AN ENGINEERING GROUPING OF NEW YORK STATE SOILS

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SYNOPSIS

During the past year the Bureau of Soil Mechanics has prepared for the New York State Department of Public Works engineering soil maps for current projects covering a total of 3,360 square miles. This paper presents the engineering soil grouping used in New York State, the development of soil maps, and the application of the maps as aids in presenting soil information for highway design and construction.

The engineering grouping of New York State soils is based upon the following:
1. The division of the state into its physiographic provinces with analyses of the geologic history, topography, soil, rocks, and highway problems associated with each province.
2. A grouping of the soils on the basis of their deposition, parent material, soil and rock profile, land form and drainage characteristics as these factors affect highway problems.

The engineering soil maps are prepared to show the areal distribution of soils to be encountered in the particular region. The maps are assembled on the basis of existing soil and geologic information and with the aid of aerial photographs. Soil deposits, are grouped as glacial and post-glacial and are further divided into glacial ice deposits, glacial stream deposits, glacial lake deposits, glacial marine deposits, weathered bed rocks, recent stream deposits and organic deposits. The grouping at the present time consists of the following: thick till, thin till, drumlins, major moraines, outwash, kame fields, eskers, lake bottom sediments, deltas, bars and beaches, marine bottom sediments, residual, alluvial, muck and peat, meadow, and muck over marl.

The engineering soil maps form a part of both the preliminary and final soil report for each project and constitute a basis for the planning, control and review of soil work in the design and construction of highways.

For many years, Soils Engineers have relied almost exclusively upon detailed borings for the development of soil conditions and the extent of various soil profiles in connection with engineering projects. Little attention has been given to the past history of the area being investigated or to the general characteristics of the soil profile that may be common to soils in other areas. The broad viewpoint of soils as they exist because of their past history has led to the use of the area concept of soils in New York State.

This paper presents the research in soil and ledge conditions envolved in the development of engineering soil maps on an area basis in connection with the soil work for the design and construction of highways. This development has required an area grouping of soil in-

formation governed both by soil conditions and highway engineering practice. The area concept of soils in its broad aspect is a valuable aid to the Soils Engineer in the development of regional soil behavior, engineering practices and the performance of engineering structures. It has a special application to the practice of soils engineering for highways. This concept of soils depends upon the geological history of the soil deposit, the manner in which it was deposited, the material from which it was derived, and the weathering processes to which it has been subjected by erosion; drainage, mechanical disintegation and chemical reaction in the development of the soil profile and the surface topography of the deposit. The relationship of adjacent soil areas represented by a soil series from the same parent material subjected to erosion, weathering, drainage, and other climatic conditions is shown by the area concept.

The determination of whether the land forms as seen today are controlled by the deposition of the soil from the glacier or by the underlying bed rock adds to the information which is available to the engineer from a study of area soil concepts.

Area concept of soils provides a background on which to base the detailed soil studies, so that more information is available to the engineer in interpreting the subsoil investigation for the purposes of the design of the engineering structure. It is the opinion of the authors that more mutual understanding between the behavior of soils in different areas of the country will result from the use of the area soil concept as a basis for detailed soil work and the performance of engineering structures.

GEOLOGY OF NEW YORK

New York State has an area of 49,170 square miles including 1550 square miles of water. The state has been covered by multiple glacial ice advances leaving the entire State glaciated except for a small section in the southwestern plateau. The average elevation of the state is about 900 feet above sea level with a maximum of 5344 feet at Mount Marcy in Essex County in the Adirondacks.

Geologists have divided the state into well defined physiographic provinces. The authors have modified these provinces somewhat to fit the regional soil conditions of the state. Wide variation of soil and geological conditions make it necessary to divide the state into its physiographic provinces to facilitate the analysis of soil conditions and the related highway problems. In New York the provinces are roughly indicated by differences in elevation as shown in Figure 1. The following description of the provinces also refers to Figure 1.

