Airphoto Interpretation of Coastal Plain Areas

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THE engineering soil survey of New Jersey by the Joint Highway Research Project at Rutgers University concentrated its early efforts in areas where the parent material of the soil is either residual or glacial. Recently, attention has been directed to the Atlantic Coastal Plain Province. The techniques of airphoto interpretation and their application in this area are herein described. Emphasis is placed on the differences in importance of the various basic principles of airphoto interpretation in the coastal plain as contrasted with those of residual or glaciated areas. Several map units are described and soil test data for each included.

● IN June of 1947, through a cooperative effort by the New Jersey State Highway Department, the Bureau of Public Roads, and Rutgers University, the Joint Highway Research Project was established to conduct research in various engineering problems associated with highways (1). A major phase of this research program is the preparation of engineering soil maps in which the interpretation of aerial photographs is extensively employed (2, 3). The mapping procedure consists of supplementing the wealth of information gained from airphoto interpretation with numerous field observations, the procuring of soil samples, and the testing of these samples in the laboratory for classification purposes. Progress has been satisfactory and at present accurate engineering soil maps are available for 8 of New Jersey's 21 counties, there being maps of five additional counties in various stages of completion.

Essentially, the parent material of the soil in seven of the completed counties is either residual or glacial. This portion of the Appalachian Province has conspicuous land forms (4) and drainage patterns; with numerous soil profile developments of engineering significance. The area is rather typical of other residual and glaciated areas in the United States: highly developed agriculturally with a good network of highways and roads and with ample reference material concerning its geology and soils. Numerous papers have been presented describing the techniques of airphoto interpretation (5) employed in such areas and these techniques were found readily applicable in the Appalachian Province of New Jersey. After completion of the engineering soil mapping in this portion of the state, attention was directed toward Ocean County (Fig. 1), which is located in the Atlantic Coastal Plain Province.

A generalized approach to the preparation of an engineering soil map in coastal regions has been employed in the past. Rapid preliminary investigation of field conditions and study of associated aerial photographs could give the impression that a regorous study of the area is unnecessary. Upon closer examination, significant differences in the engineering characteristics of the soil become evident. An engineer would welcome a guide enabling him to locate expected troublesome soil areas; thus an engineering soil map would be of practical value. This paper was prepared to indicate the difficulties inherent in the application of the techniques of airphoto interpretation, or soil mapping, to the Coastal Plain Province.

DESCRIPTION OF THE AREA

The work used as a basis for this paper was performed in an area midway along the eastern coastline of New Jersey and extending westward for some distance. Ocean County (6), which comprises the major portion of this area, is located in the northeast corner of the outer portion

of the Atlantic Coastal Plain Province. This area, approximately 630 sq. mi., may appropriately be termed a broad, comparatively level to gently undulating plain, rising gradually from sealevel at the east coast to elevations averaging between 100 and 150 ft. further inland.

Geologic references of New Jersey (7, 8, 9) define two major unconsolidated formations of marine origin with practically horizontal bedding (Table 1).

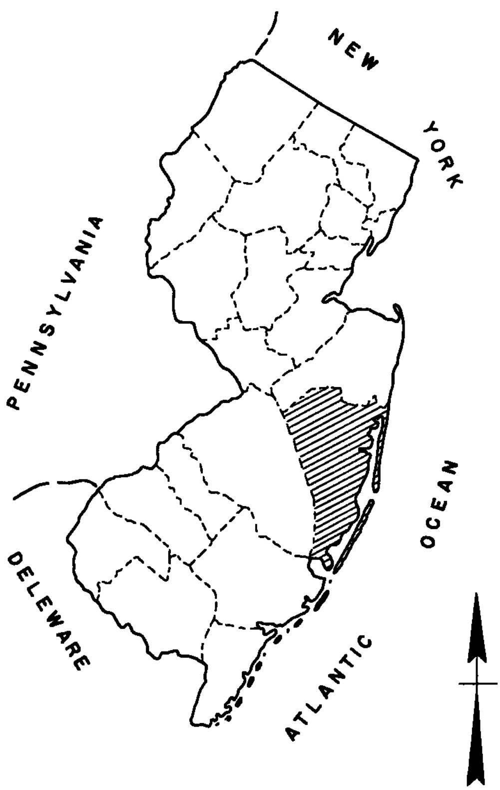

Figure 1. Map of New Jersey. Shaded area is Ocean County.

