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Soil Mapping: Methods and Applications

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Soil Mapping: Methods and Applications

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Dedicated to

FRANK ROBERT OLMSTEAD

1904—1958

As Chairman of the HRB Committee on Surveying, Mapping and Classification of Soils from its inception in 1944 until 1956 and Chairman of the HRB Department of Soils, Geology and Foundations from 1954 to 1958, and as Chief of the Soils Branch, U.S. Bureau of Public Roads, he exerted widespread influence in the development and promotion of the use of geologic and pedologic information and aerial photographic interpretation in soil mapping for highway engineering purposes.

Foreword

Various papers sponsored by the HRB Committee on Surveying, Mapping and Classification of Soils in the past two decades have described the application of geologic and pedologic information, other published or unpublished soil information, and aerial photographic interpretation to soil mapping for use in planning, design, and construction of highways. The Committee decided in 1960 to determine the present concepts regarding the preparation and use of soil maps by the state highway departments. Each of the highway departments was asked to submit: (a) a brief statement regarding its preparation and use of soil maps, and (b) an outline of a paper that it might prepare if invited to participate in a soil-mapping symposium. After reviewing the information submitted by the state highway departments, the Soil Mapping Subcommittee (J.H. McLerran, Chairman) decided on a program of papers that would present a good cross-section of the preparation and use of soil maps by the highway departments.

Several of these symposium papers describe either the direct use of pedologic information or its adaptation to highway engineering. The current policy of Soil Conservation Service, U.S. Department of Agriculture, of including an engineering applications section in the county soil survey bulletins has made this source of information more valuable to highway engineers.

Although the Maine paper stresses the use of the aerial photographs and the Massachusetts paper stresses geologic mapping, most of the papers indicate that all the available soil and geologic information, as well as photographic interpretation, should be used in mapping soils for highway purposes. Several symbol systems have been developed for use on soil maps, each of which has some specific merit, as stated by the authors.

In general, it is not intended that the soil maps be used to replace the detailed highway project soil survey. The detailed survey is needed for collection of soil samples for testing and the development of other data needed in highway design. The soil maps are useful in the reconnaissance stage of highway route location, in planning the detailed soil survey of the selected route, and in the search for coarse-grained construction materials. Some of the strip soil maps are based on considerable field reconnaissance, sampling and testing; hence they may be extremely useful to the highway design engineer.

Some state highway departments submitted outlines of papers on materials surveys or aggregate inventories. The Subcommittee on Soil Mapping decided not to have the papers on these subjects prepared for the symposium on soil mapping, but that a symposium on materials surveys might be appropriate for a later meeting of the Highway Research Board.

P.C. Smith
Supervisory Highway Research Engineer
U.S. Bureau of Public Roads

Contents

Preparation of Soil Strip Maps for Michigan State Highway Projects

A. E. MATTHEWS, Engineer of Soils, and L. J. COOK, Assistant to the Engineer of Soils, Soils Division, Office of Testing and Research, Michigan State Highway Department, Lansing

This paper describes present methods and procedures used in preparing pedological soil strip maps for proposed highways in Michigan. It includes an explanation of the organization, education, and training of personnel who perform this work and discusses the responsibilities and types of work performed by Michigan district soils engineers. The types of information collected in soil surveys and their relation to the planning, location, and design of highways are discussed. Examples of soil type descriptions, pedological soil strip maps, design charts, and a resistivity-survey profile are also included.

● SOIL MAPPING in Michigan for highway purposes is done by the Department's own soils engineers, using the pedological method of soil classification, supplemented by point investigations where deemed necessary. This system has been used for the past 35 years. Information regarding the application of each soils series for highway design and construction, as acquired from experience, is available in the Department's "Field Manual of Soil Engineering" (Fourth Edition).

For the purposes of this paper, it is not deemed necessary to trace the history or explain the theory of the pedologic system of soil classification. This system with or without modifications is now being used by many highway organizations. Instead, this discussion concentrates on the organization and training of the personnel who perform the work and on detailed description of preparing a pedological soil strip map in the field.

PERSONNEL ORGANIZATION AND TRAINING

Michigan has ten highway districts, varying in size from 2 to 13 counties, with 427 to 1,356 miles of state trunkline highway. At present, in each district there is one district soils engineer with one or two assistant soils engineers, depending on the work load. These men are responsible for all of the soils engineering work in their particular district. In general, this consists of: reconnaissance soil appraisals for route location; soil surveys, peat and rock soundings for design purposes; and location and investigation of borrow sources (not including sources of produced aggregates). During the construction stage, it is also the soils engineer's responsibility to investigate the following: subgrade for potential frost heave and differential heave areas, seepage zones, and water tables; quality of sand subbase; quality of compaction; the methods of treatment of peat swamps; and to recognize and assist in the solution of embankment and structure foundation problems. Also, it is his responsibility to provide soils information which may be necessary for maintenance of the highway system.

The central soils office correlates this information; acts as liaison between route location, design, construction, and maintenance; establishes policies; and offers advice and administrative assistance. Scheduling and performing the routine work is the responsibility of the individual soils engineer. The special point or area investigations, which are not performed by the district soils engineers, are foundation borings, resistivity, and seismic surveys. The foundation boring work is the responsibility of the central soils office, and resistivity and seismic surveys are carried out by the central testing laboratory.

There are 26 engineers in the soils division including men in the central office and in the field at the district level. Twenty-one have degrees in civil engineering, three have degrees in geology, and two have degrees in soil science and long experience in highway engineering. Of the 26 engineers, 13 are registered professional engineers. In addition to the engineers, there are four technicians who assist in the district work. These men are former foundation boring crew chiefs.

In general, the policy is to obtain men with civil engineering degrees and then train them for the soils mapping work. Usually, they are assigned to a district which will have one or two experienced soils engineers. They assist in mapping four or five projects along with the district soils engineer, and from the experience gained in this manner can start making soil surveys on their own. In case they run into soils with which they are not familiar, they can call on the district soils engineer for assistance in mapping these areas. An invaluable aid in gaining soil mapping experience is to map a project, and then during the construction stage, to study the exposed profiles and correlate them with the original.

Each summer in a selected area of the state, soils classification tours are conducted by the Soil Science Department of the College of Agriculture of Michigan State University, primarily for local county extension agents, agriculture teachers, and the local United States Department of Agriculture (USDA) soils mappers. These tours are also attended by the highway soils engineers and aid in their training and knowledge of pedological classification. If geology tours are held, they are usually attended by the local soils engineers to aid them in landform identification and the associated soils.

PREPARATION OF A PEDOLOGICAL SOIL STRIP MAP

To illustrate the soil mapping procedure as used in Michigan, the various stages through which a project is followed by the soils engineer are discussed. The first use of soil mapping is in connection with the planning office and its long-range program studies. The soils engineer is consulted as to whether there may be any soils factors influencing the cost of the job and affecting long-range budgeting. In this stage, these factors consist primarily of long or deep swamp deposits which cannot be avoided, bedrock, extensive areas of soft lacustrine clays requiring special treatment, and longer than average haul distances for borrow materials.

The next stage in which soil information is used is during the route location study. During this study, the route location division makes use of the existing USDA county soil maps and the state geology maps in trying to avoid swamp sections and to use borrow sources. Where necessary, these are often supplemented by more detailed soil classification or peat soundings obtained in the field by the soils engineer. This study for route location may cover an extensive area, and therefore is not made in the detail which is used after the final line has been selected.

After the final location has been established and the line staked by the survey crew, the complete detailed soil survey is made. It is made at this time so that the design office will have full use of all necessary soils information in selecting the preliminary design and grade. The special point or area investigations will be made at a somewhat later date.

The base which is used for the soils map will vary, depending on what is available for the project. For projects on which aerial surveys have been made, aerial mosaics will be available using a scale of 1 in. to 200 ft. These are often used as base maps. The photographs are obtained by special line flights. The aerial base map is a positive print on photographic paper. Advantages of the aerial photos are (a) topographic features are readily determined and the soils survey can easily be made if the survey stakes have been removed, (b) soil boundaries are easier to define, and (c) drainage characteristics are more apparent. The main disadvantage is the smaller scale of the photo; they are somewhat bulky to use in the field. Also, the scale is smaller than that used by the design office in the preparation of plans and the information cannot be traced directly. The soil boundaries as shown on the aerial photo are transposed to the plan sheet, using the stationing shown on the aerial photo.

Where the aerial photographs are not available, the most common base sheets are 8½- by 11-in. cross-section paper using a scale of 1 in. to 100 ft. The plan sheet may be used as a base map if the survey has already been plotted.

Once the base map has been selected, the soils engineer is ready to prepare the soils map. Before beginning the detailed field survey, several sources of information are studied. One of these is the state surface geology map. With this, he can readily determine which geologic landforms and associated soils may be encountered. If the USDA county soils map is available, this is also studied. Ordinarily, this does not cover enough detail for highway mapping purposes; however, it does assist in narrowing down the number of anticipated soils series. Also available are small-scale aerial mosaics of the entire state, although at present Michigan does not use them to any great extent in making soils surveys. They may be studied, however, as an indication of what to expect. The major use of these available aerial mosaics by the soils engineer is during the stage of borrow study and location.

After this available information has been studied, the soils engineer is ready to begin the detailed soil survey. Tools used for this purpose consist of a tile spade, orchard or bucket auger, and a soil auger. As he progresses with the soils survey, he constantly observes the topography, the landform, the vegetation, and the agricultural use of the land. Each of these provide valuable tips in soil mapping. He then proceeds to examine the soil profile. This is done by exposing the profile in a cut section or side hill, or by boring a hole. As the material is removed, it is laid out in the form of a soil profile and he notes the texture, color, consistency, and the depths at which the various horizons are encountered. From the information which has already been gained by studying the county soils map and the geologic landforms, he can now anticipate perhaps five or six different soil series. Then by using the soil profiles in the Department's "Field Manual of Soil Engineering" and studying the exposed profile, he can identify the soil series which he is examining (Fig. 1).

As the pedological system shows area significance, it is not necessary to bore holes at certain specified intervals or to specified depths. Conditions at the site determine the spacing and depth of the borings. Only enough profiles are exposed to determine the soils series which is being mapped and its boundaries. This is dependent on the

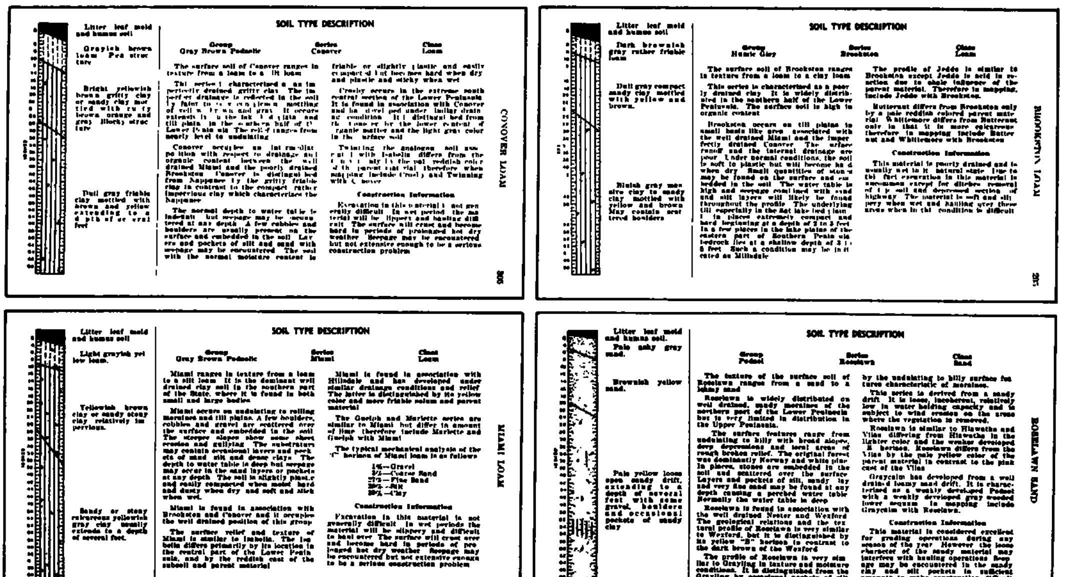


Figure 1. Soil series profiles from "Field Manual of Soil Engineering" (Fourth Edition).

judgment and experience of the soils engineer. Soil boundaries are quite often recognized by changes in topography, changes in vegetation, or changes in the color or feel of the natural ground (Fig. 2). The entire area within the proposed right-of-way is mapped.

At each boring, the soils engineer will record the depth of topsoil. However, when the final soils map is submitted, the topsoil depths may be submitted either for each boring or as an average depth for an entire soils series within its boundaries. Depending on the soils series mapped, the soils engineer may obtain the depth to water table, underlying clay, or bedrock. When water tables are mapped, he not only shows the existing water table but also the expected high water table which can be determined by the color and the amount of mottling in the soil. Water tables are taken at intervals of 200 to 400 ft. As the field soil survey progresses and boundaries are mapped, the soils engineer notes where point investigations will be required. Mapping in this manner the experienced soils engineer can map from two to five miles per day.

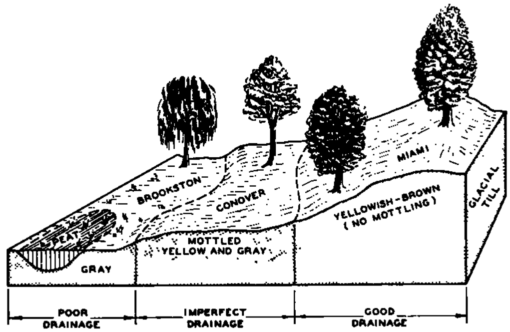


Figure 2. The drainage and relief characteristics of a soil catena.

On the map which is being made the soils engineer will show the boundaries between soil series by dashed lines and denote the name of the soil series. Also, on this map he shows depth of the topsoil and the depth to the water table, underlying clay, and bedrock if encountered (Fig. 3).

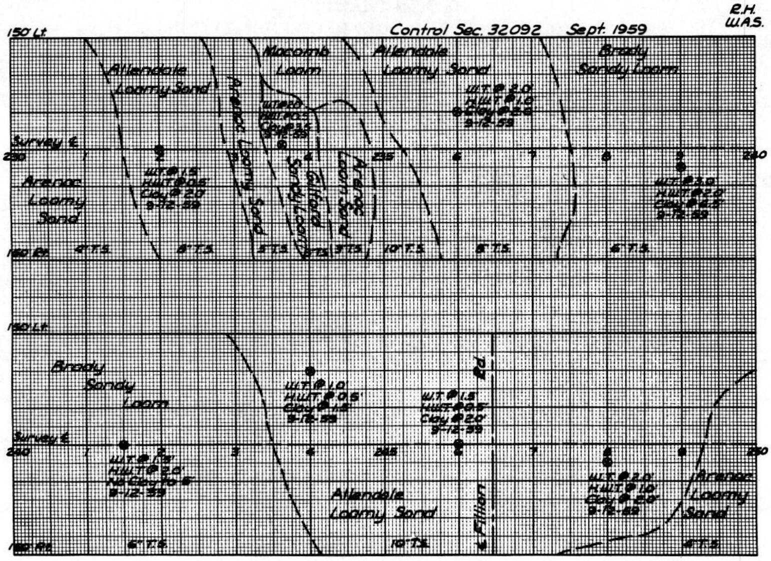
DESIGN RECOMMENDATIONS

The soils strip map, along with recommendations pertinent to the project, are transmitted to the engineer of soils in the Lansing central office. Recommendations for design purposes are usually not made in detail. These are provided in the Department's "Field Manual of Soil Engineering" and particularly its soils design chart which has recommendations concerning the engineering properties for highway design of each soils series. The design chart is the result of intensive correlation of experience and performance of each soils series since the pedological system was adopted in Michigan. It is revised periodically to conform with new policies and specifications. The recommendations can be applied for each soils series no matter where it is mapped in the state, and the only recommendations which need be submitted with the soils strip map are those which vary from the recommendations given in the design chart (Fig. 4). The Department does not recognize all of the soils series which are mapped by the USDA in the state. Many soils which have only slight differences in texture, drainage, pH values, etc., are grouped together under one series. However, the 141 series mapped by the Highway Department have the same names and essentially the same profile descriptions as those adopted by the USDA. Although 141 series may seem like a large number with which to be familiar, it must be recognized that many series are found in only certain parts of the state and that with the information available and the soils engineer's experience, the anticipated number of soils series on a particular project can be narrowed down to 10 to 12.

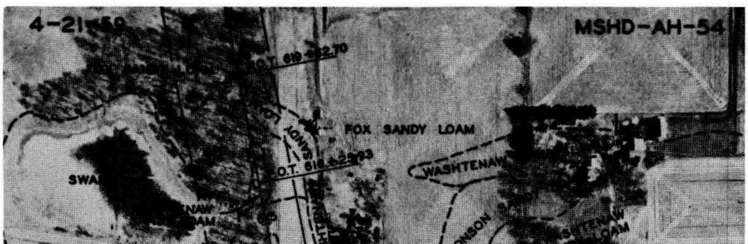
POINT INVESTIGATIONS

As previously mentioned, the district soils engineer ordinarily does not make extensive point investigations during the preparation of the detailed soils strip map. However, while the project is still in the preliminary design stage, he will return for these investigations.

The type of investigation which occupies the majority of his time is peat sounding. He refers to the soil survey for these areas and boundaries. Soundings are taken at



On cross-section paper



On aerial survey

Figure 3. Soil strip map: (a) on cross-section paper and (b) on aerial survey.

50- to 100-ft intervals along the line and at not less than 50-ft intervals across the grading section. The soundings are usually made by hand with the Davis Peat Sampler. As

DESIGN CHART
SOIL ENGINEERING DATA AND RECOMMENDATIONS

SERIES	CHARACTERISTICS: Brief Description of Typical Profile	Adapted to Water Grading	Normal Depth to Water Table	TREATMENT — GRADE: Recommended Location of Plan Grade with Respect to Natural Ground	Recommended Protection of Slopes	Estimated Percent of Boulders (Rock Excavation)	Estimated Depth of Topsoil (ft.)	Subbase Recommended (See Specs 2.11) (See note o)	Selected Subbase Recommended (See Specs 2.11)	Est. Lineal Ft. Per 1000 Ft. of Cut below Natural Ground Elevation: Frost Heave Excavation (Per Roadbed (m))	Edge Drains	Bank Drains: Use only if cut is deeper than	Bank Drains: Lin. Ft. per 1000'	EMBANKMENT: Suitable Borrow	Recommended Method of Restoring Borrow Pits where Restoration is Necessary (See Specs 2.00 03-k)	Percent of Shrinkage	RESOURCES: Porous Material Grade A (See Specs. 7.02.03-g)	Possible Source of Gravel	Source of Topsoil (See Specs. 2.06.03-a)	REMARKS
		1	2	3	4	5	6	7	8	9	10	11		12	13	14	15	16	17	
Brockston	Poorly drained clay	No	Shallow (g)	Fill 4 —5 (n)	Seed (n)	0 0	7—1 0	Yes		300 (a)	600 (a)			No		25—35	No	No	Excellent	
Conover	Imperfectly drained clay	No	Indefinite(f)	Remarks	T S. (c)	0 0	6— 9	Yes		300	600			Ltd.	F S. & M. (c)	25—35	No	No	Excellent	(3) Controlled by surface drainage
Miami	Gently rolling clay uplands	No	Deep	Anywhere	T S. (c)	0 1	4— 7	Yes		300	600			Yes	F S. & M. (c)	25—35	No	No	Good	
Roselawn	Well drained sand rolling to hilly topography	Excellent	Deep	Anywhere	F S. & M.(c)	0 0	1— 4	No (k)	Yes	300	300			Yes	Plant (b)	10—30	Yes	No	No	

GENERAL NOTES

(a) These answers apply only where standards of vertical alignment require cut sections in variance with recommendations in column 3.

(b) Plant collected stock. (See specification 7 21-a-4)

(c) The method of treatment by T S. (Topsoil and Seed) and by F S. & M. (Fertilize Seed and Mulch) where recommended, should be used on all 1 on 4 slopes or flatter and, also on 1 on 2 slopes through shallow cuts and fills The 1 on 2 slopes through deeper cut and fill areas should be sodded.

(d) A fill will always be required due to the wet condition of the soil and the possibility of overflow

(e) Fine grading difficult due to stoniness.

(f) Indefinite: No true water table Possible seepage water at any depth.

(g) Shallow: Indicating that at times this series will be under water but after the water has receded there is no apparent water table.

(h) Additional excavation required for transition from cut to fill and in shallow cut and fill areas, as per sketch in Field Manual of Soil Engineering, page 94.

(k) Subbase recommended if grade line is in "B" horizon (upper 3' of soil profile)

(m) Lineal feet of cut to be measured along a line below plan grade determined by the maximum depth of frost heave excavation so specified. (See Specs 2.06.03-b).

(n) The higher grade heights are a minimum standard for primary trunklines expressways and interstate routes

(p) Extremely variable due to its origin.

(o) These answers apply when the grade line is cut or when the embankment is constructed of material from the same series.

Figure 4. Excerpt from the design chart, "Field Manual of Soil Engineering" (Fourth Edition).

the peat soundings are taken the depths at which changes in classification occur are recorded. Experience has shown that in many swamps, sand layers may be encountered which cannot be penetrated by hand tools, thus giving an impression of a true bottom. To prevent this, in swamps more than 500 ft long, supplemental borings are made at intervals of 200 to 300 ft to determine whether the swamp may have a false bottom. This is done by two special crews which operate out of the central office, using lightweight hydraulic boring equipment.

Rock soundings are also the responsibility of the district soils engineer. Where

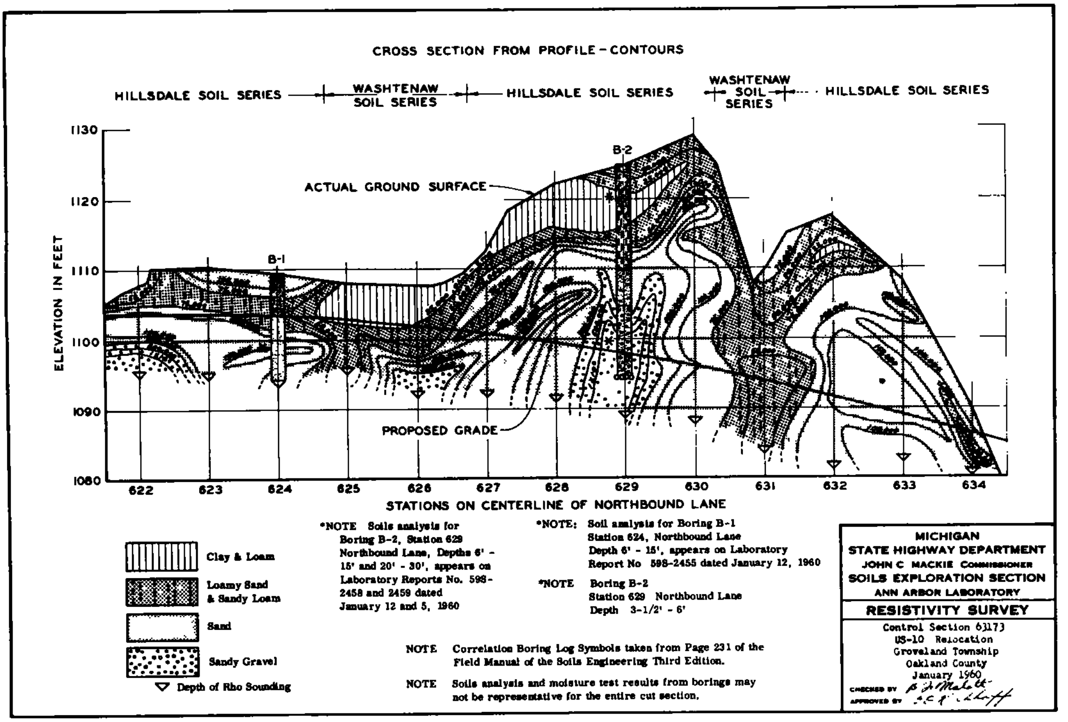


Figure 5. Typical resistivity survey.

possible, these are made with a truck-mounted power auger. At every station, at centerline, and at the ditch lines these borings are made to a depth of 4 ft below the proposed plan and ditch grades. In inaccessible areas, a Barco Hammer driving 1-in. steel rods is used. Rock soundings are often made with seismic or resistivity apparatus.

Resistivity and seismic surveys are used extensively in Michigan for area investigation. In all cuts more than 10 to 12 ft deep, resistivity surveys are made. Seismic apparatus is used primarily where it is anticipated bedrock may be encountered. These surveys are made by a special section which operates from the central testing laboratory. Wherever correlation borings are made, samples are submitted for mechanical analysis and Atterberg limits. This information is shown on the resistivity report (Fig. 5).

The foundation borings for larger culverts and bridges are not the responsibility of the district soils engineer. Foundation borings are made by special boring crews from the Lansing office.

Another responsibility of the district soils engineer, involving soil mapping but for which a formal strip map is not prepared, is that of borrow survey and location. In Michigan, with the exception of a very few projects, the only borrow materials the contractor is required to furnish are the processed aggregates. It is the district construction engineer's responsibility to locate all needed embankment material, swamp backfill, sand subbase, material for culvert backfill, sewer pipe edge drains, etc. This is delegated to the district soils engineer.

In making a borrow study, the district soils engineer relies on the available aerial mosaics, the USDA county soil maps, and the surface geology maps. In counties which do not have soil maps it has been found that the local offices of the Soil Conservation Service often may have a large part of the county mapped for individual farmers who participate in the program, and therefore they can be a valuable source of information. With this available information, the soils engineer begins his location study for the various materials needed. With his knowledge of pedological classification and its resources, the amount of field reconnaissance necessary can be held to a minimum.

Potential borrow areas are noted when the detailed soils strip map is prepared for the project. The soils engineer usually investigates these borrow areas by hand auger borings to determine the feasibility of using the material. If it appears to be a possible source, these borings are then supplemented by power auger borings or a resistivity survey. In granular materials, samples are ordinarily taken and submitted to the laboratory for analysis and specification gradation.

The only detailed map prepared by the soils engineer is for his own use in determining the amount of borrow material. This consists of an area soils and topographic map showing prominent topographic features, soil boundaries, and the locations at which borings were made. However, when the information is submitted to design so that overhaul and other quantities can be estimated, this map is not submitted. The information which design receives gives the location and use of the material, the amount available, and the amount of work necessary to prepare and to restore the pit.

CONCLUSIONS

In Michigan one of the advantages of the pedological system is that it has been developed over a long period of years and is backed by extensive field correlation, experience, and performance. The qualities peculiar to each soils series are summed up in its name and are easily recognized by design and construction engineers and contractors. Also, by mentioning a soils series the one name brings to mind the geology, topography, texture, and drainage characteristic of the particular soil. Thus, a poorly drained soil can be recognized at any time of the year. The soils series name also expresses a three-dimensional concept in that it not only describes depth but also area significance along and on either side of a survey line. As one man can map from two to five miles per day, the system can be applied not only to major highways but also to all reconstruction projects on a highway program. One of the major differences between the pedological system and other methods of soil classification is that in the pedological system, laboratory investigation and testing supplement field investigations, whereas in the other systems the field investigations furnish the information for the laboratory classification.

The reliability of the information depends to some extent on the experience and ability of the soils engineer who prepares the soils strip map and on the amount of detail shown. As has been mentioned, the Michigan Design Chart is a result of years of correlation and experience. Errors which might result from incorrect interpretations of this chart are usually prevented by a close liaison between the central soils office and the design and construction offices.

Use of Pedologic Map in a Highway Soil Survey

MILES E. BYERS, Soils Engineer, Bureau of Materials, Illinois Division of Highways

This paper briefly explains the method of producing soil strip maps based on the pedologic (agricultural) system of soil classification and the interpretation of aerial photographs, for proposed highways in Illinois. It discusses the types of information presented in the engineering soil reports that accompany the strip maps and the way in which they are used for highway soil surveys. Examples of the strip maps and the methods of presenting engineering soil data are included.

● PEDOLOGIC MAPS in Illinois date back to 1911, and have been prepared and published by the University of Illinois Agricultural Experiment Station at various intervals since that time. Highway engineers have long felt that this information, properly correlated, could be useful in the planning stages of highway design and construction, but the variation in quality of the maps over the long period was an obstacle not easily overcome.

In 1950 the cooperative research program of the Illinois Division of Highways and the University of Illinois Engineering Experiment Station was expanded to include "Soil Exploration and Mapping." In 1952, the United States Department of Commerce, Bureau of Public Roads, joined as a co-sponsor of the project. The project was undertaken by the University of Illinois to furnish the Illinois Division of Highways information for planning detailed soil surveys and for use in location and design of highways.

After project personnel had prepared soil maps and reports for several counties, the policy of using pedologic soil-type classification in preparing maps for strips four miles wide along the right-of-way of highways where work is contemplated, rather than on a county basis, was adopted.

The soil mapping project in Illinois has been previously reported by others (2, 8), but a brief summary seems required to provide a better understanding of the mapping units and the engineering reports prior to discussing their actual use. The difference in nomenclature of the agricultural and engineering fields is a common cause for misunderstanding unless resolved whenever representatives of the two groups meet to exchange ideas. In the following discussion, it is indicated when a "highway" survey or report is referred to rather than a survey or report prepared by other agencies.

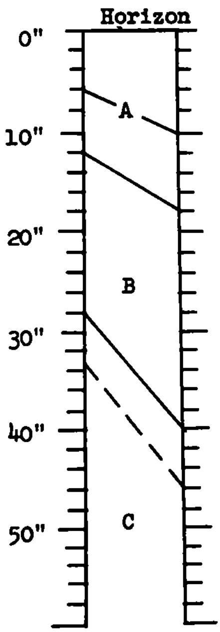
PEDOLOGIC PRINCIPLES

Although the pedologic system of soil classification is widely used, its methods are unfamiliar to many civil engineers and a brief description of it and its basis seems appropriate. An understanding of the pedologic system of classification should be valuable to the highway engineer, because many published soil reports and maps using this system are available. In addition, the data on the engineering characteristics determined for a map unit occurring in one area may later be used in other locations for which pedologic information is available.

Under any given set of conditions of soil formation it may be expected that a certain type of soil profile will develop. This profile is typical of all areas where that particular set of conditions prevails. A soil profile may, therefore, be considered as a geologic entity and classified just as other geologic features are classified. This is the basis of the science of pedology.

The profile studied by the pedologist is exposed in a vertical section from the ground surface to a depth of 40 in. or more (Fig. 1). Normally the profile will consist of three

Soil No. and Name - 148 Proctor SL County McHenry



Profile Description

Surface	Brown to very dark brown silt loam
Subsurface	Dark brown to dark yellow brown silt loam
Subsoil	Dark yellow brown clay loam mottled with yellow brown silty clay loam
Substratum	Silty, sandy or mixed silty, sandy or gravelly glacial outwash.

Topography	Slope 1 to 4%
Parent Material	Water-laid or wind-laid silty sediments of Wisconsin age.
Surface Drainage	Moderate
Underdrainage	Moderately rapid

Estimated Engineering Properties and Problems

Horizon	A	B	C
AASHO Class	A-4, A-6	A-6, A-7-6	A-2-4, A-3 or A-4
Group Index	8-10	15-20	0-8
LL %	30-40	40-60	NP-40
PI %	10-20	20-40	NP-15
Max dry dens, pcf	90-102	95-102	110-120
Opt w, %	20-25	20-24	15-18

Remarks: Subgrade performance fair to good. Occasional pockets of frost heaving material may be encountered. A 5-6 inch layer of silty material will be found between subsoil and substratum. Sometimes a sticky sandy clay loam or gravelly clay loam 8-12 inches thick occurs below the substratum. Loose sandy or gravelly outwash material lies below this sticky layer.

