 survey for specified areas where intensive land use is anticipated. The other approach is to carry these two steps in one project; first, go through the whole survey area at lower intensity, then, as the survey progresses, identify the areas of high potential and come back to delineate more detail. In the land-use and resource-planning process, starting from preinvestment, reconnaissance planning to execution (Vink 1975), there are different intensities or survey required.

Map Unit Inclusion

Soil scientists map landscapes based on the information collected along transects and extrapolate information to areas between transect lines with the help of aerial photographs, aerial observation, and field checks and verifications. They try to get the maximum amount of information from the data. However, a map unit is rarely a homogeneous body of one soil. Rather, it is dominated by one or two soils with inclusions of other soils of minor extent. Soil properties within a

Table 2. General guidelines for identifying intensity of soil survey[1]

Intensity of soil surveys	Kinds of map units	Kinds of taxonomic units	Appropriate field mapping scale	Minimum size delineation	Uses or objectives
				(acres)	
Order 1	Mainly soil consociations, a few soil complexes	Phases of soil series	1:10,000	1.0	Project execution On-site appraisals: individual lots or building sites Surface mining reclamation plan
Order 2	Soil consociations, associations, and some soil complexes	Mainly phases of soil series	1:10,000 to 1:20,000	1.0 to 6.2	Project execution Urban planning Farm plans Soil and water conservation Farm allotment plans
Order 3	Soil associations, some consociations, and some complexes	Phases of soil series or families, a few subgroups	1:25,000 to 1:75,000	6.2 to 36	Agricultural project planning Range management Forest land and watershed management Regional planning Riverbasin study
Order 4	Soil associations and a few consociations and complexes	Phases of soil families or subgroups	1:60,000 to 1:200,000	36 to 400	Regional and area planning Grazing plans Resource management Project planning Pre-investment
Order 5	Soil associations	Phases of soil subgroups, suborders, or orders	1:200,000 to 1:500,000	400 to 2,500	National or statewide resource planning
——	Soil associations	Soil suborders or orders	1:500,000 to 1:10,000,000	——	National or world soil map

[1] Cline, 1984; Mapping Systems Work Group, 1981; Vink, 1975

[2] For reference only, still being reviewed and not official NCSS policy yet.

map unit may vary spatially and sometimes change within short distances. The variation depends on the complexity of soil distribution patterns. Soil scientists usually recognize greater detail than they can map due to limitations of map scale. It would add to confusion and difficulty in reading the map if units or delineations were too small for certain map symbols.

Soils of minor extent, contained in delineations, are called *inclusions*. If the properties of inclusions do not affect map-unit interpretations, the inclusion is called a *similar inclusion*. A map unit may contain up to 50 per cent similar inclusions. For example, a soil with silt loam texture may contain a significant portion of soil with very fine sandy loam texture without affecting cropland management. Wysocki (1978) has run transects in many map units of three detailed soil surveys in a glaciated area near Puget Sound in Washington State where he found 30 to 60 per cent similar inclusions.

Inclusions with contrasting properties which would have a detrimental effect on land use are dissimilar inclusions; these require special attention. Examples are the depth to restrictive layers such as bedrock, hardpan, water table, contrasting texture, surface stones, or slopes which are markedly different from most of the map unit. According to NCSS, the allowed limiting inclusion in a map unit cannot exceed 15 per cent. Wysocki (1978) pointed out that this value is an underestimate in highly heterogeneous areas.

It is very important that the map user be aware of these impurities and inclusions in map units which may have adverse effects on land use. In a soil survey report, the kinds of inclusion are listed in each map unit description but are not included in the interpretative tables. *Therefore, it is important for map users to read carefully the map unit descriptions in addition to the interpretation tables.* Only the map unit descriptions provide information concerning purity of units and the limitations which may result from some of the inclusions. Understanding the map unit description is the key to using a soil survey report correctly.

Land Capability Classification

Land Capability Classification is a system developed by the SCS to group individual soil map units "primarily on the group basis of their capability to produce common cultivated crops and pasture plants without deterioration over a long period

Massive ice lenses below the soil surface can result in subsidence problems as the cleared soil thaws. The presence of such ice lens can be predicted in a map unit, but the exact location of the ice lens cannot be mapped without extensive probing and drilling. Note the size of the thermokarst compared to the man at lower left.

This big boulder, exposed by timber harvest, constitutes a contrasting inclusion to this map unit which has a silt loam surface texture. Such an inclusion is hard to detect under dense forest cover without closely spaced transecting.

of time'' (Klingebiel and Montgomery 1961). The groups are based on a uniform national guideline. The SCS recognizes eight different land capability classes according to the limiting factors significant to agricultural land use and management. The eight classes are differentiated on the basis of relative degree and kinds of limitations. The capability class of a map unit in Alaska is designated by a symbol which is composed of two parts such as IIIe. The land is graded from Class I to Class VIII with the higher numbers representing land with greater limitations to farming practices or increasing risk of soil erosion. The lower-case letters designate subclasses representing major conservation concerns: e = erosion and runoff; w = excess water; s = shallow soils, stones, salt, etc.; and c = climate.