Overlying both marine formations (Fig. 2) are four additional formations of lesser extent, considered to be either fluvial or fluviomarine in origin.

These latter deposits are usually more granular in texture and occupy the higher positions in the area. The Agricultural Soils Survey of the Chatsworth Area (10) lists two major soil series that are subdivided into many phases, with apparently no direct correlation with any geologic formation (Table 2).

The drainage system serving the area has an interesting nature. Recent earth

TABLE 1

Major Geologic Formations

(Descriptions taken from the Geologic Map of New Jersey)

Kirkwood Sand	- Fine micaceous sands with local beds of dark clay
Cohansey Sand	- Chiefly quartz sand with local beds of clay and gravel
Beacon Hill Gravel	- Quartz gravel, with some chert and sandstone pebbles.
Bridgeton Formation	- Gravel and sand, in part solidified by iron oxide.
Pensauken Formation	- Gravel and sand.
Cape May Formation	- Gravel and sand with some clay.

movements have caused a general "drowning" of the major streams and consequently the water level of the minor estuaries has been raised. Due to the development of this drainage system (Fig. 3), broad tidal marsh areas or swampy conditions can be found adjacent to most of the stream courses.

The native forest, which covers approximately 85 percent of the county, consists primarily of scrubby or stunted oaks and pines. In most poorly drained areas, white cedar predominates. Relatively little agriculture is practiced due to the inherent low fertility of the soils.

If one gains a 20-ft. advantage in elevation above the existing ground surface, a feeling of loneliness and uniformity prevails, for as far as the eye can see there is nothing but a sparsely populated, gently

TABLE 2

Agronomic Soil Series

(Descriptions taken from the Soil Survey of the Chatsworth Area, New Jersey)

Sassafras	Brown or light-brown sandy surface soils, underlain by a reddish-yellow or orange-colored to dull-red, friable loamy sand subsoil. Generally the lower subsoil is coarser-textured than the soil or upper subsoil Usually well drained and easily worked.
Norfolk	Closely associated with the Sassafras Series. Distinguished by their grayish to light-brown sandy loam surface soil and pale-yellow to yellow, friable fine-sand to clayey sand subsoils. Usually good to imperfectly drained.
Scranton	Black sandy loam surface soils, underlain by a pale-yellow sandy clay subsoil, mottled in places with gray. The drainage is imperfect to poor.
Portsmouth	Dark-gray or black loamy surface soils overlying white, gray, or pale-yellow sandy loam to sandy clay subsoils Located in Depressions with the subsoil saturated. Poor to very poor drainage.
Lakewood	White sands overlying orange or orange-yellow sandy subsoils Mostly quartz sand with a low organic matter content Usually excellent to excessively drained.
Leon	White or light-gray sandy surface soils overlying a white fine sandy subsoil The presence of a hardpan-layer in the subsoil is common, with the soil below becoming looser. This series is generally imperfectly drained.
St. Johns	Dark-gray or black sandy surface soils overlying a hardpan-layer which in turn overlies white, gray, or brown sands. Usually occurs in depressed areas with poor drainage.

undulating land surface, covered with forests and practically inaccessible by automobile (Fig. 4).

AIRPHOTO INTERPRETATION

Successful airphoto interpretation, providing an evaluation of the engineering characteristics of soil, can be accomplished when certain basic principles or guides are studied on each set of contact prints. The following are those principles the authors have employed during their experience in the airphoto interpretation of Ocean County, New Jersey, and of other areas in the United States: (1) reference material, (2) land form and specific topographic relationships, (3) drainage patterns, (4) erosional features and gully characteristics, (5) color tone, (6) vegetation, (7) land use, (8) special features, and (9) field and laboratory experience.

Each of the above factors is important, but the factors will vary in relative value from one general physiographic division to another. Due to this variability in importance, each factor will be individually discussed as it applies to Ocean County. By this procedure, it is believed a clearer understanding of airphoto interpretation of coastal plain soils can be obtained.

