A Technique for Soil Mapping

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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:

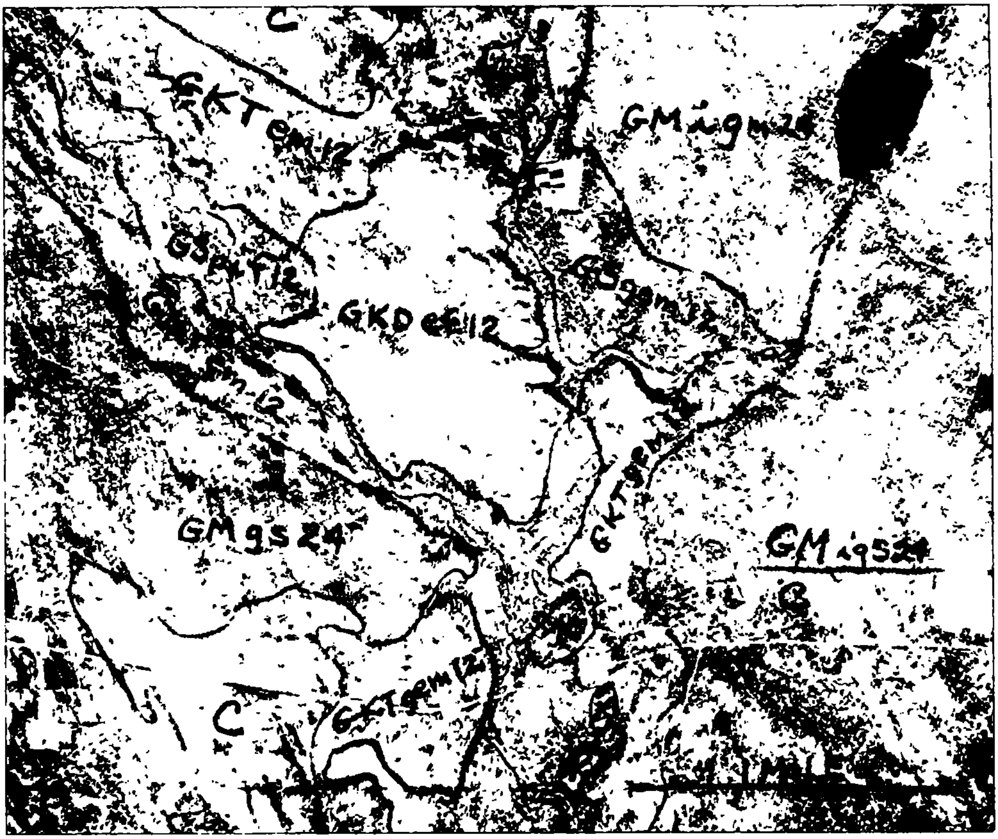

Figure 2. This figure shows the portion of the soil map corresponding to the area shown in Figure 1. On the actual map the map base is printed in red and the soil information is printed in black for contrast.

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

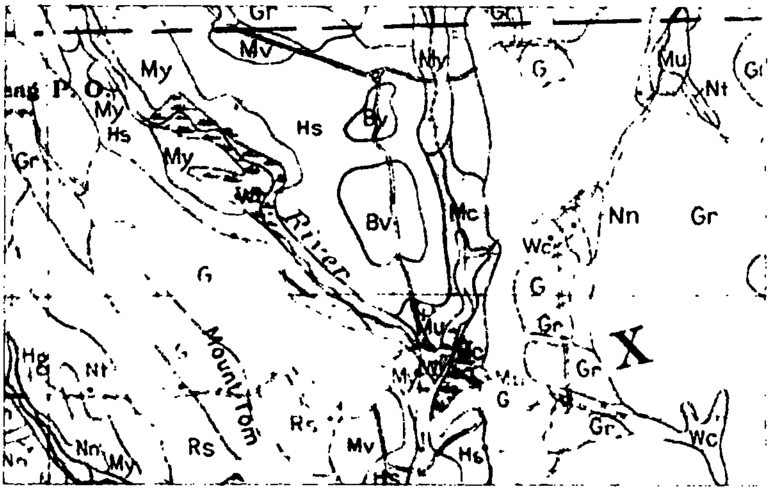

Figure 3. A portion of the agricultural soil map showing the area illustrated in Figures 1 and 2. B_v = Bridgehampton very fine sandy loam; H_s = Hinckley loamy sand; G = Gloucester stony sandy loam; Gr = Gloucester stony fine sandy loam; M_y = Merrimac fine sandy loam; M_c = Merrimac gravelly coarse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