Briefly, the land capability classes are defined in USDA Handbook No. 210 (Klingebiel and Montgomery 1961) as follows:

Class I. Soils have few limitations that restrict their uses.

Class II. Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.

Class III. Soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.

Class IV. Soils have very severe limitations that reduce the choice of plants, require very careful management, or both.

Class V. Soils with little or no erosion hazards, but with wetness restrictions which are impractical to remove or correct, that restrict their use largely to pasture, range, forest, or wildlife habitat.

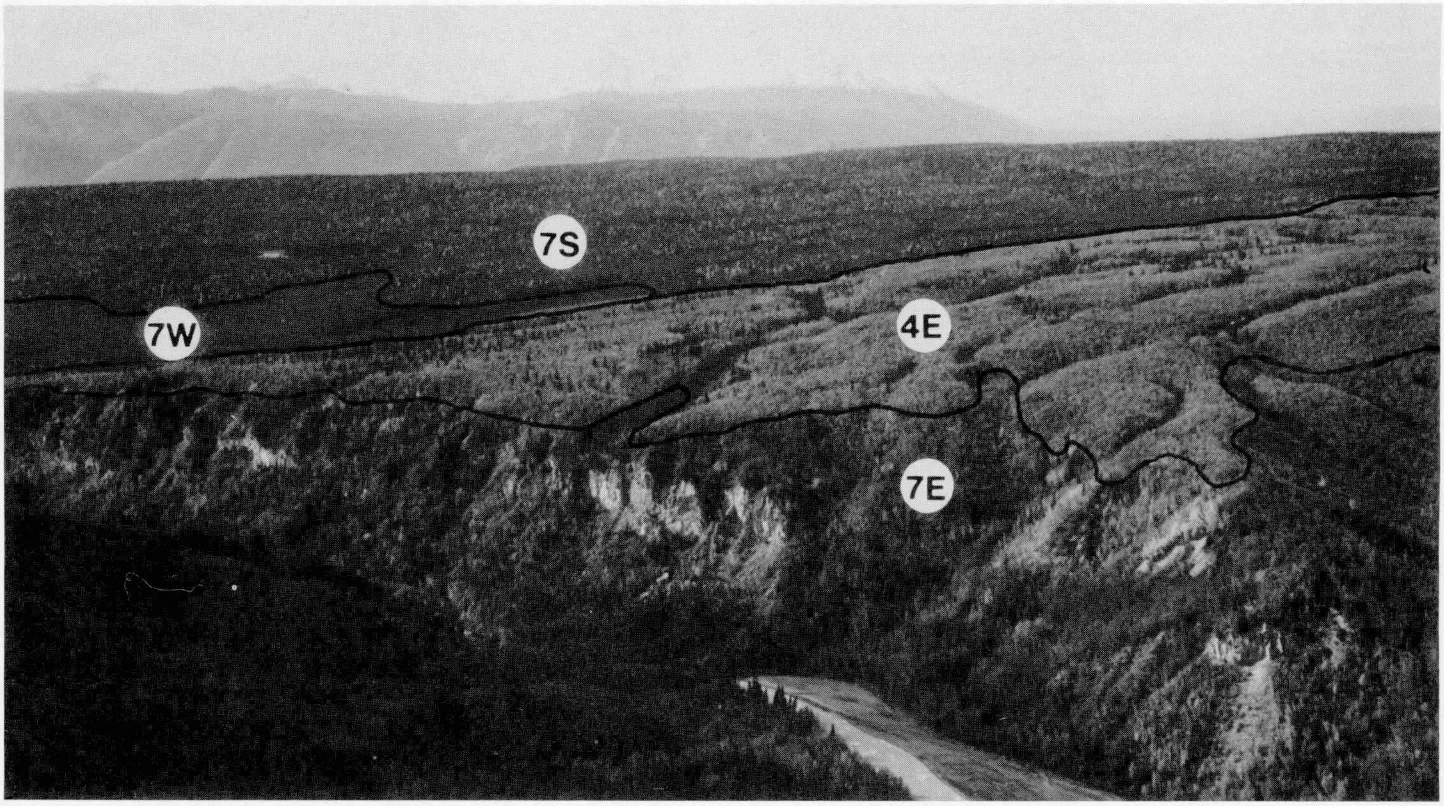
Class VI. Soils have severe limitations that make them generally unsuited to cultivation and largely limit their use to pasture or range, woodland, or wildlife habitat.

Class VII. Soils have very severe limitations that make them unsuited to cultivation and that largely restrict their use to pasture or range, woodland, or wildlife habitat.