Figure 1. Typical soil type data sheet.

or more distinct layers or horizons which lie roughly parallel to the surface. Soils having similar profile characteristics are grouped together and given a soil series name for the purpose of identification. The name is usually chosen from the geographic area in which the series was first identified. The system is based only on the in-

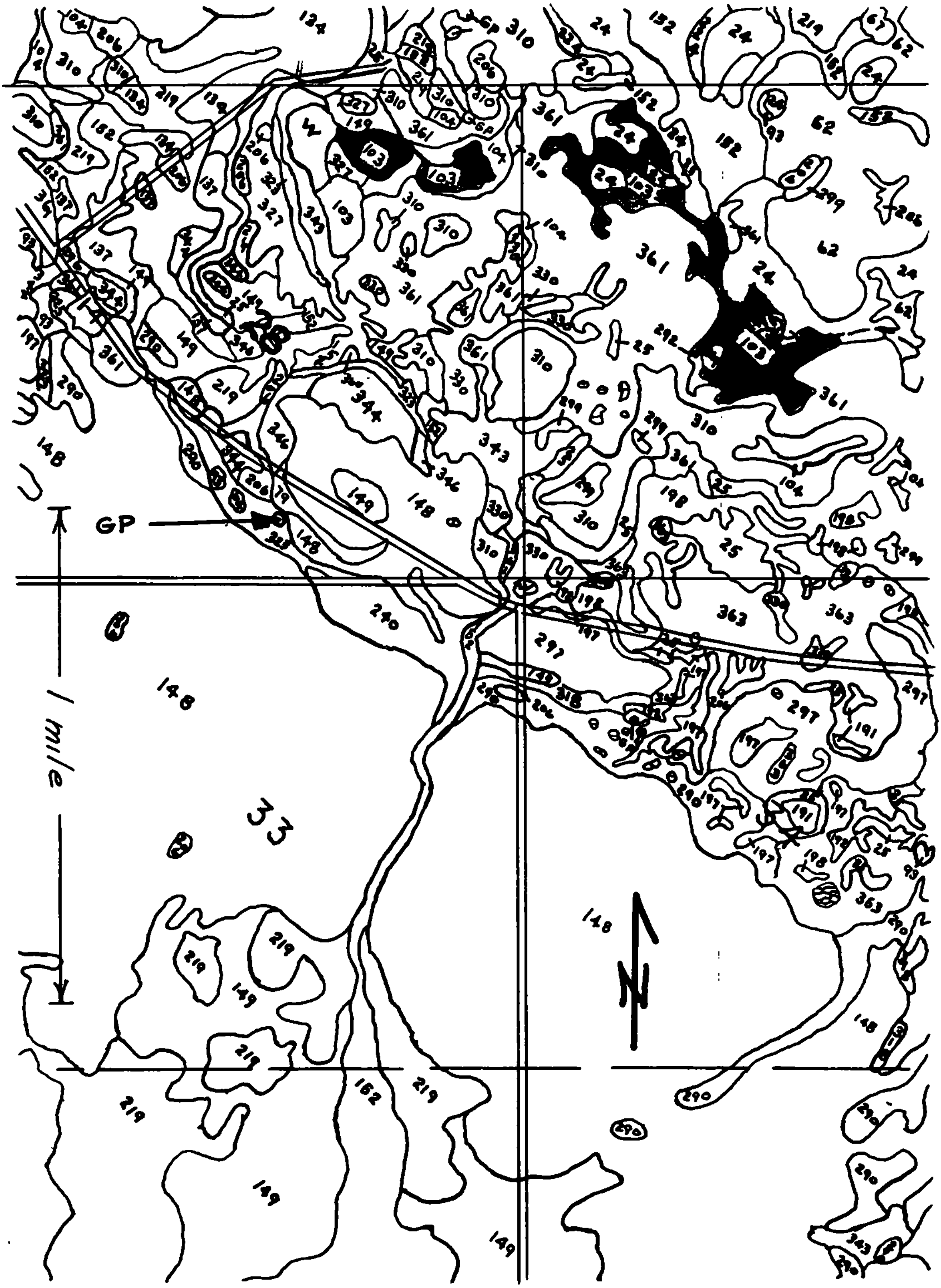


Figure 2. Portion of McHenry County pedologic map. Number 93: Rodman gravelly loam, parent material—coarse gravel; Number 103: Houghton muck, parent material—silty sediments; Number 152: Drummer silty clay loam, parent material—water deposited sediments; Number 198: Elburn silt loam, parent material—loess.

herent properties of the soil materials typically found in the profile and is not dependent on their agricultural characteristics.

Due to many variations in the surface texture of soils having otherwise similar profiles, an almost infinite number of soil series would be possible. By combining the textural name of the surface horizon with the soil series, a soil type is identified within each larger soil series. This soil type is the basic pedologic mapping unit. "Peotone silt loam" is an example of a typical soil type name. Peotone identifies the soil series and silt loam indicates the texture of the surface horizon. The textural characteristics are based on a classification system which has been adopted by the United States Department of Agriculture and which differs slightly from those commonly used in highway engineering work.

If all of the counties in Illinois had been mapped on the basis of present-day nomenclature and criteria, it would be possible to relate engineering properties of the soils directly to the pedologic classification by means of physical tests and some field experience (4). Unfortunately this is not the case. Of the 102 counties in Illinois, only 76 have agricultural maps in published form, and of these only 25, the reports published since 1933, use the present mapping technique and consistent nomenclature. The need for a method of up-dating the older maps and preparing strip maps in other areas was thoroughly studied and a procedure based on airphoto interpretation was developed.

MAP PREPARATION BY AIRPHOTO INTERPRETATION

Airphoto interpretation may be defined as the method of obtaining information from photographs and by logic and reasoning determining the effect on a particular problem (11). It is a specialized art that requires deductive and inductive reasoning ability combined with broad technical knowledge in several sciences. In the type of investigations being considered, the sciences will include not only engineering but also geology and pedology.

Varying types of soil may be formed from the same parent material under the varying effects of other soil-forming factors such as natural vegetative cover and degree of surface slope. The soil type names are assigned to these different profiles on the basis previously discussed. The preparation of pedologic soil type maps for engineering use now consists of outlining, on aerial photographs, the boundaries of the different soil types present in the strip being studied. This is done by means of stereoscopic examination and interpretation of the strip.

Inasmuch as the soil-forming factors of climate and time of exposure of the parent material may be assumed to be uniform in the small area being studied for any one map, they are not usually considered in the study of the airphotos. The character of the parent material is determined from available geological and agricultural information. Thus the soil type boundaries in the area being studied may be delineated on the airphoto primarily by denoting changes in vegetative cover, color, and slope characteristics within the region derived from the same parent material and the proper soil type name assigned on the basis of these characteristics.

Information on parent material, natural vegetative cover, slope, etc., is available, for most of the soil types encountered, in the publication, "Illinois Soil Type Descriptions" (9). A very complete presentation of airphoto interpretation techniques has been published by the Civil Aeronautics Administration (4).

For the Illinois soil strip mapping, actual soil boundaries were delineated on aerial photographs by the use of airphoto interpretation techniques and transferred to a base map using a scale of 2½ in. = 1 mi (Fig. 2). Various other aids, such as soil association maps were used, but there was no ground control. It was anticipated that the maps would not be as accurate in detail as those prepared by pedologists in the field. The present technique reproduces the aerial photographs directly (Fig. 3) and has an approximate scale of 1 in. = 800 ft. The additional detail available to the engineer in the field has proved to be quite helpful.

Inasmuch as only limited distribution is required for these maps, they are reproduced by a blue-print process. The airphotos, with the soil boundaries indicated, are assembled in mosaic fashion along the appropriate strips and are then photographed.

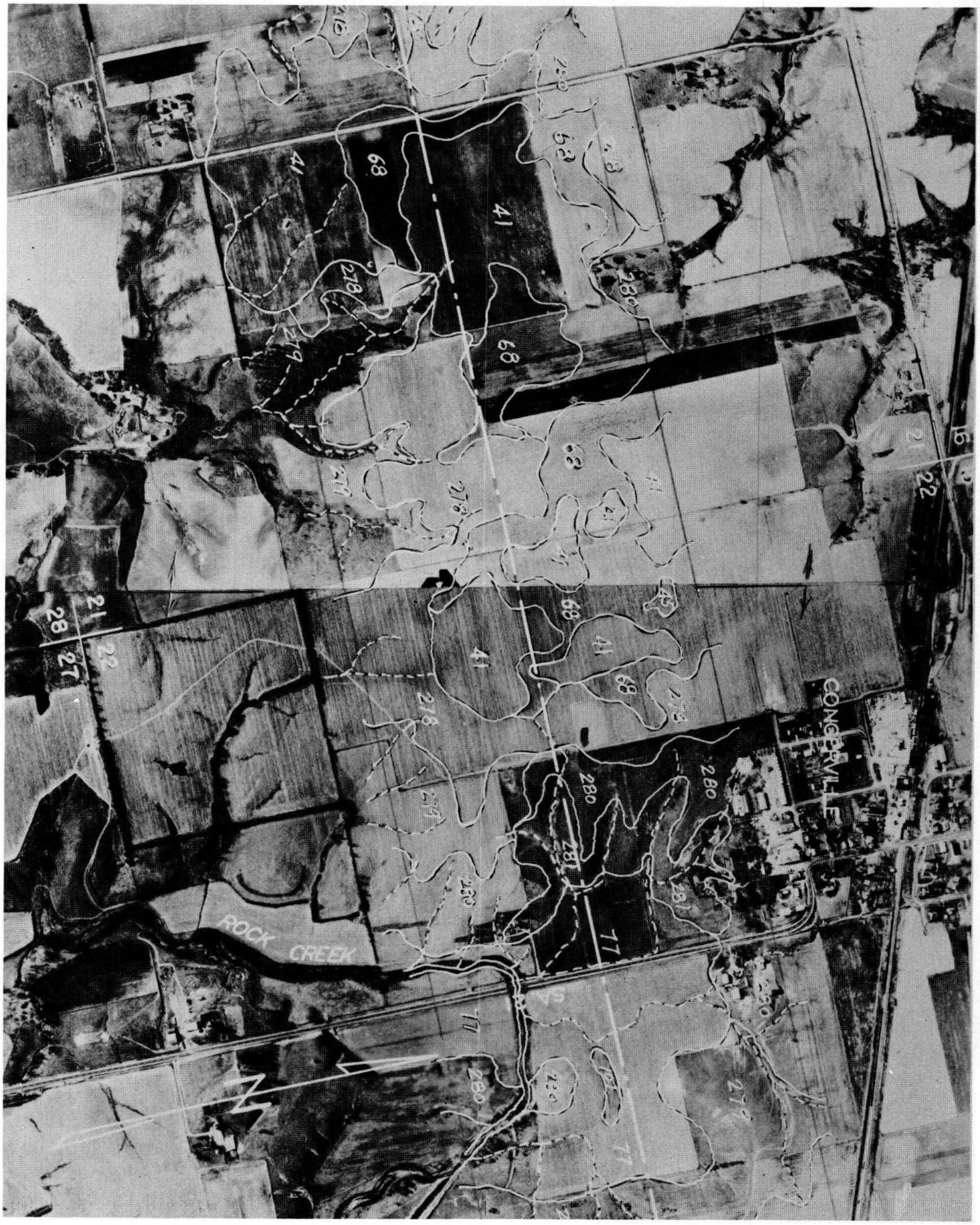


Figure 3. Airphoto on which soil type boundaries have been outlined. Number 41: Muscatine silt loam, parent material—loess; Number 68: Sable silty clay loam, parent material—loess; Number 77: Huntsville silt loam, parent material—water-laid sediments; Number 278: Stronghurst silt loam, parent material—deep loess.

The negative is then used to make contact blue-prints. The quality of the prints obtained provides satisfactory reproduction of the airphoto details.

ENGINEERING SOILS REPORT ACCOMPANYING THE STRIP MAP

Of course the strip map alone would be of little value, and an engineering report is prepared to present the pertinent information required for the highway engineer to intelligently interpret the map. Such information includes geologic background of the area, correlation between pedologic description and engineering classification and comments on construction problems likely to be encountered with some of the soil types present.

The first item usually presented in the report is a description of the physiography and topography of the area, and this is followed by a discussion of the geology of the area considering both surface and bedrock formations. This information is gathered from various publications of the Illinois State Geological Survey and the Geological Society of America. Much of Illinois has been covered by glaciation and possesses the variability in surface topography and material usually associated with this type of area. Loess deposits have later covered large areas adjacent to the major rivers and vary in depth from a few inches to over 25 ft in some locations along the Mississippi and Illinois Rivers.

A brief description of the pedologic classification system used and the mapping units involved is presented in the body of the report and a more complete discussion is attached as an appendix. The pedologic soil types possessing similar engineering characteristics are grouped according to a classification system developed by Thornburn and Bissett (8). This system considers the plasticity of both subsurface and subsoil in conjunction with the permeability characteristics of the substratum. This is a broad classification which does not indicate all of the significant differences but can be useful in the preliminary study of an area. It is anticipated that this grouping may be dropped from future reports, because it requires acquaintance with a classification system that is rather limited in use.

A note on the occurrence of granular materials is included as such information is quite valuable in consideration of availability of construction material. Although the Illinois Division of Highways does not furnish the borrow pits required for construction, information of this type is necessary for the preparation of cost estimates and in other planning phases. Soil type 93, Rodman gravelly loam, for example, indicated "0-10 inches of gravelly loam material over calcareous coarse gravel." In section 28 (Fig. 2) this soil type occurs. The gravel pit (GP) indicated near the southern boundary of the section is probably operating in this type of material.

The possible construction problems associated with the various soil types are discussed both from the viewpoint of design and that of construction. In areas where the depth of loess is such that cuts are likely to encounter un-weathered loess, note is made of the erosion problem and specific design recommendations are made. The difficulty of compacting loessial soils is mentioned, if the area is one in which material of this nature is likely to be used for embankments, and the need for careful control of the moisture content explained. These are just two examples of the types of information presented in the section of construction problems.

A bibliography of pertinent references is usually the last item in the body of the engineering report accompanying the map. This lists the publications used in preparing the report and is a handy guide in the event that further information is required on one particular phase of the report. Items indicated by an asterisk in the "references" in this paper are some of the common sources referred to in the engineering reports and were not necessarily used herein.

APPENDIX TO THE ENGINEERING SOILS REPORT

The most important items presented in the appendix to the reports are the descriptions of the pedologic soil types (Fig. 1). These descriptions indicate the profile characteristics, topography, parent material and drainage characteristics for each soil type encountered. The estimated engineering properties of each horizon are presented and remarks are given as to probable subgrade performance and any special probem likely to be associated with each profile. The engineering properties are either based on actual test data or estimated from agricultural data. Statistical analyses of the Atterberg limits (liquid limit, plastic limit and plasticity index) and some of the chemical and physical properties commonly contained in agricultural soils reports indicate that there is a very close relationship between the Atterberg limits and these latter soil properties (6).

Also included as an appendix is a description of the pedologic classification system used. This system has been briefly described earlier in this paper. The appendix to the engineering report also contains considerable information on the Thornburn-Bissett engineering group classification system which has been used as a basis for a map similar to the one now being prepared on the pedologic system. As mentioned previously, this classification system was too broad to be of use to the highway engineers except in a general study of an area.

TRAINING HIGHWAY PERSONNEL

In June of 1958 a program consisting of several conferences and field-trips was conducted to familiarize the division of highways soils engineers with the soil mapping and sampling techniques of agronomists. At the same time, the agronomists had an opportunity to become acquainted with engineering problems and techniques. As a result of this exchange of ideas, the highway soils engineers became more aware of the capabilities of existing agricultural soils maps and more confident of their own ability to use these maps to better advantage.

The response to this initial program was such that a second one was held in 1959. This meeting emphasized soil conditions in the southern portion of the state because the first program primarily considered the northern portion. Once again representatives of the Agronomy and Civil Engineering Departments of the University of Illinois met with the highway engineers and discussed the pedologic classification and mapping system, as normally used, as well as the strip map technique used in preparing maps and reports for use by the divison of highways. The close cooperation of the groups involved made both of these programs quite successful.

This cooperation has continued in subsequent operations. A general working arrangement was made so that the maps and reports provided by the project staff were also checked for accuracy and adequacy by the engineers as they were being used to aid in the preparation of the detailed soil surveys for the highway projects. In this manner the staff was kept informed of the usefulness of their work and could make any changes that seemed necessary. It is the opinion of the project staff, and its advisory committee, that the procedure for preparing reports and strip maps based primarily on air-photo interpretation has progressed to the stage that it may be considered operational rather than experimental. The maps and reports prepared by the methods just described can, and are, being used in the Illinois Division of Highways as aids in the preparation of highway soil surveys.

APPLICATION TO A SPECIFIC HIGHWAY PROJECT

The following discussion presents, in general terms, the use of the report on "Engineering Soils of Part of McHenry County" (1), and its companion strip map in preparing the detailed highway soil survey and report for FA Route 20, Section 28R, in McHenry County. No attempt will be made to give the station limits of areas involved, the specific recommendations for base or subbase thickness, or special construction procedures outlined. Most of these items depend to a large extent on local policy and procedure, a discussion of which would tend to detract from the subject of the use of pedologic strip maps.

Preliminary Analysis

In the first step of the preliminary analysis, the centerline of the proposed improvement was drawn on the strip map and checked to see if it crossed any undesirable areas. Inasmuch as the map provided, used color to indicate the various soil types, this was a quick procedure. The highly organic areas, for example, were indicated in black and were easily identified (Fig. 2). The following remarks are taken from the pedologic data sheet for soil type 103, Houghton muck. "Depth of muck may vary from 3-12 feet or more. Adjustment of highway line to bypass these areas advisable. Otherwise complete replacement of muck by selected material or use of some other corrective measures necessary." In the specific case involved, nearly all of these areas had been avoided and no line change was deemed necessary. Replacement of this material was recommended however. Although the present system of outlining the areas directly on the airphoto does not require coloring (Fig. 3), it is still easy to determine the soil type numbers that are troublesome and a quick study of the proposed centerline will indicate their existence and the areas may be marked in color. By having such a graphic picture of the undesirable areas, the design engineer can plan alternate routes for consideration before too much other work is completed that would require costly revision if the line were to be moved at a later date.

Prior to beginning the field boring and sampling program, the field crew made a study of the strip map in order to become familiar with the terrain involved. A review of the profiles and the remarks on problems associated with each type gave then an indication of the soils that they would encounter, of those areas in which they could expect uniform conditions for a fairly large distance, and of those areas in which they could expect a large degree of variability. Certain areas were picked where more extensive borings were indicated to be necessary to determine more accurately depth and extent of unsuitable material so that reasonable estimates of quantities for removal and replacement could be made.

In glaciated areas such as this, it is not always possible to pinpoint the actual locations for the field borings, but a general idea may be obtained as to the amount of work necessary and the field work scheduled on this basis. It is especially helpful to be able to spot highly organic or other soft areas in advance because quite often the work may be scheduled so that borings can be made in these areas during the winter months when the ground is frozen and the more stable areas can be checked later. Such procedure is common practice in the areas in Illinois where peat deposits are numerous. By being familiar with the area, the field crews can often pick up some of the changes that are marked only by subtle changes in appearance, or have been masked by construction or farming operations.

Soil Profile and Description

The soil profile included with the highway soil survey report is normally drawn by connecting the similar horizons indicated by plotting the logs of the individual field borings. In relatively uniform areas this is a rather simple procedure but in many areas the question of determining whether the soil exposed in two adjacent borings is the same, indicates a transitional area, or belongs to two distinct profiles, is rather difficult to answer with any degree of assurance. Often there is a tendency to simplify the profile by assuming that a particular horizon is continuous if there is perhaps only a slight change in the field description of the center of three borings, when actually a distinct difference in engineering properties exists. The presence of a change would be indicated on the strip map and laboratory tests could be made to verify this. The use of the pedologic profile descriptions also provides information as to those areas that are likely to contain pockets of different materials and this information is included on the highway soil profile. Often this will also explain an apparent discrepancy in borings through an area which had been assumed to be uniform. For example, the pedologic data sheet for Proctor silt loam (Fig. 1) indicates the variability that may be expected in this soil type and states that: "Occasional pockets of frost heaving material may be encountered." By presenting information of this nature, the pedologic strip map serves as a valuable supplement to the engineers' experience when preparing the highway soil profile.

Laboratory Analysis

As mentioned earlier, the strip map occasionally indicated the need for additional laboratory tests but the general result was a reduction in the number of tests required. The pedologic map was a great help in assisting the engineer in "pairing up" field samples. Of course some testing of two or more samples from the same horizon is advisable to determine variability within a particular soil type, but otherwise it is possible to eliminate some testing by identifying two soils as being the same type although existing in separate areas, or being separated by a discontinuous profile. It was hoped that definite information could be presented on the number of tests that had been eliminated by the use of the strip map but a "post-mortem" analysis provided rather inconclusive evidence. The increased accuracy of the finished report was perhaps the more valuable result of the assistance afforded by the pedologic maps. If careful notes are made during the actual preparation of a highway soil survey with the aid of pedologic strip maps, it may be possible to determine actual savings realized, but the greatest good seems to lie in the additional information provided the engineer.

Soil Survey Report

The final step in the highway soil survey was the preparation of a soils report containing recommendations for base and subbase thickness, as well as discussions and recommendations concerning other items to be considered during the design and construction stages. Areas were indicated in which removal of unsuitable material and replacement with granular material or select borrow was recommended. Material that could be excavated from cuts and used in embankments was indicated as well as that cut material that was unsuitable for use as embankment and had to be wasted. The remarks for 152, Drummer silty clay loam indicate that "A and B horizon material should not be used as subgrade." This particular material would not likely be available from a cut, but might be included in a proposed borrow pit. Possible adverse moisture conditions that might be encountered were mentioned so that they could be considered in the planning of construction operations and so that the necessary drainage could be considered during the design of the highway through the area.

Such items are determined by the experienced engineer based on the field examination and subsequent tests and guided by certain established policies and procedures. The engineering soils report accompanying the pedologic strip map serves to supplement the experience of the engineer and provide him with additional information for his consideration during the preparation of his report. Drainage classification is one of the items to be considered during the determination of base and subbase thickness and the soil type descriptions provide information on permeability and topography which, when combined with knowledge of surface drainage being planned, make a much more accurate classification possible.

CONCLUSION

The use of pedologic soil strip maps, when accompanied by a report on the engineering properties and characteristics of the soil types, can be an invaluable aid to the highway soils engineer. Although claims that the use of these maps will result in less field sampling or less laboratory testing would be hard to either prove or disprove, it is unquestionable that they do make possible a more intelligent interpretation of such data as are obtained. This in turn provides a better basis for highway design and construction, resulting in more economical highway transportation.

The joint conference, field-trip meetings between the highway soils engineers and the Agronomy and Civil Engineering Departments of the University of Illinois have been quite beneficial in promoting better mutual understanding which has already increased the use of the available pedological soils maps in Illinois. Highway engineers are now taking advantage of not only the published agricultural soil reports but also much of the unpublished information available through such sources as the Soil Conservation Service and various departments of the University of Illinois.

Although this report contains little material of a statistical or numerical nature, such as most engineers seem to best understand and appreciate, it is hoped that it will encourage others to investigate the use of pedologic maps in their own area, if they are not already being used, and to exchange ideas with others interested in this technique. More efficient use of engineering man-power and better service to the motoring public are sure to result.

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Use of Agricultural Soil Maps for Highway Engineering in Nebraska

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● THE Nebraska Department of Roads makes rather extensive use of the agricultural soil maps which are published by the Conservation and Survey Division of the University of Nebraska and the U.S. Department of Agriculture. It has often been said that this group of maps is one of the most valuable aids for soil survey and materials prospecting work. A tremendous saving in time and money has been effected in the past 20 years through the daily use of these maps.

The agricultural soil maps are used for the purposes shown in the following table:

PURPOSES FOR WHICH AGRICULTURAL SOIL MAPS ARE USED IN NEBRASKA

Stage of Project Development		Use
Programing		Estimating costs of flexible pavements for programing purposes.
Design	Before soil and materials survey	Locating slope stability problems. Estimating the required thickness of flexible pavements. Estimating the granular foundation course requirements for rigid pavements. Estimating the need for a clay blanket on gravel surfaced roads.
	During soil and materials survey	Planning and conducting the soil survey. Locating deposits of materials for highway construction.
	During period of plan preparation	Estimating drainage and runoff characteristics for drainage structure design.

The existing soil maps are considered to be quite adequate in 47 of the 93 counties of Nebraska. High priority has been assigned by state and Federal agencies to the resurvey of the soils in about 15 additional counties. The existing soil maps are considered to be of some assistance in about 15 other counties. The soils in 4 counties are chiefly dune sand and are so well known that no survey is needed. It will be seen that the coverage is fairly complete with these maps, and that the situation will be even better in the near future.

The Nebraska Department of Roads has indicated its great interest in the continuing improvement and availability of the agricultural soil maps by joining with the Bureau of Public Roads of the U.S. Department of Commerce, the Conservation and Survey Division of the University, and the Soil Conservation Service of the U.S. Department of Agriculture in the preparation of an engineering chapter for each of the reports for counties presently being surveyed or to be surveyed in the future. The department of roads performs the tests on the samples taken by the surveying organizations and assists in the review of the tables and text materials for each county. The department also reviews its records for test data which may be added to those obtained on the samples submitted for each county. This procedure provides a more complete set of test data in each case.

A word of caution perhaps should be inserted at this point. The information obtained from the soil maps must not be expected to be precise. Even though careful work is performed by those who conduct the soil surveys in the field and every effort is made to make the maps as accurate as possible, it is obvious that soil changes in the horizontal, as well as in the vertical direction cannot be delineated exactly without an unreasonable amount of work. In the use of these maps one becomes accustomed to a certain amount of variation and allows for it when it is found. He is not surprised, when he drills a hole in a spot indicated by the soil map to be a possible source of sand, to learn that the sand which was noted by the original surveyor did not extend as far or as deep as indicated. One learns to use the map as a guide in his work in soils, but does not expect it to be infallible.

PROGRAM ESTIMATES

Agricultural soils maps are of great value in preparing program estimates for flexible pavements in Nebraska. They are used in conjunction with the cost summary map (Fig. 4) which is maintained up-to-date by the division of materials and tests. By the use of the two maps together a quick cost estimate can be obtained for any proposed flexible pavement in any area of the state.

The Nebraska Department of Roads usually programs construction work for a 2-yr period. At this time, the materials and tests division provides cost estimates for flexible paving for a large number of proposed projects within a short period of time. Also, quite often during the biennium the materials and tests division is asked to furnish cost estimates for programing purposes within such short periods that time is not allowed to investigate the soils in the field. The procedure used is as follows:

1. The alignment of the proposed project is superimposed on the soil map showing the approximate locations of the soil changes.
2. The soil profile for each of the soils encountered along the alignment is determined by reference to tabulated information available in the office. In many cases the trained individual is already familiar with the soil from previous experience.
3. The type of flexible pavement to be constructed in each section is determined on the basis of the soil profile.
4. The estimate for the selected type of flexible pavement is made by averaging the cost of similar roads in the immediate area, as shown on the cost summary map.

A typical example where this procedure was used is the Bellwood West project. In Figure 1 the alignment for the project has been indicated on the soil map. It will be noted that four soils are encountered within the project. These are soils of the Sparta, O'Neill, Waukesha and Judson series. From the typical soil profile sketches (Figs. 2 and 3) the general type of soil material is determined. It will be seen that the soils between Station 100± and Station 240± are of the Sparta and O'Neill series. The parent materials for both of these soils are sands. There are two standard procedures in Nebraska for flexible pavement construction in sand, the choice depending on the traffic density:

1. Bituminous sand surface course. Filler and cutback asphaltic oil are added directly to a 5-in. depth of subgrade sand. After thorough mixing, aeration of the excess diluent, laydown and compaction, a seal coat is constructed thereon. This type is for light traffic.
2. Bituminous sand base course. This is similar to the bituminous sand surface course, but instead of the seal coat, a 2- or 3-in. asphaltic concrete surface course is applied for roads carrying heavier traffic.

Between Station 240± and Station 310± of the project the soils are predominantly of the Waukesha and Judson series. A study of the typical profiles shown for these soils indicates that they are silt-clay in nature, containing little sand. The typical construction on this type of soil consists of granular subbase course, soil aggregate base course, and asphaltic concrete surface course.

Thus, on this project there are two sections requiring entirely different designs for flexible pavement. In the preparation of an accurate cost estimate this information is essential. Figure 4 shows a small section of the cost summary map previously men-

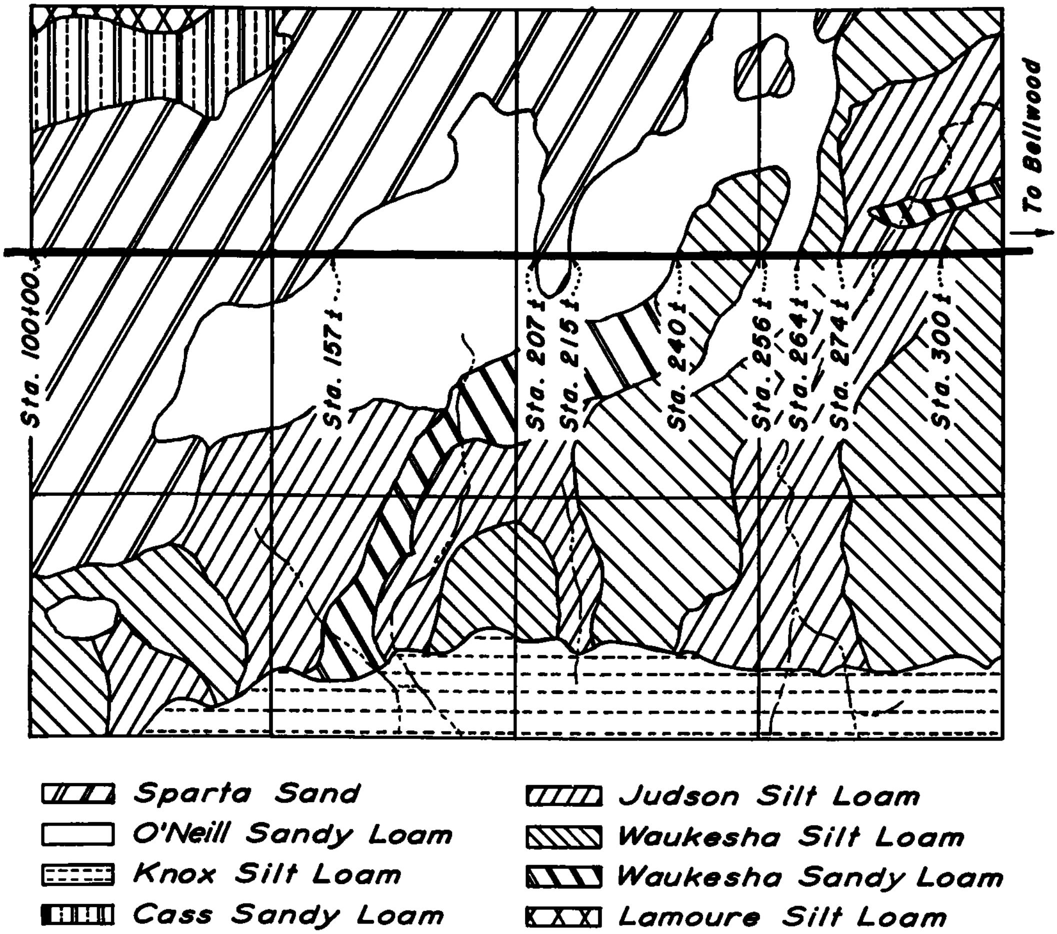


Figure 1. Agricultural soil map, section near Bellwood West project, Butler County.

tioned. It may be observed that the actual costs of recently constructed flexible pavements are shown for the region near Bellwood. Costs are available for both of the types of construction which will be required on the Bellwood West project. The project immediately south of Genoa is representative of the western end (Station 100± to Station 240±) of the Bellwood West project, where the soil is largely sand and an estimate of approximately $18,000 per mile for this type of construction is obtained.

Several of the other recently constructed projects in the vicinity are of the type required for the silty-clay soils on the eastern end (Station 240± to Station 310±) of the project. An average of the actual costs of these projects is about $27,500 per mile and this figure may be used as a program estimate for this section of the Bellwood West project.

This procedure is based on similar drainage characteristics and traffic density. If an estimate is to be made for a road having markedly different traffic or drainage conditions, appropriate adjustments are incorporated for these factors.

The estimate would not have been as accurate had it been based on the cost summary map alone without the information from the soil map.

SLOPE STABILITY PROBLEMS

Nebraska has three general types of slope stability problems which can be identified on the soil map:

1. Wind erosion on slopes consisting of fine or dune sand.
2. Water erosion on slopes consisting of extremely silty loess.
3. Sloughing of cut slopes consisting of clayey shales such as in the Pierre formation.

Approximately ⅓ of the State of Nebraska is covered with a dune sand material which is extremely susceptible to wind erosion when exposed by the removal of the vegetative cover which normally protects it. The dune sands occur principally in one large area;

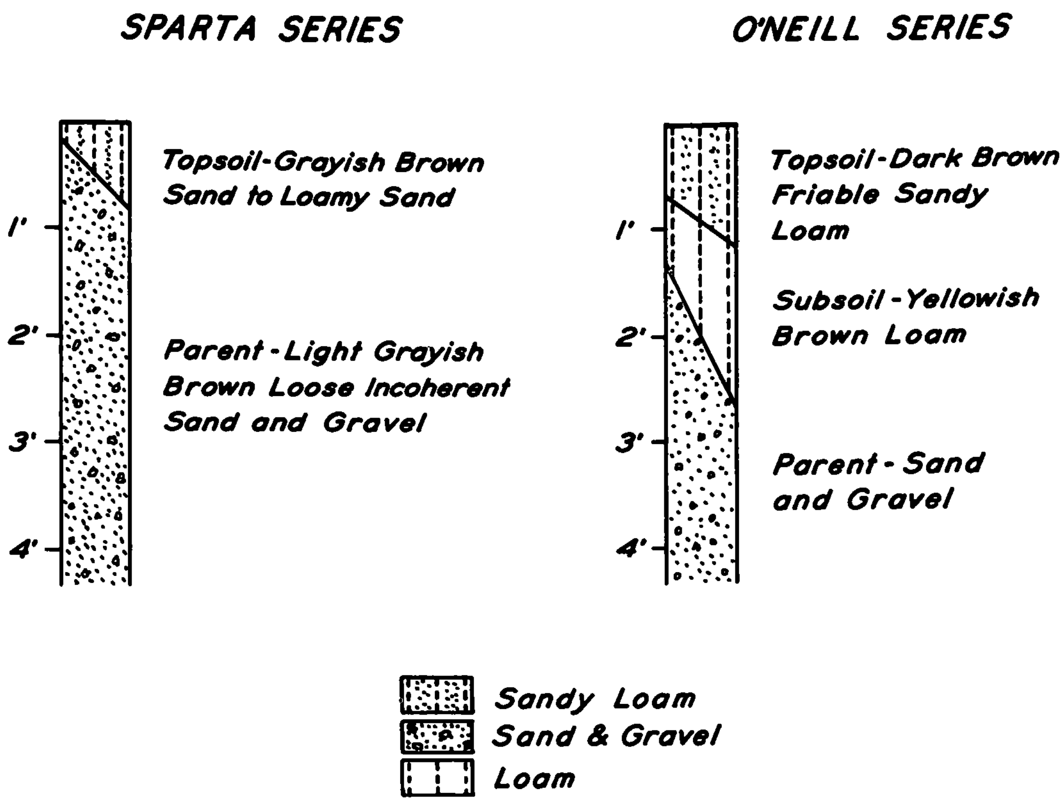


Figure 2. Typical soil profile.

however, there are also innumerable smaller areas of sand scattered throughout the western ¾ of the state. In the early programing and planning stages of project development, the department is able to forecast the necessity of slope protection for any section of road to be constructed to a sufficiently accurate degree for estimating purposes, by examination of the agricultural soil map. Then later, after the soil survey is completed, the exact locations of the protection to be planned is determined on the basis of the soil survey.