Southwestern Plateau This is the largest clearly defined province in the state, covering about one-third of the total area. It contains unaltered sediments of Devonian rocks which are predominantly shales and contain some sandstones and conglomerates. Only minor disturbances have occurred in the form of a slight tilt to the south or southwest of 20 to 30 feet to the mile. Major relief is afforded by north-south trending valleys that, during glacial times, served both as drainage channels for the flow of melt-waters and as basins for ponded lakes. The soils in these valleys vary from assorted granular deposits that occur as kames, kame terraces, and outwash, to the la-

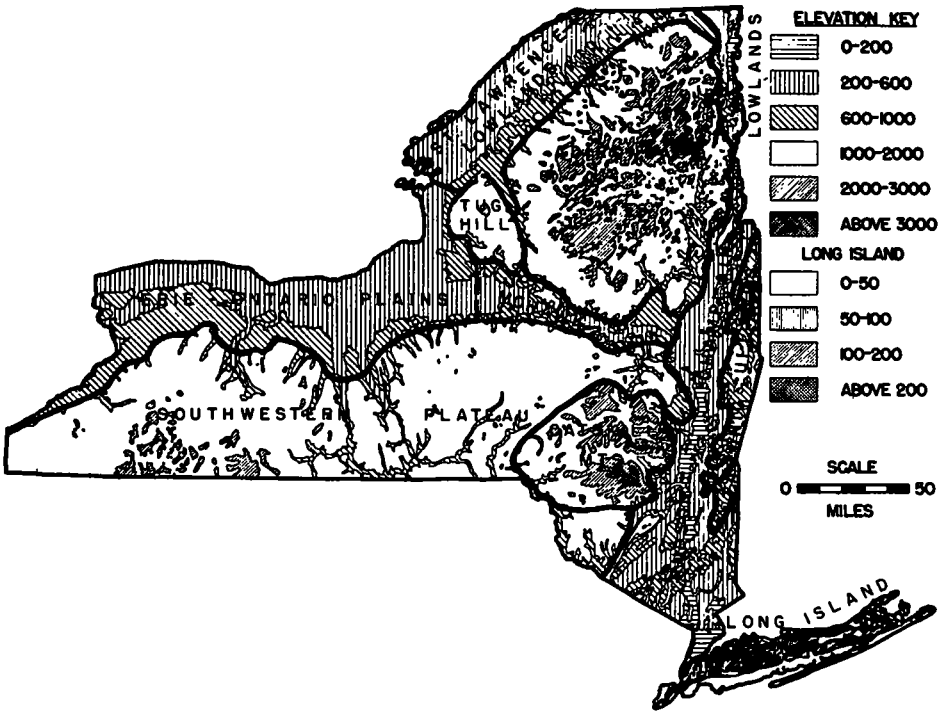

Figure 1. Elevation Map of New York State showing Physiographic Provinces

custrine fine sands and silts. While the glacial history of the valleys is very complex, the sequence of deposition can usually be determined within small areas with the accuracy required to identify the general engineering characteristics of the deposits.

The soils of the uplands are predominantly glacial till in origin and are usually underlain at shallow depth by bedrock. They are mainly silts with a varying percentage of rock fragments derived from the native bedrock. A major moraine crosses the province in an east-west direction, which, because of its soil profile characteristics and topographic expression, offers particular engineering problems.

Erie-Ontario Plains This province provides the east-west routes for all up-state New York transportation. The original Clinton's Ditch, the old Erie Canal, the present Barge Canal, the New York Central Railroad main line, and the new Thruway, now under construction, all traverse this province.

The entire province is one of low relief with a prominent escarpment marking its southern boundary and hundreds of elongated glacial hills or drumlins in the section between Rochester and Syracuse.

The area was flooded for a considerable period of time by a large glacial lake which, in its contracted form, constitutes the

present-day Lakes Erie and Ontario. This lake was superimposed on an area consisting of glacial tills and glacial stream deposits. Its occurrence modified and altered the previously deposited sediments to such an extent that the present soil pattern is very complex. Difficulty is encountered in grouping the soils of this area and many borderline cases exist.