Class VIII. Soil and land form have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife habitat, water supply, or aesthetic purposes.

The land capability class guide in Alaska was substantially revised in 1983 by the SCS staff to fit the environment in Alaska, although it still follows the national guidelines. The revised guide became policy in the fall of 1984. Soil properties and environmental factors affecting land capability class in Alaska include: soil depth to bedrock, compact glacial till, or permafrost; available water-holding capacity; surface soil texture, gravel or stones; permeability; slope; drainage and growing season water table; flood hazard; climatic limitations; and water and wind erosion potential.

Most Alaska soils are acid, and the exchangeable sodium in soils is too low to be of any concern. However, there are some soils in Alaska developed from lacustrine (lake) deposits which can require that salinity be included in the capability guide.



This landscape shows capability classes in Copper River Basin. Class VIe land can be used for agricultural purposes with consideration of water and wind erosion hazard. Class VIIs land has severe limitiations due to steep slope and shallow soils over bedrock. Class VIIw land is wetland due to its perched water table over permafrost layer. Class VIIe land has a very high erosion hazard.

Some users of soil surveys question whether climate should be considered. Climate is an important soil-forming factor. Three key crops — barley, potato, and pasture grass — have been selected as index crops of agricultural capability of different Alaska soils. The soil is Class II if all three key crops can mature in 8 out of 10 years, Class III if only two crops can mature, or Class IV if only one (usually pasture) can mature. Climatic factors which determine whether these crops can be economically feasible include: soil temperature, frost-free days, moisture, wind, and growing-degree days. A growing-degree day is a heat unit which is an accumulation of values for each day after the minimum temperature ceases to go below 40°F and until a 40°F temperature is reached later in the year (Searby and Branton 1974). Due to climatic limitations, there are no Class I soils in Alaska. Some people may find it amazing that there are Class II soils in Alaska. Actually, such limiting factors as short growing seasons are compensated by the very long hours of sunlight during the summer, as expressed by growing-degree days.

Soil drainage presents a special problem in the Alaska land capability classification. There are considerable acreages of land under natural vegetation, mainly spruce and moss, which have perched water tables for prolonged periods due to shallow permafrost. Once the land is cleared or vegetation surface is disturbed, the permafrost recedes to greater depths, and the water table either disappears or falls below the rooting zone (Kalio and Rieger 1969, Clark 1983). A capability class is assigned to both the frozen phase of the soil and the thawed phase (Moore 1984).

Land capability classification of soils has been used by the state and boroughs in land disposal operations. There have been problems and disputes over some land parcels because people relied entirely on capability designation and not on map unit description or other interpretations. One misconception about the land capability classification has been that only class II and III soils are agricultural soils. The capability classes only address the potential and limitations of soils to be used for sustained production of common cultivated crops. The capability classification system was not intended to dictate land use. As stated in the USDA Handbook No. 210 (Klingebiel and Montgomery 1961), "The risks of soil damage or limitations in use become *progressively greater* from class I to class VIII. Soils in classes I to IV can safely be used for the common crops if properly managed. However, soils in class II to IV need additional practices to overcome limitations or control erosion. Soils in classes V, VI, and VII are suited to the use of adapted native plants. Some soils in classes V and VI are also capable of producing specialized crops under highly

Left: This barley field, north of Palmer, is on deep and productive Bodenburg silt loam. It was previously classified as IIc, due to the climatic limitations to the selection of variety.

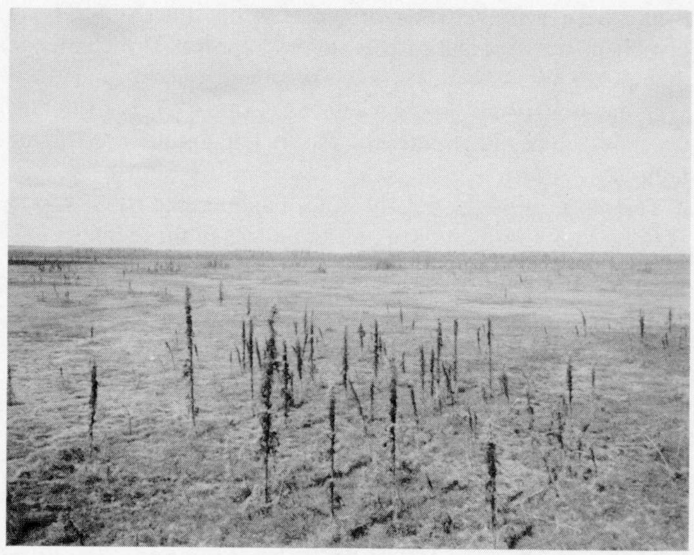
Right: This soil was later reclassified as IIIe due to its wind erosion hazard, and special conservation practices have to be considered. (*Soil Conservation Service photo*)

intensive management.''