Approximately ½ of Nebraska is mantled with Peorian or recent loess. The loess is usually high in silt content and contains little sand. This material is quite susceptible to water erosion on exposed slopes, and in many cases special measures are required, such as construction of ditch checks and the placement of selected topsoil. Inasmuch as the soil series name always reveals the parent material, it is possible by reading the soil map to locate these problem areas for preliminary estimating prior to making the soil survey.

Certain limited areas have outcrops of Cretaceous shales, principally the Pierre.

These shales are subject to sloughing and the development of slides of serious nature for highways. If precautionary measures are not taken during the construction of any project having such conditions, the maintenance problems become enormous. In many cases, alignment changes can be made to avoid locations of exposed shales. A study of the soil map is made early to identify the areas where these problems may be encountered.

FLEXIBLE PAVEMENT THICKNESSES

In the normal course of events the materials and tests division is required to provide the estimated total required thickness of flexible pavements prior to the soil survey.

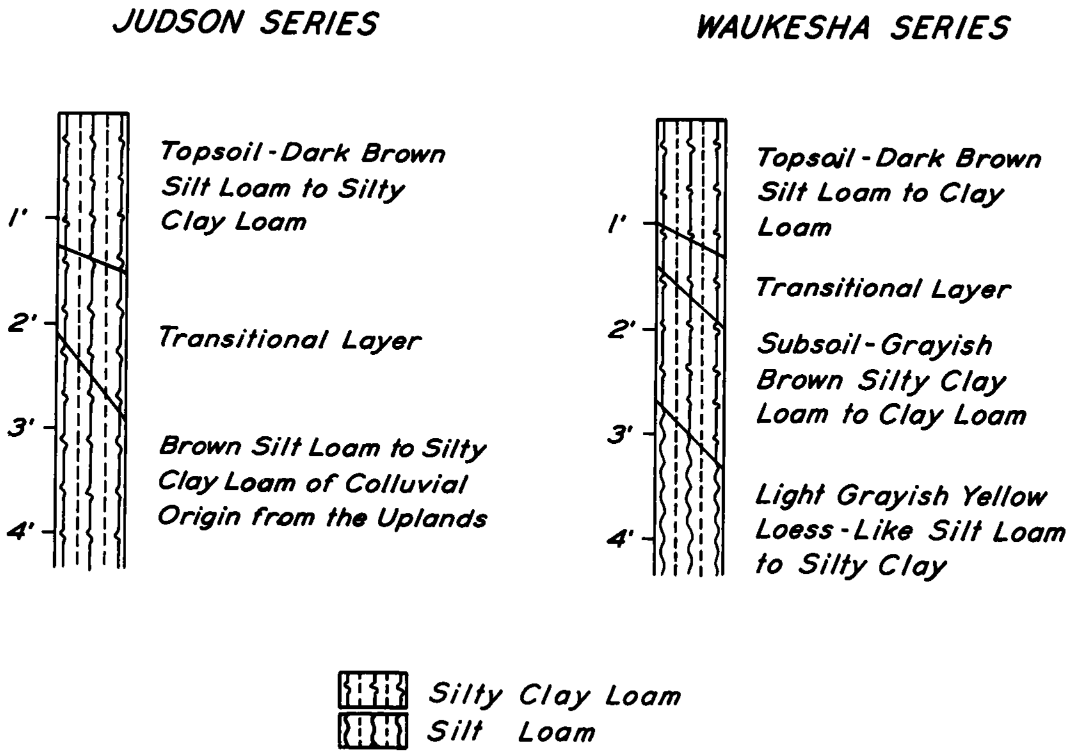


Figure 3. Typical soil profile.

vey. The design division uses this information in the early stages of plan preparation. The excavation and embankment quantities are balanced on a tentative basis until the data from the soil survey are available. Occasionally rebalancing of cut and fill is necessary, based on recommendations furnished by the materials and tests division after the soil survey is completed.

The Bellwood West project in Butler County will be used to illustrate the use of soil maps in estimating required thicknesses of flexible pavements prior to the highway soil survey.

The procedure for determining the locations and extents of the different soil areas along the project is exactly the same as that under "Program Estimates."

Tabulated information for each soil series (see example in Fig. 5) common in Nebraska includes test data developed from samples taken on highway soils and materials surveys over a period of many years. From the tabulated data, the summary (Table 1) and following table can be prepared for the Bellwood project:

Sta. to Sta.		Soil Series	Terrain Conditions	Soil Test Data % Ret. No. 200	G.I.
100±	240±	Sparta and O'Neill	Level to gently rolling terrace	50-93	0-3
240±	310±	Waukesha and Judson	Level to gently rolling terrace	3-8	8-11

The Bellwood project is in eastern Nebraska where the average annual rainfall is about 27 in. The axle loading factor (defined in Table 2) is about 50. Applying the four factors (axle loading, group index, situation, and rainfall) in Table 2, the approximate

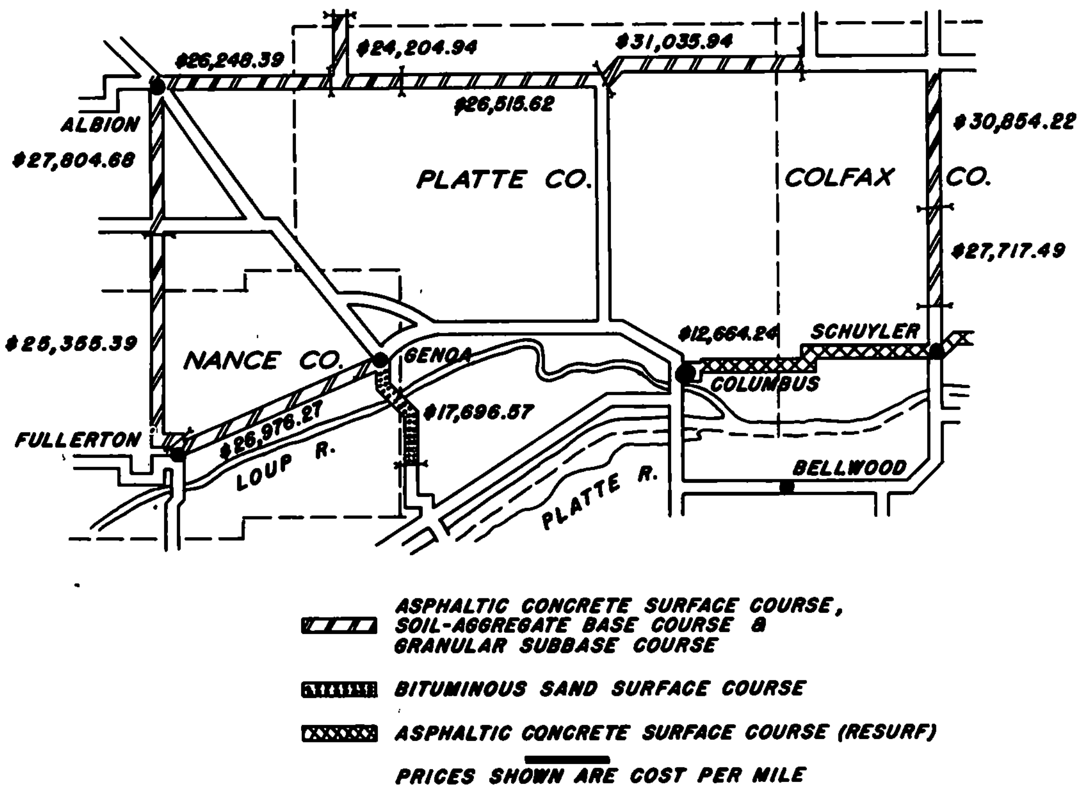


Figure 4. Cost summary map.

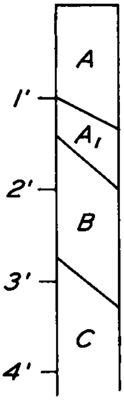
required thicknesses of flexible pavement are as follows: Station 100± to Station 240±, 6 in.; Station 240± to Station 310±, 10 in.

RIGID PAVEMENTS

The need for granular foundation course for rigid pavement is tentatively determined by inspection of the soil map, prior to the soil survey. Soil survey data are later used to confirm or adjust the tentative requirements established by the soil maps.

Nebraska's criteria for construction of granular foundation course for rigid pavements are based on the sieve analysis and the plasticity index. Sandy soils with a min-

WAUKESHA SERIES *



THIS SERIES INCLUDES FRIABLE PRAIRIE SOILS DEVELOPED FROM WATER LAID MATERIAL OR OUTWASH PLAINS AND STREAM TERRACES THE SOILS ARE USUALLY WELL DRAINED AND ARE LEACHED OF THEIR CARBONATES TO A DEPTH OF MANY FEET. THE TOPOGRAPHY IS FLAT TO GENTLY ROLLING.

- SOIL PROFILE -

A - TOPSOIL - DARK BROWN SILT LOAM TO CLAY LOAM

A_1 - TRANSITIONAL LAYER

B - SUBSOIL - GRAYISH BROWN SILTY CLAY LOAM TO CLAY LOAM

C - LIGHT GRAYISH YELLOW LOESS-LIKE SILT LOAM TO SILTY CLAY

* PEDOLOGICAL DATA FROM THE UNIVERSITY OF NEBRASKA DIVISION OF CONSERVATION AND SURVEY AND U.S. BUREAU OF CHEMISTRY AND SOILS

HORIZON	HYDROMETER ANALYSIS		LL	PI	SIEVE ANALYSIS, % RETAINED						AASHO CLASS
	% SILT	% CLAY			4	10	40	50	100	200	
			BUTLER COUNTY								
TOPSOIL	67	25	35	12				1		8	A-6(9)
SUBSOIL	70	27	41	16				0		3	A-7-6(11)
PARENT	78	17	32	9				0		5	A-4(8)
			THAYER COUNTY								
TOPSOIL	68	24	31	7				0		8	A-4(8)
SUBSOIL	62	37	41	17				0		1	A-7-6(11)
PARENT	71	28	39	14				0		1	A-6(10)
			YORK COUNTY								
TOPSOIL	74	22	34	8				0		4	A-4(8)
SUBSOIL	68	30	37	11				0		2	A-6(8)
PARENT	68	31	36	12				0		1	A-6(9)

Figure 5. Nebraska Department of Roads—soil test data.

imum of 60 percent retained on the No. 200 sieve and having a PI of 6 or less on primary roads are considered to be suitable for pavement subgrades without granular foundation course.

TABLE 1

SUMMARY OF TYPICAL TEST DATA FOR FOUR SOILS IN BUTLER COUNTY

Soil Series	Horizon	Hydrometer Analysis % Silt	Hydrometer Analysis % Clay	LL	PI	Sieve Analysis % Retained No. 10	Sieve Analysis % Retained No. 50	Sieve Analysis % Retained No. 200	AASHO Class.
Sparta	Topsoil	19	3	NP	NP	0	31	73	A-2-4(0)
	Parent	6	1	NP	NP	3	61	93	A-3(0)
O'Neill	Topsoil	20	9	NP	NP	0	37	71	A-2-4(0)
	Subsoil	34	16	24	8	0	25	50	A-4(3)
	Parent	5	2	NP	NP	2	49	93	A-3(0)
Waukesha	Topsoil	67	25	35	12	0	1	8	A-6(9)
	Subsoil	70	27	41	16	-	0	3	A-7-6(11)
	Parent	78	17	32	9	-	0	5	A-4(8)
Judson	Topsoil	67	25	35	12	0	1	8	A-6(9)
	Colluvium	68	25	24	12	-	0	7	A-6(9)

TABLE 2

REQUIRED THICKNESS FOR FLEXIBLE PAVEMENT[a]

Group Index	Required Thickness (in.) ALF[b] 50	ALF[b] 100	ALF[b] 200	ALF[b] 300	ALF[b] 400	ALF[b] 500	Adjust.[c] (in.)
-4	3	3½	4	4½	5	5½	±½
0	5	5½	6½	7	8	9	±1
4	6½	7½	8½	10	11	12	±1½
8	8½	9½	11	12½	14	15½	±2
12	10	11½	13½	15	17	19	±2½
16	12	13½	16	18	20	22	±3
20	14	15½	18	20½	23	25½	±3½
24	15½	17½	20½	23½	26	29	±4
28	17½	19½	23	26	29½	32½	±4½
32	19½	21½	25½	29	32½	36	±4½

DEFINITIONS

Rainfall:
- Light—less than 19 in. per year
- Medium—19 in. to 26 in. per year
- Heavy—more than 26 in. per year

Situation:
- "A" upland and terrace—ridges and good drainage
- "B" upland and terrace—level
- "C" bottom land and basin—water table deep
- "D" bottom land and basin—water table high

Axle loading factor:
- Axle loading factor is equal to the sum of the number of axles per day exceeding five tons and the number of axles per day exceeding seven tons

[a]From Nebraska flexible pavement design curves.
[b]Axle loading factor.
[c]Adjustment for situation and rainfall.

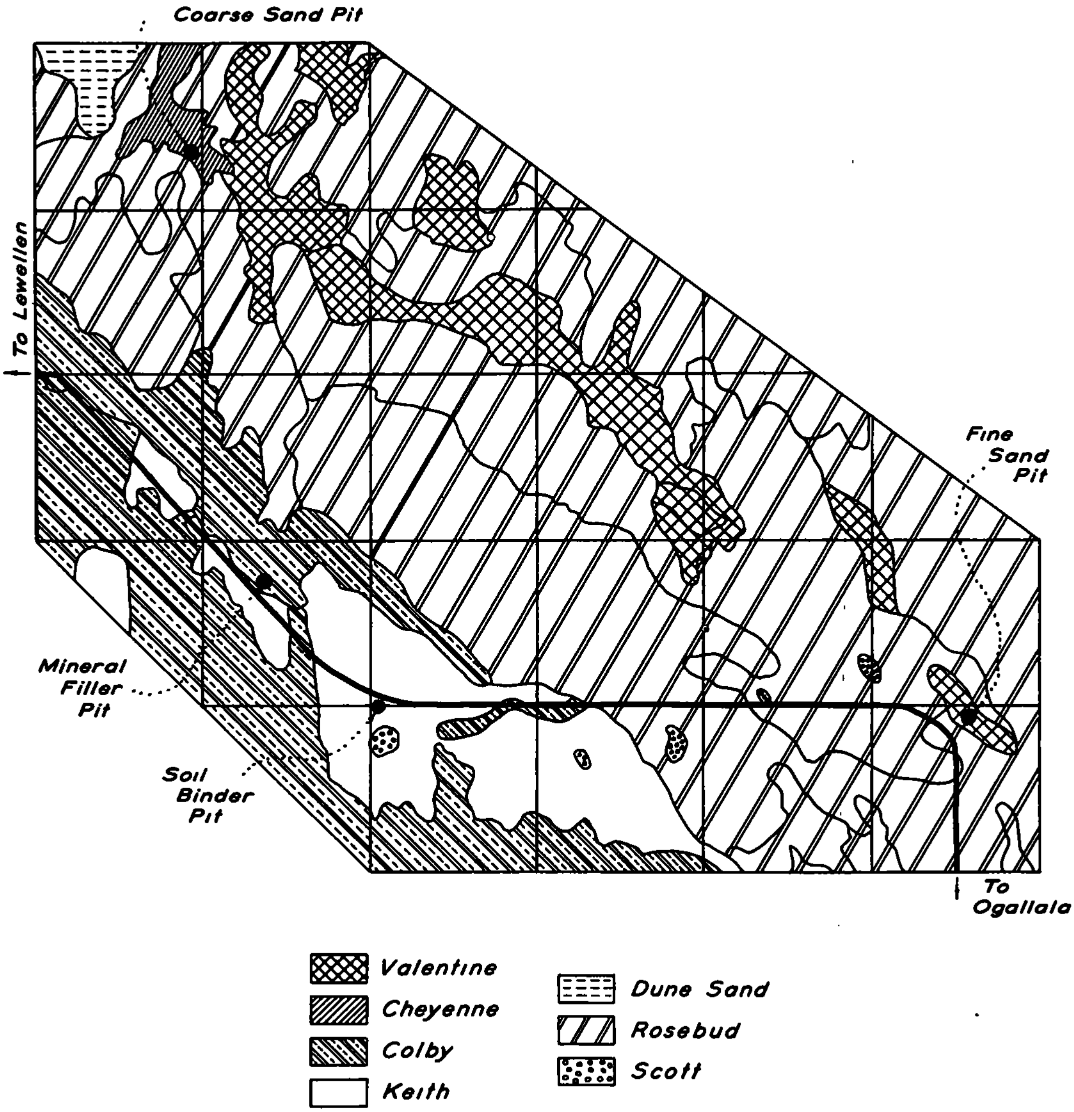


Figure 6. Agricultural soil map: section near Ogallala-Lewellen project, Keith County.

In the case of the Bellwood West project, the sandy section between Station 100± and Station 240± would be considered to be satisfactory without granular foundation course. Although the soil map and the tabulated information indicate that some of the topsoil and subsoil may have slightly less sand than required under the established criteria, these probably could be avoided in the subgrade by selective placement of soils.

The section between Station 240± and Station 310± obviously would require granular foundation course throughout most of its length.

GRAVEL SURFACED ROADS

Occasionally it is desirable to have a project lie over for a year or two after grading and prior to construction of pavement. This is possible in silt clay areas, by constructing a gravel surface course for temporary use. However, in the sandy soils of Nebraska, this procedure is not feasible unless a silt-clay blanket is placed on the subgrade sand before applying the gravel.

A glance at the soil map in the early stages of project development will reveal to the designer if the soils are adaptable to temporary use as a graveled road.

SOIL AND MATERIALS SURVEYS

The party chief preparing to conduct a soil and materials survey for a proposed project in Nebraska always makes a thorough study of the agricultural soil map covering the area within 5 or 10 miles of the project. It has been found through years of experience that much time, effort and expense can be saved by making such a study before leaving the office.

In planning for the soil survey, the party chief superimposes the alignment of the project on a soil map and observes which soils series will be encountered, thus establishing the terrain and soil conditions. If the soil map indicates a wide variety of soils along the project, he will know beforehand that many borings and much sampling will be required to accurately delineate the different materials to be excavated. On the other hand, if the soil map indicates a great degree of uniformity in the soils from one end of the project to the other, he will be able to reduce the number of borings and samples, and, in some cases, the survey can be abbreviated to the extent that only a few borings are made per mile.

The assistance provided by the agricultural soil map in locating construction materials is probably the basis for the greatest saving of all. In connection with the materials surveys, it should first be pointed out that the Nebraska Department of Roads locates a large portion of the materials used in the construction of base and surface courses. Among the items which are almost always located by state prospecting crews are soil binder for use in construction of base courses and subbase courses; soil type mineral filler used in the construction of road-mixed bituminous surfacing; and fine sands, coarse sands and gravels used in the construction of base courses, subbase courses and bituminous surfacing. The right-of-way division takes options on these local materials, and the pit locations and test data are shown in the plans. Inasmuch as it is not necessary for the several contractors interested in bidding on a project to conduct individual materials surveys, a considerable saving is effected. Also this plan makes it more difficult for a contractor to obtain an exclusive option on a source of scarce material.

In the use of the soil map as an aid in prospecting for local materials, the party chief should become so well acquainted with the materials indicated by any soil series that he can see the locations of different deposits on the soil map without reference to the descriptive text.

Figure 6 is an example where materials suitable for construction of the entire subbase, base and surface courses were located by inspection of the agricultural soil map. Figure 6 shows a portion of the area along the road between Ogallala and Lewellen. The materials needed for the construction of the flexible pavement on this road included soil binder, mineral filler, fine sand and coarse sand or gravel. Through previous experience and by the examination of the soil map and tabulated data in the office, the party chief was able to locate the following materials:

1. Soil binder. Keith soils are formed on level uplands and have parent materials consisting of Peorian loess. Their topsoils and parent materials are, for the most part, silt loams. However, due to the slow surface drainage and vegetative cover, there has developed a subsoil having somewhat greater cohesive characteristics than the parent material or the topsoil. The party chief knew before he left the office that he would make borings into Keith areas in attempting to find sufficiently cohesive material to serve as soil binder. Table 3 and Figure 7 indicate the characteristics of the material which was found in a Keith area and which served satisfactorily as a soil binder.

2. Mineral filler. The Peorian loess in this area is a silt loam, which has served as a mineral filler in many miles of Nebraska's roads. Finding suitable mineral filler was no problem, because this material was so widespread in this area. However, if the mineral filler was taken from a Keith area, an unsightly hole would be left which could not be drained, because Keith areas are level. In addition to this, the topsoil

TABLE 3

SUMMARY OF TYPICAL TEST DATA FOR FOUR SOIL MATERIALS USED IN CONSTRUCTION OF FLEXIBLE PAVEMENTS, KEITH COUNTY

Soil Series	Horizon	Hydrometer Analysis % Silt	Hydrometer Analysis % Clay	LL	PI	Sieve Analysis % Retained No. 4	No. 10	No. 50	No. 100	No. 200
Colby	Parent	84	7	24	3	-	-	-	0	9
Keith	Subsoil	61	26	34	14	-	-	-	0	13
Valentine	Parent	-	-	NP	NP	-	-	3	50	92
Cheyenne	Parent	-	-	NP	NP	12	31	84	90	94

and subsoil would have to be removed as overburden. The party chief knew that Colby soils are formed on Peorian loess in areas having steep slopes. Due to the fast run-off, little or no soil development has taken place on Colby areas. A satisfactory source of mineral filler with no overburden in a drainable pit was found in the Colby area (Table 3 and Figs. 6 and 7).

3. Fine sand is found as a parent material for many different soil series in Nebraska. In the particular area under discussion, the most likely prospect seemed to be the Valentine series. Inasmuch as these soils are formed on gently rolling terrain with loose, incoherent sand as the parent formation, the party chief prospected these areas and easily found the fine sand pit indicated in Table 3 and Figures 6 and 8.

4. Coarse sand and gravel. Nebraska has very little coarse gravel within its borders. In this particular area, the coarsest materials available are the coarse sands

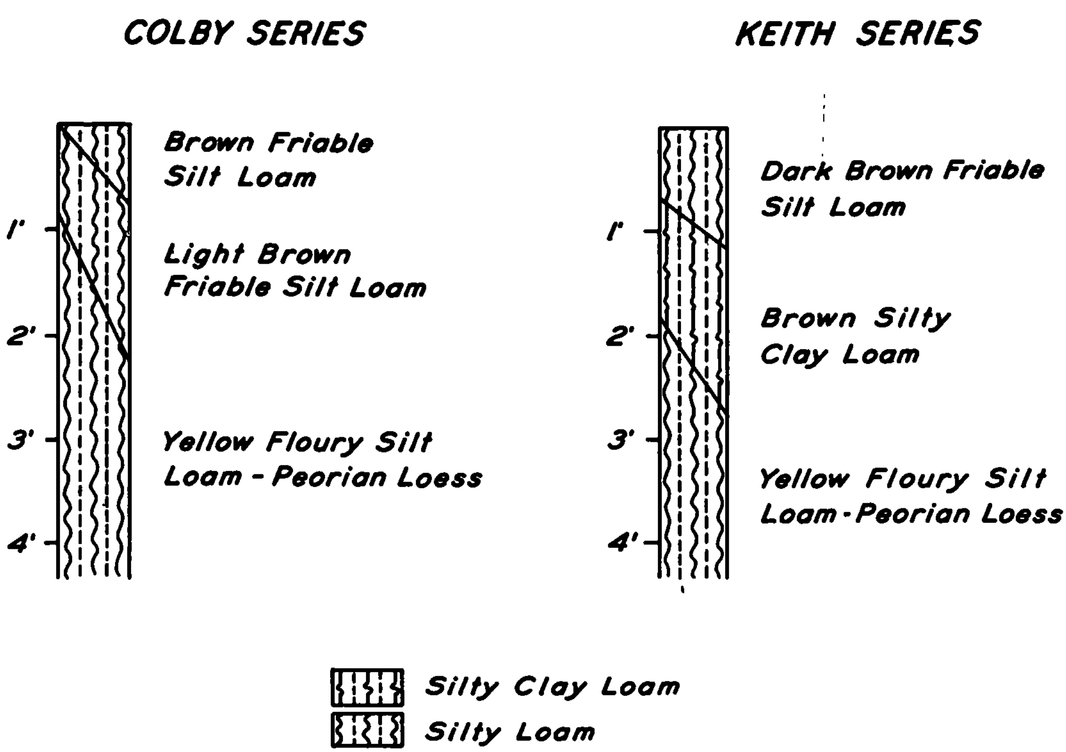


Figure 7. Typical soil profile.

which are the parent materials for the Cheyenne series. These were transported from the Rocky Mountains in stream channels during Tertiary and Pleistocene periods, and have therefore become worn and rounded. Sometimes they are used as found, but more often the finer materials are screened out and the coarser fractions are then used as gravel. The soil map showed the party chief the nearest source of these materials which are indicated as Cheyenne soils in Table 3 and Figures 6 and 8.

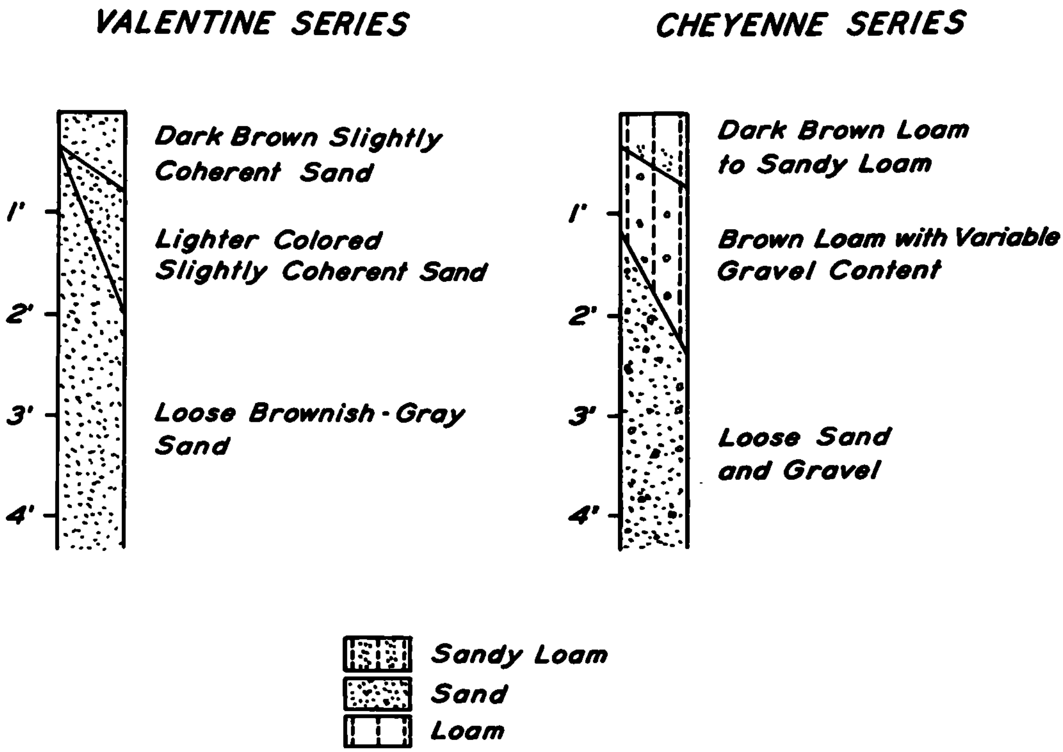


Figure 8. Typical soil profile.

The materials shown in Table 3 were located solely by review of the soil map, before leaving the office. It is obvious that a tremendous saving in time, effort and money can be effected by use of the soil maps in this manner.

It perhaps should be mentioned here that every suitable pit which is located during the materials survey is shown on a county map in the office and typical test results are tabulated. The party chief also examines this storehouse of information prior to departing for his soil and materials survey.

DRAINAGE AND RUNOFF CHARACTERISTICS

The design division uses the agricultural soil maps to determine drainage and runoff characteristics for large areas. A sheet of transparent acetate is placed on the section of the soils map for which the drainage area is to be determined. The drainage areas and streams, as shown on the soil maps, are traced on the acetate. The area outlined on the transparency includes a part of the upland ridges determined to be the divides between two drainage areas. The locations of the divides are estimated by halving the distances between two dendritic drainage patterns. A knowledge of the soils series descriptions is of some help in locating the divides.

The area traced on the transparent acetate then is determined in square miles by use of the planimeter. Large upland sink-like depressions or basin areas are usually excluded from the area outlined by the main drainage streams. The principal soil texture included within the drainage area is determined by the soil series shown on the soil map. A runoff factor is selected according to the texture of the principal parent soil. This runoff factor is applied to the entire drainage area with no consideration given for minor occurrences of soils developed on widely different parent materials.

This method applied to soil maps for upland or rolling terrain. Ordinarily, drainage areas for terraces bordering major streams are considered to be less accurate than those for the upland areas.

CONCLUSIONS

By using the information available on the soil maps for tentative design purposes, prior to the soil survey, significant savings in time are regularly effected. By using the soil map information great savings in prospecting and soil survey costs are accomplished. The soil map information backs up and supplements the soil survey information, thus improving its quality.

Application of Airphoto Interpretation Techniques

E.G. STOECKELER, Airphoto Interpretation Specialist, University of Maine

A soil classification system comprising seven units is described with respect to: physical characteristics of the soil, subsurface drainage conditions, frost susceptibility, settlement characteristics, relief, ease of excavation, and other significant characteristics. Reconnaissance engineering soil maps for an area of about 4,000 sq mi, and hundreds of miles of soil strip maps, have been prepared. Application of the procedure in soil and materials studies for a specific route study, and accuracy of the soil mapping, are described.

● THE Maine State Highway Commission in cooperation with the U.S. Bureau of Public Roads initiated a soils mapping program, employing airphoto interpretation techniques, in 1948. For the next six years a soils classification system based on geomorphological nomenclature was used for the preparation of engineering soils maps.

Because most of the engineers in the highway commission had little or no formal training in the earth sciences and were not familiar with the technical terminology designating various landforms, the soils maps were not fully appreciated and, as a result, were rarely used. To rectify the situation, it was obvious that a fresh approach was necessary to stimulate the engineer's interest in the utility of soils and terrain studies for various phases of highway engineering work. Also, it was necessary to demonstrate that airphoto interpretation techniques were ideally suited for the purpose of providing adequate terrain information rapidly and at a minimum of cost.

MAINE RECONNAISSANCE ENGINEERING SOILS CLASSIFICATION SYSTEM

In 1954, a soils classification system was developed to satisfy the following requirements:

1. The system should have an absolute minimum number of soils map units, yet provide adequate information required by engineers for planning and preliminary engineering phases of highway location work.
2. The system should employ non-technical terminology in describing the soils units which should be tailored for terrain and climatic conditions found in Maine.
3. The system should be adaptable to airphoto interpretation procedures and techniques to such a degree that adequate engineering soils maps could be produced with a minimum of costly and time-consuming field checking.

In the process of formulating a system to fulfill these objectives, it was recognized that in this climatic region the frost action phenomenon is of paramount interest to the highway engineer. Apart from complex local climatic factors, the amount of frost action, or the degree of frost susceptibility, is principally a function of soil texture and structure and the availability of ground moisture during the cold seasons of the year. Briefly, wet fine-grained mineral and organic soils are highly frost susceptible, whereas dry granular soils are not susceptible to detrimental frost action. Differential heaving due to frost action results in extensive damage to roadways and highway structures. During the spring break-up period the melting of segregated ice lenses formed in frost susceptible soils results in unstable subgrades and pavement deformations which comprise one of the major expenditures of the maintenance budget in Maine.