St. Lawrence Lowland This lowland area borders the present river and has in the past been visited by both glacial and marine waters. Most of the area is underlain at shallow depths by limestone of Ordovician age with some Cambrian sandstone. Deep deposits of silt and clay exist over a portion of this area.

Adirondack Mountains These mountains are the highest in the State and are composed of igneous rock injected into highly metamorphosed pre-Cambrian sediments.

The glacial till encountered is sandy, and crystalline cobbles and boulders are the rule. Deep swamps are common.

Tug Hill This area is a plateau separated from the Adirondacks by the Black River. It constitutes an outlier of the Southwestern Plateau and is composed of nearly horizontally bedded Ordovician limestone and shales and Silurian sandstones. Because of the more favorable topography around this area, it is not crossed by any main highway.

Mohawk Valley This valley provides the lowland connection between the Erie-Ontario plains and the Hudson River. It was a major drainageway in glacial times and immense granular deposits now occur along the valley walls in the form of outwash terraces. In the bordering uplands there are large areas of silt and clay that were deposited in high-level glacial lakes. The river-flats are deep valley-fill with a wide variation on soil characteristics and profile.

Catskill Mountains These mountains were formed by the deep dissection of a high plateau area. The bedrock is nearly horizontally bedded Devonian rocks, consisting chiefly of sandstones and conglomerates. Valley type of glaciation is common with numerous small moraines, deltas, and outwash fans. Localized glacial lakes resulted in deposits of silt and clay that are especially troublesome in highway construction.

Hudson-Champlain Lowlands The Hudson Valley completes the water level route from New York City to Buffalo. The province as a whole represents a number of distinct topographic features that have been considered as a unit as a matter of convenience. A prominent feature occurs in the southern portion of the province where an area of crystalline rock, known as the Hudson Highlands, interrupts the lowlands.

It is known that marine waters have existed in both the Champlain Valley and in the southern portion of the Hudson Valley, but the extent of the deposits resulting from these waters has not been defined. Another featured soil area is the extensive sand plains existing in the Schenectady-Saratoga area which was deposited by glacial waters from the Mohawk Valley. The thickness of this deposit decreases with the distance from the intersection of the Mohawk and Hudson lowland and becomes absent south of Albany where the underlying varved silts and clays are exposed. It is these clays that present the major engineering design and construction problem of the province.

Taconic Uplands The highlands along the eastern border of the state are a part of the Taconic Mountains.

The rocks are intensely folded and are comprised of metamorphosed shales, sandstones and limestones. In general, the soils are thin and prominent glacial deposits are confined to the major drainageways. The identification of the type of underlying bedrock and its structural characteristics are of importance in design and construction considerations.

Long Island This province is essentially a complex glacial terminal plain to the south. The latter slopes vary gradually down toward the ocean. The soils are predominantly sands and gravels.

ENGINEERING GROUPING OF SOILS

The division of the soils of an area into groups is extremely diffcult. If a very broad grouping is desired, borderline cases constantly occur. If it is intended that the grouping will provide detailed soil identification it will be found that the number of groups will continue to increase as additional data is obtained. It has been found desirable to group the soils of New York State on a broad basis and to subdivide this grouping only after an accumulation of data indicates that such a subdivision is absolutely necessary. The detailed identification of soils is not included in the area grouping and is made only after borings and samples have been analyzed for a project.

The soil grouping now used gives consideration to many factors of soil and bedrock history, topography, drainage, and soil profiles; however, each division within the grouping must exhibit individual engineering characteristics that distinguish it from other divisions. No compromises are made with this last provision.