Figure 2. Granular capping overlying Cohansey sand. Note line of demarkation. Quartz pebbles are evident in the upper layer.

DISCUSSION OF EACH ITEM

Reference Material

Included are the available geologic map, agronomic soil maps, with bulletins accompanying both maps, and several papers and articles dealing with the general nature of the existing natural deposits. The geologic map presents an overall picture of the type of soil materials present but is much too broad in scope for our use. It overlooks numerous areas, small in extent, that are of considerable importance to a soils engineer. Further, the major geologic formations, as mapped, are texturally variable in both plan and profile, much more so than in glacial or residual areas. The agronomic soil maps are more helpful but lack sufficient detailed accuracy for our particular purpose. The relationship between geologic formations and agricultural soil series is not clearly defined as contrasted to existing relationships in other physiographic provinces (Fig. 5).

Texturally, the soils tend to blend from one classification to another rather than

having a sharp delineation. The resultant broad transition zones make the placing of finite soil boundaries rather difficult, but this problem has been partially overcome by adhering to a broader textural grouping in such cases.

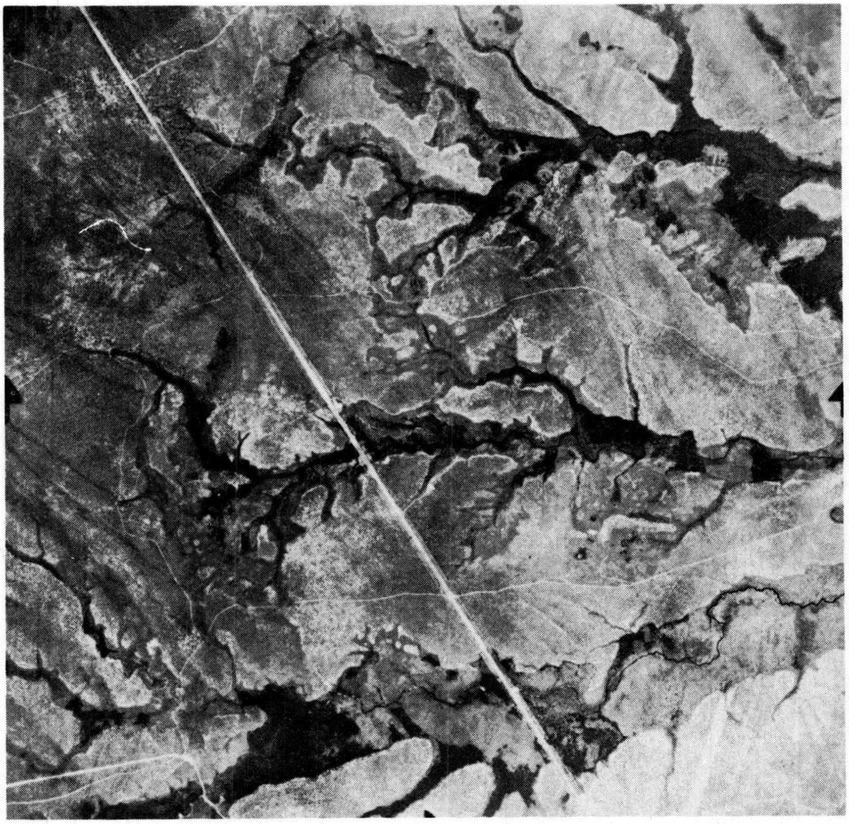

Figure 3. Typical drainage pattern in Ocean County. Wide alluvial channels, numerous tributaries, and poorly-drained areas adjacent to the channels are clearly visible.

Land Form and Specific Topographic Relationships

The major portion of the area is either level or gently undulating with all of the various soil textures partaking of this uniform ground expression. It can safely be stated that definite topographic relationships are absent and land form is of minor value as an aid in interpretation (Fig. 6).

In some areas of limited extent, land form is a determining factor in the mapping. A hummocky or miniature badland effect is prevalent in those soil materials where sand particles are coated with clay (H. R. B. A-2-6 to A-2-7). The "capped" positions, containing appreciable amounts of gravel, and the "outliers" (Fig. 7), which are odd occurrences resulting from a resistant covering of iron-oxide-cemented sand and gravel (Fig. 8), are prominent geomorphic features and thus readily detectable. Broad low-lying silty flats adjacent to the coastal tidal marshes, resulting from fluviomarine activity, are encountered all along the eastern portion of the county and are recognized quite readily on the airphotos.