In addition to frost susceptibility, several other physical characteristics of the ground were taken into consideration. Settlement properties, subsurface drainage characteristics, relief and other natural influences which might affect, to one degree or another, an area as a highway construction site were evaluated and incorporated into the soils classification system.

Airphoto analysis of terrain conditions is based principally on the interpreter's ability to identify various geologic landforms and to translate the significance of these landforms into terms of the physical characteristics of the soil as described in the last few paragraphs. Although glacial history, mode of deposition, drainage patterns, peculiar relief forms, vegetation cover, land use and other features are of prime importance to the interpreter, the engineer is interested only in the soil per se and not its origin.

On the basis of these considerations, a classification system composed of seven basic soils units was developed. Each of the soils units is described with reference to the physical characteristics of the soil, subsurface drainage conditions, frost susceptibility, settlement characteristics, relief, ease of excavation and other significant characteristics where applicable.

Map Symbol	Soils Unit	Description
R	Rock	Bedrock within 5 ft of the surface, outcrops generally common. Type of rock and possible engineering problems at specific areas are described in text accompanying strip maps. Over-all drainage is generally good, except for local swampy pockets on flattened hilltops. Overburden is generally stony or bouldery till on upper slopes, and similar to that of adjacent soil units on lower slopes. Seepage and icing problems should be expected. Degree of frost susceptibility is dependent on character of overburden and local drainage conditions.
BG	Boulder granular	Very bouldery till and occasionally colluvial or alluvial deposits having a sandy or gravelly matrix. Boulders up to 5 ft in diameter are numerous. Volume of ledge-size boulders (in Maine, a 1-cu yd boulder is classed as ledge for excavation payment) is often 10 percent or more. Surficial and subsurface drainage is good. Slopes are usually smoother and less irregular than the rock type. Materials are slightly to moderately frost susceptible. Boulder granular areas are considered as good construction sites.
B	Bouldery clay	Bouldery till containing a matrix of silt or clay. Relief varies from rolling to practically flat. Permeability is very poor. Ledge-sized boulders occur infrequently in the densely packed fine-grained till. Excavation is often very difficult in well-drained sites. Frost susceptibility varies from moderate to very high. Local drainage ranges from poor to good. Adequate drainage must be provided to insure good road performance.
G	Granular	Well-drained sandy and/or gravelly materials not subject to detrimental frost action or only slightly frost susceptible. Included are such landforms as eskers, outwash, kames, dunes, deltas, terraces, beaches and flood plains. Coarse, clean granular materials suitable for base course construction are generally of glaciofluvial or alluvial origin. Granular soils of lacustrine and marine origin as well as wind-deposited soils are usually sandy and are suitable for fill materials. Well-drained granular areas are excellent construction sites.
F	Fines	Alluvial, lacustrine, marine or occasionally glacial and aeolian deposits composed principally of silt or clay. Surficial drainage is generally poor. Frost susceptibility varies from high to very high. In low-lying areas these soils are often soft and are subject to considerable settlement. This soil type should be avoided, especially in poorly drained sites.

Map Symbol	Soils Unit	Description
S	Swamp	Low-lying areas having the water table at or very near the surface throughout the year. Surficial organic layer is generally less than 3 ft thick. Small swamps are associated with ground moraines, valley plains, flat-topped bedrock hills, or any terrain type having local depressed areas containing a perched water table. Soils contained in small swamps of this type are similar to those found in the adjacent areas. Larger swamps are usually found in alluvial, lacustrine and tidal marsh areas where the soils are generally extremely soft, highly compressible silts and clays which are very frost susceptible. These areas are very poor construction sites and should be avoided where possible.
P	Peat	Boggy sites characterized by a high water table and a surficial layer of peat at least 3 ft thick, and often in excess of 10 ft. The thickness of peat is indicated at select sites on soil strip maps. Deepest peat deposits are primarily associated with filled-in lake beds, glacial kettles, back water swamps, old stream channels and other relatively deep depressional areas. Peat is highly compressible and frost susceptible. This soil type represents the worst type of construction site and should be avoided if at all possible.

In addition to the seven soils units described, water (W) is incorporated into the classification system. Natural and artificial ponds, beaver flowages, pulpwood water storage areas, lakes and other bodies of water generally over 2 ft deep are included in this category.

Reconnaissance engineering soils maps, covering an area of approximately 4,000 sq mi, about one-eighth of the total area of Maine, have been completed at this writing. These maps, having a scale of 2 in. = 1 mi, were prepared in blocks of about 100 sq mi (15-min USGS topographic quadrangles split into two sections, north and south halves). Maps of this type are used in the initial phases of planning. In addition, several hundred miles of soils strip studies along proposed construction projects have been made. The width of these strips varied from 0.5 to 5.0 mi depending principally on the distance between terminal points and the character of the terrain encountered. For more detailed strip studies, the classification system described previously was modified somewhat to provide additional information, especially in areas having organic and highly compressible mineral soils. Maps of this type were used in the preliminary engineering phase of highway construction.

APPLICATION

Three types of strip studies—soils, drainage and materials—made along the Augusta-Fairfield section of the Interstate Highway System, which was opened to traffic in November 1960, are described in the following paragraphs. Terrain information can be presented in a variety of formats, depending on the type of project and the preferences of the engineering personnel involved.

Detailed Engineering Soils Strip Map

One method of presenting soils information suitable for more advanced stages of highway engineering is to superimpose soils delineations on topographic maps of adequate scale and contour interval. Large-scale maps covering the tentative route of the Interstate Highway System north of Augusta were considered ideal for this type of format. Following are brief discussions on the use of the maps by highway engineers and an evaluation of mapping accuracy.

After the preliminary planning phase of the Augusta-Fairfield Interstate project was completed, large-scale aerial photographic coverage was obtained along the proposed route. This photography, taken at a scale of 1:5,400 with a 6-in. focal length precision camera, was flown in spring after the snow had melted and before leaves were developed on deciduous trees. Photography of this type is ideal for photogrammetric purposes and also for terrain photo analysis. Topographic maps at a scale of 1 in = 200 ft and a contour interval of 5 ft were made by a private photogrammetric concern for the entire length of the project.

A detailed airphoto analysis was made of a strip of photos centered on the preliminary line. Soils areas, based on the classification system previously described, were delineated on the photos. Because of the "hurry-up" nature of the project, no field checks were made. Time permitted only brief reconnaissance along the 20-mi long

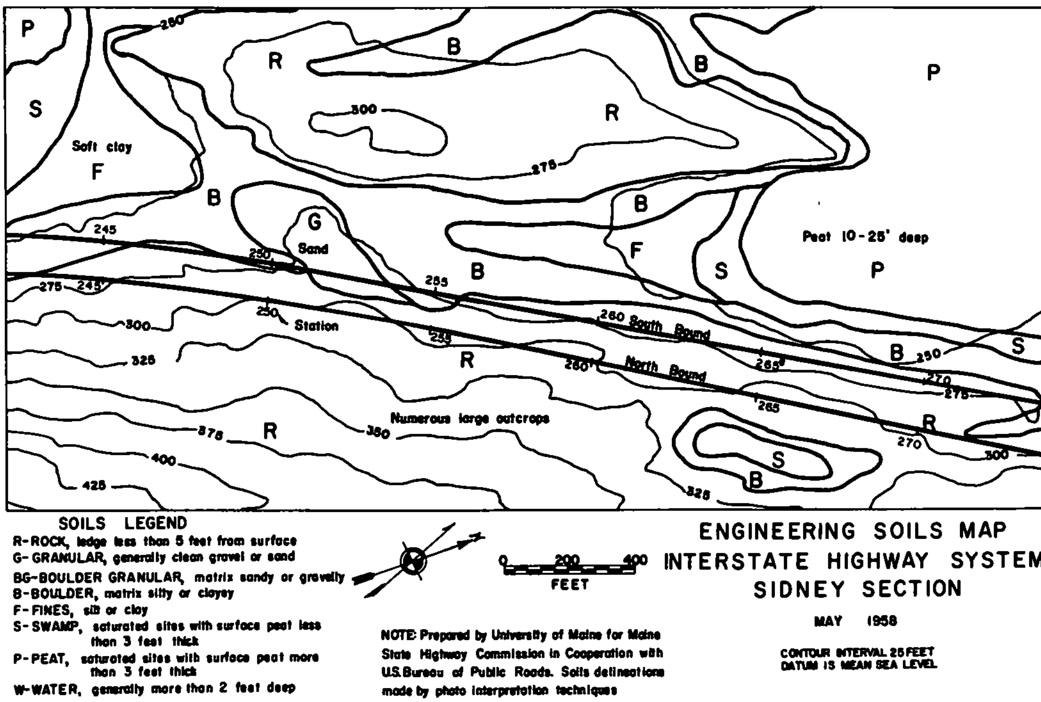


Figure 1. Engineering soils map units superimposed on a topographic base map. Original map was at a scale of 1 in. = 200 ft, with 5-ft contour interval.

study strip. In effect, the soils areas delineated were based only on airphoto interpretation. The soils areas were then transferred from the photos to the topographic maps described in the previous paragraph.

The location engineer then evaluated a number of median lines placed on the soils topo maps. Additional terrain information supplied by the airphoto interpreter included estimated thickness of peat, problem clay areas, potential seepage and icing slopes, extensive outcrop areas, location of granular deposits and other pertinent information which would, to one degree or another, contribute to the ultimate cost of the roadway.

After a more or less firm median line was selected the centerlines of the north and south lanes were plotted. Figure 1 shows the tentative road location on a soils-topo map about 10 mi north of Augusta. The map was modified slightly for reproduction purposes. Figure 2 is an uncontrolled mosaic of a strip of annotated photos centered on the area depicted in Figure 1, illustrating how two deep bogs were skirted in this particular area.

With plans and profiles in hand, field crews under the direction of the soils engineer conducted a detailed soils investigation along the north and south centerlines and offset locations where required. This information was used for design and cost estimate purposes.

For the purpose of evaluating the accuracy of the soils maps prepared by airphoto interpretation techniques, a portion of the 20-mi long study strip was selected for analysis. A total of 418 auger borings and soundings (for bedrock) were made along a 42,400-ft section of the Interstate. The locations of field checks were pinpointed on the soils map and actual field conditions were compared with the soils type indicated on the map. Table 1 gives the results of the evaluation.

Because of the relatively small number of field checks in the G, S and P soils areas encountered in this accuracy study it was not feasible to present a detailed statistical analysis of the data contained in Table 1. However, for a total of 418 field checks in all soil types, the mean error was 14.3 percent, and the range of error at 19.1 odds was 11 to 19 percent. In other words the engineering soils maps, based solely on airphoto interpretation with no field checks evaluated for this study, were accurate about 85 percent of the time.

It is emphasized at this point that the accuracy of a particular terrain analysis study is dependent not only on the competency and general background of the individual photo analyst, but also on such factors as the suitability of the aerial photography for interpretation purposes, complexity of the terrain and, especially in wilderness regions, the amount and type of forest cover.

Interpreters frequently use vegetation as soils indicators. In Maine, where the forests have been cut-over or burned-over a number of times during the past two centuries, the climax species composition of the forest has been so disturbed that the value of particular forest type as a soils indicator is limited. The significance of the present cover must be diagnosed in terms of general environment and probably botanical history of the area. Terrain blanketed with dense coniferous forests is very difficult to interpret because the surface of the ground is often completely obscured. In areas covered with mixedwood or hardwood forests it is possible to see the ground through the canopy on photos taken in spring or late fall when deciduous trees are barren of leaves. Consequently, the accuracy of the interpretation is considerably higher in these areas than in those having a dense softwood cover. From the point of view of vegetation cover

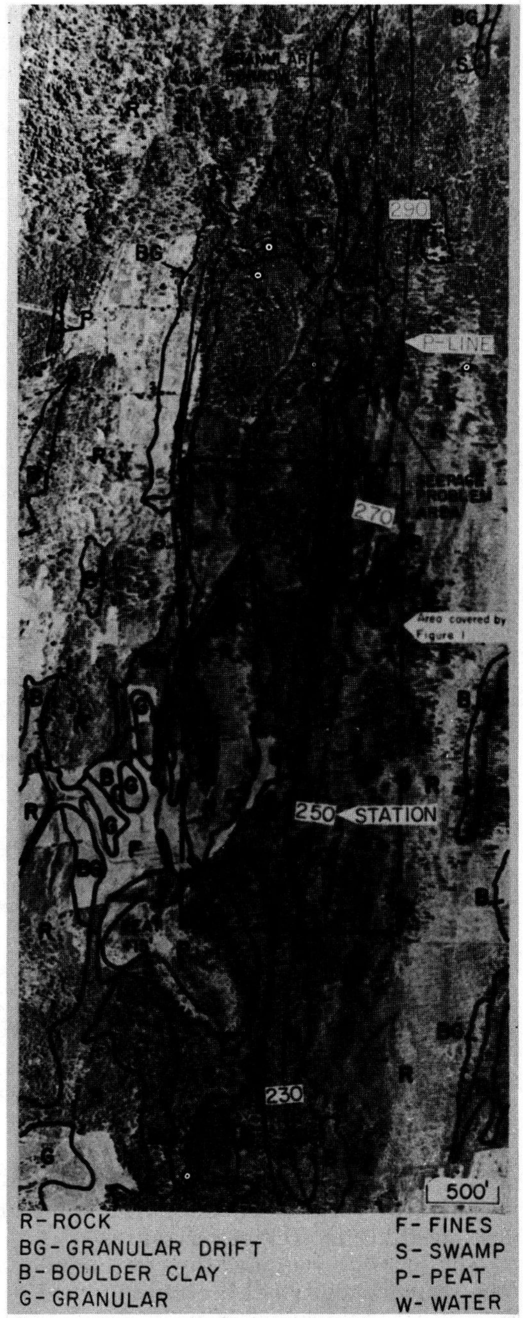


Figure 2. An uncontrolled mosaic strip showing soils delineations and annotations. Original photo scale—1 in. = 450 ft.

TABLE 1

COMPARISON OF SOIL UNITS AS MAPPED WITH ACTUAL FIELD CONDITIONS
(Map Classification by Photo Interpretation)

Soils Unit	R	BG	B	G	F	S	P
R	186	1	10	1	2	0	0
BG	5	46	0	2	4	0	0
B	2	1	48	5	19	0	0
G	0	0	0	4	4	0	0
F	0	0	2	1	63	0	0
S	0	0	0	0	0	11	1
P	0	0	0	0	0	0	0
Totals	193	48	60	13	92	11	1

Note: Underlined numbers indicate correct photo interpretation of soil unit designations confirmed by field checking; that is, in the B (boulder clay) column, out of a total of 60 field checks in areas classed as B on the soils map, 48 of the locations sampled were boulder clay, 10 areas were R (bedrock within 5 ft of the surface) and two areas were water-deposited silty soils.

only, regions containing some non-forested or partially forested areas are the least difficult to interpret. In coastal glaciated regions, such as Maine, the general geomorphological character of the landscape varies from very complex to relatively simple to evaluate by photo interpretation techniques.

As is suggested in the foregoing brief discussion of some of the factors which affect photo interpretation accuracy, it is evident that a considerable variation in accuracy should be expected. In any event, the quality of a soils study could be materially improved if the interpreter can make a brief reconnaissance of the study area, with photos in hand, before delineating the soil types on the photo. A review of previous soils studies made in the general area may provide useful data on soils conditions at specific points. Too often, however, information contained in published papers is too general to be of much value. In Maine the best source of reliable soils data which can be pinpointed is unpublished soil survey reports prepared by the soils laboratory of the state highway commission. After the office study is completed, a field check of questionable areas should be made and interpretation miscues can be readily rectified to improve the map accuracy. Obviously, the accuracy evaluation data contained in Table 1 are applicable only to the particular soils strip maps covering the study area discussed in this paper.

Drainage Study

A detailed photohydrological study was made of a portion of the Interstate Highway System described previously. Approximately 75 percent of the area was covered by hardwood and mixedwood forests. The aerial photography used for this study was taken in early spring before the deciduous leaves were developed, so it was possible to see most of the drainageways and ridge lines through the canopy. Photography taken in summer or late spring when foliage is fully developed is not satisfactory for drainage studies. The particular set of photography used for this survey was considered ideal, because the ground was saturated and every shallow depression was filled with water, making it relatively easy to trace small rills even in mixedwood forests which contained up to 50 percent softwood species. Figure 3 is an airphoto showing drainageways and ridge lines outlining watersheds in rolling terrain covered by several forest types.

Runoff information on 169 watersheds was gleaned from airphotos along a 15-mi section of the Interstate. The data on each watershed area were presented in the form as given in Table 2.

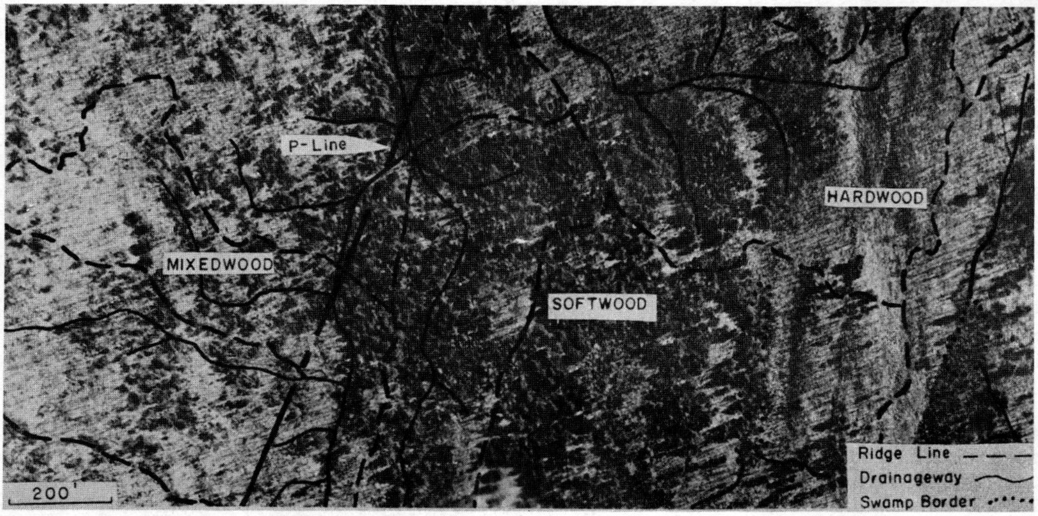


Figure 3. Drainageways and ridge lines visible beneath different forest types on an airphoto taken in early spring before foliage on deciduous trees was developed.

The information contained in this drainage report was used as design criteria for drainage structures in this section of the Interstate. Spot checks conducted by the design engineer and subsequent checks made during the construction stage revealed that the information extracted from the airphotos was substantially accurate with the exception of three watershed areas out of a total of 169. The three erroneous interpretations were misplaced ridge lines in heavily wooded softwood forests where it was not possible to see minor relief expressions through the dense canopy. All questionable interpretations should be field checked.

TABLE 2

RUNOFF INFORMATION OBTAINED BY PHOTO INTERPRETATION TECHNIQUES

No.	Station	Area (Acres)	Mean Slope (%)	Forest or Brush Cover (%)	Shape[a]	
54	799+20	52	6	95	800 x 3,200	A 12-acre storage area is located about 600 ft L℄ at Sta. 797. About 60 percent of the watershed contains some outcrops.
55	803+60	4	8	100	200 x 525	Can combine with Area No. 56.
56	805+00	27	3	80	600 x 1,900	See existing culvert 390 ft L℄ at Sta. 804+10. Northbound lane crosses a 20-ft wide swamp.

[a]General shape of watershed, width x length (in feet).

In more recent drainage studies, the column heading of "Forest or Brush Cover (%)", in Table 2, has been refined. Land use categories now used include (a) forested, (b) pastureland or hayland, and (c) cultivated land.

In Maine, engineers do not use soil type as design criteria in determining size of drainage structures. Peak runoff, principally in the form of melt water, occurs during the break-up period at which time the soil beneath the snow cover is frozen. This conditon effectively prevents percolation of melt water into the ground regardless of soil type.

In addition to the runoff factors given in Table 2, the rate of snow melting and, in effect, the ultimate runoff peak is also dependent on a number of complex environmental influences including air temperature variations, intensity and amount of spring rainfall, thickness and density of the snow cover, vegetation cover type, and slope gradient

Figure 4. A sample of an annotated airphoto furnished to field crews conducting materials investigations. Best access to suggested sampling points, distances, compass bearings and information useful for orientation purposes are noted on the photos. Crews are equipped with stereoscopes and scales for each set of photography.

and aspect. Considerable research is required to evaluate the relative contribution of these watershed influences to peak runoff volumes. As additional research data on runoff characteristics are incorporated in the design formula, information presented in the future drainage studies will be supplemented to meet the needs of the design engineer.

Materials Inventory

A photo analysis of potential granular deposits was made of a 6-mi wide band centered on the proposed Interstate location between Augusta and Fairfield. More than 100 granular deposits and about a dozen potential quarry sites delineated on the photos were sampled by field geologists and the materials were tested by the soils laboratory. Crews were furnished with annotated airphotos showing a variety of information designed to expedite the field investigation (Fig. 4).

A Materials Inventory Report, covering approximately 150 sq mi, contained the following information: (a) maps, at a scale of 2 in. = 1 mi, showing the location of each deposit (Fig. 5); (b) results of lab tests on rock samples; (c) tables containing detailed information on each deposit sampled; (d) grain-size distribution curves for each sample; and (e) large-scale sketch maps of deposits where detailed field investigations were made (Fig. 6).

Illustrated in Table 3 is the type of information and the method of presentation of

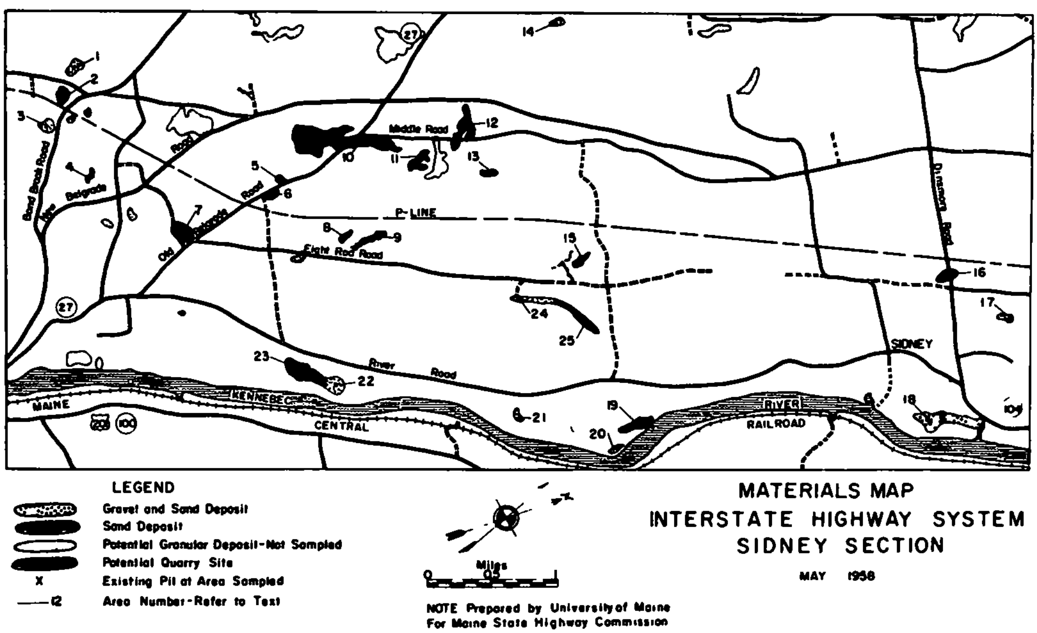


Figure 5. A portion of a granular deposit location map contained in a Materials Inventory Report. Original scale - 2 in. = 1 mile.

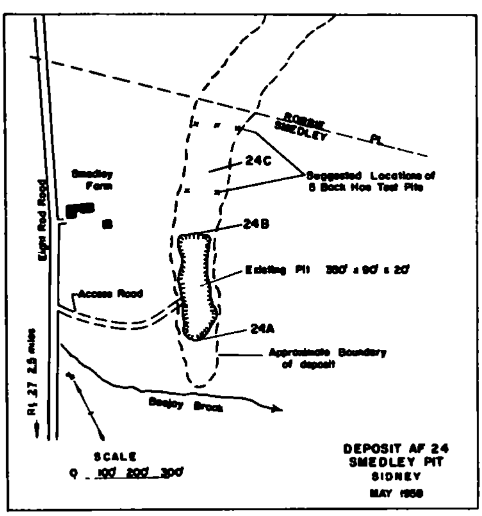


Figure 6. Sketch map of an individual deposit included in a Materials Inventory Report.

data on each of more than 100 deposits sampled.

In Maine, the free-haul distance is two miles. The maximum amount of admissible overhaul mileage is based on information contained in these reports and on the state construction engineer's evaluation of nearby deposits containing suitable quantities and qualities of materials for an individual project. Materials Inventory Reports were made available to bidders on construction projects located in this section of the Interstate covered by the study described in the previous paragraphs.

The Materials Inventory was also used for the selection of sources of maintenance and winter sand materials for this section of the Interstate.

CONCLUSION

The Maine Reconnaissance Engineering Soils Classification System described in this paper is accepted by Maine highway

TABLE 3

GRANULAR DEPOSIT EVALUATION SHEET[a]

Sample No.	Depth of Sample (ft)	Over-burden (ft)	Pit	Volume Estimate (cu yd)	Sieve Analysis % Passing					Passes MSHC Specs.	Remarks
					3 in.	1 in.	¼ in.	No. 100	No. 200		
24A1	3-6	3	Yes	38,000 (see remarks)	100	68	44	5.1	3.3	-	Owner. John Smedley, West Sidney Existing pit—350x90x20ft. Loc. A - East side of south face. Boulder clay floor. Can expand pit to south 125 ft. Volume estimate, 6,000 yards, gravel base, lower course. Loc. B - Center section of north face Boulder clay floor, water table at floor elevation. Loc. C - Hand dug pit located 200 ft NNE of Loc. B. Top strata similar to Samples 24B1 and B2. Materials at depth probably similar to 24B3 and B4. Volume estimate—extend existing pit 425 ft NNE to property line. Can remove top 10 ft separately for 12,000 yards of gravel borrow and lower 15 ft layer for 20,000 yards of gravel base, upper course. If entire 25 ft face is mixed, the material (Composite 24B1-B4) passes for gravel borrow See Sketch B-4 showing sampling locations and suggested locations of additional test pits, if desired
24A2	6-14	-	-	-	100	85	50	6.8	5.5	-	
24A3	14-19	-	-	-	92	70	38	5.0	2.8	-	
Composite (24A1, A2, A3)	-	-	-	-	97	77	45	5.9	4.2	Gravel base lower course	
24B1	1-7	1	Yes	-	100	100	98	12.6	9.1	-	
24B2	7-11	-	-	-	88	65	40	8.7	7.4	-	
24B3	11-19	-	-	-	100	66	48	4.9	4.0	-	
24B4	19-26	-	-	-	100	74	57	4.1	3.6	-	
Composite (24B1 and B2)	-	-	-	-	95	86	75	11.0	8.4	Gravel borrow	
Composite (24B3 and B4)	-	-	-	-	100	70	52	4.5	3.8	Gravel base upper course	
Composite (24B1, B2, B3, B4)	-	-	-	-	98	76	61	7.1	5.7	Gravel borrow	
24C1	2-5	2	No	-	100	100	92	10.8	8.0	-	
24C2	5-7+	-	-	-	95	61	44	8.0	6.8	-	

[a]Area No.—AF 24.

engineers and is readily adaptable to airphoto interpretation mapping techniques.

Reasonably accurate engineering soils maps suitable for planning purposes can be prepared directly from adequate airphotos with little or no field checking. Sufficient field checking is suggested, however, to improve map accuracy for use in the preliminary engineering phase. Soils maps are being used efficiently and effectively by Maine state highway location engineers both in the planning and preliminary phases of location studies.

For new location projects, Maine highway engineers are using, as the principal source of design criteria, drainage information obtained by airphoto terrain evaluation methods.

Materials inventory studies can be conducted most efficiently by employing an effective combination of airphoto analysis, field investigation and laboratory testing. Material sources near to construction projects can be used to minimize haul distances and to reduce construction costs.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Raymond Woodman, Jr., Assistant Airphoto Interpreter, University of Maine, and various members of the Maine State Highway Commission, especially Robert Furber, Primary Division Location Engineer; Frederick Boyce, Jr., Soils Engineer; and Mrs. Arlene Waddell, Secretary. Airphotos in Figures 2, 3, and 4 are reproduced with the permission of the Maine State Highway Commission.

Cooperative Soil Mapping Projects in Indiana

ROBERT D. MILES, Research Engineer, Joint Highway Research Project, Purdue University; and W.T. SPENCER, Soils Engineer, State Highway Department of Indiana

The Soils Section of the State Highway Department of Indiana uses agricultural soil maps, surficial and bedrock geology maps, aerial photographs, and published literature to assist in preliminary engineering studies of soil along a proposed highway. In cooperation with the Joint Highway Research Project, Purdue University, special soil strip maps have been prepared, several county engineering soil maps have been and are being compiled, and special publications on use of agricultural soil maps by soils engineers have been developed.

A cooperative project between these highway agencies, the Bureau of Public Roads of the U.S. Department of Commerce, and the Soil Conservation Service of the U.S. Department of Agriculture has been initiated to develop and compile data on agricultural soil profiles within the various counties. These data will be used in an engineering section of the agricultural soil survey report, and will be used as supplementary data to the engineering soils maps.

This paper is a discussion of the applicability of the strip maps and area soil maps to highway planning and the development of field exploration programs in Indiana. The methods of map presentation are discussed.

●THE Soils Section of the State Highway Department of Indiana, in making recommendations for the design of a proposed highway, bases its decision on the analysis of soils information obtained by indirect and direct methods of exploration. The direct methods of soil sampling and laboratory analysis are standard and need not be discussed. They furnish criteria on engineering soil types and physical properties on which design recommendations are based.

The indirect methods, whereby actual contact is not made with the soil, involves the use of (a) published agricultural soil survey reports, (b) aerial photography, or (c) combinations of the two with additional information obtained from geological publications and maps.

To assist the engineer in evaluating these data contained in the published reports and portrayed on aerial photographs, cooperative soil mapping projects were developed at Purdue University by the Joint Highway Research Project.

These cooperative projects evolved from an early attempt to use published Agricultural Soil Survey Reports. This study resulted in the publication of an engineering soils manual in January 1943, on "The Formation, Distribution, and Engineering Characteristics of Soils," Bulletin 87, Purdue University. This manual which discusses the variables of parent material, topography and agricultural soil profile divelopment, is used in conjunction with aerial photographs to make preliminary engineering soils maps. These preliminary engineering soils maps may be prepared for entire counties or for individual highway sections in the form of strip soils maps.

A new cooperative soil mapping project was established in July 1960. This new project involves the development of an engineering section in the Agricultural Soil Survey

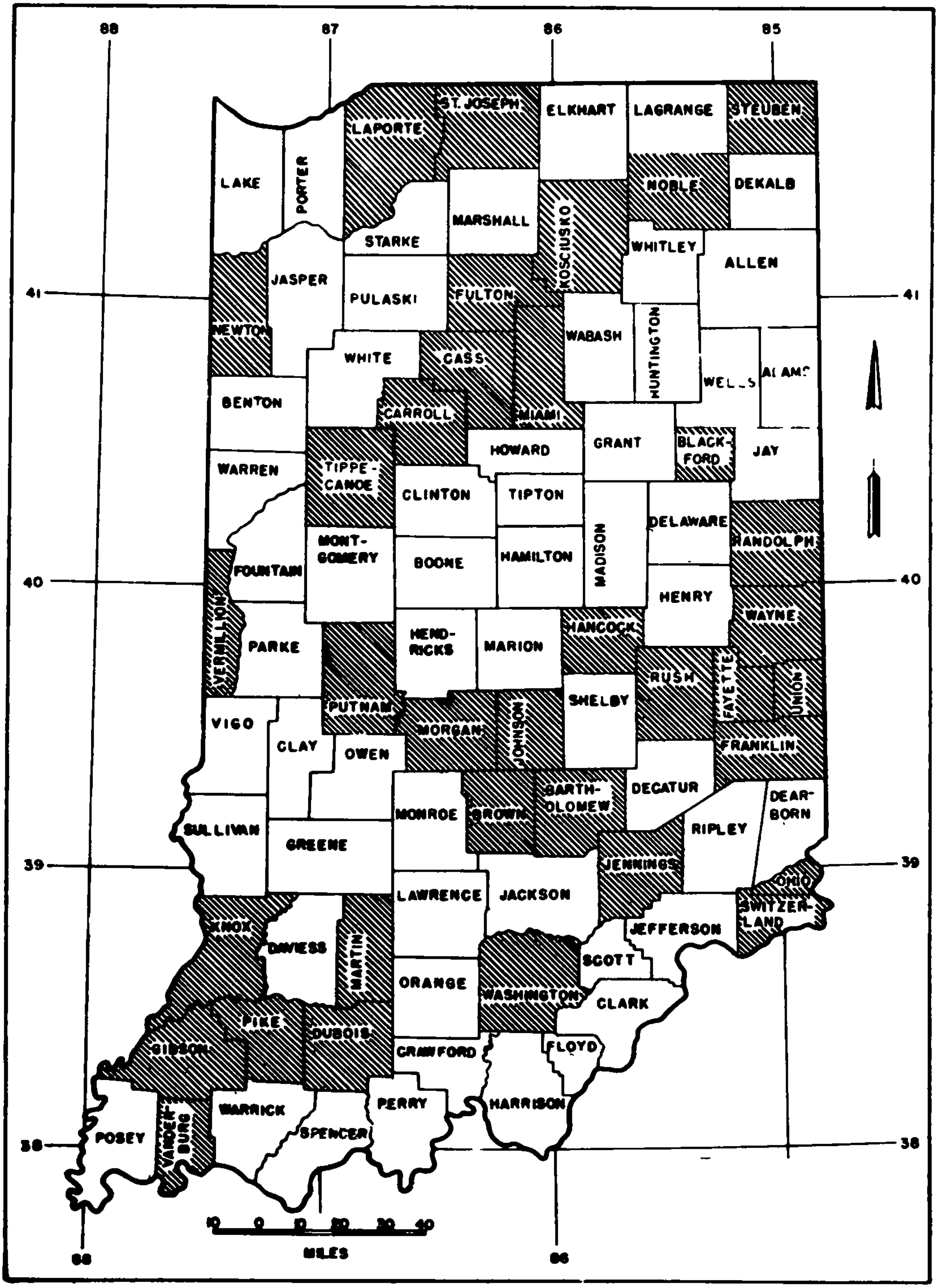


Figure 1. Agricultural soil surveys, 1925-1960.