The designation of each group employs geologic terminology and reflects primarily the mode of disposition of the formation. The details of the grouping are shown in Figure 2 and the characteristics peculiar to each division are discussed below:

ENGINEERING GROUPING
NEW YORK SOILS

GEOLOGIC AGE	GEOLOGIC ORIGIN	DEPOSITIONAL UNIT	KEY
GLACIAL	ICE DEPOSIT	THICK TILL	YELLOW
		THIN TILL	YELLOW
		DRUMLIN	YELLOW
		MAJOR MORAINE	YELLOW
	STREAM DEPOSIT	OUTWASH	RED
		KAME FIELD	RED
		ESKER	RED
	LAKE DEPOSIT	BOTTOM SEDIMENTS	BLUE
		DELTA	BLUE
		SAND & BEACHES	BLUE
	MARINE DEPOSIT	MARINE BOT. SED.	BLUE
POST GLACIAL	WEATHERED BEDROCK	RESIDUAL	GREY
	STREAM DEPOSIT	ALLUVIAL	BROWN
	ORGANIC DEPOSIT	MUCK & PEAT	GREEN
		MEADOW	GREEN
		MUCK OVER MARL	GREEN

GRAVEL
SAND
SILT

MAJOR STREAM
ROCK OUTCROP
OPEN PITS

Figure 2. Engineering Grouping of New York Soils

Thick Glacial Till These soils were deposited as glacial drift and have assumed a wavy or slightly hummocky land form. Their textural composition varies widely from one area to another, but in general, consists of an unassorted mixture of soils with a predominance of silt. Cobbles and boulders are common and internal drainage is moderate. Excavations in these deposits may encounter troublesome wet silt pockets that will require underdrainage or special handling. In general, the material is suitable for embankments; however, in the Southwestern Plateau province, the material often contains a sufficient quantity of large slabby pieces of shale to make compaction operations and control difficult.

Thin Glacial Till A distinction is made in the thickness of glacial till deposits primarily because of the importance in engineering design of the depth to bedrock. The thin tills are predominantly silts with varying percentages of fragments of the underlying bedrock and little foreign gravel is encountered. The topography in these areas is controlled by the nearness of bedrock, the type of rock and the inclination of the bedding planes. The uniformity of subgrade in cuts must be checked and special attention given to the area of transition from cut to fill. Underdrainage will be required at many sites to intercept flow along the surface and bedding planes of the rock.

Drumlins Drumlins are elongated, cigar-shaped hills, composed of compact unassorted till that has been overridden by the glacial ice. They occur as the major relief feature in a part of the Erie-Ontario Plains Province and for this reason are of engineering importance as a source of common borrow. They are given special designation within the grouping because of their topographic form.

Major Moraines The soils found in the major moraines of New York consist of assorted granular materials. The percentage of fines contained in the soils varies considerably. Some deposits consist of acceptable foundation course gravel while other have more of the characteristics of an assorted till because of the high percentage of fine material. The moraines appear as discontinuous, smooth to slightly hummocky ridges and are made a separate division in the grouping because of this special topographic form. In general, the materials are only medium compact, and in many cases pockets of wet fine sand and silt are encountered.

Outwash The identifying land form of glacial outwash is a smooth to pitted plain that gradually slopes down-valley as valley-wall terraces. The deposits consist of clean horizontally stratified sand and gravel and usually offer the best source of run-of-bank gravel. However, some sites are unacceptable because of the predominance of sand. In a few areas of the State, the percentage of shale gravel is an important consideration.

Kame Field This classification is used to encompass all glacial stream deposits other than Outwash and Esker. Such deposits are identified in the field by their characteristic knob and sag topography. They consist of roughly stratified sand and gravel with occasional pockets or strata of silt. They represent a likely source of run-of-bank gravel but must be carefully explored because of wide variations in texture.

Esker Glacial deposits formed by ice-walled streams which flowed either in canyons cut in stagment ice or sub-glacial tunnels are termed eskers. They are long, narrow, steep-sided ridges and are almost triangular in cross-section. Eskers consist generally of sand, gravel, and cobbles. They are usually a source of run-of-bank gravel and always an excellent source of select borrow.

Bottom Sediments Those soil deposits laid down in glacial lakes are referred to as Bottom Sediments. The topography is level to hummocky with frequent deep disection by modern streams. In the Hudson-Champlain valleys, the Catskill Mountains and the uplands of the Mohawk area, these deposits consist of varved silts and clays. In the Southwestern Plateau they are in

general stratified fine sand and silt, and, in the Erie-Ontario Plains, they are predominantly silts. It is this group of soils that present the most troublesome engineering problems. Their shearing strength and consolidation characteristics must be determined when they are to serve as embankment foundations; as material for embankments they are rated from poor to unsuitable; cut-slopes must be given special attention to prevent severe sloughing and erosion. A high grade line is generally recommended in these areas.