The capability class of a soil may change. The capability classification was developed based on a series of assumptions. One of the assumptions states: ''capability groupings are subject to change as new information about the behavior and responses of the soils becomes available.'' Therefore, a soil which was classified as II or III in an early soil survey report may now be reclassified as III or IV. Some soil survey users, including both farmers and planners, were troubled by this change. The soil itself has not changed, but our knowledge of what constitutes class II or III soils under Alaska environments has improved over the years. There has been a substantial increase in the estimate of potentially arable land in Alaska from nearly 15.5 million to 20 million acres (Clifford 1983). This is partly due to new data on the amount of land available, but is due more to a better understanding of what constitutes arable land under Alaskan climatic conditions. Therefore, economical and technological feasibilities are the key factors to determine what constitutes agricultural soil. According to the guides to land capability class in Alaska, which follows the guidelines of Handbook No. 210 (Klingebiel and Montgomery 1961), soils in class IV can be used for agricultural purposes.

Misuse of Soil Surveys

Alaska has faced the same problem in the use of soil surveys as many other states — misuse. One of the main causes of misuse of soils information is rapid economic growth and development which always press for up-to-date soils information for land-use planning. Users of soil surveys usually try to get more detail out of a soil survey than its fixed scale and data base can provide. There are always many other demands for soils information which exceed the original design and objective of the survey. The most common problem in the use of soil surveys is the enlargement of the soils maps. In the beginning of every NCSS report, it clearly states that ''enlargement of these maps could cause misunderstanding of the detail of mapping. If enlarged, maps do not show the small areas of contrasting soils that could have been shown at a larger scale.'' An example is the enlargement of Order 2 soil surveys for subdivisions whose working plan may need a scale larger than 1:12,000. Most NCSS detailed surveys were mapped on



This view of an open Muskeg near Caswell area is of an area where peat moss occurs with scattered black spruce. This is wetland with capability Class VIIw. (*Soil Conservation Service photo*) field sheets with larger scales ranging from 1:12,000 to 1:24,000, then published at reduced scales from 1:20,000 to 1:31,680. The enlargement, therefore, should not be larger than the original scale of the field sheet. Many district conservation offices use field sheets for soil and water conservation plans. There is less risk in enlarging a soil map if the soils are homogeneous and the distribution patterns are simple. But if soil patterns are complex and cannot be mapped at the original map scale, then soils of contrasting properties will not appear on the enlarged scale even though they occur in the field and pose problems for land use. Therefore, *onsite* soil investigation or verification of smaller-scale soil maps is necessary when they are used for such high-intensity purposes as nurseries, building sites, commercial lots, subdivisions, trailer courts, or small farms — all of which require a larger scale.

The inherited philosophy of soil science has placed an emphasis on the top 60 inches of land surface. This is the zone of biological activity. Some users of soil surveys are interested in the material deeper than 60 inches. Sometimes map users erroneously extrapolate information to a greater depth. On the other hand, geological surveys normally treat the top 60 inches in a very general manner and often call it overburden. Nevertheless, in integrated resource inventory, soil surveys and geological surveys can complement each other, even though one cannot replace the other.

Over-Interpretation of Soil Surveys

The NCSS, mainly SCS, is highly praised throughout the international community of soil science and land use groups for its leadership in the development of Soil Taxonomy, land capability classes, and the publication of soil survey manuals. Still, these achievements do not exempt the NCSS from criticism of its format in soil survey reports. The challenge that NCSS has been facing is to implement a uniform national system to carry out soil surveys at various levels of detail, yet meet the needs of individual users and unique geographic areas.

The most useful quantitative information in the NCSS report is to be found in its interpretation tables. In these interpretation tables, the capability, limitation, and suitability for different land uses (including cropland, rangeland, wildlife, recreation, engineering, and forest land) of each map unit are accessed from the classification of component soil(s) for which the map unit is named. This kind of format and information are well received among users of soil maps, especially those who work with automated systems, because the tables are direct and easy to use: one map symbol, one interpretation. However, such an approach has certain limitations which are often overlooked by many report users.

First, even the interpretation tables convey several kinds of land uses. These land use interpretations may not have the same degree of confidence because each soil survey was designed for different purposes or emphasis. In other words, each soil survey report is unique. Land use planners and other soil survey users should be reminded of the validity of the interpretation tables in the "Exploratory Soil Survey of Alaska" (Rieger et al. 1979). This survey is designed only for general land use planning at the statewide level and not for definitive activities in the field. Its units are associations which do not contain individual soil boundaries. It cannot be used for specific purposes at a larger scale, such as river basin studies or regional planning with base map scales larger than 1:250,000.