Report. The cooperating agencies are the Bureau of Public Roads of the U.S. Department of Commerce, the Soil Conservation Service of the U.S. Department of Agriculture, the State Highway Department of Indiana, and the Joint Highway Research Project of Purdue University. The engineering section will be based on soil test data of the important pedological soils in a county.

It is the purpose of this paper to discuss the applicability of the various types of maps to highway engineering and the development of field exploration programs.

COUNTY AGRICULTURAL SOIL SURVEY REPORTS

County agricultural soil survey reports and maps prepared under the soils mapping program of the U.S. Department of Agriculture have been published in Indiana since about 1900. The early reports and maps developed prior to about 1925 are of little value to the engineer except as a reconnaissance-type soil survey. Current soil mapping techniques have shown that care must be exercised in evaluating the pedological soil types shown in these early reports.

The reports and maps published since about 1925 are suitable for interpretation into engineering terms and to locate engineering soil problem areas. The soil mapping scheme used presently by the Soil Conservation Service was essentially standardized about that time. Figure 1 shows those county soil surveys presently being used in preliminary soil studies for highway engineering purposes.

The interpretation of these maps and reports in Indiana is facilitated by the use of information published in the engineering soils manual on "The Formation, Distribution and Engineering Characteristics of Soils." This manual includes an engineering summary of 146 major pedological soil profiles as mapped in Indiana by the agricultural soil scientists. The soil profiles are correlated with engineering test data to include physical soil properties and highway performance data in relation to subgrade, embankment and foundation conditions. The pedological soil names as such are not used in Indiana highway mapping projects; however, they are used for evaluation and comparison of soil textural changes and profile development that might influence design.

The engineering soils manual published in January 1943 was prepared by personnel of the Joint Highway Research Project for the State Highway Department of Indiana. Although it contains only the pedological soil profile information that had been accumulated up to the year of publication, it continues to be of great value in assessing soils on even the most recently published soil survey reports. Numerous new soil series, types, and phases have been added by the Soil Conservation Service since the publication of the manual; therefore, it is necessary to correlate the new soil series and their parent material types with those published in the engineering soils manual. This may be done by reference to the report section of the agricultural soil survey and determining the slope and parent material class for the new soil series and comparing this with a similar series in the engineering soils manual. Valuable information may be obtained by reference to the tentative and adopted soil series descriptions that are published by the National Cooperative Soil Survey, U.S. Department of Agriculture.

To further enhance the value of the agricultural soil survey report to the engineer, an engineering section is needed to complement the information presented. To accomplish this, the Joint Highway Research Project, the Bureau of Public Roads, the Soil Conservation Service and the Indiana State Highway Department have entered into a cooperative agreement. The purpose of the project is to provide engineering test data on the important soil series that occur within a county. These engineering test data will assist in developing an engineering section to be included in all future agricultural soil survey reports.

The preparation of the engineering soils section as it is being developed in Indiana is primarily the responsibility of the agricultural engineer, Soil Conservation Service, with advice and review by the highway engineer. The soil samples of the major pedological soil series within a county will be collected by field personnel of the Soil Conservation Service. The samples with complete field notes including location on an aerial photograph will be forwarded to the Joint Highway Research Project for testing.

Engineering tests will be performed by the Joint Highway Research Project on all soil samples from the various soil horizons. The data for the preparation of a table on physical constants will be supplied to the Bureau of Public Roads for transmittal to the Soil Conservation Service for inclusion in the report. The summary of the soil test data will include the pedological soil type, soil horizon sampled and depth, parent material type, soil textural description, mechanical analysis, liquid limit, plasticity index, AASHO standard density and optimum moisture content, CBR values, and both the AASHO and Unified soil classification. Appropriate explanatory notes will be included in the report section to explain the table and its use. A summary table to explain both the AASHO system of soil classification and the Unified system of soil classification will be included.

As a part of the engineering section of the agricultural soil survey report, information will be presented in tabular form on all the soil series and types mapped within the county. Estimates will be made of the physical properties or characteristics within the soil profile that may affect the design or the application of treatment measures for engineering structures. Qualitative or quantitative data will be presented on such items as: seasonally high water table; soil permeability; shrink-swell potential; susceptibility to frost action; erosion potential; internal and external drainage conditions; landslide potential; suitability of soil material as a pavement subgrade, road fill, source of topdressing, source of sand and/or gravel; and other soil data that may affect highway design and construction.

The new agricultural soil survey reports with engineering sections developed by the Soil Conservation Service will contain soil maps prepared on an airphoto base map. The engineering soil test data combined with the land-use information shown on the airphoto mosaics will make these maps and reports of inestimable value in preliminary studies of highways or any other civil engineering project.

As engineering test data is accumulated on the major pedological soil series in the State of Indiana, it is contemplated that a new engineering soils manual will be prepared to replace Bulletin 87 that is currently out-of-print. The general format of the previous engineering soil manual will be followed, but important new pedological soil series and test data will be included. A manual of this type will be of great value to all highway engineers.

COUNTY ENGINEERING SOIL MAPS AND REPORTS

County engineering soil maps and reports prepared by the use of aerial photographs have been developed for the Indiana State Highway Department by the Joint Highway Research Project. These maps serve a need in those counties for which agricultural soil surveys are not available. In some cases, the engineering soils map has been or is being prepared for a county that has an existing agricultural soil survey. In such cases both the soil survey and the aerial photographs are used to prepare the engineering soils map. This procedure is used in an attempt to expedite the development of the county engineering soils mapping program. It will be used extensively in conjunction with the new agricultural soil surveys that contain engineering test data. Figure 2 shows the 31 county engineering soils maps that have been completed as of December 1960. Four more are in various stages of completion. The present rate of production is about two per year.

An example of a published county engineering soils map is shown in Figure 3. Selective sampling of major soil profiles and parent material areas are conducted in conjunction with the mapping program. Laboratory soil tests are performed on these samples. A summary table of soil tests is presented as a part of the map. These data (reproduced as Table 1) show the range of engineering soil types that may be expected in the county; however, no attempt is made to sample in the quantity needed to develop pavement designs.

The standard system of line symbols used in the county engineering soils mapping program is shown in Figure 4. Persons familiar with this symbol system will recognize that it is an attempt to show parent material-landform conditions, topographic conditions, soil drainage conditions, and soil textural conditions of the parent material. Only line symbols are used, and problems naturally arise in such a mapping system.

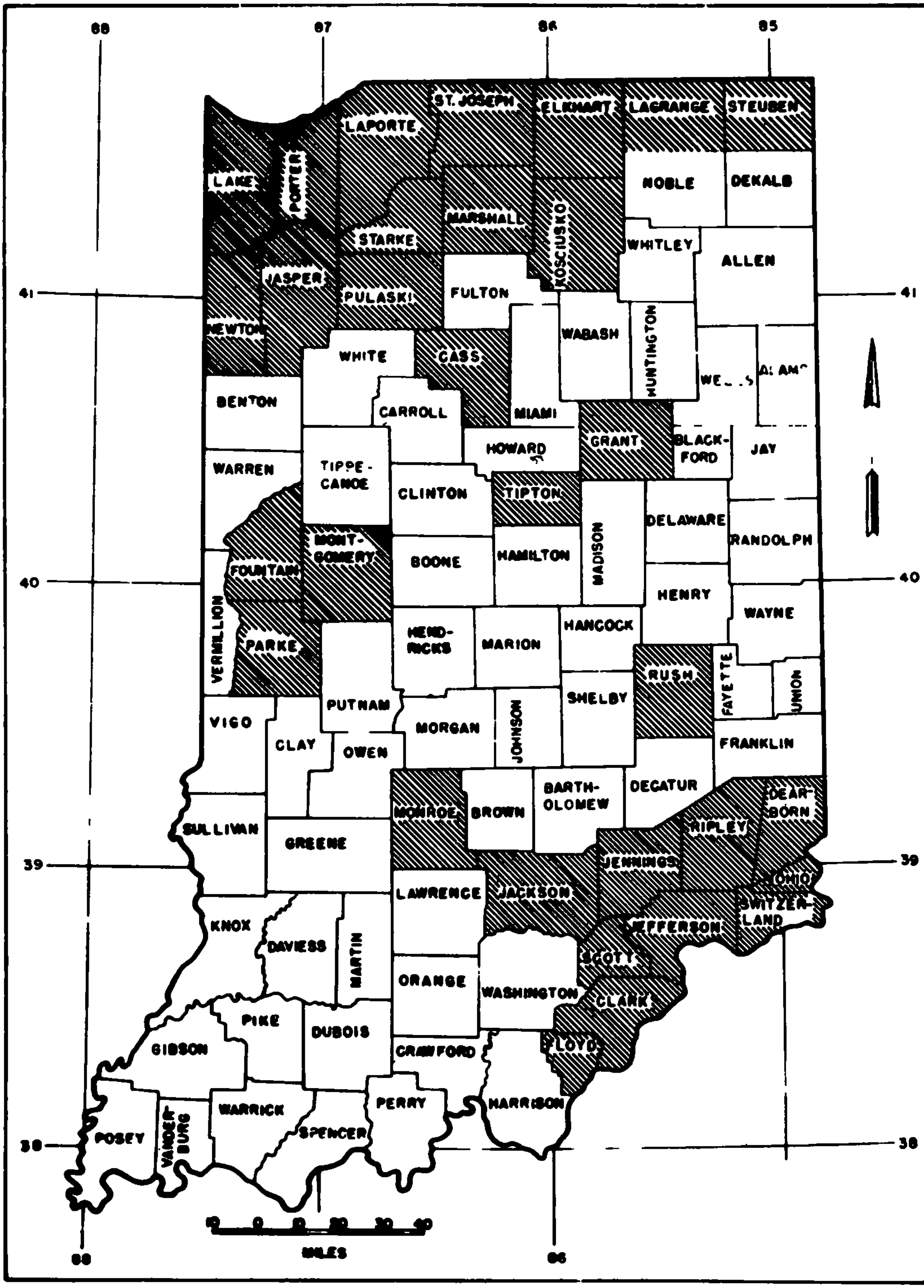


Figure 2. County engineering soils maps, 1960.

Because the maps presently being developed are limited in detail, using a scale of 1 in. per mile, the line symbols are serving their purposes.

These maps are used in preliminary studies to anticipate problem soil areas or to locate areas that may be developed for borrow materials. In essence they provide the soils engineer and the location engineer with information on the distribution of coarse-textured soils, fine-textured soils, and peat deposits. This information assists in the

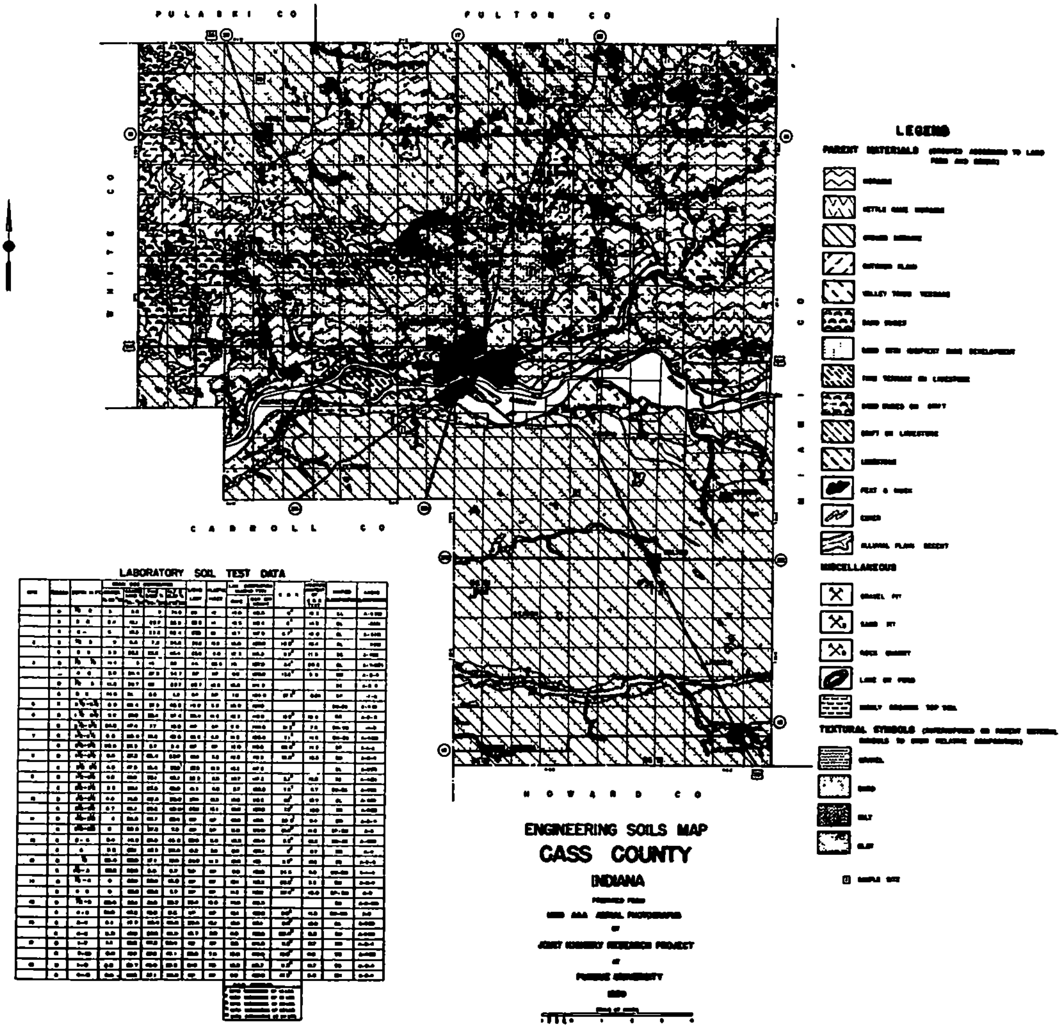


Figure 3. Engineering soils map of Cass County, Indiana.

study of alternate routes. It assists in determining those soil areas of somewhat uniform conditions versus those areas of complex soil conditions; thus, enabling the development of a field survey to secure maximum soil information with limited testing.

All county engineering soils maps are prepared at a scale of 1 in. = 1 mi. No attempt is made to obtain the detail that is presented on the recent agricultural soil surveys. Such detail could not be obtained by the art of airphoto interpretation unless the airphoto was used as a plane-table base map in the field, and supplemented by extensive borings. In most cases, it is believed that this detail is not warranted. It is believed that the location and preliminary design is influenced by the average textural conditions of soil horizons and parent material types with special designs required for organic deposits, questionable foundation conditions, or other special terrain types.

TABLE I

LABORATORY SOIL TEST DATA

SITE	HORIZON	DEPTH IN FT.	GRAIN SIZE DISTRIBUTION				LIQUID LIMIT	PLASTIC INDEX	LAB. COMPACTION (AASHO T99)		C. B. R.	MOISTURE CONTENT OF C. B. R. TEST	UNIFIED CLASSIFICATION	AASHO CLASSIFICATION
			GRAVEL % ON #10	COARSE SAND % #10 - #60	FINE SAND % #60 - #200	SILT & CLAY % LESS #200			O.M.C	MAX DRY WEIGHT				
1	B	½ - 2	3.7	9.6	11.9	74.8	29.1	12 1	14.8	112.6	4.6[4]	15.2	CL	A-6 (16)
	B	2 - 5	2.4	19.1	22.7	55.8	33.5	14.4	16.5	110.4	4.9[4]	14.5	CL	A-6(6)
	C	5 -	5.1	19.3	23.2	52.4	27.9	10.7	12.7	117.9	6.7[4]	12.0	CL	A-6(4)
2	B	½ - 3	1.5	6.6	7.3	84.6	36.8	19.9	16.6	109.5	10.0[3]	16.4	CL	A-6(16)
	C	3 - 6	3.9	26.2	23.5	46.4	23.0	8.0	12.5	118.2	8.9[4]	11.9	SC	A-4(2)
3	B	½ - 1 ½	11 4	11.5	14.7	62.4	44.7	26.6	19.1	107 0	3.4[4]	20.2	CL	A-7-6(7)
	C	4 - 6	3.0	24.4	37.9	34.7	NP	NP	8.6	130.0	13.6[3]	9.8	SM	A-2-4
4	B	½ - 3	11.5	36.7	29 1	22.7	25 7	12.8	15.0	114.9			SC	A-2-6
	C	3 - 6	41.6	51.7	5.5	1.2	NP	NP	1.8	124 6	37 5[2]	0.84	SP.	A-1-b
5	C	2 ½ - 3 ½	6.9	24.4	37.9	40.5	18 8	5 2	10.9	124.0			SM-SC	A-4 (1)
6	B	1 ½ - 2 ½	9.2	35.0	28.4	27.4	30.4	11 6	12 3	119 0	15 0[3]	12.6	SC	A-2-6
	C	2 ½ - 3 ½	34.0	47.4	7.7	10.9	NP	NP	9 0	144.8	21 2[2]	7 6	SW-SM	A-1-b
7	B	1 ½ - 2 ½	5.2	20.6	31.6	42.6	19.2	6.9	11.2	125.6	7.1[2]	11 8	SM-SC	A-4 (2)
	C	2 ½ - 3 ½	62.6	27.3	6.7	3.4	NP	NP	12.0	119.2	55.0[3]	11.2	GP	A-1-a
8	B	1 ½ - 2 ½	0.6	27.3	48.4	23.7	18.4	3.2	12 0	119.2	12.0[3]	12 5	SM	A-2-4
	C	2 ½ - 3 ½	4.5	17.5	19.4	58.6	27.5	13 9	13.2	117.0			CL	A-6 (7)
9	B	1 ½ - 2 ½	4.8	19.0	33.1	43.1	25.3	8.5	14.7	117 2	5.1[5]	14.0	SC	A-4(2)

	C	2½-3½	[illegible]	20.1	[illegible]	49.5	18.3	[illegible]	9.7	129.0	7.6[3]	9.7	SM-SC	A-4(3)
10	B	1½-2½	4.8	14.6	25.6	55.0	27.4	10.3	16.0	112.2	3.4[4]	18.9	CL	A-4(4)
	C	2½-3½	6.7	16.1	28.2	49.0	25.6	12.1	12.0	124.0	7.5[5]	13.0	SC	A-6(3)
11	B	1½-2½	1.4	24.5	44.7	29.4	NP	NP	10.2	119.6	20.0[1]	9.4	SM	A-2-4
	C	2½-3½	0	35.2	57.8	7.0	NP	NP	11.0	114.0	21.8[3]	11.5	SP-SM	A-3
12	B	2 - 4	9.4	19.5	24.9	46.2	23.6	5.8	12.3	118.4	9.8[4]	12.2	SM-SC	A-4(2)
	C	6	9.2	27.1	27.3	36.4	15.2	3.0	8.6	126.1	4.8[4]	9.7	SM	A-4
13	B	1½	25.4	38.9	17.1	18.6	24.9	11.3	13.6	122.1	8.8[3]	13.2	SC	A-2-6
	C	1½ - 3	53.2	35.5	5.6	5.7	NP	NP	9.6	131.0	24.8	9.0	GW-GM	A-1-0
14	B	½ - 4	0	28.1	58.4	13.5	NP	NP	10.1	113.3	26.6[1]	9.2	SM	A-2-4
	C	4 - 6	0	29.5	62.8	7.7	NP	NP	11.2	115.2	37.4[3]	10.6	SP-SM	A-3
15	B	½ - 3	25.4	22.1	21.8	30.7	32.4	16.5	14.8	113.2			SC	A-2-6(1)
	C	4 - 6	31.8	47.2	12.8	8.2	NP	NP	12.1	122.2	8.0[4]	11.5	SW-SM	A-3
16	B	2-4	6.1	17.7	30.4	45.8	26.4	13.1	12.4	115.1	8.6[4]	12.8	SC	A-6(3)
	C	4-6	5.5	17.0	28.6	48.9	15.7	2.0	8.5	128.2	22.4[2]	8.5	SM	A-4(3)
17	B	1-7	1.1	21.2	47.3	30.4	NP	NP	8.6	114.0	6.2[3]	8.7	SM	A-2-4
	C	7-10	6.4	18.3	29.2	46.1	22.6	7.6	13.0	116.4	10.5[5]	11.6	SC	A-4(2)
18	B	1-3	2.2	22.7	48.9	26.2	21.9	7.5	12.2	119.7	5.3[4]	11.7	SC	A-2-4
	C	4-6	6.4	23.5	37.1	32.0	NP	NP	8.5	129.0	17.3[3]	8.6	SM	A-2-4

C.B.R. NOTATION

1 WITH SURCHARGE OF 10 LBS
2 WITH SURCHARGE OF 15 LBS.
3 WITH SURCHARGE OF 20 LBS
4 WITH SURCHARGE OF 25 LBS
5 WITH SURCHARGE OF 30 LBS.

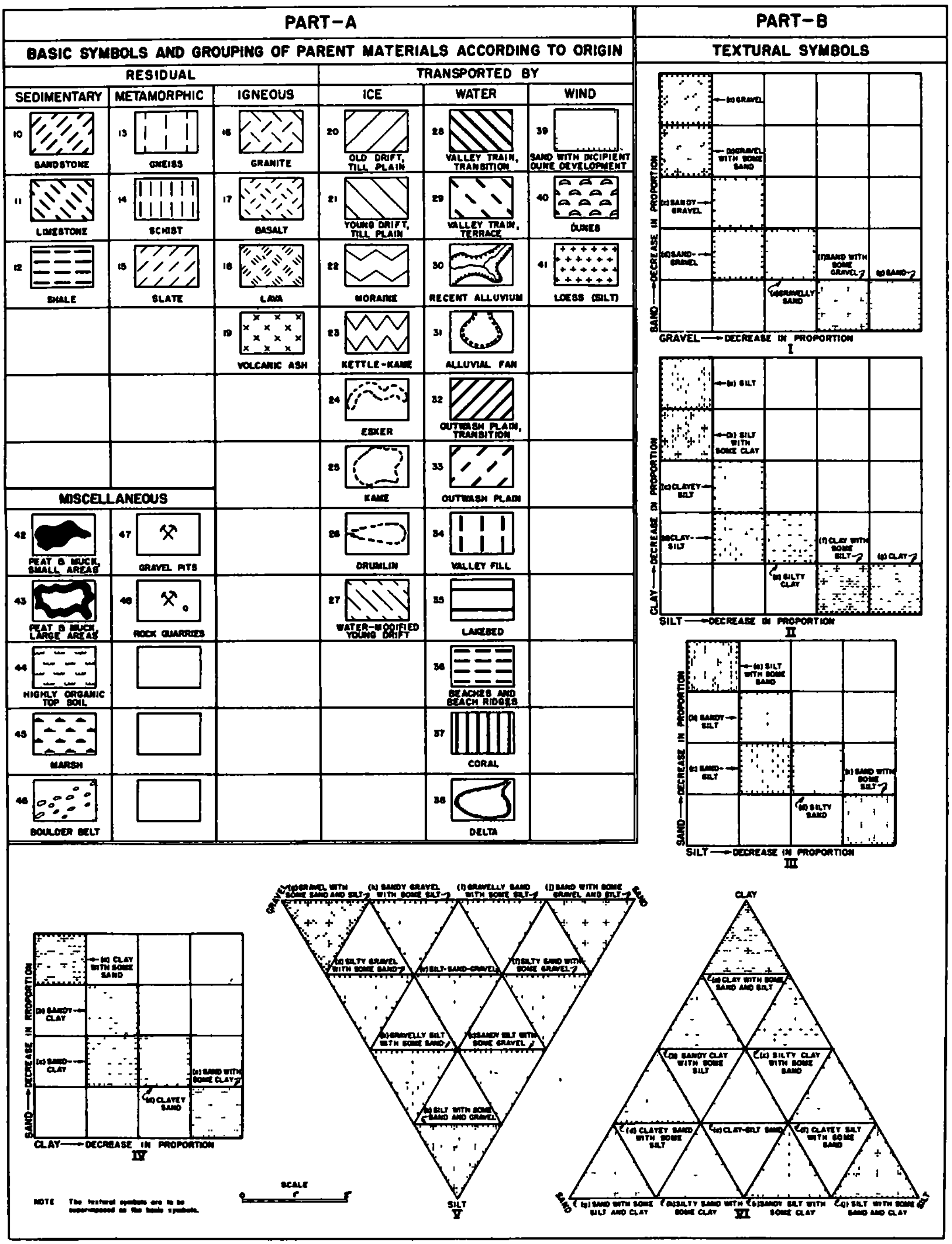


Figure 4. System of symbols for engineering soil-materials mapping.

HIGHWAY SOIL STRIP MAPS

The Joint Highway Research Project has prepared special soil strip maps from aerial photographs. The purpose of these maps was to provide the Soils Section of the State

Highway Department of Indiana with advanced information on soil types and drainage conditions along proposed routes. The maps serve as a guide for the planning of any detailed investigation that may appear advisable.

Two types of strip maps have been prepared. One type is a line drawing showing the distribution of engineering soil materials as inferred, using aerial photographs.

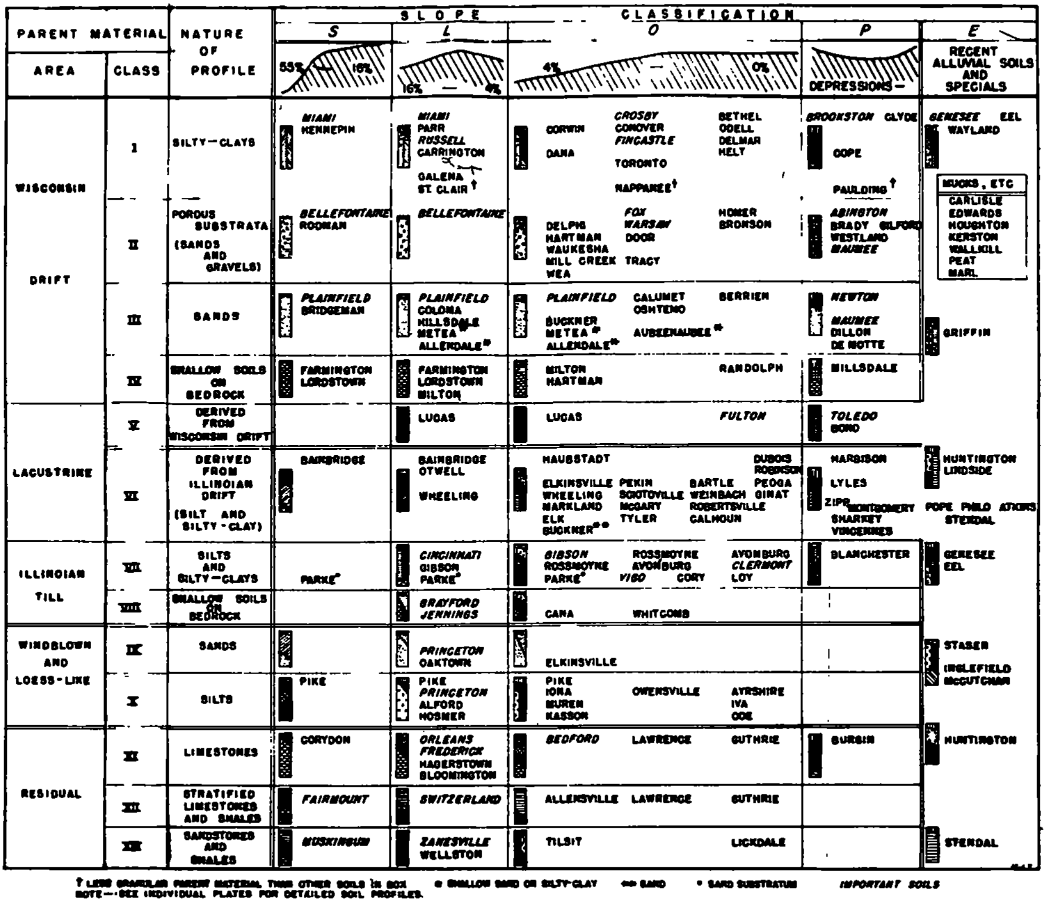


Figure 5. Pedological soils and their relationship to parent materials and topography.

Typical soil profiles as shown in Figure 5 and as obtained from the engineering soils manual previously mentioned, provide a guide to the three-dimensional development of soils within the region mapped. The profiles are intended to indicate either uniform soil development where extensive sampling is not required, complex soil development that requires detailed field sampling and the probable depth of organic soils that may require removal. An example of this type of map for use in preliminary surveys is illustrated in Figure 6. The maps are prepared at a scale of 3 in. = 1 mi or larger. They are prepared by direct tracing of the aerial photographs, and are symbolized in the standard manner as used by the Joint Highway Research Project (Fig. 4).

The second type of strip map that has been prepared consists of a plan showing soil borders with the actual aerial photographs serving as the base map. It is produced by photographic reproduction of annotated aerial photographs. It may be prepared at the scale of the photographs or it may be enlarged two to four diameters. A difficulty that has been encountered in the enlarging process has been that the smooth borders drawn on the aerial photographs are irregular and much larger than needed on enlargement (Fig. 7).

The soil strip map prepared with the aerial photographic base is much preferred over the line drawing, It should be prepared at the largest scale possible, and if en-

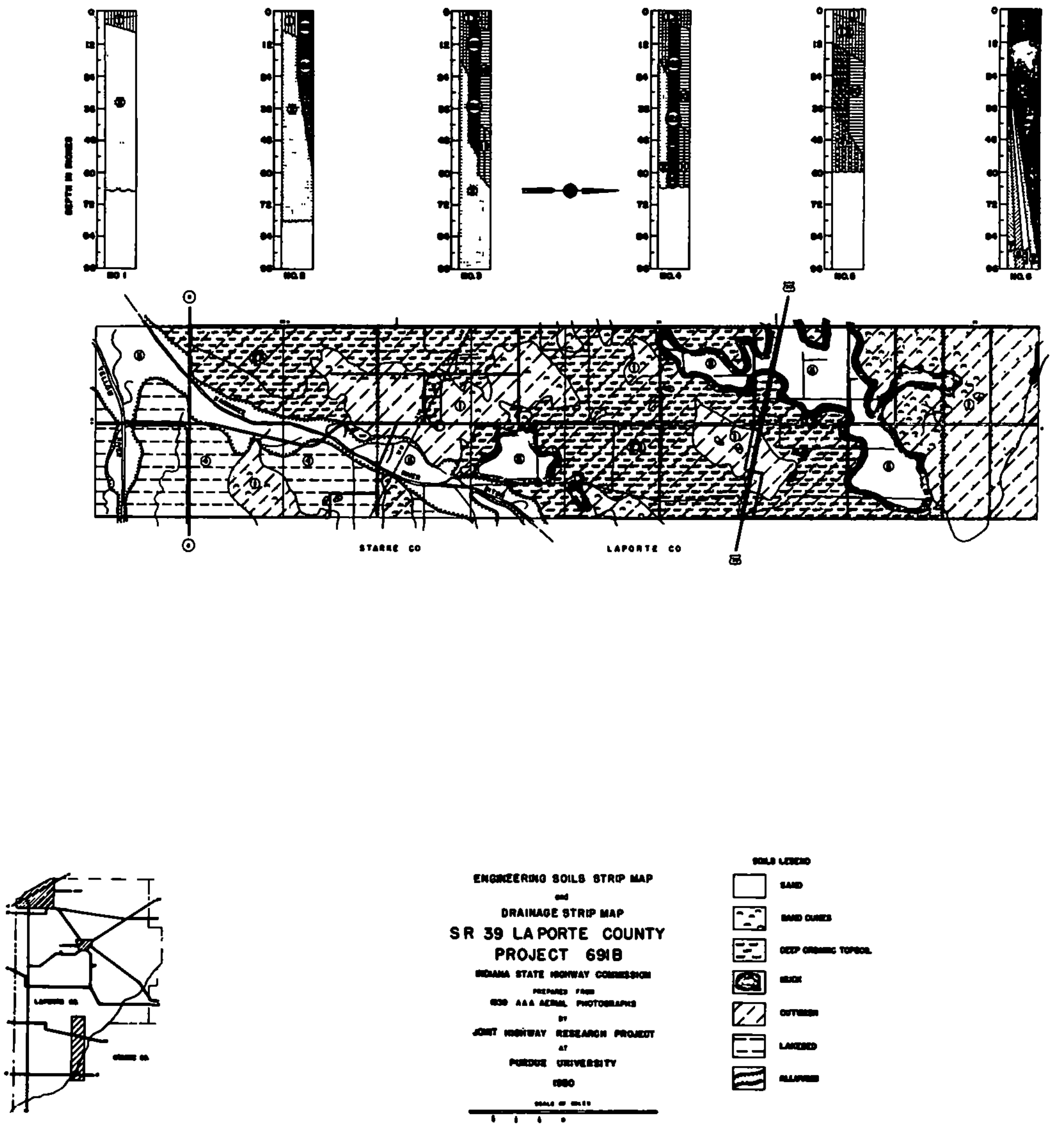


Figure 6. Engineering soils strip map prepared from aerial photographs by direct tracing.

largement is desired, the aerial photographic stereopairs should be enlarged prior to annotation. A written report should accompany each map, or the qualitative description of the soils may be typed and attached to the photo base so that it will reproduce as a part of the strip map.