Land form and specific topographic relationship have proven themselves to be of major importance in the majority of areas where airphoto interpretation has been undertaken. In the coastal plain, they are of minor value.

Drainage Patterns

This is a useful tool but full use could not be enjoyed for several reasons. First, the geologic deposits are relatively young

and much of the drainage has not developed sufficiently for detailed study. In addition, a low stream gradient coupled with the proximity of the ocean results in the backing up of runoff and the development of an unnatural pattern of drainage. Much of the internal drainage system is masked or obliterated by a high ground-water table, with resultant large swampy areas. The differential permeability of the various soil materials has no opportunity to be of significance. Both width and depth of the major streams are rather uniform, due to the overall level topography and low elevation of the area. Surface runoff tends to enlarge stream width (Fig. 9), regardless of soil texture, rather than to cut deep channels.

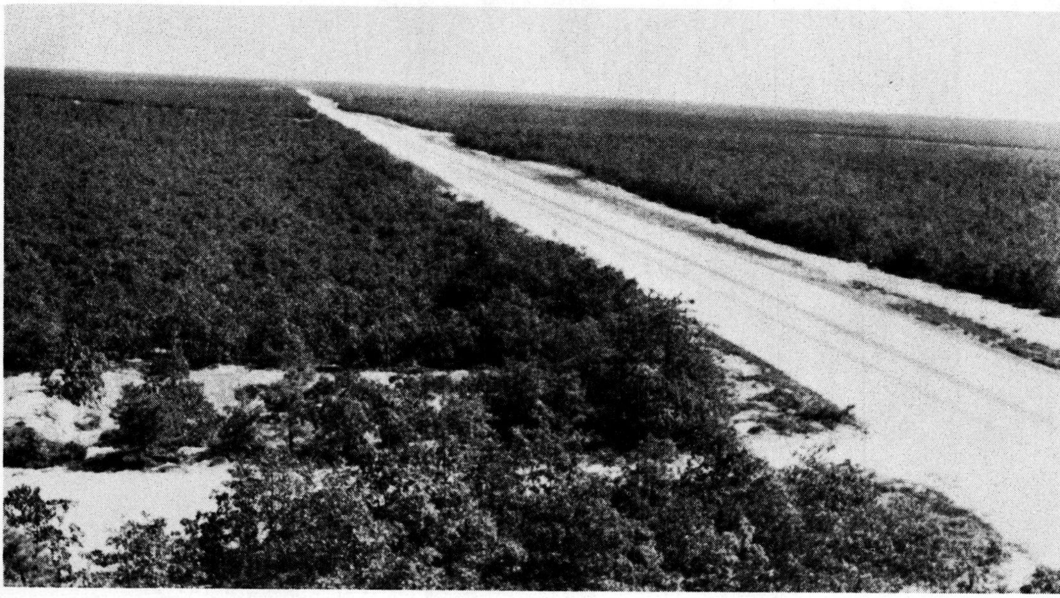

Figure 4. Level land form. View from a fire tower showing pine barrens and lack of ground expression.

In those areas with fair to good drainage potential, the drainage patterns are found to follow the usual occurrence in major soil textures. In the gravel (AASHO Designation: M 145-49 of A-1-a and A-1-b), there is a noticeable lack of surface runoff in definite channels or there are short and stubby tributaries pointing towards the general area of granular materials. In the sand and silty sand, (A-3 and A-2-4), the tributaries are extensive, winding, and smoothly curved with no particular direction in mind. In the siltier soil (A-2-4 to A-4), the dendritic pattern is present. The sand-clay series (A-2-6 to A-2-7), shows a type of amputated drainage pattern (Fig. 10), with short stems of rather uniform direction and length.

This item of consideration, drainage patterns, is especially important when noting the direction of surface flow and the changes in this direction, together with the number of smaller tributaries to any one main artery.