Second, the accuracy of the tabulated interpretations depends upon map unit purity. The map units in detailed soil surveys are primarily consociations of phases of soil series. The interpretations do not cover the whole span of map unit characteristics, i.e. what is mapped and what are considered inclusions. Instead, these interpretations are constructed based partly on the family criteria in the taxonomic classification system and partly on the series and phase criteria which are based on landscape and surface conditions, and these characteristics have nothing to do with the taxonomic system. More often, the tabulated interpretations account for major portions of the characteristics of the map units, but not all. This is due to map unit inclusion caused by soil heterogeneity as described earlier (Wysocki 1978). Therefore, the soil survey users must acknowledge the existence of map unit inclusions to be a *norm* rather than just inclusions.

Automated Data-Processing in Soil Survey

Automated data-processing systems are used not only in the making of soil surveys, but also in the interpretation of soil surveys for the user. The SCS has developed a coding system for profile descriptions (Swanson 1973). The Montana Automated Data Processing System for Soil Inventories (Decker et al. 1975), has for example, developed mark sense forms based on a coding system to record soil profiles and map unit data in the field. Computers are then used to retrieve and read the stored data and print profile descriptions, map unit descriptions, soil classification tables, and map unit identification legends. The most widely adopted automated data processing in the NCSS programs in the 1970s was computer-assisted writing (CAW), which greatly facilitates preparation of manuscripts and interpretative tables. This simplifies the use of the soil survey. Currently, the SCS in Alaska has adapted CAW and used the word-processing system.

There are many facts and data in each soil survey report, and many interpretations can be generated from that data. Soil survey users sometimes cannot help but get confused in the face of many apparent conflicts of fact and interpretation. They may wonder if they are using correct and adequate data for interpretation. The introduction of computers has greatly expanded the user's ability to extract the needed information from soil surveys (Yahner 1983, Anonymous 1980, Decker et al. 1975, Jansen and Fenton 1978). Automated data-processing systems allow the user to interpret and rapidly print out reports for specific uses, such as tillage groups or vegetation communities/habitats which are not normally listed, but for which a data base exists. These are provided in the soil survey data file but not the published report. Users can also acquire needed information without going through the logistics of acquiring the original data or volumes of paper. The automated data-processing system also allows easy addition to and alteration of data when a soil survey is updated.

One of the greatest advantages of the computer is the digitized soil map. It has long been observed that usefulness of soil maps can be improved greatly by overlays for specific purposes (Boyer 1969). However, it would be difficult for the NCSS to present overlays for every possible purpose from a base soil map. The digitizing process not only can reproduce the detailed soil maps from previously published soil surveys (Baxter 1980), but can also produce interpretative maps based on digital files of soil map unit data. An example is the Purdue Model, FACTS, which reproduces soil maps and also replaces the soil map unit symbol for each cell in the row-column grid with direct interpretative data such as yield data, yield index, or other interpretive ratings (Yahner 1983). The digitized soil map allows users to locate specific sites and to produce a tailored map to suit their specific needs. The digitizing of soils and other geoscience data maps are used in Alaska in land planning (Rummel 1982). The Alaska Department of Natural Resources is working on a statewide orthophoto base map program, which would facilitate fitting the row-column grids of the digitized map into the legal descriptions of lands on the controlled map base.

Despite all the convenience and advantages of automated data-processing systems, users should keep in mind the fact that the computer only helps us manipulate, simplify, and access the data from soil survey reports faster. In no way can it improve the quality of the original survey report because the automatic data-processing system does not change the original data base. Therefore, map users will still have to deal with the problem of inclusions. On-site verification and investigations are often necessary when the land-use planning process requires more detail than existing soil maps can provide.

Caution should be exercised when users try to digitize two or more soil surveys published at different times, i.e. the 1950s vs. the 1970s. Mapping concepts may have changed from one survey to another due to advancing technology or different survey objectives. A soil survey is consistent within its survey boundary, but may have discrepancies with one next to it. Survey objectives ultimately control map unit design in each individual survey.

Taxonomic Unit vs. Map Unit

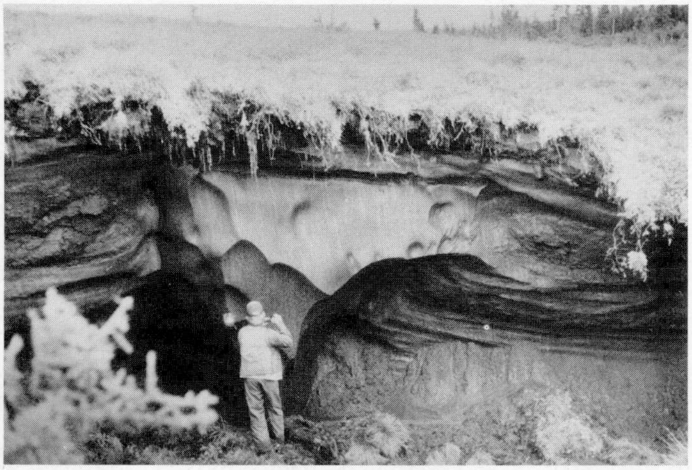
To address the issue of map inclusions or map "impurity," it is necessary to bring up the controversy of taxonomic unit vs. map unit. According to Guy Smith (1981), there would be no controversy if one referred to Chapter 19, *Soil Taxonomy* (Soil Survey Staff 1975). However a question still exists because mapping is, in part, an art. Soil taxonomic units are conceptual, while map units are our attempt to portray real bodies of soil that we find in the field. We must remember that soil is a natural body and the delineations are arbitrary lines used to separate these natural bodies into usable units. The soil-catena concept is no longer used in modern soil mapping, yet it stresses the idea of a soil continuum.