The soil strip maps shown in Figures 6 and 7 illustrate primarily a region of glacial-fluvial outwash plains with low sand dunes and broad muck basins. The regional extent of the soil materials can be readily outlined on the airphotos, and good correlation can be obtained with typical engineering soil profiles contained in the engineering soils manual on the basis of topographic position and photo tonality. A field inspection of the project by the soils section confirmed the accuracy of the information supplied by the written report and the strip maps. Since the low, flat terrain dictated a high level profile and deep special side ditches, the only problem that needed special attention was limited to the profiling of the muck and organic sand deposits. The organic sands were found not to be objectionable, but the removal of the muck areas was incor-

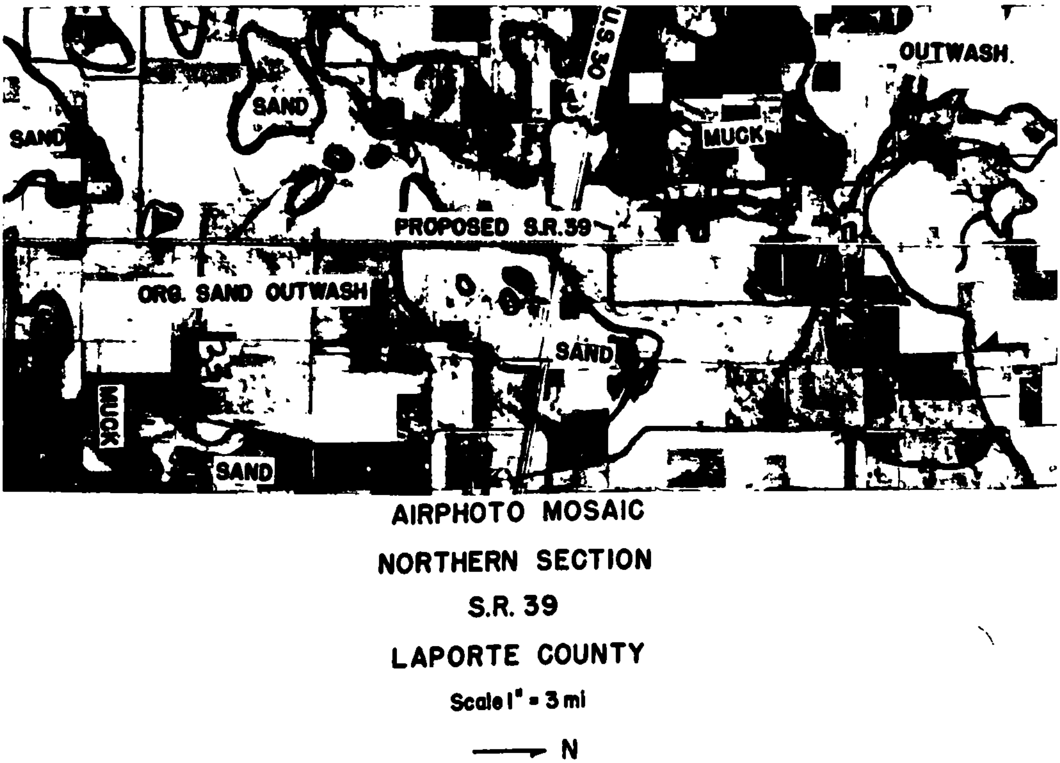


Figure 7. Engineering soils strip map prepared by photographic reproduction.

porated in the construction project. The limits of removal were defined by field surveys.

Figure 8 illustrates an engineering soils strip map along two highway sections that were programmed for reconstruction. The soils strip map was made from aerial photographs, and a soil survey was conducted in the field to verify the accuracy of the map. The field survey also served to define the limits of the peat and organic deposits so that the soils section could determine the type and extent of treatment required.

The engineering soils strip map shows symbolically that the area consists of a sand plain, scattered sand dunes, an organic sand plain underlain with sand, and muck depressions and channels. The soil profiles illustrated were taken directly from the engineering soils manual by reference to Figure 5, using topography and parent materials as the variables in the airphoto study. It was expected that the sand deposits would be classified as either A-3 or A-2. The organic deposits were expected to be of variable depth with some exceeding 8 ft.

The field inspection confirmed the accuracy of the map and report, and verified its use as a source of information in preliminary studies. Only limited testing seemed advisable. Table 2 is a summary of the tests performed on field samples secured along the alignment of State Road 10.

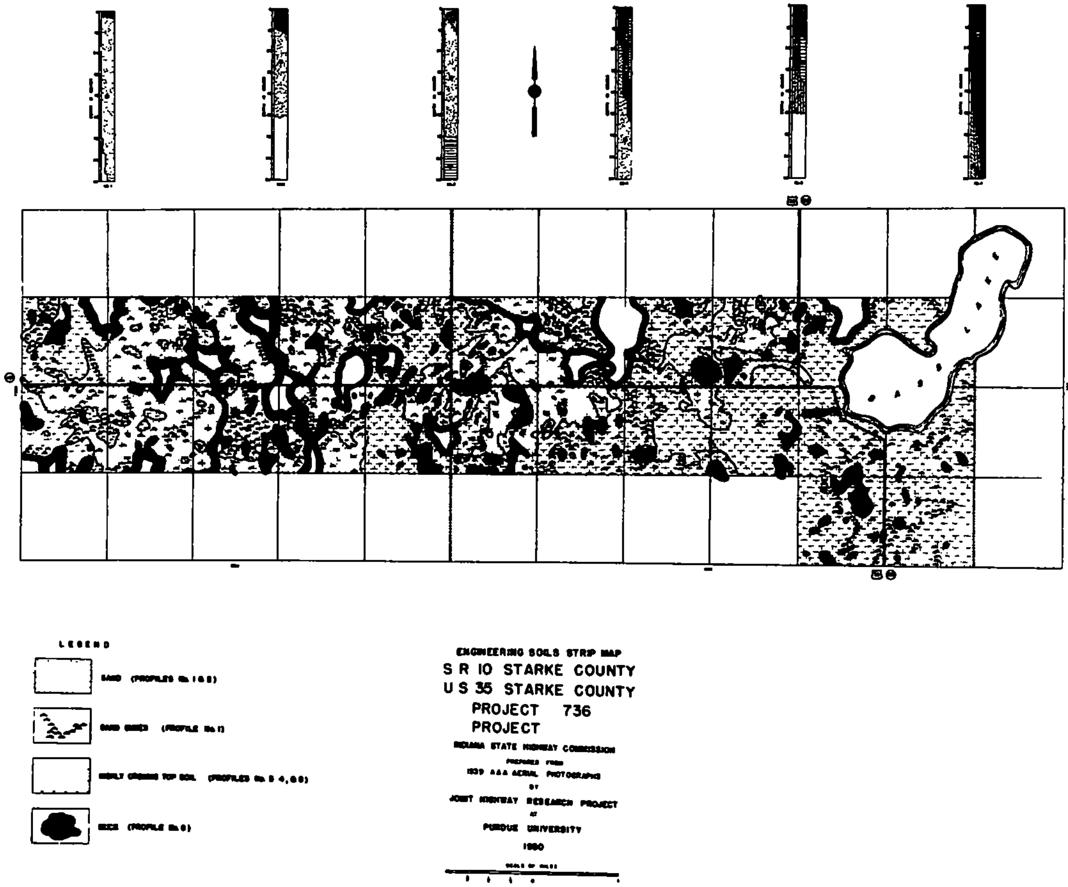


Figure 8. Engineering soils strip map along two highway sections programmed for reconstruction.

TABLE 2

SUMMARY OF SOIL TESTS, SR 10

Test Location Sta.	Offset	Depth (ft)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL	PI	Loss on Ignition (%)	Texture	Laboratory Classification
380	10' Rt	0.0- 1.5	2	85	7	6	22	3	5	Sand	A-2 (0)
405	15' Rt	0.0- 4.5	0	94	4	2	19	NP	-	Sand	A-3 (0)
411	45' Rt	0.0- 2.6	0	79	-	21	97	2	40	Org. sandy loam	A-8 (Peat)
467	5' Rt	0.0- 7.7	0	71	-	29	99	8	73	Org. sandy loam	A-8 (Peat)
561	15' Rt	0.0- 4.0	0	91	5	4	17	NP	-	Sand	A-3 (0)
580	30' Rt	0.0- 0.7	0	83	12	5	33	2	7	Sand	A-2 (0)
635	10' Lt	9.5-11.8	-	-	-	-	48	8	6	Marl	Marl
636	11' Lt	1.5- 4.5	-	-	-	-	83	3	35	Peat	A-8 (Peat)
		4.5-13.0	-	-	-	-	62	NP	32	Peat	A-8 (Peat)
636	40' Lt	0.0- 2.8	-	-	-	-	155	12	67	Peat	A-8 (Peat)
		2.8-10.8	-	-	-	-	172	9	77	Peat	A-8 (Peat)
723	25' Lt	0.0- 2.0	0	87	6	7	19	2	3	Sand	A-2 (0)
730	26' Rt	1.2- 3.0	0	85	4	11	17	1	-	Sand	A-2 (0)

Information obtained from the airphoto study and, of course, from the field study dictated a high level grade line with a deep side ditch. Construction of the project confirmed the accuracy of the information obtained from the written report, strip maps, and field soil survey.

SUMMARY

The cooperative soil mapping projects discussed are valuable in preliminary studies. The agricultural soil survey maps properly evaluated, the county engineering soils map, and the individual engineering soil strip maps with typical soil profiles are highly adaptable to highway planning, design and construction. The consistency or variability of soils to be encountered in cuts can be determined for establishing the pavement grades and types of treatment to be used. Locations of possible sources of granular materials for project uses can be indicated. Areas for special borrow, where materials are needed for embankment construction and not available within the right-of-way, can be selected.

The system of soil mapping symbols is suitable for uniform mapping practices of counties and small-scale strip maps. Even these symbols require "interpretation," and typical soil profiles are needed to complete the soils information. The soil profiles as contained in the engineering soils manual for Indiana are suitable for preliminary studies.

The ideal soil strip map should be prepared by using large-scale aerial photographs or enlargements as the base map with annotations to show soil areas and soil profiles. To determine the applicability of this type of map, it is anticipated that a cooperative soil strip mapping project will be developed using contact prints at a scale of 200 ft per inch and enlargements at 50 ft per inch. This scale should provide the detail for a master soil plan along proposed routes.

Terrain Reconnaissance and Mapping Methods in New York State

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This paper describes the methods used by the Bureau of Soil Mechanics of the New York State Department of Public Works for the reconnaissance of terrain conditions; how the information obtained is presented to engineers concerned with the location, design and construction of highways in New York State; and how the information is used by those engineers.

● WITH few exceptions, all engineering works are founded on soil or bedrock. The exceptions are floating structures and structures founded on the polar ice. Even aircraft are supported on soil or rock during a major portion of their life. Sufficient knowledge of the foundation conditions is essential to the economic location, design and construction of all engineering works. Obviously, an adequate knowledge of such conditions is essential to the proper location, economical construction and satisfactory performance of any highway. Highways differ from most other engineering works in that they have considerable linear extent, and consequently may, particularly in glaciated areas, involve a large variety of subsurface conditions.

The Bureau of Soil Mechanics of the New York State Department of Public Works has been performing terrain reconnaissance and mapping operations for public works projects from the time of its formation in 1945. During 1959, the Bureau produced such reports with maps, covering 530 square miles, for 106 route miles of projects and for an entire county. During the design of the New York State Thruway, the Bureau prepared maps covering approximately 400 route miles for that project.

The purpose of this paper is to describe the technique used for terrain reconnaissance, to illustrate the method used to present the resulting data and to describe how the information is used in the location and design of highway projects. A portion of the map and report prepared for a section of the Route 17 Expressway, from the Broome County Line to the Village of Owego, in southwestern New York State, is used for illustration and demonstration purposes.

DEFINITION

Terrain reconnaissance is the operation of reviewing available information from various sources and reconnoitering the landscape, to view it with regard to its suitability for engineering purposes, describing the extent and characteristics of the areas encountered, and making an engineering interpretation of the findings.

PURPOSE OF TERRAIN RECONNAISSANCE

Too often, in highway engineering work, there exists a wide gap between the planning and location considerations and the design and construction considerations. Although highways are usually planned and located with due regard for the topography, the relationship between subsurface conditions and topography is often ignored. This often results in uneconomical location, expensive and difficult construction, poor performance and high maintenance costs.

It should be realized that approximately one-third of the cost of the average modern highway is spent on earthwork, and that a very large percentage of the volume of materials handled during construction consists of earth materials. The characteristics of the earth materials handled and the characteristics of the earth materials comprising the foundation of the highway have a major influence on the cost and performance of the highway.

Proper use of a thorough terrain reconnaissance, mapping and appraisal program in the very early stages of any proposed highway project, particularly on new location, will invariably result in suitable location, reasonable costs and satisfactory performance of the completed highway. It must be emphasized that the greatest value of terrain reconnaissance and appraisal operations to the highway designer exists during the early preliminary planning stages of design for a major project, for it is during these stages that adjustments in line and grade can most easily be made to adapt the route to the actual terrain conditions.

Terrain reconnaissance and appraisal operations are performed by the New York State Department of Public Works for at least six main purposes:

1. To serve as a basis for the appraisal of terrain conditions by correlating the characteristics of the various soil areas with the past construction experiences and performances of existing highways on similar areas.
2. To indicate to the highway planning and location engineers the relative merits and potential design and construction problems for the mapped areas of different terrain conditions along the general route, so that, if feasible, the optimum areas be occupied and the adverse areas avoided.
3. To serve as a guide in establishing the optimum grade line relative to topography and subsurface conditions.
4. If the adverse areas cannot be readily avoided, to serve as a guide for subsurface investigation and analysis programs, resulting in cost estimates, and indicating the relative costs of traversing the adverse areas or avoiding them.
5. To serve as a general guide for the efficient planning of the necessary subsurface exploration, testing and analysis program for the line finally selected. This reduces the surveys in the "good" areas to an efficient minimum, and permits effective concentrations in the problem areas.
6. To indicate the general earthwork construction material situation, and to indicate the probable locations of borrow and granular materials so that those areas may be explored and sampled for specification and cost estimate purposes. The results of these investigations are reported to the designer in the form of a "Material Resources Report" for the project. In this respect, every effort is made to adjust the specifications and design so that, if possible, readily available local materials are economically used.

PROCEDURE

Sources of Information

Terrain reconnaissance and appraisal surveys are based on the following sources of information:

1. Research of the available scientific literature concerning the area. This includes reports and publications on geology,. physiography, pedology and land use.

The soil survey reports, particularly the more recent ones, prepared by the U.S. Department of Agriculture are excellent sources of information. Where air photos are used for base maps for the agricultural soil maps, the accuracy of the boundaries is usually satisfactory. Much information pertinent to engineering can be gleaned from such soil maps and reports, even though they are prepared primarily for agricultural purposes. The pedological series boundaries and characteristics can usually be readily translated into areas of different geologic origins and, consequently, different soil characteristics. This is particularly true of glaciated areas, such as New York State, where the soils are relatively young and hence the glacial geology of the soil material is a major influence in soil formation.

Land-use information is sometimes available and is used in the economic evaluation of the various soil areas.

2. An analysis of terrain patterns on air photos of the area. Air photos are an excellent tool for terrain reconnaissance purposes and are particularly valuable for the interpretation of physiography and land use. The scale and quality of the prints and the time of year of flight are extremely important to the proper use of air photos for such purposes. The Bureau never relies entirely on air photos for terrain reconnaissance purposes, but recognizes air photos as one of the valuable tools available. Their use must be properly correlated with other sources of information if accurate results are to be obtained.

3. A field inspection of the areas, including studies of the topography, rock and soil conditions, vegetation and performance of existing highways and other engineering works. This information is correlated with a review of the results of subsurface explorations and analyses performed, in the past, by the Bureau on similar terrain in the general area, and with a review of past construction and maintenance experiences with existing highways in the general area under similar terrain conditions. Terrain patterns are repetitious, and engineering experiences can be anticipated for one pattern area by correlation with past experiences with similar pattern areas elsewhere. It must be emphasized that it is the policy of the Bureau that terrain reconnaissance reports are never based solely on air photo, map and other office paper studies, but that the terrain must actually be occupied and inspected in order that all aspects and factors be properly evaluated.

Area Grouping

After all available field and office information, gathered for any terrain reconnaissance survey, is correlated and compiled and the areas of various soil and rock conditions delineated, the areas are grouped into units, each unit possessing significantly different engineering characteristics.

The selection of mapping units is of the utmost importance in any terrain mapping program. The units in use by the Bureau of Soil Mechanics have been developed on the basis of five criteria:

1. The units must be recognizable by terrain reconnaissance procedures.
2. There must be significant differences in engineering considerations between each of the units.
3. The same general characteristics and engineering considerations should apply wherever the unit is encountered.
4. The number of units should be limited to the minimum that is practical and necessary to adequately define the variation in conditions and engineering considerations.
5. The units must be based on actual conditions and not on factors assumed for convenience.

These criteria are very important in glaciated areas where significant variations in terrain conditions are usually numerous along any line and, consequently, engineering design must sometimes be based on average conditions, and sometimes on limiting conditions rather than adjusted locally for each soil variation.

The Bureau uses a method of grouping based on the geologic origin of each deposit as identified by landform and characteristics of the materials contained in the deposit. The groups are depositional units, each unit having a different name. The depositional unit grouping method is not an arbitrary classification, but is based on field investigations and experiences throughout New York State over a period of approximately 15 years. Each depositional unit is an individual entity possessing surface and subsurface conditions that will significantly affect some important aspects of highway design and construction quite differently than any other unit.

At present, the Bureau uses a total of 20 general depositional units, as follows:

1. Thick till
2. Thin till
3. Variable till
4. Bedrock
5. Outwash deposits
6. Kame field deposits
7. Lacustrine bottom sediments
8. Delta deposits
9. Beach and bar deposits
10. Recent alluvial deposits

11. Esker deposits
12. Old alluvial deposits
13. Organic deposits
14. Alluvial fan deposits
15. Man-made fills
16. Windblown sands
17. Marine bottom sediments
18. Coastal plain sediments
19. Tidal marsh deposits
20. Undifferentiated urban areas

It is recognized that other units exist; however, these units have been sufficient for the Bureau's terrain reconnaissance purposes to date.

In addition, significant variations in bedrock conditions may exist. Where these variations will affect design and construction, a bedrock map will be prepared. For the purposes of clarity, the terrain and bedrock are mapped separately. Bedrocks having similar engineering characteristics are grouped together as in soil-terrain mapping.

Some rock conditions which may affect highway design decisions are:

Rock Structure and Rock Composition.—These may influence excavation methods and costs, rock cut slope design and the suitability for processing into granular materials if natural deposits of such materials are unavailable.

Thickness of Soil Overburden and Elevation of Buried Rock.—These conditions influence the selection of a grade line and the availability of the soil overburden for earth borrow.

Generally, only a portion of the foregoing 20 units will be involved in any single project. Figure 1 shows a portion of the strip map prepared for Route 17 Expressway, Broome County Line to Owego, Tioga County, New York.

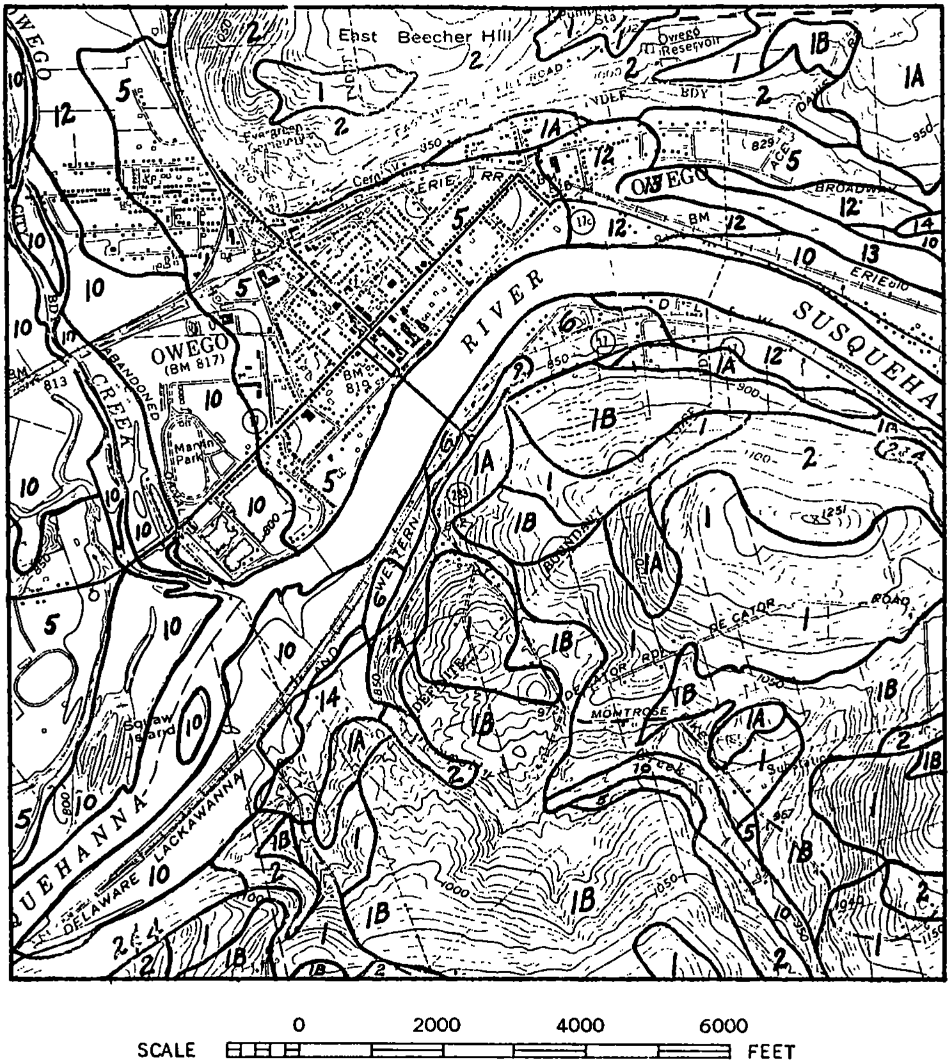
Description of Depositional Units

Throughout the state, there can be a considerable variation in the characteristics of certain of the depositional units. For example, the matrices of the thick tills range from non-plastic, predominately granular materials in certain general areas of the state to plastic silts and clays in other general areas. The natural densities of the tills range from loose to compact, and the origin of the parent materials ranges from hard crystalline rock to soft shales. Variations on a statewide basis occur in other depositional units as well.

Consequently, it is necessary to adequately describe the local characteristics of each depositonal unit involved in any particular report. If the general depositional units are separable into units having significantly different characteristics, the units are subdivided and each subdivision is described.

To illustrate this point, the description of the thick till units of the aforementioned Route 17 Expressway report is as follows (note that on Figure 1 the subdivisions of the thick till deposits are delineated):

Map Symbol	Depositional Unit	Unit Description
1	Thick till—compact	Mostly sloping upland areas of very compact, unstratified long-graded ice-laid mixtures of all soil fractions, ranging from silt and clay to boulders with silt being the dominant material. This till is derived from weak sandstones and brittle shales. These deposits have a drainage retarding hardpan layer in the B-horizon of the soil solum. Below this horizon is the C-horizon of parent soil-forming material which, in its upper weathered portion, is less compact than the same material at lower depths. The till deposits occupy valley sides and drainage is mostly run-off. In the lower portions of the valley sides, the



SOIL KEY

1 - THICK TILL (COMPACT)	5 - OUTWASH DEPOSITS
1A - THICK TILL (LOOSE)	6 - KAME DEPOSITS
1B - THICK TILL (POORLY DRAINED)	10 - RECENT ALLUVIAL DEPOSITS
2 - THIN TILL	12 - OLD ALLUVIAL DEPOSITS
2&4 - THIN TILL (WITH SOME OUTCROPS OF BEDROCK)	13 - MUCK DEPOSITS
	14 - ALLUVIAL FAN OUTWASH DEPOSITS

Figure 1. Portion of engineering soil map for Route 17 Expressway, Broome Co. line to Owego, Tioga County, N.Y.

Map Symbol	Depositional Unit	Unit Description
		accumulation of run-off is considerable because these areas not only receive rainfall, but must accommodate the run-off from higher areas. Compact till soils

Map Symbol	Depositional Unit	Unit Description
		have good surface drainage and with depth they are generally at low moisture contents because they are so compact. The depth to bedrock in till deposits is variable, but the thickness generally decreases as the degree of slope increases near the upper valley slopes. Local deposits of poorly sorted material and some silt pockets can be expected.
1A	Thick till—loose	These areas are mostly sloping upland areas of relatively loose, mostly unstratified, generally long-graded, ice-laid mixtures comprised of dominantly silty material with considerable rounded stones, but in a few places, including large flaggy rock fragments. In these deposits, some local sorting has occurred, and so silt pockets and pockets of granular material will be found. These deposits usually occupy some of the upper slopes of the valley sides. They receive run-off and run-in from areas above. In general the 1A till deposits have no hardpan layer such as is found in Type 1 deposits, and so run-in is not seriously restricted. Drainage is both by run-in and run-off. Deep cuts may intercept the water table. The depth to bedrock is variable. It generally decreases toward the valley walls.
1B	Thick till—poorly drained	These areas are ice-laid material similar to Type 1 soils. However, in 1B areas drainage is restricted either by a practically impermeable layer near the soil surface or in other places by topographic position. At the surface these materials have an organic layer. In most instances the organic material is mixed with some inorganic soil. The natural vegetation may include cat-tails and sedges. It should be noted that in general even the poorly drained deposits in tills become less wet with depth.

Engineering Significance Tables

The information compiled from the previously described terrain reconnaissance and appraisal operations must be so organized and presented that it will be readily available to the highway planning, location, and design engineers, with a minimum amount of time-consuming reading and interpretation. The number of mapping units is kept as small as is practical and necessary to present and explain the significant differences in characteristics. The influence of each depositional unit on the various aspects of highway location, design and construction and the engineering considerations involved with each depositional unit are indicated on an "Engineering Significance Table." Table 1 gives the "Engineering Significance Table" for the Route 17 project.

TABLE 1

GENERAL ENGINEERING SIGNIFICANCE, SOILS, ROUTE 17 EXPRESSWAY, BROOME COUNTY LINE TO OWEGO

Map Symbol	Depositional Unit	Design Considerations: Embankment Foundation	Design Considerations: Cut Slope Treatment	Design Considerations: Rock in Deep Cuts	Design Considerations: Rock in Shallow Cuts	Design Considerations: Optimum Grade Line	Construction Considerations: Compaction	Construction Considerations: Condition of Subgrade in Cuts	Source of Materials: Common Borrow	Source of Materials: Select Borrow	Source of Materials: Select Subgrade	Source of Materials: Foundation Course
1	Thick till, compact	Good	Standard	Possibly	No	Anywhere	Normal as required	Possibility of silt lenses[1]	Yes	No	No	No
1A	Thick till, loose	Good	Standard[2]	Possibly	No	Anywhere	Normal as required	Possibility of silt lenses[1]	Yes	No	No	No
1B	Thick till, poorly drained	Good	Standard[3]	Possibly	No	Anywhere	Normal as required	Possibility of silt lenses[1]	Yes	No	No	No
2	Thin till	Good	Probably a composite-soil over rock[4]	Yes	Yes	High[5]	Normal as required	Rock in bottom of cuts[6, 7, 8]	No[9]	No	No	No
2 and 4	Thin till and rock outcrops	Good	In places a composite-soil over rock	Yes	Yes	High[5]	Normal as required	Rock in some cuts[6, 8]	No[9]	Possibly[25, 10]	No	No
5	Outwash deposits	Good	Standard[3]	Possibly	No	Anywhere[11]	Normal as required[12]	Variable, possibility of silt strata[13]	Yes	Yes[14]	Yes[14]	Yes[14]
6	Kame deposits	Good	Standard[15, 3]	Possibly	No	Anywhere	Normal as required	Variable, possibility of silt strata[13]	Yes	Yes[14]	Yes[14]	Yes[14]
10	Recent alluvial deposits	Variable[16, 17]	Avoid cuts[18]	-	-	High[18]	Variable, may be wet[19]	Avoid cuts	Variable[14]	Variable[14]	Possibly[14]	Possibly[14]
12	Old alluvial deposits	Variable depending on underlying material[16]	Variable[15, 20, 19, 3]	Possibly	No	Anywhere[21]	Normal as required[12]	Variable, possibility of silt strata[13, 22, 19]	Yes[15]	Probably[14]	Possibly[14]	Possibly[14]
13	Muck deposits	Very poor[23, 24]	Avoid cuts	-	-	High[18]	Unsuitable material[23]	Very poor, unsuitable[23]	No	No	No	No
14	Alluvial fan deposits	Variable	Avoid cuts[18]	-	-[18]		Variable, may be wet		Yes	Possibly[14]	Possibly[14]	No

Note The information shown is considered general and preliminary only and is based on the following work by the Bureau of Soil Mechanics, N Y S , D P W (a) A review of existing literature on the subject project, including an engineering interpretation of the pedologic and geologic maps of the area (b) A limited field surface reconnaissance survey of the area (c) A soils engineering interpretation of aerial photos of the route (d) A correlation of past engineering and construction experiences in this area

[1]Remove and replace silt lenses to sufficient depth to obtain uniformity and trafficability [2]Slope blanket should be provided, to be used A O B E , for correcting slope instability due to adverse water conditions [3]Skim cuts and fills should be avoided, where possible [4]High rock slopes may require special treatment, including variable slopes and benches as recommended by Bureau of Soil Mechanics [5]In areas of flat topography, grade line should be high to avoid rock excavation in ditches [6]See Standard Sections use optional deep ditches in rock or blasted rock trench where adverse seepage conditions exist [7]Where rock excavation is used for embankments, account for swell factor of broken rock in estimate [8]Proper benching and transition treatments are extremely important to assure uniform subgrade support [9]Generally uneconomical, low yield per acre. [10]If 2EC of broken rock is to be placed on soft material, provide granular foundation blanket to prevent rock from penetrating soft material [11]Except as modified by character of underlying material if intercepted by grade line or by the elevation of the water table [12]These materials generally require addition of water during construction season [13]Susceptible to frost heaves in cuts, due to possibility of adverse drainage conditions and non-uniform subgrade To reduce possibility, care should be taken to provide adequate drainage and uniform subgrade Each cut a separate problem in this respect [14]The suitability of each deposit must be individually determined [15]If predominately sandy, may present severe problems in fill slope, cut slope, and shoulder edge erosion, necessitating positive methods of run-off disposal, and slope treatment [16]Possible settlement and stability problems in fills of moderate height and over [17]This material becomes wetter with depth and even cuts of moderate depth usually involve the handling of material that considerably exceeds the optimum moisture content Depending upon prevailing weather, this may require the wasting of the wet material for practical reasons For quantity estimate purposes, all cuts in this material should be thoroughly explored and natural and optimum moisture contents profiled, hence, cuts are not recommended [18]A high grade line is necessary to avoid possible inundation of road during flood or high water periods [19]These deposits may have a high water table and may contain a wide range of good and poor materials, and excavation may involve the handling and disposal of fine grained, saturated, flowing, unstable materials, presenting problems in poor subgrade, slope stability and compaction Each deposit a separate problem, depending upon adequate subsurface explorations [20]These slopes frequently present problems in seepage and subsequent erosion and sloughing Therefore, special treatment may be necessary to achieve a stable slope [21]Deep cuts may encounter the water table [22]Frequently requires installation of layer of suitable granular material under foundation course to obtain trafficability during construction [23]Organic deposits should be considered unsuitable for highway foundation purposes, such material should, therefore, be removed, wasted, and replaced with suitable granular material [24]Consider wasting these materials or using to flatten slopes beyond normal 1 on 2 side slopes of embankments [25]Feasibility of crushing and processing only sound acceptable rock from cuts should be investigated

Use of Reports

Each terrain reconnaissance report always includes three basic features: an engineering soil map, a complete description of each depositional unit involved, and the general engineering significance of each depositional unit in tabular form. The reports may contain other information of importance to the particular project involved. Frequently, the over-all conditions of a project are summarized in the form of a synopsis. A concise summary is frequently of value in briefly describing the important general terrain considerations for the project.