Erosional Features and Gully Characteristics

Due to the overall lack of gradient, the development of these features is negligible and is of minor importance as an aid in interpretation. Certain minor areas do show sufficient development. On granular sandy materials, of raised land form, the V-shaped, short, stubby gullies are quite pronounced (Fig. 11). Along the narrow strip adjacent to the Atlantic Ocean, sand dune development has progressed concurrently with wave and wind action. Unique erosional features, present along forested roads, are wind blowouts. These unforested oval-shaped areas usually occur in sandy (A-3) material.

Color Tone

The pine growth prevalent in the area tends to produce uniform color tones.

Further complications result from the past occurrence of numerous forest fires and a general "hazy" appearance on a number of the photos. Regardless of these obstacles, the item of color tone was of major value in interpretation. Upon comparing separate airphotos, or groups of photos, a preliminary delineation of soils was accomplished. The full value and effective utilization of this guide was attained by stereoscopic study of minute tone differences and alterations of the various shades.

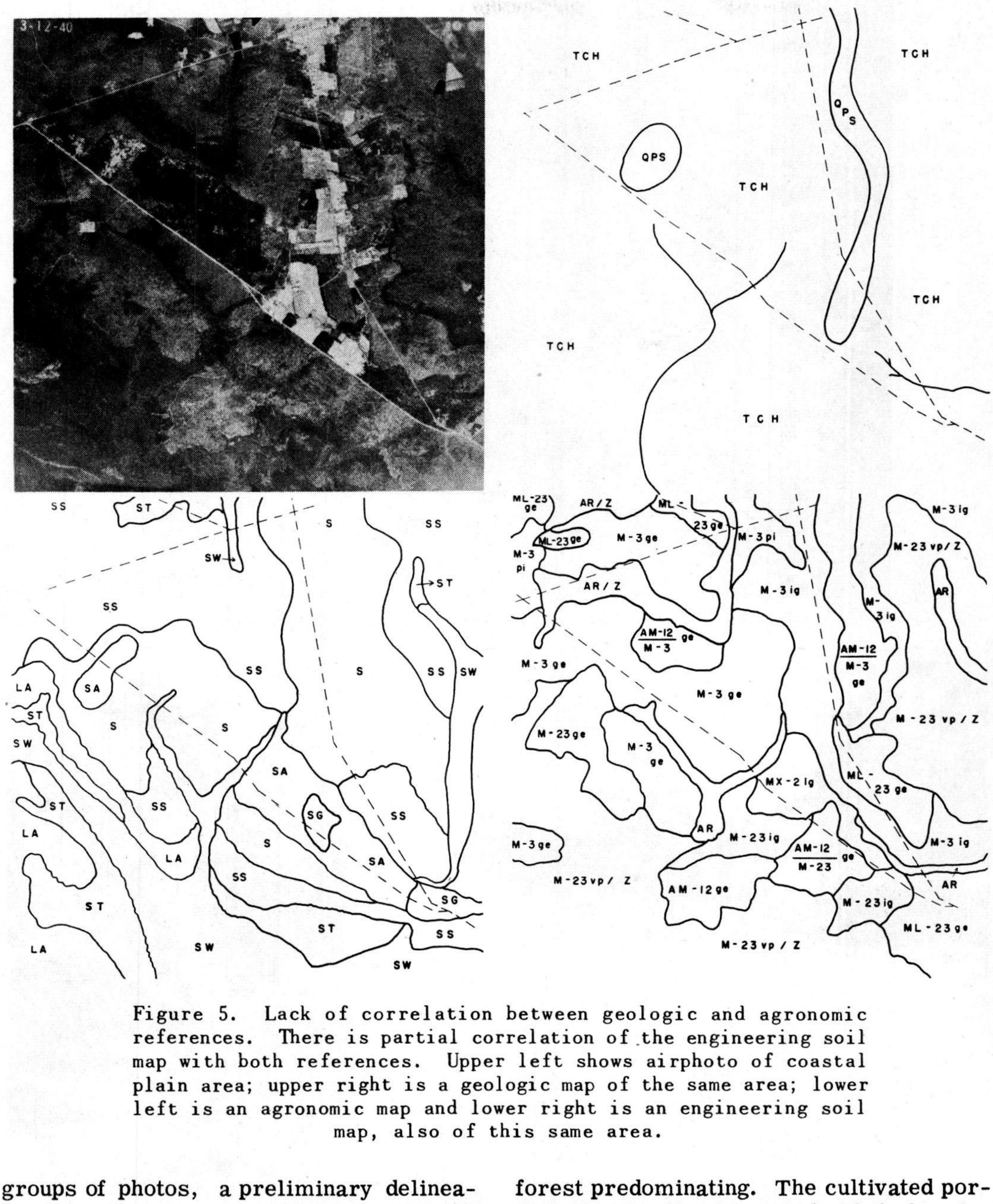

Figure 5. Lack of correlation between geologic and agronomic references. There is partial correlation of the engineering soil map with both references. Upper left shows airphoto of coastal plain area; upper right is a geologic map of the same area; lower left is an agronomic map and lower right is an engineering soil map, also of this same area.

Vegetation

Approximately 85 to 90 percent of the area is uncultivated, with pine and oak forest predominating. The cultivated portions are usually associated with the heavier soil textures (A-2-4 to A-4); but many of the farms are located in poorly drained

areas, where an available source of moisture is the prime consideration, rather than because of heavier soil textures. The pine barrens of New Jersey (Fig. 13) cover many acres of Ocean County and consist of a stunted growth of pine trees about 2 to 4 ft. tall. By giving particular attention to the distribution and density of these

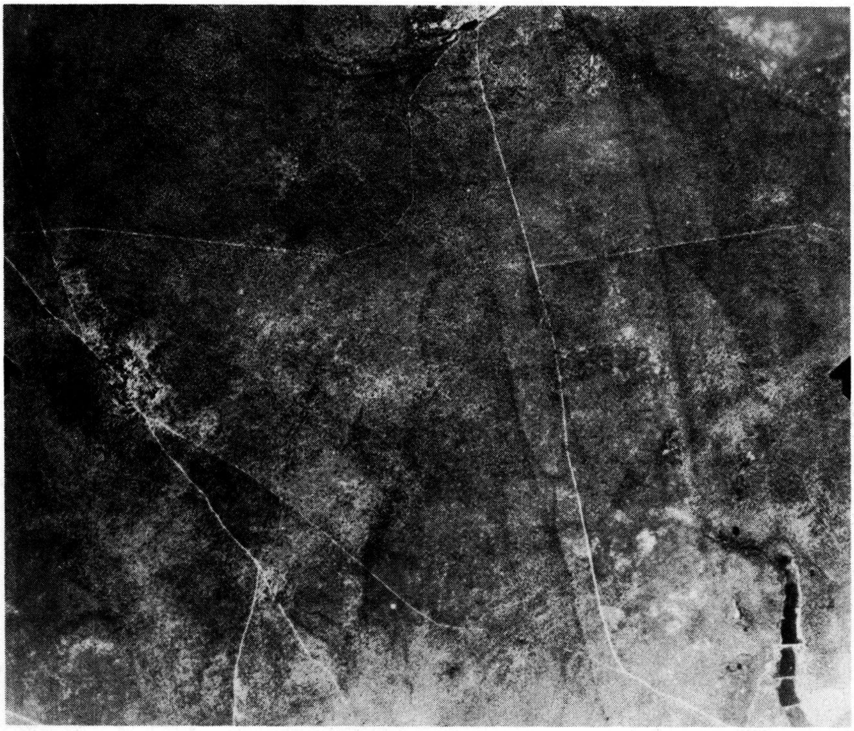

Figure 6. Airphoto stressing absence of land form.