When Soil Taxonomy was first introduced, Thorp (1947) expressed his concern that "soil surveyors and correlators need to give more attention to segments of soil catenas or entire catenas as complexes to be used as mapping units, remembering that each soil type in the unit should be described in the report." Alexander (1983) suggested classifying a soil in the taxon which encompasses the salient features of the soil and gives the *true* range of characteristics, assuming the soil is a natural body, without regard to taxonomic limits in higher categories, although this can be a nightmare for the SCS correlators. Edmonds et al. (1985), Miller (1983), and Sombroek and van de Weg (1983) also urged describing and quantifying the whole span of the map unit components and inclusions. With these points in mind, soil surveyors can name the map delineations to reflect the kinds of soil variabilities as they affect probable uses (Smith 1981). Valentine et al. (1981) commented on the approach to a national system for mapping soils in Canada: "Soil mapping is not construed as the geographic delineation of soil taxonomic classes. Rather it is the mapping of portions of the landscape . . . . Taxonomy forms the thread for characterizing map units, organizing information about them, and naming them, but it is not the 'be all and end all' of soil mapping."

Soil Taxonomy is the guide for soil survey and mapping, but it should not control line placement on the map. The conceptual soil taxonomic units are well controlled, quantitatively discrete, and mutually exclusive. However, in the description of the map unit, it is only practical to allow some degree of overlapping of characteristics to reflect the real world. This is why map unit inclusions were introduced into mapping practices. However, some surveyors tend to treat the inclusion lightly because they are inclusions. They should receive no less attention than the major component(s) in the map unit.

Soil Survey Report Format

There are two directions for the soil survey report — depending on the client, or intended user. One is required by the planners using automated data processing. In this case, the simpler the format the better. They are hardly interested in technical data. They want a quick insight into a soil pattern, a short description, and a simple key to limitations and suitabilities of map units for specific uses (Sombroek and van de Weg 1983). On the other hand, such users as soil conservationists and small-farm owners doing farm planning, realtors and homeowners looking for properties, or consultants and engineers doing on-site inspections need a soil survey report



This thermokarst, formed in tundra soils near Council, Seward Peninsula, was caused by melting ice wedge.

with complete descriptions in addition to conventional interpretive tables. The NCSS report has been organized to meet both needs. The general soils map in each detailed soil survey report is designed for the first function, but it's often overlooked because it's not included in the interpretive tables.

The soil survey report includes more than just soils data. It is a documentation of material and methods of the investigation, i.e. how the survey was made. Actually there is variation among surveys. The section entitled "How this survey is made" includes such information as field sheet map scale along with the published scale. Kinds, origin, and flight date of the base maps (aerial photographs) would be of interest to some users for comparing cultural changes and other features, or as a source of photos for their own use. The helicopter transect interval and special tools used in the survey could also be useful.

The soil interpretations are from well controlled taxonomic criteria and quantitative data. However, there are many observations and much information equally important to survey users that are not contained in the soil survey report. This information is lost during manuscript preparation especially when CAW is used. Soil surveyors should be encouraged to document those observations which may not be conventional or do not fit the format. The NCSS may consider attaching these notes of observations as an appendix to the report or publishing them as a separate document. One has to be aware that the soil surveyor may be one of the few that has ever been to a particular area, especially one that is hard to reach.

Soil Mapping on the Acrtic Slope

Soil survey and mapping in the Arctic slope areas were covered rather generally in the early works (Kellogg and Nygard 1951) and in a modern survey (Rieger et al. 1979). Detailed mappings are limited to specific sites and are generally small in area. Everett and Brown (1982) gave comprehensive reviews of the mapping of tundra soils in the Arctic slope of Alaska. Drew (1957) was the first to introduce the principle of soil-landform (pattern) mapping for tundra soils. Because of the lack of soil continuity and the diversity of microrelief of Arctic soils (Brown 1969), mapping of the Arctic slope still strongly relies on landforms in combination with soils. Soil Taxonomy is still being tested on the Arctic slope. Rieger (1983) pointed out the lack of a category for the dry desert polar soils. As the need for soil mapping increases with resource exploration and development, we need to expand our knowledge of the vegetative communities, soil properties, and landforms. This is especially true when applied to subarctic areas and the Arctic. Linell and Tedrow (1981) pointed out that it "should never be considered more than a step in the geotechnical design process; one that furnishes the engineer a general rather than a specific indication of behavioral characteristics." The NCSS is expected to develop criteria for classifying and mapping tundra soils in the future and for making appropriate interpretations for land use planners and map users whose planning and management philosophy and approach are quite different from those currently in use.