Delta In some sections of the State, run-of-bank gravel occurs only in deltas formed in glacial lakes. These deposits are recognized in the field by their smooth to pitted top and by the steep sides around their border. The textural composition of these deposits varies considerably and may be predominantely silt or an acceptable quality of gravel. The materials are sorted and in general exhibit a horizontal stratification in the top beds and bottom beds with an inclined stratification in the middle portions.

Bars and Beaches Remnants of glacial bars and beaches are found in many locations. They consist of assorted sand and gravel with a predominance of sand. The bars are elongated ridge-like land forms and the beaches appear as smooth slightly sloping areas. Both land forms represent an excellent source of select borrow and are considered good subgrade material.

Marine Bottom Sediments Deposits laid down by marine waters consist primarily of silts and clays and in general do not exhibit the characteristic varve structure of the fresh water lake deposits. The materials exist at a very high natural moisture content and are greatly affected by remolding. They appear in the field as smooth, almost level plains and their thickness may be as great as 100 feet. The same general engineering recommendations hold in these areas as for the bottom sediments deposited by glacial lakes.

Residual The soils in the small unglaciated area in the southwestern plateau are termed Residual. These soils vary in texture from sand to silt and clay. Bedrock is usually encountered at a shallow depth. The topography is controlled by the type and characteristic of the underlying bedrock and the engineering characteristics of these deposits are the same as those for the thin till areas.

Alluvial Materials deposited by modern streams are termed alluvial. They are generally found in a fairly loose condition, and are silty with occasional lenses of fine sand and gravel. These deposits represent the smooth flat areas adjacent to present streams and are in some instances terraced. During field exploration work in these areas, special attention must be given to the location of old ox bows and abandoned channels. If serving as foundation material for embankments or structures, a careful check must be made of the strength characteristics of these soils. In some areas alluvial deposits have been superimposed on previous muck areas.

Muck and Peat All deposits representing an accumulation of vegetable matter are termed muck and peat and it is always recommended that such materials be excavated beneath embankments. These deposits occur as flat smooth surfaces and a high grade line is always required. If the depth of the material is excessive, special analysis is necessary to determine the most advantageous means of removal.

Meadow Those poorly drained areas occuring as minor depressions in comparatively level topography and containing some organic matter are termed meadow deposits. In general they represent a drainage condition rather than a deep accumulation of vegetable matter. Unsuitable material in such areas is always removed and the structure of the underlying material determined if it is to serve as an embankment foundation.

Muck over Marl In numerous areas of the state, there are extensive deposits of marl overlaid by vegetable muck. The marl is generally of very low stability and represents an unsuitable material for highway construction. The general recommendation in such areas is that the muck and marl be removed until a firm strata is found for the placement of embankment materials. Numerous areas will require a detailed analysis for the adequate and economic handling of the problem.

PRODUCTION OF AREA SOIL MAPS

The area concept of soils is best presented to the engineer in map form using colors and symbols for the basic grouping. The preparation of engineering soil maps includes the identification of the soil deposits as well as the determination of the areal extent of these deposits. For assistance in this latter problem, reference is first made to the pedological maps prepared by the State and Federal Agronomists for agricultural purposes. While the identification of the soils on these maps is not accepted without verification, it has been found that in general the soil boundaries have been thoroughly and accurately determined. The use of these maps as a starting point has the additional advantage that they are at a scale of approximately 1-inch to the mile which is the same scale as the USGS Topographic Maps.

The soil classification shown on the Pedological Maps is analyzed together with the description for each class given in the soil bulletin. Usually it is possible to interpret the Agronomist's description of a particular soil deposit in terms of the engineering soil grouping. A tentative grouping of the pedological classes is made and tested against other known information concerning the area.