Copies of the reports are furnished to all departmental units involved, including the appropriate district engineer and his district soils engineer. The reports are then used for the purposes described in the foregoing "Purpose of Terrain Reconnaissance." The reports are particularly useful in "line" conferences held to select or review the preliminary line and profile for projects on new location. These conferences are attended by representatives of all departmental units concerned, including the Bureau of Soil Mechanics.

During these conferences, significant terrain conditions are emphasized and discussed. This is the time when the possibility of adverse foundation conditions must be emphasized. Unless terrain reconnaissance reports reach the engineers responsible for the location, design and soils investigations in the very early stages of any project, the effort expended in the preparation of such reports may be largely wasted. Provided such reports are available in the early stages of the project, terrain reconnaissance reports can be effectively used for any project, large or small.

Practically all engineering data have their limitations, depending on their nature. Terrain reconnaissance reports are no exception. Terrain reconnaissance is an extremely useful tool, provided it is properly used by experienced engineers who recognize both its advantages and limitations. It must be emphasized that these reports are never intended to supplant subsurface investigations that should be an important part of any engineering program. Such reports serve as guides, indicating both desirable locations and potentially troublesome areas. Adequate subsurface exploration, testing and analysis programs can then be properly concentrated on the troublesome areas occupied by the line, and the most suitable areas covered by a minimum program sufficient to indicate the actual conditions. This method, therefore, furnishes an efficient, effective, economical and time-saving procedure for line location and subsurface investigation programming. It is certainly far more efficient and economical, at least in New York, than progressing subsurface explorations arbitrarily at certain predetermined distances along a line to locate the line and ascertain the foundation conditions.

To achieve reasonably accurate, effective and practical results from terrain reconnaissance operations, it is essential that the personnel assigned be thoroughly experienced in the area and with the actual highway design and construction problems of the depositional units involved. Unless this condition prevails, it is quite possible that the results of terrain reconnaissance operations will be meaningless or misleading to the planning and location engineers.

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Use of Geologic Strip Maps in Highway Location and Design

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Under a cooperative program between the Massachusetts Department of Public Works and the U.S. Geological Survey, the state is securing valuable information relative to the surficial and bedrock formations for the location and design of highway projects.

● IN THE DESIGN and construction of modern major highways the engineer faces a diversity of problems. These are in considerable measure concerned with the topographic characteristics of the terrains, and the physical properties and structures of the underlying materials. In the days of narrower and lower-speed highways there was greater latitude in choosing a road site. Today the highway route must be as direct as possible, and the design must meet all the requirements of modern highway standards, with curves of adequate sight distances, easy grades, and well-drained foundations capable of sustaining heavy traffic loads. To fulfill these requirements, less favorable topographic features must be traversed rather than avoided in many places, so that deep and wide cuts, and long, heavy fills are frequently necessary. Costs of excavation are greatly increased because many of the cuts penetrate well into bedrock. Likewise, costs of filling rise, because the greater volume of suitable material to be provided is often obtainable only at a considerable distance from the fills. In places, as in boggy areas, unsuitable materials must be removed and suitable ones substituted. Shallow or perched water tables may exist and require special construction to provide good subgrade drainage. Footings of heavy bridge piers must, in places, be spread in soft or even in plastic materials instead of on sound bedrock. In the design of such piers it is advantageous to know if bedrock can be reached economically, or if the overlying unconsolidated material is uniform and can adequately support the loads to be imposed. Thus, the engineer is faced with problems of design and construction that involve many geologic factors. The concern, therefore, is with the techniques of the engineering geologist insofar as they can contribute valuably to the analyses and solutions of the problems, or facilitate the work of construction. The engineer is not ordinarily prepared by either training or experience to make geologic interpretations.

The engineer who is untrained in the applications and techniques of geologic science is, therefore, not only unable to project his local experience from point to point in a glaciated area with reasonable assurance, but many times he cannot interpret even the local soils and rocks with sufficient certainty. It is the third dimension that is not disclosed to him, and it is the variation in this vertical dimension of the terrain with which he is particularly concerned. The surface deposits may be misleading, the soil zone greatly variable even within shallow depths, and hidden boulders may, and often do, mislead or confuse him with regard to the position and nature of the bedrock. It is true, of course, that the geologist cannot always make accurate interpretations from surface data alone, but must rely on some other techniques; nevertheless, even where surface data are inconclusive to him, the geologist's guess is considerably better than the engineer's and is based on laws of geologic probability as suggested by the local surface geology. He is, by virtue of training and experience in his science, in a far better position to make directive interpretations and give warning of probable or possible difficulties. He should, in general, be better equipped to work with specialists in the fields of seismology and soil mechanics, and, indeed, should be in a position to advise when such collateral services are needed or desirable; moreover, he should not be reticent or hesitant in recommending such services.

The geologist's aim is to call the attention of the engineers to the kinds of data available through geologic techniques, and to make such data as directive and quantitative as possible. It is helpful if he knows something about the technical methods of the engineer, but he should not presume to advise in purely engineering methods. Upon the engineer, on the other hand, rests the responsibility to seek and use all available data that will contribute to sound and economic design or construction of highways and bridges. This, then, is the philosophy that determines the pattern for engineering geologic work under the Massachusetts program.

The Massachusetts geologic program was started in July 1938, as a cooperative project between the Massachusetts Department of Public Works and the U.S. Geological Survey. The primary purpose is to make a complete and detailed geologic study of the state, the results of which are to be embodied in two geologic maps and accompanying brief reports. The maps are to be printed in colors. One of them is to show the distribution and structures of bedrock units beneath the soil mantle, as interpreted from bedrock exposures and available subsurface data; the other is to show the distribution and nature of the unconsolidated, superficial formations, the "soils" in an engineering sense, that overlie the bedrock, and also to show the actual bedrock exposures. Among the mineral resources to be indicated on these maps are the materials used in highway construction, such as gravel, sand, and rock for crushed stone. Mapping is being done by quadrangles, on new 7½-minute topographic base maps, the scale being 1 in. = 2,000 ft and the contour interval, 10 ft. These maps permit considerable detail and accuracy, and engineers and geologists engaged in either public or private work will thus have fundamental geologic control for their own more detailed work in small areas or on special problems. Two compiled geologic maps of the state will be prepared from the quadrangle maps, on a scale of 1:125,000, or about ½ in. to the mile.

Special geologic studies are made under the program at the specific request of the location engineer of the department. These studies are of four types, as follows:

1. Gravel and sand resources of particular areas. For areas of projected highways where the resources are as yet unknown, or the known deposits are unavailable or inadequate, detailed geologic maps are made to show the distribution and land forms of all deposits of sand and gravel. An accompanying table indicates for each potentially important deposit the approximate volume, areal extent, dimensions, accessibility, and type of material. Pertinent general observations are made regarding the quality of the material, pebble sizes, proportion of sand, freshness of pebbles, and probable utility. No grade sizing tests are made, as these are considered to be outside the province of the geologic program. The map is intended as a guide to point out apparently favorable deposits for further investigation by engineers of the department.

2. Reconnaissance geology. When a segment of a proposed highway has been located by engineers, a detailed geologic map is made along the centerline for the purpose of determining the kinds of materials, the geologic structures that may have a bearing on engineering operations, and the distribution of bedrock outcrops (Fig. 1). Usually, the reconnaissance strip so mapped is from ¼ to ½ mile wide, but may be greater or less according to the complexity of the area and the need for finding additional data to aid in the interpretation of the geology along the centerline. A brief report summarizes the geology and calls particular attention to features that may prove troublesome. Where the geologic data appear to be clear and unequivocal no further studies are made. Where geologic conditions are complex or obscure, and more specific data are needed, other kinds of studies (such as ground-water investigations or seismic tests) are indicated by the geologist. Occasionally this preliminary reconnaissance study leads to a consideration of other possible locations for the highway segment. It is always desirable to have an engineer review the strip in the field with the geologist; in this way interpretations are clarified and pointed up, the geologist becoming more acute with respect to the engineer's problems, and the engineer learning how to use the geologic data with greatest profit and to judge the limitations of geologic studies.

3. Ground-water investigations. The highway engineer is concerned with ground-

EXPLANATION

Swamps, composed of peat and sandy peat; underlain by clay, silt, sand, gravel, or till, generally similar to the surrounding material. Generally unsuitable as a source of granular material.

Sand and/or gravel of variable texture, including some large boulders. Generally suitable for construction purposes.

Ground moraine (till); a heterogeneous to poorly sorted deposit of mixed boulder to clay sizes; known locally as "hardpan." Generally good for subgrade and fill only.

r Rock outcrop

Areas of scattered ro
covered by surficial d

Mantled by ground mo

Mantled by sand and/c

Sand and/or gravel pi
in decreasing abundan
c = cobble).

AF Artificial fill

Figure 1. Surficial geologic

Geology compiled by Carl Koteff;
geology modified from Newton E. Chute

and of bedrock thinly

SCALE 1 24000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

s indicated by letter symbol
le, b = boulder s = sand,

; proposed Interstate Route 95.

water conditions along the highway site because of the effects of ground saturation and seepage upon the stability of the subgrade, especially in freezing weather, or on the walls of cuts that have reached to or even penetrated the local water table. Perched water tables are quite commonly found in glaciated regions where lakes have once existed. Even certain types of compact till overlain by loose till or sand and gravel are so impervious as to cause seepage into the walls of a cut during the more humid seasons. The engineer wishes to foresee such conditions and to provide for adequate drainage. The conditions vary from place to place and the variations are direct functions of the geologic materials, structures, and topography. In places, the possible effects on highway construction of local ground-water supplies and individual wells present problems that require study by ground-water specialists. When necessary, ground-water problems are referred to geologists of the ground water division of the geological survey, working also under a continuing cooperative program with the department of public works, for ground-water studies in Massachusetts. Separate reports or statements are prepared by this division on request of the supervising geologist.

4. Seismic studies. Where more exact knowledge of the subsurface materials is needed and especially where the depths to bedrock or to compact or hard till is desired, seismic tests are recommended by the geologist.

When seismic surveys are deemed necessary, they are made by a field party consisting of one geologist from the United States Geological Survey and one engineer and four laborers from the Massachusetts Department of Public Works. At present, two parties are performing this work.

In addition to the other elements that control the location of the highway such as the traffic desire lines, geographic obstacles, land use, service to the communities along the right-of-way, the data furnished on the strip maps allow the location engineer to get a better picture of what may be encountered during construction. The line thereby established will have introduced a new dimension in economy that would not otherwise have been possible.

The Strip Map will indicate:

1. Exposed bedrock location which should, if possible, be avoided—due to the increased cost of this type of excavation.
2. Material which may be unsuitable for roadway fill and, therefore, would have to be disposed of as waste and replaced by suitable material.
3. Areas where soil stabilization of existing material may become necessary.
4. Areas where soil conditions would not allow sufficient absorption of surface water and, therefore, cause excessive run off which could create a problem of embankment erosion.

With this information at hand, the best possible locations are established and become the basis for flights from which the photogrammetric plans, at a scale of 1 in. = 200 ft, are made. On these plans are plotted the final location of the baseline of the highway and mark the final stage in the determination of the approved location.

As the highway construction program of the Massachusetts Department of Public Works continues to expand, the geologic and seismic studies will continue to play their very helpful part in providing Massachusetts with highway facilities designed to meet existing subsoil conditions.

A Technique for Soil Mapping

KENDALL MOULTROP, Associate Professor of Civil Engineering, University of Rhode Island

This paper describes the technique of soil mapping used to prepare an engineering soil map for the State of Rhode Island. This technique, which is very similar to that used in New Jersey, makes use of airphotos for the interpretation and delineation of soil types. The map symbols indicate geologic aspect, drainage, slope, soil texture, and special features. Engineering test values are given for a typical soil type. Factors affecting the various phases of the work, including cost, are discussed. Information on the use of the map is presented.

IN ORDER that information concerning the type and areal distribution of soil in Rhode Island might be readily available for use in an expanded highway construction program, the Division of Engineering Research and Development (formerly Engineering Experiment Station) in 1952 in cooperation with the Rhode Island Department of Public Works and the U.S. Bureau of Public Roads undertook the preparation of an engineering soil map of the state together with a report on soil properties.

At that time available soil maps of the state consisted of U.S. Department of Agriculture soil surveys, three 7½ min quadrangle sheets of the U.S. Geological Survey showing surficial geology and several small maps showing generalized soil conditions in areas related to specific studies mainly concerned with the availability of ground water. Although the agricultural soil maps were rated as excellent, having been prepared in the mid 1930's, it was felt that they were in considerably more detail than was needed for engineering purposes and that they required the engineer using them to have a greater background knowledge of pedology and related sciences than is usually the case. It was also felt that if the soils were classified according to an engineering soil classification the map would possibly be more generally accepted.

The U.S. Geological Survey was in the process of preparing maps showing surficial geology, but it would be a number of years before the mapping would be completed. Therefore, it was decided to make an engineering soil survey.

Maps showing the areal extent of soils, classified according to an engineering classification, were prepared for each of the five counties. Although Rhode Island is divided into five counties, the total land area is only about 1,058 sq mi. Rather than publish a separate report for each county, one report was prepared for the whole state with all of the individual county maps included.

THE SOIL MAPPING TECHNIQUE

In preparing the "Engineering Soil Survey of Rhode Island" (1), airphotos were interpreted with the soil boundaries delineated directly on the vertical aerial photographs. The airphoto interpretation was supplemented by the laboratory testing of soils, observation of soils in the field, and by other information such as U.S. Geological Survey maps, both topographic and geologic, and U.S. Department of Agriculture soil surveys.

The evaluation of engineering soil properties by means of airphoto interpretation is based on the premise that airphotos record the results of the development of the earth's surface, that these results will be similar when created under similar conditions, and that similar geologic landforms have similar airphoto patterns. The airphoto pattern is composed of various elements which consist of landform, drainage, erosion, color tone, vegetation, and land use. By studying these elements of pattern, it is possible by

PROVIDENCE COUNTY

Table 1.

SUMMARY OF SOIL TEST DATA

Boring No	Agronomic Name (as mapped)	Airphoto No	Lat Deg Min Sec	Long Deg Min Sec	Slope @ Sample Hole	Horizon	Depth to Bottom Inches	TEST RESULTS: Sieve Analysis Cumulative Percent Passing ¾	4	10	40	200	Physical - Minus #40 LL %	PI %	Proctor Max Dens pcf	Opt MC %	AASHO Designation Group	Group Index
							GM-24—(Continued)											
P 7	Whitman	5H 102	41	71		A	4	—	—	—	—	—	—	—			—	—
			48	45	f	B	21	93	79	72	54	15	NL	NP			A-2 4	0
			35	30		C	35	98	81	72	56	19	NL	NP			A-2 4	0
P-8	Scituate	5H-2	41	71		A	4	—	—	—	—	—	—	—			—	—
			51	40	f	B	24	87	82	78	63	22	45	3			A 2 5	0
			22	3		C	38	93	78	70	52	17	NL	NP			A 2-4	0
P-9	Gloucester	5H-98	41	71		A	2	—	—	—	—	—	—	—			—	—
			52	45	s	B	20	99	80	70	57	19	23	6			A 2-4	0
			21	51		C	34	95	81	74	59	19	NL	NP	118	11	A 2-4	0
P 10	Gloucester	5H 132	41	71		A	2	—	—	—	—	—	—	—			—	—
			58	46	s	B	11	85	66	58	42	10	28	2			A 1-b	0
			30	59		C	25	90	79	71	58	21	NL	NP	117	12	A-2-4	0
P-11	Whitman	5H 90	41	71		A	3	—	—	—	—	—	—	—			—	—
			58	45	s	B	15	100	94	86	64	27	42	1			A-2 5	0
			38	24		C	29	94	89	83	67	31	21	0	114	12	A 2-4	0
P 12	Narragansett	4H-168	41	71		A	3	—	—	—	—	—	—	—			—	—
			59	39	f	B	9	94	85	79	60	20	52	0			A 2 5	0
			9	5		C	23	95	86	80	64	29	24	5			A 2 4	0

means of deductive reasoning to obtain a general evaluation of soil conditions and to determine the areal extent of a particular soil (2, 3, 4, 5).

Mapping Procedure

The first step in the preparation of the county maps consisted of a review and study of all available soil information applicable to the area. The agronomic soil surveys and maps were studied with a view to correlating agricultural soil series, types, and phases with engineering map units. These maps and a preliminary study of available airphotos were used as a guide for the selection of soil sampling sites. Soil samples were then obtained from areas which it was felt would be representative of the various major soil groups. Tests for classification of the soil samples were then performed in the laboratory. Based on these tests, the soils were classified and summary sheets prepared as references for the soil maps. Soil data for a typical map unit (GM24) are given in Table 1.

The preliminary use of the airphotos involved the marking of tentative soil borders which were used as basic map units. Red crayon was used to delineate the soil borders directly on the airphotos. The existing soil conditions and the patterns that appeared on the airphotos were correlated. Then the mapping of the subdivisions was completed. For this purpose, map symbols were used to describe the various conditions in each area. It was found that some areas could be mapped quite easily by this method without much checking in the field; but other areas were so complex that considerable field checking was necessary. In those places where it was not possible to determine a reasonably definite boundary, the area in question was enclosed with a broken line rather than a solid line.

The airphotos that were used for the mapping were 9- by 9-in. contact prints having a scale of approximately 3 in. to the mile. These photos, which were taken in 1951 and 1952, were purchased from the Production and Marketing Administration, U.S. Department of Agriculture. Reference was also made to 9- by 9-in. contact prints of photos that were taken in 1939. They have a scale of 4 in. to the mile. Since these photos were of a larger scale and were taken at a different time than the other photos, they proved to be very valuable in checking some of the areas in greater detail.

When the marking of the soil borders on the airphotos was complete, they were transferred to a paper base map by means of a vertical sketchmaster. By using the sketch-

Figure 1. The soil borders were marked on the airphotos with a red wax crayon. The area marked "C"—crystalline rock—is an area with so much rock outcropping that it is essentially a non-soil area.

master, it was possible to reduce the scale of the photos to match the scale of the base map. This base map was a county map, formed by assembling the separate town sheets that were prepared by the Rhode Island Department of Public Works in cooperation with the Bureau of Public Roads. The scale is 2 in. to the mile. To facilitate handling, some of the large county maps were cut into smaller sheets. The soil borders were then transferred from the base map to overlay sheets. These overlay sheets were of acetate, and once the soil borders were traced on them in ink, good reproductions were possible. Copies of the map have been prepared in two sizes; a small map at a scale of 1 in. to 1 mi and the full size map at a scale of 1 in. to ½ mi. The small scale maps were included in the published report. The large scale maps are available, but did not accompany the report.

MAP UNIT SYMBOLS

In addition to indicating the type of soil of each area, environmental conditions were described by means of symbols. These symbols were combined to form map units. Within each map unit, the parent material, landform, soil profile, topography and drainage are relatively uniform.

The system of symbols used in preparing the engineering soil map of Rhode Island is a modification of the system developed by the Joint Highway Research Project at Rutgers

University for preparation of the engineering soil map of New Jersey (6). This system has been presented in detail by Lueder (7) and by the Joint Highway Research Project, Rutgers University (8). The principal modifications include the use of a slope symbol and an indication of drainage potential as used by Smith (9). The textural classification of the soil is placed at the end of the group of symbols rather than in the middle.

Most of the symbols used to describe soil conditions in each map unit are made up of four parts as follows:

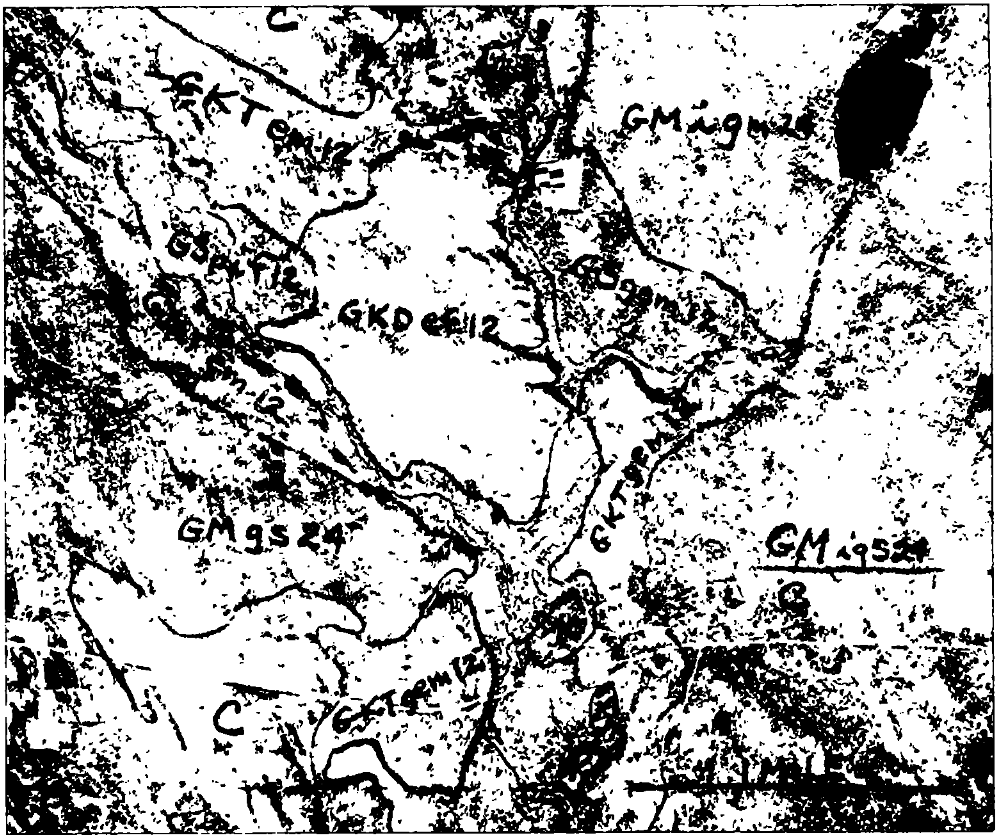

Figure 2. This figure shows the portion of the soil map corresponding to the area shown in Figure 1. On the actual map the map base is printed in red and the soil information is printed in black for contrast.

1. A designation of the parent material or geologic formation from which the soil is derived;
2. An estimate of the drainage conditions to be expected;
3. An indication of the topography expressed by the typical slopes encountered; and
4. The textural classification of the soil.

Figure 1 shows the marking of the soil areas with appropriate symbols on the airphoto. A portion of the final map showing the area of Figure 1 is shown in Figure 2. This same area as mapped on the agricultural soil map is shown in Figure 3. The glacial kame delta mapped as GKDef 12 in Figure 1 is mapped as H_s (Hinckley loamy sand) and B_v (Bridgehampton very fine sandy loam) in Figure 3.

Geological Symbols

The first part of the identification symbol indicates the geologic aspect of the soil area. The letter G of a symbol, such as GE, designates the material as being of glacial origin. The letter E indicates the landform as being an esker. These symbols such as GO, glacial outwash plain, and GKT, glacial kame terrace, specify the character of the material and imply the topographic situation in which the soil occurs. These symbols also imply the soil texture and density and the ground water conditions. This implication may be affected by unusual surrounding conditions which have to be considered and variations in the climate.

Drainage

The second part of the map unit symbol indicates by lower case letters an estimate

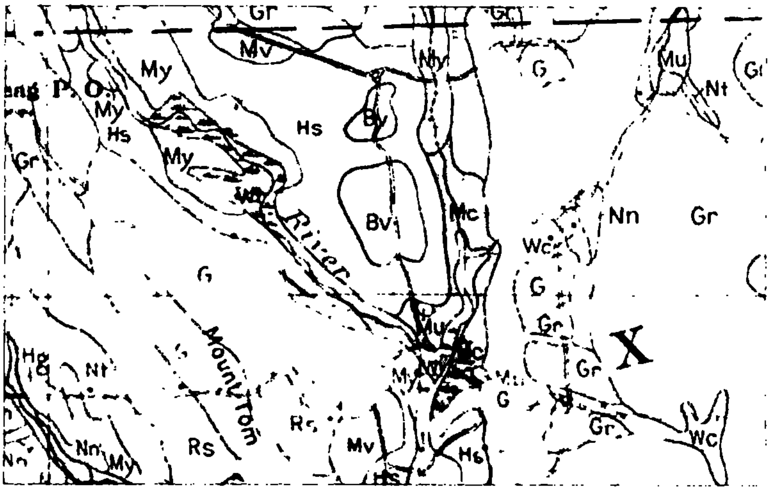

Figure 3. A portion of the agricultural soil map showing the area illustrated in Figures 1 and 2. B_v = Bridgehampton very fine sandy loam; H_s = Hinckley loamy sand; G = Gloucester stony sandy loam; Gr = Gloucester stony fine sandy loam; M_y = Merrimac fine sandy loam; M_c = Merrimac gravelly coarse sandy loam; Wi = Whitman loam; and R_s = Rough stony land.

of the drainage characteristics of the area. This estimate is based on a series of factors such as the texture of the soil, topographic position, profile development, known or suspected presence of impermeable strata, and the probable depth to the ground water table.

The drainage symbol used on this map is the first letter of the word that describes the quality of the drainage: e, excellent; g, good; i, imperfect; and p, poor. The significance of each word is as follows:

e = Excellent—Used where there is granular material and the ground water table is at such depth that it is not significant.

g = Good—Normally permits traffic or excavation soon after rain; position of ground water table normally not significant.

i = Imperfect—Traffic restricted and excavation impractical during significant periods; has occasional high ground water table particularly in low areas and when soil is underlain by impervious or semi-impervious strata.

p = Poor—Ground water table usually at or near the ground surface.

Slope Symbols

The third part of the map unit symbol presents the predominant ground slope. This symbol indicates the nature of the area and the probable maximum natural slopes to be encountered.

The slope symbols are as follows:

f = Flat—Slopes range from 0 to 3 percent.
m = Medium—Range in slope from 3 to 7 percent but may have flatter slopes and short steep slopes.
s = Steep—Most slopes greater than 7 percent but may include flatter slopes.

To prevent excessive subdivision of map units on the basis of slope, a combination of two of the symbols was made in some areas. Where the slopes were predominantly flat but greater slopes were known to exist and it did not seem feasible to separate them, the symbols f and m were combined and shown as fm. When steep slopes were found in an area of medium slopes and it was not feasible to map them separately, the symbols m and s were combined and shown as ms.

Textural Symbols

The textural classification of the soil has been indicated by an abbreviated form of the classification system adopted by the American Association of State Highway Officials. This system (Table 2) ranges from the notation A-1-a for well-graded granular materials to A-7-6 for clay soils. The number that follows the A of the AASHO system is used as the textural symbol on the maps. For a soil which varies from A-1-a to A-2-4, the identifying symbol is 12. Table 2 gives the grain size limits and plasticity values for the symbols used. This textural classification refers to the C horizon or parent material.

TABLE 2

CODE SYMBOLS FOR SOIL TEXTURE

Symbol[a]	Percent No. 40	Passing Sieve No. 200	Liquid Limit	Plasticity Index
1	50 max	25 max	NS[b]	6 max
3	51 min	10 max	NS	Non-plastic
2	NS	35 max	NS	NS
4	NS	36 min	40 max	10 max
5	NS	36 min	41 min	10 max
6	NS	36 min	40 max	11 min
7	NS	36 min	41 min	11 min

[a]Note that the use of a symbol indicates that the soil satisfies the particular set of requirements listed for that symbol and will not satisfy any of the set requirements appearing in a higher position in the table.
[b]Values not significant.

Special Symbols

In some areas, special conditions exist which are more readily designated by means of special rather than by the general symbols.

The following symbols are used alone or in combination, but are not further modified by the environmental symbols of the basic system.

F = Fill—Used to indicate areas where fill has been used either to reclaim marshy land or to level irregular topography. The material used varies considerably depending on its source. This symbol is commonly used with a diagonal bar and an additional symbol where the separation is difficult.

Z = Swamp—Used without additional designations. Denotes low or depressed areas where the water table is at the ground surface most of the year. The surface or near-surface soils are generally of high organic content and the underlying soil is generally similar to that of the surrounding deposits. Deposits of peat may be found in the deeper swamps. Neither the depth nor the type of the underlying soil has been indicated.

B = Coastal Beach—Used to indicate those areas where the shore line is a sandy to stony beach of wave-deposited material. It also includes dune areas where beach sand has been shaped into ridges and dunes by wind action.

TM = Tidal Marsh—Low, flat, salt marshes which are found along the beaches and around salt water ponds and inlets. These areas consist of shallow tidal flats commonly subjected to regular tidal inundation. The soil consists of dark-gray sand with finer sediments which, in the upper layers, is quite compact. Below 30 in., the gray sand is coarse and loose. Where vegetation exists, a heavy brown, fibrous mat has been developed in the top 6 in.

/ = Diagonal Bar—Used to separate two mapping symbols where both may occur at the surface and it is not feasible to map them separately.

_ = Horizontal Bar—Used with code symbols above and below the bar. Where it is anticipated that rock will be found close enough to the surface to warrant consideration in design and construction, the surface material is indicated above the line and the rock is indicated below the line. Two rock symbols were used, C for crystalline rock and S for sedimentary rock.

-- = Broken Line—Used where the boundary between map units is not clearly defined. Its use is limited to areas where the soil change is transitional rather than abrupt and to areas where the horizontal bar is used to indicate rock at shallow depths.

Contents of Engineering Soil Bulletin

The engineering soil survey is published as a bulletin with the county maps for the entire state included. The bulletin presents a few facts concerning climatic conditions, precipitation, temperatures, and topography in the state and a description of the bedrock and surficial geology which in this case is entirely the result of glaciation. Included are descriptions of the soil sampling and testing procedures used, the mapping technique, and the map unit symbols. Each basic map unit is described in considerable detail to provide information concerning the soil conditions to be anticipated in each area. These descriptions include information concerning land formations, the types of soil, drainage characteristics, and engineering aspect. The soil test data are presented in an appendix. Each sample site is indicated on the soil map.

Cost of Mapping

This mapping project was undertaken by the Division of Research and Development of the University of Rhode Island on the basis that the work would be performed by faculty and students of the College of Engineering. Because no one was employed full time on the project, the total elapsed time was approximately 3½ yr. However, more than 6 months of this was the result of delays in getting the maps and bulletin printed. A breakdown of the time (man hours) spent on the various phases of the project shows that the time was used as follows:

Mapping, including field verifications	22 percent
Soil sampling and testing (129 sites)	41 percent
Preparation of the maps and report	30 percent
General administration	7 percent

The cost of the project, including 500 copies of the report, was just under $11.00 per square mile.

USE OF THE SOIL MAPS AND BULLETIN

Since the publication of the bulletin "Engineering Soil Survey of Rhode Island" (1) copies have been widely distributed to consulting engineers, other engineering agencies, public utility companies, contractors and many non-engineering agencies interested in the soils in Rhode Island. An inquiry made of a number of these firms and agencies indicates that the soil survey has been used quite extensively. Reference has been made to the soil survey in connection with various types of projects including:

1. The location, basic design, and final design of major highways within the state.

2. As a guide in selecting locations for soil borings and the interpretation of boring data.
3. The location of potential sources of granular material for highway and other uses.
4. Estimating subsoil conditions for various geologic reports and specific projects such as various types of underground utility lines.
5. Estimating soil conditions in connection with various phases of community planning.

Although this listing indicates the principal ways in which the soil survey has been used, there are undoubtedly other miscellaneous uses.

CONCLUSION

Based on the general acceptance of the Engineering Soil Survey of Rhode Island by the state and the ways in which the information has been applied, it is concluded that its preparation has been a substantial and practical contribution to soil engineering in general and highway soil engineering in particular.

ACKNOWLEDGMENT

This report is based on information developed in a soil study and mapping project by the Division of Engineering Research and Development, University of Rhode Island, in cooperation with the Rhode Island Department of Public Works and the U.S. Bureau of Public Roads. Figure 2, and Tables 1 and 2 come from the Engineering Soil Survey of Rhode Island (1) and Figure 3 from the U.S. Department of Agriculture (11).

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Maryland Engineering Soil Study

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● IN 1959 the Civil Engineering Department of the University of Maryland undertook the integration of engineering soil data for the Maryland State Roads Commission with the cooperation of the U.S. Department of Commerce, Bureau of Public Roads. It was intended to bring together data from various sources, correlate it and present it for ready reference.

Conferences with representatives of the divisions of the State Roads Commission showed several sources of information and indicated potential uses of the engineering soils data in selecting preliminary lines, making cost estimates, finding select material, and planning borings for bridges and roadway design. Two common problems are uncertainty of presence and characteristics of rock in cuts and material too wet for foundation or fill construction. In addition to highways, use for housing developments and sanitary facilities were suggested.