FUTURE CHALLENGES FOR NCSS IN ALASKA

Alaska is a large area, with most of its natural resources untapped. Activities involving surface mining, resource exploration, agricultural projects and settlements, associated population increases, and ecological impacts are expected to increase dramatically. These activities would certainly accelerate the need for biogeophysical information. The NCSS has to face the challenge of meeting these requirements, both qualitively and quantitatively.

The NCSS in Alaska is in the process of updating older surveys and is also planning on covering many new areas. As Maryland and many other states are beginning a third-generation of soil surveys (Miller 1983), the NCSS in Alaska is just starting. There are four soil surveys covering the Matanuska-Susitna Valley: Matanuska Valley, Susitna Valley, Willow, and Yentna. There are also four soil surveys covering the Kenai Peninsula: Kenai Moose Range, Homer-Ninilchik, Kenai-Kasilof, and the current Deep Creek project. These surveys were done at different times, and the philosophy and concepts have changed as technology has advanced from one to the next. Therefore, even though each one is a good-quality survey and consistent within itself, there are apparent discrepancies. The SCS and its cooperators are in the process of updating these surveys to make the interpretations consistent among individual surveys to allow future digitized work for regional planning and land use purposes. Other surveys completed during the 1960s using different classification systems are being correlated into the Soil Taxonomy. The NCSS is also cooperating with the USFS to incorporate Forest Service soil surveys into the NCSS program.

Some soil surveys and on-site soil investigations in the past few years have been done by private consultants. Such activity is likely to increase with accelerating resource exploration or surface mining. A soil survey involving public funds or being used in the permit process for surface mining is generally required to follow the NCSS standard. Therefore, the contracting agency can sign a cooperative agreement with SCS and become cooperators of NCSS.

There is also need for research in the following areas:

1) Benchmark soils need to be studied to relate their genesis, classification, interpretation, productivity, and management to other soils.

2) The variability of map units in each survey area needs to be studied and related to farm practice and management.

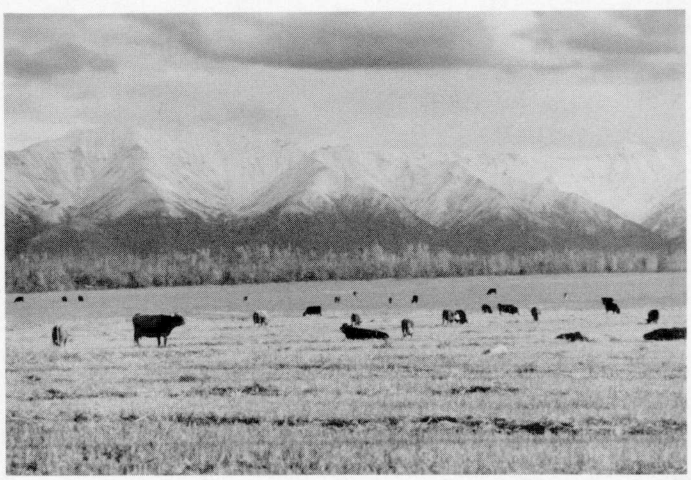
3) The relationship of agricultural projects to the environment in terms of air and water quality needs to be studied.

4) The soil taxonomic classification system is to be tested, especially in higher latitudes in the subarctic zone and in permafrost areas with perched water tables.

5) Soil temperature and moisture regimes in Alaska need to be studied.