Review is then made of all existing geological information for the area involved. The history of the section, the glacial drainage features, the bedrock characteristics and the topography are reviewed. The tentative grouping based on the pedological map must fit the geological and topographical data.

By use of the aerial photograph index sheets, the general aspects of the entire area are checked when trouble is encountered in the identification of a particular portion of the area. Detailed examination is made of aerial photograph contact prints. This procedure of analysis is excellent and is being used to a greater extent as personnel and equipment permit. After utilizing all existing information concerning the type and extent of the different deposits in the area under consideration, a field inspection is made to check the general conditions in the overall area and any questionable areas. At the conclusion of this inspection, a final conference is held by the Soils Engineers, Agronomist and Geologist on the accuracy of the soil grouping. If agreement is reached, the soil grouping is given to the draftsmen together with the Pedological Map on which any revised boundaries have been noted. It has been found that the superimposing of the soil boundaries of a large

area on USGS Topographic Sheets offers the best method of presenting these data to the design and construction forces. Colors are used to indicate the geological origin of the deposit and symbols to indicate the depositional units. All map reproduction and coloring are hand work at the present time.

Some maps have been prepared to a scale of 500 feet to the inch from aerial photograph contact prints with a large sized Saltzman Projector. This projector greatly expedites the preparation of the maps by permitting photographs and maps of different scales to be superimposed on a drawing at any desired scale. Since the preliminary highway plans are prepared on a scale of 500 feet to the inch emphasis is also being placed on the development of maps at this scale.

Figure 3 is an engineering soil map for a section of the proposed State Thruway. The section lies just west of the city of Utica and is in Oneida County. The plain area in the central portion of the figure is thick glacial till and is a portion of the southwestern plateau province. The immediately bordering cross hatched areas are the thin glacial till soils. In the eastern section of the map is shown the outwash granular deposits bordering the Mohawk Valley and the alluvial sediments in the immediate vicinity of the present river. In the extreme western section of the map, the thruway will enter the Erie-Ontario Plains Province which consists of bottom sediments in this area. The northerly projection in the central portion of the map also provides information for the connection from the city of Rome to the Thruway. It will be noted that a large muck area is shown in this vicinity and that bars, beaches and delta formations are prominent features. The original map was produced with colors and symbols.

It is expected that the mapping will improve through the continued use of soil survey work in connection with current projects and that the ground work will be done for the development of a statewide engineering map.

USE OF ENGINEERING SOIL MAPS

The area concept of soils embodied in the engineering soil maps is used extensively by the Bureau of Soil Mechanics of the New York State Department of Public Works in organizing and controlling the soil work of the department. The bureau has been organized during the past four years at a time when the largest highway program of the State has been in progress. Many plans were prepared during the war years and a large volume of work is being designed at the present time.

Engineering soil maps have been made during the past year on current projects which required the mapping of a total area of 3,360 square miles. The new Thruway has required the mapping of 1,353 square miles; regular highway projects and one complete county, 1,537 square miles; and, the location of sand and gravel deposits, 470 square miles. In addition to the areas for which maps have been produced, the soil boundaries have been determined in outline form for all projects reviewed by the bureau.

It would have been impossible for the bureau to be organized, check soil conditions on projects already designed and to progress soil surveys on current designs as well as on construction projects without the aid of the area concept of soils.

The first use of an area soil map is in the study of general location problems before actual alignment surveys are started. General soil conditions, the extent of