The principal source of unpublished data is the project reports of the Materials Division which had been indexed to project locations shown on overlays—one overlay for each of the 23 counties. These files are being reduced to tables. Table 1 shows the soil classification, rock and water conditions and design recommendations. Table 2 shows test data on representative samples. The Maryland soil classification is a modification of the AASHO classification related to typical test properties but strongly controlled by judgment based on field performance.

The tabulated data plus some construction notes marked on plans (more are desired) were plotted on drafting film to the scale of the agricultural and geologic maps which are available for each county. Figures 1, 2 and 3 show, respectively, the soil classification, rock encountered, and water conditions noted along the lines of the projects. Some examples of the code used to represent observed conditions are explained in the figures. These are the record maps which are a major product of the study. The record maps are to be kept up to date for ready reference by the Materials Division.

Data from several other sources are being collected to supplement the above. The Maryland Geological Survey published, starting in 1899, a series of bulletins on application of geology to highways. Well logs published by the Maryland Department of Geology, Mines and Water Resources give an indication of rock depth. Except for a few dug wells, the water depth shown in these reports is generally not significant for highway construction. Bridge division borings show detailed data in isolated areas. Some commercial structural borings are also available. Quarries and materials pits will be studied intensively. Some data will be available from sanitary districts. Trenches for long pipe lines show good cross-sections when they can be inspected during construction.

For preliminary planning, fairly detailed county engineering soil maps are desirable. Since specific data are still insufficient to alone permit delineation of boundaries of soil units, the agricultural soil survey maps are being used to indicate boundaries. Soil series occurring in each county are shown in Table 3. The record maps are placed over the agricultural soil map and the data regarding soils, rock and water for each soil series are summarized as in Table 4.

The newer agricultural soil survey reports being prepared by the U.S. Department of Agriculture in cooperation with the Maryland Agricultural Experiment Station contain an engineering chapter. This new type report has been published for Frederick County and survey work is under way in several other counties of Maryland.

To classify areas where specific data is insufficient and to combine areas with sim-

Table 1

In-Place Soil Conditions and Design Recommendations

1 Contract Number and Date	2 Location	3 Station	4 Soil Materials Summary: Sta.	5 Soil Materials Summary: Class	6 Soil Materials Summary: Descript	7 Bedrock: Sta.	8 Bedrock: Depth	9 Bedrock: Type	10 Bedrock: Excav.	11 Top Soil	12 Root Mat	13 Moist. in Cuts	14 Soft Fill Found	15 Water Table: Sta.	16 Water Table: Depth (Feet)	17 Water Analysis: pH	18 Water Analysis: Res. ohms	19 Water Analysis: Cl ppm	20 Water Analysis: So₄ ppm	21 Subdrains and/or Ditches	22 CBR	23 Subgrade Treatment: Cut	24 Subgrade Treatment: Fill	25 Sub-base Thickness & Type: Cut	26 Sub-base Thickness & Type: Fill	27 Pavement and Base: Type	28 Pavement and Base: in.	29 Borrow Spec.: Cut	30 Borrow Spec.: Fill	31 Shoulder: Type	32 Shoulder: in.	33 Slope Design: Cut	34 Slope Design: Fill	35 County—Montgomery. Remarks
M 474-1-315 DEC 1950	River Road Route 190 Locks Rowe and Wilson Lane	0+00 to 36+00	1+00 to 3+00		Marshy	2+00 to 5+00		Rock Outcrop		✓	6"-9"									1+00 to 3+00 9+00 to 14+00									LL=40 PI=12 MD=105					
M 517-2-320 AUG 1955	Md. Route 193 Chevy Chase to Kensington	9+00 to 256+08	183+00 to 187+00		Soft mica schist rock outcrops					✓				147+45 155+78 158+67	Stream Stream Rock Creek	7.5 7.8 7.0	4500 4600 6000							6" Compacted Gravel	12" Compacted Gravel	Reinforced Concrete	9"		LL=45 PI=15 MD=105					
M 536-320 JAN 1958	U.S. Route 29 White Oak to Ashton	0+00 to 319+03				126+00 to 137+00 400' North ℄		Rock	Regular Constr. Equip.	✓				17+35 119+40 119+75 35'L 130+75 25 L	Stream River Stream Spring	6.5 6.9 6.8 6.9	7000 9400 10000 10000				5 to 8			6" Compacted Gravel	12" Compacted Gravel	Bituminous Concrete	12" and 6"		LL=40 PI=10 MD=105					
M 531-214-320	New Columbia Pike Cedarcroft Sanatorium to Sligo Creek Parkway	1277+03 to 1317+03	1252+ to 1311+03	A 4	1" carries decomposed rock	1234+00 to 1237+03 1121+75 1121+80 1121+90 1121+95 1121+00 1124+00 1124+03 37'L 8'L	4.5 to 12.5 4 3 4 4.5 3.5 2.5 4 5	Rock One man stone and heavy gravel	Blasting required Regular Constr. Equip.	✓				1127+03 1176+99 1113+ 1235+45 60'R 1229+25 1223+20	Spring 8'	5.4 7.2 5.4 7.2 7.3	24000 17000 11000 5500 4800					Cut clay and replace with Type 2 sub-base	A 2 12"	12 Gravel	12" Gravel	Reinforced Concrete	9"		LL=40 PI=10 MD=105					

Note Data in this table were obtained from highway project files of the State Roads Commission

Table 2

Physical Properties of Soil Samples

1 Contract Number	2 Station or Coordinates	3 No. of Samples	4 Depth	5 Class	6 Group Index	7 Grain Size - % Passing: 2½"	8 Grain Size - % Passing: 1"	9 Grain Size - % Passing: ½"	10 Grain Size - % Passing: #10	11 Grain Size - % Passing: #40	12 Grain Size - % Passing: #100	13 Grain Size - % Passing: #200	14 Compaction: max Density	15 Compaction: % Water	16 LL	17 PI	18 FME	19 Shrink. Limit	20 Shrink. Ratio	21 % Silt	22 % Clay	23 CBR	24 Footage: Cut	25 Footage: Fill	26 County - Montgomery Remarks
M 474-1-315	6+00 (15L) and 24+00 (15R) 30+00 (15L) 0+90 (MR)	2 1 1	3 3 19	A-2-5 A-4 A-8	0.8 3.4 3.6	100 92 100	100 76 100	100 72 100	99 58 100	92 56 95	- - -	53 48 82	113 107 110	14.2 17.6 14.7	32.8 34.7 32.9	0 6.2 3.9	31.1 30.9 34.5	36.6 22.4 29.6	1.3 1.55 1.4	51 55 49	3 14 3	- - -	- - -	- - -	
M 517-2-320	137+00 (15L) & 142+00 (17L) 151+00 1+00 to 241+73	2 1 18	4.5 2.5 0-15.5	A-5 A 4 A 5	0 10.3 3.6	100 100 100	100 100 100	99 100 99	98 100 95	79 94 69	- - -	41 69 53	- - -	- - -	41.6 42.1 37.2	2.7 11 8.9	- - -	32.6 22.3 34.0	1.4 1.6 1.6	39 63 45	8 13 13	- - -	- - -	- - -	
M 536-320	22+00 to 229+00 37+00 116+00 to 152+50	18 1 3	0-32 5 0.5-11.5	A 5 A-4 A-5	2.76 3.76 5.85	100 100 100	100 100 100	100 100 100	91 95 98	77 91 86	- - -	35 50 41	109 - 111	16.4 - 17.5	39.0 31.9 31.6	9.4 11.8 7.3	36.0 27.6 22.4	33.4 25.4 23.0	1.45 1.63 1.70	24 32 36	17 26 26	6 - 5	- - -	- - -	
M 531-214-320	1143+00 to 1294+50 1176+00 1093+00 to 1178+40 1159+00 1090+82 to 1236+00 1137+00	8 1 5 1 12 1	0-26 13.5 0-21 3 0-30 6.5	A-5 A-4 7 A-5 A-4-7 A 5 A 7	0 5.6 1.17 6.8 1.5 4.59	100 100 100 100 100 100	100 100 100 100 100 98	99 98 99 100 99 93	99 96 92 95 92 71	99 93 79 85 74 51	72 13 - - - -	29 63 41 56 39 37	110 109 108 110 104 102	15.4 18.9 17.5 16.6 13.5 24.9	36.1 30.9 42.2 43.4 37.4 46.9	5.5 21.6 13.0 18.7 9.6 17.3	34.7 40.3 32.8 30.0 37.4 33.9	32.5 18.9 30.5 24.9 21.7 24.6	1.45 1.75 1.51 1.45 1.60 1.65	23 34 31 35 23 40	9 34 8 25 21 42	- - - - - -	- - - - - -	- - - - - -	

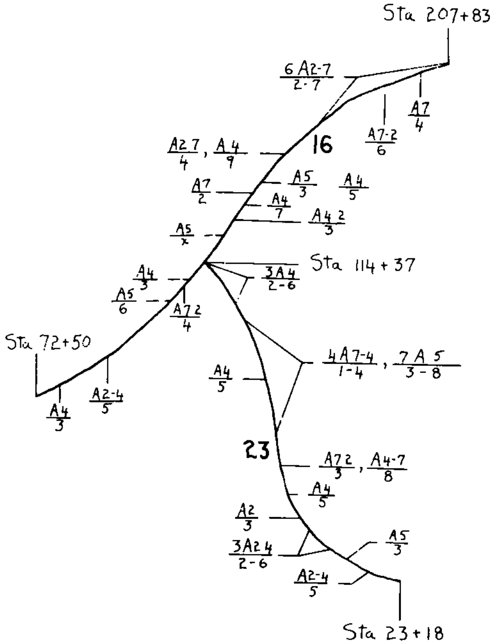

Figure 1. Example of soil record map. $\frac{3A2\text{-}4}{2\text{-}6}$ = 3 samples of A2-4 soil obtained at depths from 2 to 6 ft.

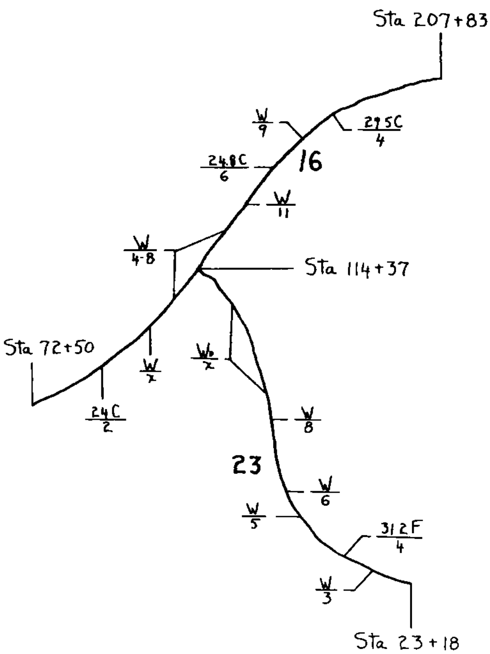

Figure 3. Example of water record map.
$\frac{W}{9}$ = free water at a depth of 9 ft.
$\frac{24C}{2}$ = 24 percent water in cut material at depth of 2 ft.
$\frac{20F}{x}$ = 20 percent water in fill material at unknown depth.

ilar engineering properties, use is made of topographic, geologic and the agricultural descriptions. It is planned that extra borings will be made to evaluate some areas. Soil limits on the county maps have been, in a few cases, on the basis of water conditions, because water may be a problem for highways where it is not for agriculture. Data on rock depth and condition is often insufficient. Some sandstone and shale areas can eventually be separated but many are so closely associated that de-

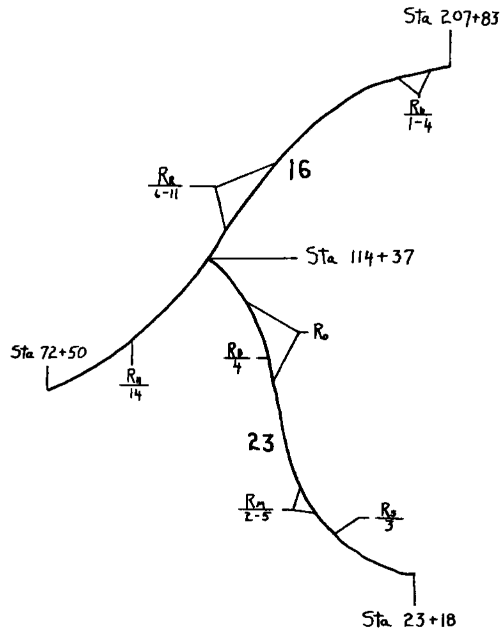

Figure 2. Example of rock record map.
$\frac{R_H}{14}$ = hard rock at a depth of 14 ft.
$\frac{R_b}{1\text{-}4}$ = rock, requiring blasting, at a depth of 1 to 4 ft.
Subscripts indicate type or character of rock.

sign will have to contend with changes from shale to sandstone in short distances.

Preliminary maps are checked by conferences with construction and maintenance engineers and by visual field inspections.

Considerable study was given to developing map symbols which give a graphic representation of conditions showing simply the predominant soil texture and the occurrence of rock and water problems. The symbol for a map unit consists of four parts:

TABLE 3.

AGRICULTURAL SOILS IN MARYLAND

SOIL / COUNTY	Allegany	Anne Arundel	Baltimore	Calvert	Caroline	Carroll	Cecil	Charles	Dorchester	Frederick	Garrett	Harford	Howard	Kent	Montgomery	Prince Georges	Queen Annes	St. Marys	Somerset	Talbot	Washington	Wicomico	Worcester
Aldino												●											
Allen										●													
Ashe										●											●		
Athol										●													
Atkins	●										●												
Berks																					●		
Bermudian						●				●					●								
Cardiff										●													
Cecil															●								
Chandler										●													
Chester			●			●	●			●		●	●		●								
Clarksville																					●		
Colbert										●													
Collington		●														●							
Congaree			●			●	●			●		●	●		●	●							
Conowingo			●				●			●		●			●								
Dekalb	●									●	●				●						●		
Dunning																					●		
Elk										●					●						●		
Elkton		●	●	●	●		●	●	●			●		●		●	●	●	●	●		●	●
Frankstown	●									●											●		
Hagerstown	●		●			●				●											●		
Hanceville										●											●		
Holston	●																				●		
Huntington	●									●					●						●		
Iredell			●							●					●								
Keyport		●	●	●	●		●	●	●			●		●		●	●	●	●	●		●	●
Lansdale										●					●								
Lehigh						●				●			●		●								
Leonardtown		●	●	●				●					●		●	●		●					
Louisa			●												●								
Manor			●			●	●			●		●	●		●	●							
Montalto			●			●	●			●		●	●										
Mecklenburg			●										●										
Meigs											●												
Moshannon											●												
Murrill										●											●		
Norfolk		●		●			●		●						●	●		●				●	●
Ochlockonee								●					●			●							
Penn						●				●					●								
Plummer					●																		
Pope	●									●											●		
Porters										●											●		
Portsmouth		●			●				●					●			●		●			●	●
Ruston								●															
Sassafras		●	●	●	●		●	●	●			●	●	●	●	●	●	●	●	●		●	●
St. Johns																						●	
Susquehanna			●										●			●							
Talladega										●													
Tuxedo		●					●					●				●							
Upshur	●										●										●		
Waynesboro																					●		
Wehadkee										●					●								
Westmoreland	●																						
Worsham							●																
Coastal Beach				●										●				●					●
Meadow		●		●	●		●	●	●			●		●		●	●	●	●	●		●	
Rough Stony Land	●						●			●	●										●		
Tidal Marsh		●	●	●	●		●	●	●			●		●		●	●	●	●	●		●	●
Swamp								●											●			●	●
Unclassified City				●																			

Table 4
Agricultural Correlation Data Sheet

Agricultural Soil Series Manor					
Project	**Location**	**Engineering Soil**	**Rock**	**Water Table**	**Wet Soil** C=Cut F=Fill
14	Eastern half	Mostly A-5 with some A-4 and A-7-4	None	Not encountered	$\frac{38-42\ C}{10-22}$
17	Entire project	Mostly A-5	Soft rock at 3 feet	–	–
27	Entire project	Almost entirely A5	Medium rock requiring limited blasting at depths of 4 to 14 feet	Water table at 20 feet	$\frac{14-31\ C}{13-33}$ $\frac{26\ F}{3}$
32	Middle third	Primarily A-5 with quite a bit A-4	Soft decomposed rock	Two springs found	–
21	Southern two thirds	A-5 and A-4	Occasional outcrops	No problem	–
		Predominately A-5 soil Very micaceous Some A-4 and A-7-4	Rock problem rare Soft and decomposed rock found occasionally	Water table low and generally not a problem	Wet soil found on occasion

(1) index number
(2) soil texture
(3) degree of rock problem
(4) degree of water problem

The symbols are shown in Figure 4. For example, Mrw indicates predominantly silt with minor rock and water problems. Similarly, mC-W indicates a silty clay with negligible rock but a major water problem. Mi --, the only exception to date, is micaceous silt with negligible rock or water problems.

Figure 5 shows the engineering soils map of Montgomery County, while Table 5 summarizes the properties of each map unit.

A map with less divisions is also being prepared for the state as a whole.

Time was allotted early in the planning of the engineering soil study to determine a suitable method of presentation—a medium which might assure active use of the results of this study. It was noted that the Maryland State Roads Commission had been successfully using an overlay system. Too much usable information was available than could be included in a single map. This single map would be possible only by compromise—this seemed to be confirmed by a review of other engineering soil studies. These observations and other considerations suggested the following essential features of the medium:

1. Accuracy at least equal to usual practice.
2. The flexibility of an overlay system.
3. Convenience in use.
4. Economical (in cost and space requirements).
5. Resolution of the variation-in-scale-problem.

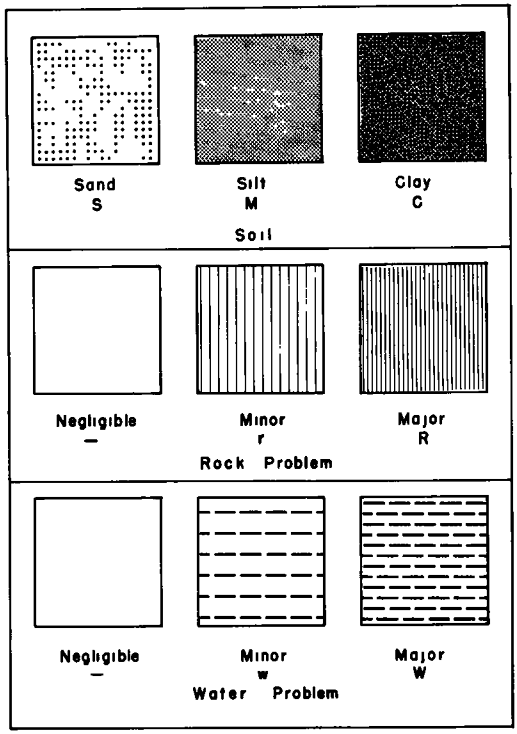

Figure 4. Mapping symbols.

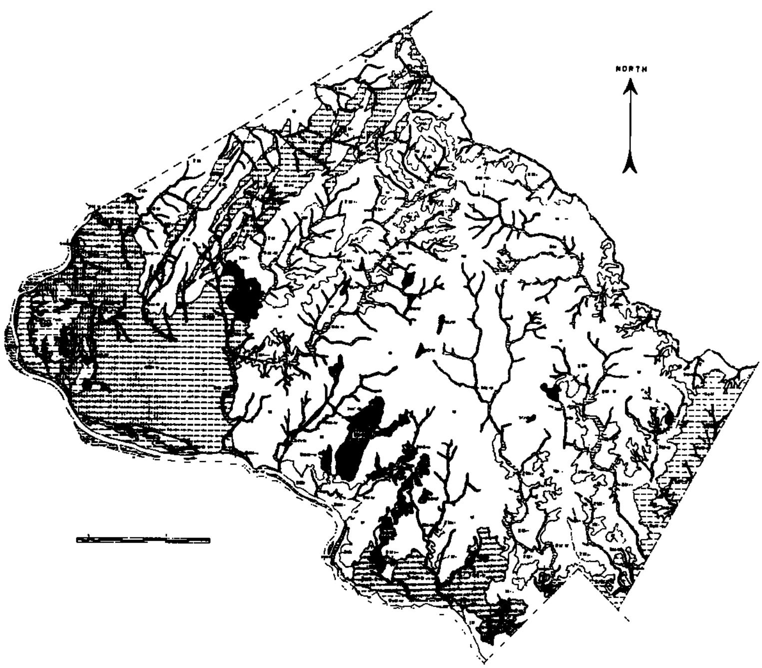

Figure 5. Engineering soil map of Montgomery County, Maryland.

Table 5

Properties of Engineering Map Units Montgomery County Maryland

Map Unit	Agric Series	Topsoil	Soil: Texture	Soil: Class	Soil: Depth	Parent Material	Rock Occurrence	Water Table	Soil Moist	Test Results: Grain Size - % Passing: 2½"	1	½	#10	#40	#200	Compact: Max Den.	Opt Moist	Liquid Limit	Plasticity Index	Field Moist Equivalent	Shrinkage Limit	Shrinkage Ratio	% Silt	% Clay	CBR	Permeability (inches per hour)	Frost Susceptibility	Shrink swell Potential	Adaptability to Winter Grading	Suitability for Septic Tanks	Source of Sand or Gravel	Erosion	Topography	Drainage: Surface	Drainage: Internal	Suitability for: Subgrade	Suitability for: Fill
1M--	Chester	8"	Silty soil with some mica	A 5 A 4	Usually 8 to 10 feet but up to 20 feet	Mica schist Gneiss	Rare More often on steeper slopes	Low	Wet soil occasionally found	100	100 98	100 90	95 65	90 50	60 35	116 104	18 14	43 33	16 6	38 33	33 29	15 13	50 18	28 8	3 7	0.2 to 2.0	Slight to Moderate	Low to Moderate	No	Good to Fair	No	Yes	Gently rolling to Rolling	Good	Good	Fair	Fair
2M--	Manor	8"	Very micaceous silty soil	Mostly A 5 Some A 4	5 to 8 feet	Mica schist Gneiss	Rare More often on steeper slopes Some decomp. rock	Low	Can absorb much water Wet soil found fairly often	100	100 98	100 88	92 57	84 46	50 37	113 105	20 14	39 31	17 8	36 32	34 26	17 14	50 22	24 13	3 7	0.2 to 6.3	Slight	Low	No	Fair	No	High	Rolling	Good	Good to Fair	Fair	Fair
3mC-w	Louisa Cecil	8	Micaceous silty clay soil	A 4 7 A 5		Schist Granite Gneiss Slate	Rare		Fairly impervious Soil often wet																		Strong				No	Yes	Gently rolling to Rolling	Good	Fair	Poor	Poor
4Mrw	Penn Lansdale Lehigh	8	Silt	A 4 A 5	3 to 5 feet	Sandstone Shale	Frequent surface rock and outcrops Medium to hard	Low	Often has high moist content	100	100 98	100 96	98 88	94 74	78 65	111 106	13 15	37 31	15 10	30 28	25 18	18 15	44 32	29 17	2 8	0.2 to 2.0	Slight to Moderate	Low	No	Poor to Fair	No	Yes	Gently rolling to Steep	Good	Fair	Fair	Fair
5CrW	Conowingo	8"	Clay with some silt	A 7 A 4 7 A 5	3 to 7 feet	Serpentine	Hard rock rare		High moisture retention Wet soil often found	100	100 97	100 96	94 62	93 45	78 37	112 106	21 17	49 40	22 15	33 28	24 19	17 16	38 29	41 22	2 6	0.06 to 2.0	Strong	Moderate	No	Poor to Not Suitable	No		Gently rolling to Rolling	Fair	Poor	Poor	Poor
6cM-w	Leonardtown	6"	Clayey silt Sometimes gravel	A 4 A 4 7 A 2 7 A 7 A 5	2 to 5 feet	Coastal plain terrace Gravel or clay	Rare	Low	Hardpan layer impedes percolation	100	100	100 96	97 80	84 62	45 55	108 104	21 17	36 31	11 5	31 25	25 22	17 15	50 23	41 24	3 9	0.06 to 2.0	Strong to very Strong	Moderate to Low	No	Poor to Not Suitable	Local gravel substrate		Level to Gently rolling	Poor to Fair	Poor to Fair	Poor to Fair	Poor to Fair
7mS-w	Sassafras	6"	Silty sand Some gravel	A 2 A 2 4 A 3	2 to 4 feet	Coastal plain terrace Gravel or sand	Rare	Sometimes high for short periods	Cemented hardpan layer often found	100	100 98	99 93	87 71	74 40	40 24	121 115	15 10	31 26	9 3	30 24	24 16	18 16	31 24	15 9		0.2 to 6.3	Slight to Moderate	Low to Moderate	Fair	Good to Fair	Local gravel substrate		Level to Gently rolling	Fair to Good	Fair	Fair to Good	Fair to Good
8cM-w	Elk	8"	Compact clayey silt	A 7-4 A 4	3 to 6 feet	Second bottom Alluvium	Rare		Usually a wet soil	100	100 96	98 88	95 67	78 60	67 43	108 104	21 17	41 36	16 14	35 26	24 20	18 16	38 35	28 18		0.2 to 2.0	Slight to Moderate	Low	No	Fair to Good	Local gravel substrate	Yes	Level to Gently rolling	Good to Fair	Good to Fair	Fair	Fair
9M-W	Congaree Huntington	6"	Heavy silt	A 4 A 5 A 7 4	Up to 10 feet	First bottom Alluvium	Much rock but rarely a problem	High	Occasional flooding	100	100 90	100 72	98 51	88 65	59 46	116 108	16 14	37 30	12 8	29 24	26 18	17 16	50 32	24 13		0.63 to 6.3	Moderate to Strong	Low	No	Poor to Not Suitable	Rare local sandy gravel	Some	Level	Poor to Fair	Fair	Poor to Fair	Poor to Fair

A projection-overlay system has been selected as probably most nearly filling the requirements outlined above. All maps are reduced to photographic images on 35 mm film. These images are inserted into openings in index file cards as shown in Figure 6. These "aperture" cards are projected through a mirror arrangement which direct the image—back to scale—onto a sheet of tracing paper (cloth or film). Figure 7 illustrates the projection-tracing table. The engineer may select a map—or a series of maps—for general study or for drawing a strip map. The table, however, should also serve as a convenient conference area.

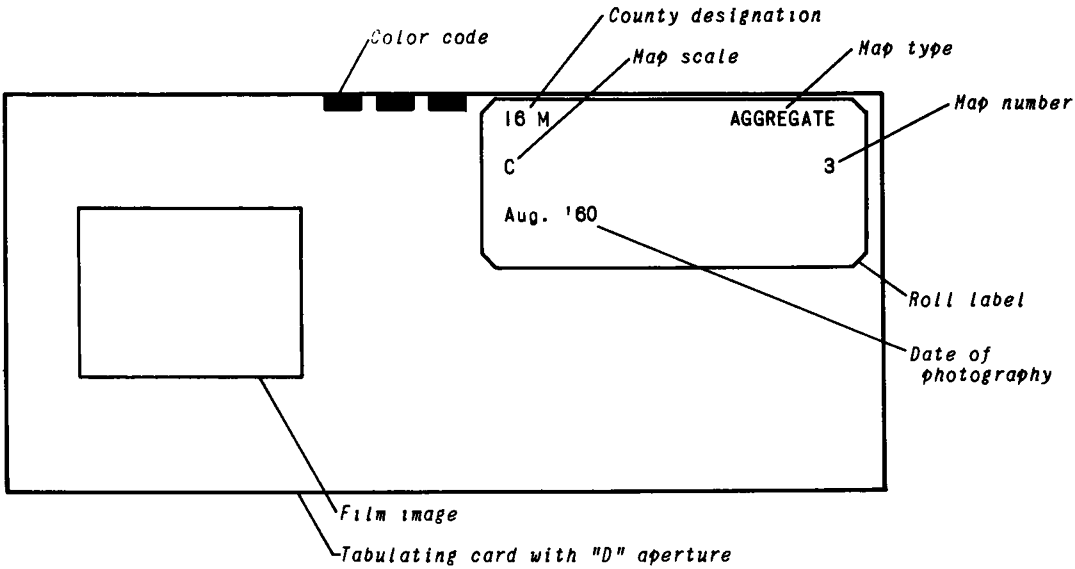

Figure 6. The aperture card.

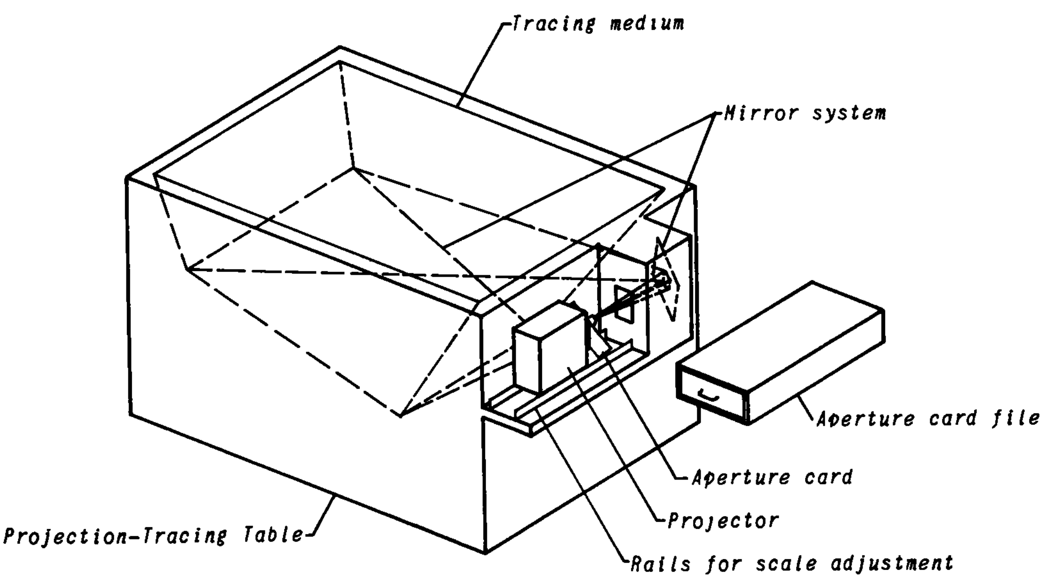

Figure 7. Projection-tracing table.

Selection of the 35 mm film size resulted from three considerations. First, it is sufficiently accurate. Second, it should prove economical. The total cost of the aperture card—black and white photography, processing and mounting—is under fifteen cents even when provided commercially. This would permit frequent revision and addition of material. Duplicate mounted cards (for replacement or for additional map centers) are of even less cost. The first cost should be compared with cost of full size paper maps, their storage equipment, handling time and wear. Third, the aperture card is convenient to use. The card chosen, the standard tabulating card, is accommodated at over 100 to the inch of file drawer. Adequate space is furnished for indexing as shown in Figure 6.

A projection-overlay system is ideal for the resolution of the scale problem. This problem arises from the array of scales in use. Only two controls are needed to provide a map at any desired scale—a range of reduction ratios at the camera; a range of enlargement ratios at the projector. Both are a part of the system adopted. Accuracy is established by use of "standard" bars—carefully machined to known distances at the required scales. Graphic distance scales and coordinate system intervals (on the original maps) are easily and precisely adjusted through projection to agree with the standards. Several working scales of the same map can be obtained by photographing at differing reduction ratios. Moreover, distortion—scale variation in two directions—can be corrected by adjustment in projection (first one direction, then the other).

The negative film, resulting from the photographic operation, is suitable as a "master" film. Positive film, which is preferred for use in the projection—tracing table, is reproduced from this negative. The master is retained in roll form and used only when new aperture cards are required. For protection of the cards in use at the map centers, the master should be stored in a fireproof vault. Several maps were found to be badly deteriorated, but once recorded on the master an unlimited number of positive aperture cards might be reproduced without requiring rehandling of the old paper maps. Similarly, out-of-print maps, which might be available on loan, become permanently preserved on the master film.

Certain of the maps are required for field use. Many methods of reproduction of maps are available with the system—diazotypy, photography, xerography, and multilithography.

Samples of a number of maps—some county and some statewide—useful for the planning of highway location, design, construction and maintenance have been made for consideration. Among those most useful with the projection-overlay system are the following:

Base Maps

- Highway
- Topographic
- Geologic
- Agricultural Soils
- Aerial Mosaics
- Coast and Harbor Charts (Maryland is ⅕ water by area)
- Hypsometric

Record Maps

- Engineering Soils Record
- Rock Record
- Water Record

Detail and Miscellaneous Maps

- Engineering Soils
- Engineering Geologic
- Slope
- Drainage Pattern
- Drainage Basins
- Aggregate

Materials (Building, Clays, etc.)
Traffic
Land Use
Temperature (with degree days)
Precipitation
Tides, Storm Damage and Wind
Physiographic
Construction Considerations
Old and out-of-print Maps

With additional file space made available, contract drawings—with "as built" notations added—could also be furnished for reference.

Less than 100 square feet of floor space accommodates a complete map center for individual study or for conference. All maps and supporting information, as pertinent—at any desired scale—is readily available through use of the projection-overlay system.

HRB:OR-448

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY–COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.