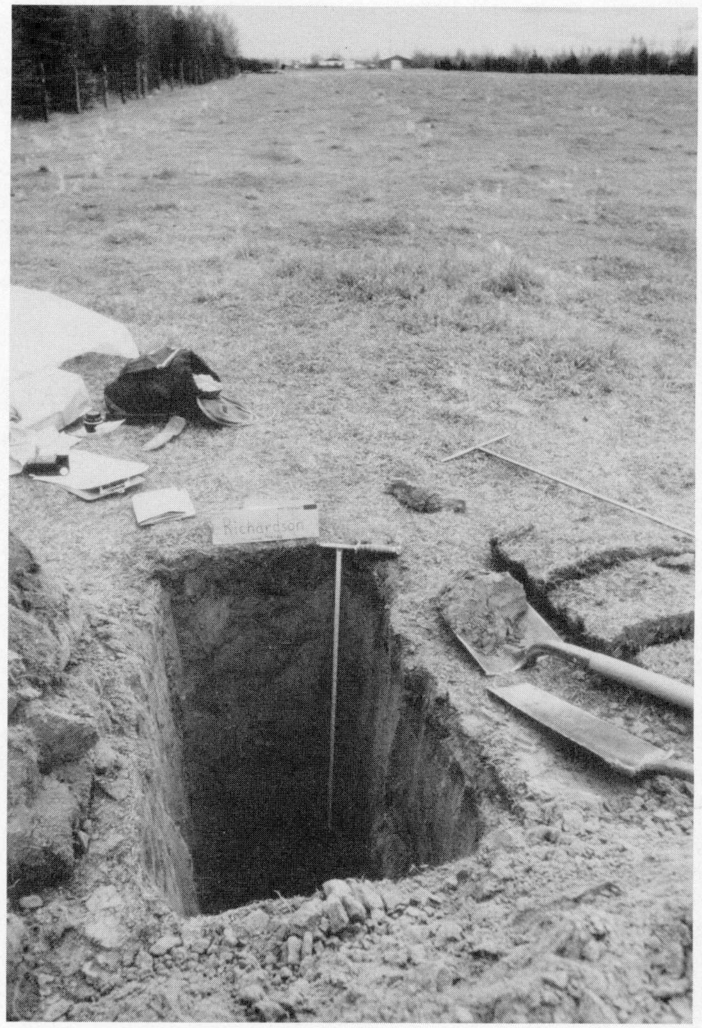
6) Field procedures and methods need to be improved.

Cooperators in the NCSS program, including the SCS state and regional offices, the SCS National Soils Laboratory, Agricultural and Forestry Experiment Station of the Univer-



Cattle graze on farmland near Delta Junction; Granite Mountain is in the background.

Left: Under spruce forest, the thick organic mat on this Richardson silt loam insulates the frozen soil and prevents thawing. The thaw shown here is less than 8 inches deep in late August. (a) organic mat, (b) thawed mineral soil, (c) melting upon exposure, and (d) frozen layer.



Right: The same soil thawed after clearing turned it into productive land. Photo shows a soil pit excavated for study on the pasture of Nestler's Farm in Delta Junction.

sity of Alaska, Department of Natural Resources, Soil and Water Conservation Districts, Cooperative Extension Service, and other agencies, need close cooperation in the conduct and support of these research projects.

CONCLUSIONS

Soil surveys have many uses and are indispensable tools in resource management and land use planning. The modern soil survey report is among the most comprehensive scientific survey and inventory of natural resources. Yet, questions and problems arise over the use of the surveys. What these questions and problems represent is not the limitation of the soil survey itself, but rather a communication gap between the soil scientists and soil survey users. The soil scientists need to understand the philosophy and processes of land use planning or management practices so they can design the survey to meet these purposes even though they don't make land use decisions. The soil survey users, especially land use planners need to understand the applicability and limitations of a soil survey and the processes used to map and classify soil. Such knowledge will alert the users to map inclusions and confidence levels of interpretations. Such communication can improve the survey and its application. The first steps in this communication are enhanced through the memorandum of understanding and special training and briefing for both the soil surveyors and users. Subsequent input from users during field reviews, correlations, and the survey reports are also important.

Automated data processing is the trend in making soil surveys and developing interpretations. It is a powerful tool for modeling thematic maps and changing map scale. Limitations of this approach have to be recognized, despite its efficiency and convenience in acquiring and using soils information. Even though pedology (the study of soils) is a science, mapping and interpretation of soils data is partly an art. Many soil characteristcs can be quantitatively measured, but the delineation of these characteristics on cartographic representations of natural landscapes and formulation of interpretations or predictions depend on the soil surveyor's mastering the knowledge of soils and application of this knowledge to a set of survey objectives. There should be room to accomodate this in the automated processing of soil survey data and interpretations.

It is unlikely that only one kind of survey will suit all purposes because each survey is unique. More than one kind of soil survey and maps are needed for land use planning and resource management. Soils information is presented in a hierarchy of surveys done at different levels of detail and intensity. Users must also keep in mind that soil surveys do not provide solutions, they only point out the capability, suitability, limitations, and possible hazards related to specified land uses. Therefore, soil surveys serve as tools to the solution of different land use issues. The NCSS provides soil surveys of Order 2 and Order 3 in Alaska and many other states because these levels of soil surveys are the most useful. They provide baseline data for more detailed surveys or on-site investigations. The NCSS in Alaska also provides Order 4 surveys for range and grazing purposes.

Map scale and the order of surveys are not only dependent upon the purposes of the survey and soil patterns, but also upon the time and money available. The resources available may not be enough to make a survey appropriate to its purposes, especially the unanticipated uses to which the completed survey may be put. The latter is especially true in that there is often a lack of interest on the part of many potential users at the beginning of a survey project. There is often a demand for more detailed information after the survey is published. Therefore, it is critical for the public to support and to have input in the program so that NCSS can better serve current needs and Alaska's future interests.

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