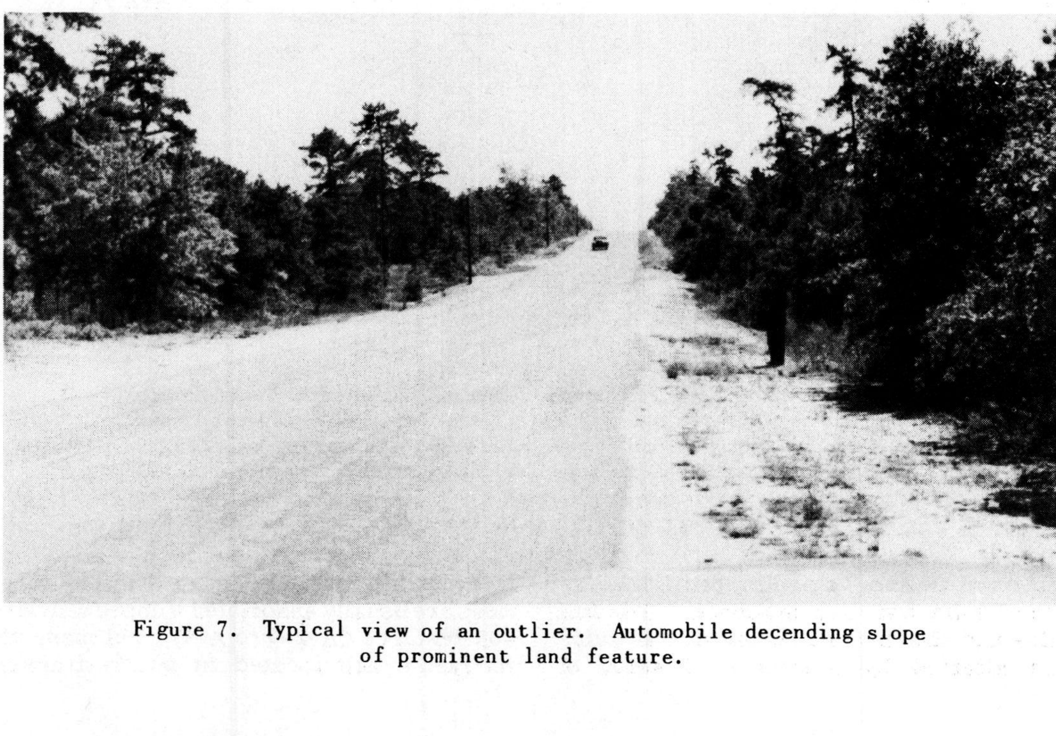

Figure 7. Typical view of an outlier. Automobile decending slope of prominent land feature.

timbered lands, one may obtain a fair idea of soil texture. Interrelated with vegetation is color tone; the one is the direct result of the other. The cedar swamps and poorly drained depressions are always darker due to a thick growth of moisture-loving trees and bushes. Like color tone, the vegetation is helpful, but only when considerable attention is given the minute details.