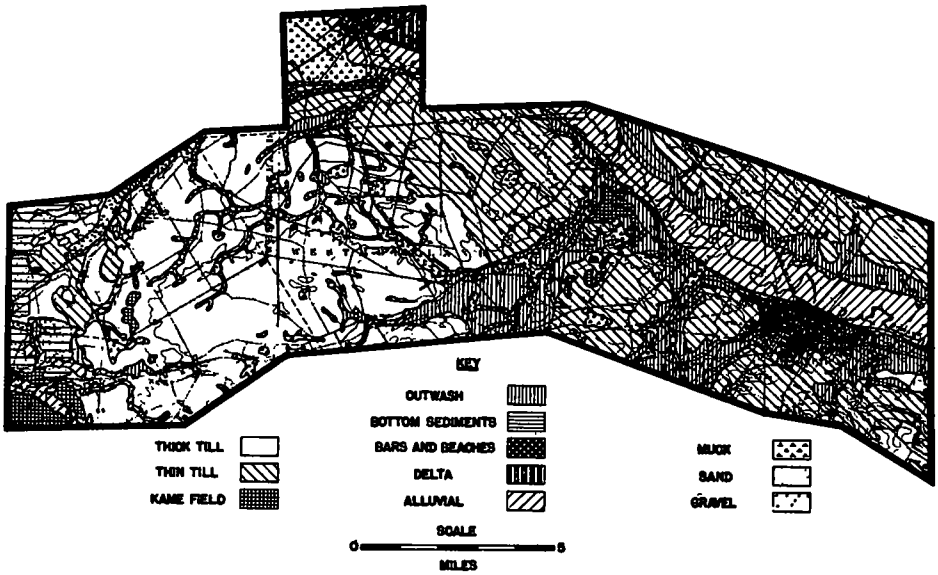

Figure 3. Engineering Soil Map of Mohawk Thruway
Oneida County, New York

swamp areas and the availability of selected borrow and granular subbase material are basic information which the engineer considers in locating the preliminary line for a highway. The maps prepared at a scale of one mile equals one inch are considered the best presentation for general location determinations. After the general location is determined, the soil map is a basis for detailed borings along the highway alignment which must be made to show detail soil conditions for every feature of the highway design. Engineering soil maps to the scale of 500 feet to one inch are best for detailed soil studies. Grade line and general soil boundaries control the spacing of borings and the extent of explorations and subsequent structural soil mechanics analyses. The detailed borings must be sufficient to answer the questions of design and construction. An important feature of the soil map is the delineation of areas in which the deposits are a possible source of selected borrow, granular base course material and local aggregate. These areas are carefully explored in connection with the detailed soil survey.

The preliminary soil report, which is based upon the engineering soil map, presents the general characteristics of the soils and their relationship to the engineering considerations of alignment and grade, earthwork, compaction, subgrade, drainage, frost action, swamps, and source of run-of-bank gravel and selected borrow. Recommendations are made on each soil problem. The engineering considerations contained in the preliminary report are based on the grouping of soils described in this paper. Reference is made to the general engineering statements contained in the description

of the soil groups. It is anticipated that with continued use of this grouping, correlation with construction experience and performance of highways, the general recommendations which can be made for any particular soil group will be of more value.

The soil survey work of the bureau is progressed with the alignment survey and design of the highway so that the soil work will be practical and provide the basis for engineering decisions which will result in the design of a highway that will include the best utilization of soils in the area. It is the policy of this bureau to include definite recommendations based on soil conditions for consideration by the Designing Engineer. All general soil information is checked by detailed borings, and final recommendations are based on the detailed soil work. At the completion of the design of the project, a final soil report is made which summarizes the preliminary soil report, the detailed boring information and recommendations which are made by Soils Engineers. This report is used by the bureau in making a final check and approval for the soil work for the project and by the department in reviewing plans, specifications and estimated quantities of contract work.

It is the present policy of the department to require final approval by the Bureau of Soil Mechanics of the soil work and the adequacy of the design and contract quantities for the soil conditions. The engineering soil maps together with the soil report, have proved very valuable in making these final inspections and review of soil work, especially on those projects which have been designed for some time and for which only a check soil survey can be made. On this type of project, the check borings are requested on the basis of the soil areas and the results obtained before the projections can be placed under contract.

The final soils report is made available for the Construction Engineer during every phase of construction.

It is the opinion of the authors that the area concept of soils and the soil grouping should not be considered in competition with existing soil classification systems and neither should notations on a single engineering soil map be used to replace highway engineering experience. Engineering soil maps should be developed on a broad regional basis and the fine detail of soil information obtained by borings should be presented in the soil report for the specific project under design.

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