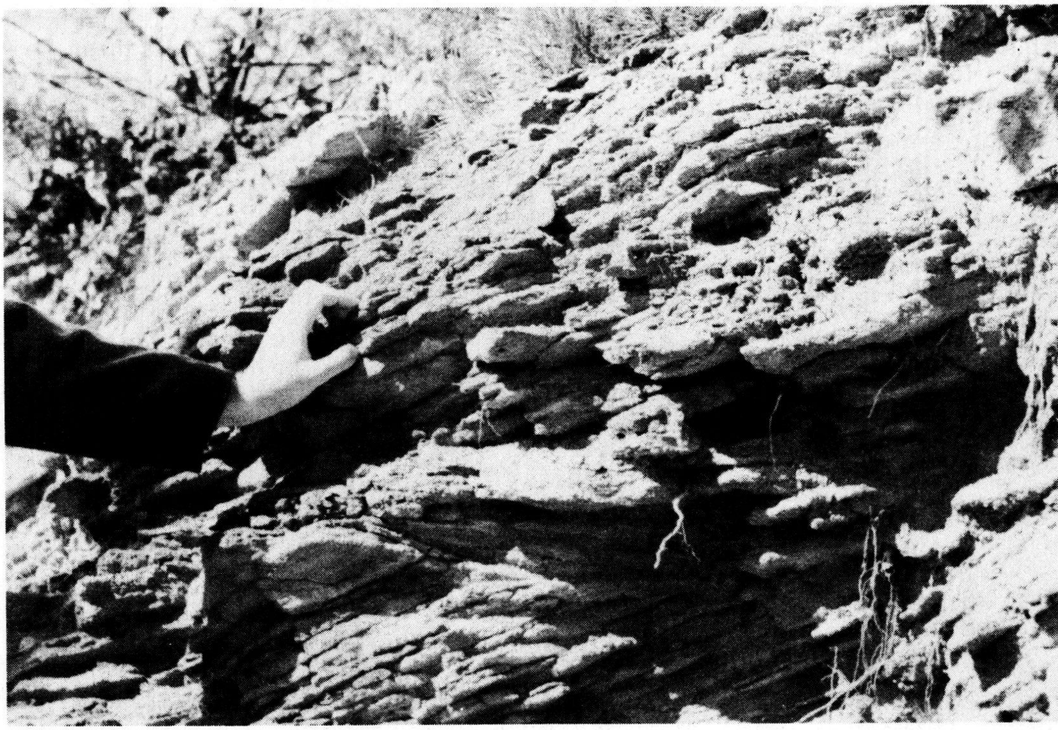

Figure 8. Iron-cemented sand and gravel. Bedded cementation has been encountered at depth in excess of 10 ft.

Figure 9. Narrow stream meandering in a wide alluvial channel.

Land Use

This guide is of little value as an aid in airphoto interpretation because of limited agricultural development. Although small in number, road cuts, gravel, sand, and clay pits give vivid clues as to the nature of the occurring deposits. An interesting item is the orderly layout (square sided and following a geometrical pattern) of the many cranberry and blueberry farms or bogs (Fig. 14), usually situated in a wide alluvial area.

Figure 10. Typical amputated drainage pattern. Clearly defined edges of streams, with stubby appearance of minor tributaries. In upper left-hand corner, noticeable lack of any surface runoff pattern.

Special Features

There are two prominant features; with one serving as an aid in interpretation and the other adding confusion due to our inability to explain the phenomenon. Those sandy soils (A-2-4 and A-3), that are uniform in grain size do not attain high densities and remain loose and unstable. Many miles of roadway throughout the county consist of the original in-place soil. Where the soil is of this sandy, uniform texture, it ruts easily and many bypasses (Fig. 15) and short alternate routes are continually being made by passing vehicles. This feature is evident on the airphotos, and the identification of the existing soil is readily accomplished.

The unexplainable feature is the occurrence of long lines (Fig. 16) seemingly radiating from a common center. Numerous groups of such lines, at times miles in length, extend over a considerable area with no apparent regard to topography, drainage, or any other natural feature. This strange pattern poses a definite challenge to one interested in further research.

Field and Laboratory Experience

Both field and laboratory knowledge concerning the soils of the area are indispensable. During field inspection, the airphotos were constantly referred to, and this association proved itself well worthwhile during subsequent airphoto map-

ping. The correlation of field experience with laboratory test results of soil samples secured was made all the easier due to our direct association with the material during testing.

TYPICAL ENGINEERING MAP UNITS

The map unit system (13) employed in Ocean County is based on that previously numbers, and corresponding to a narrow range in materials in the AASHO Designation: M 145-49 (formerly known as the H. R. B. classification), such as: 12, referring to granular material with textures ranging from classification of A-1 to A-2; or 3, signifying predominantly A-3 material. Finally, there are two lower case letters designating approximate depth to

Figure 11. V-shaped gully development in an outlier. Severely dissected outlier parallels a stream. This outlier consists of granular material.

used in engineering soil mapping in New Jersey. A capital letter is first used to designate the origin of the parent material, e. g. , "A", referring to alluvial, and "M", referring to marine. This is followed by a second capital letter, when necessary, to describe the general land form: "AM," alluvial mantle, "MB," marine beach; and "M" alone, no significant land form present (level areas). A textural designation follows, usually consisting of one or two ground-water table: ge, good to excellent drainage, with ground-water table 6 ft. or more in depth; ig, imperfect to good drainage, with ground-water table from 3 to 10 ft. in depth. The following map units are examples of those resulting from the use of this system: AM-12 ge, M-3 ig, and MX-2 ig. These three map units will be described and a summary of laboratory test results (Table 3) of samples taken in each area will follow.

AM-12 ge

Alluvial deposition, composed of non-residual, stratified materials deposited during the Quaternary and Tertiary periods and identified as primarily either the Cape May, Pensauken, or Bridgeton formations.

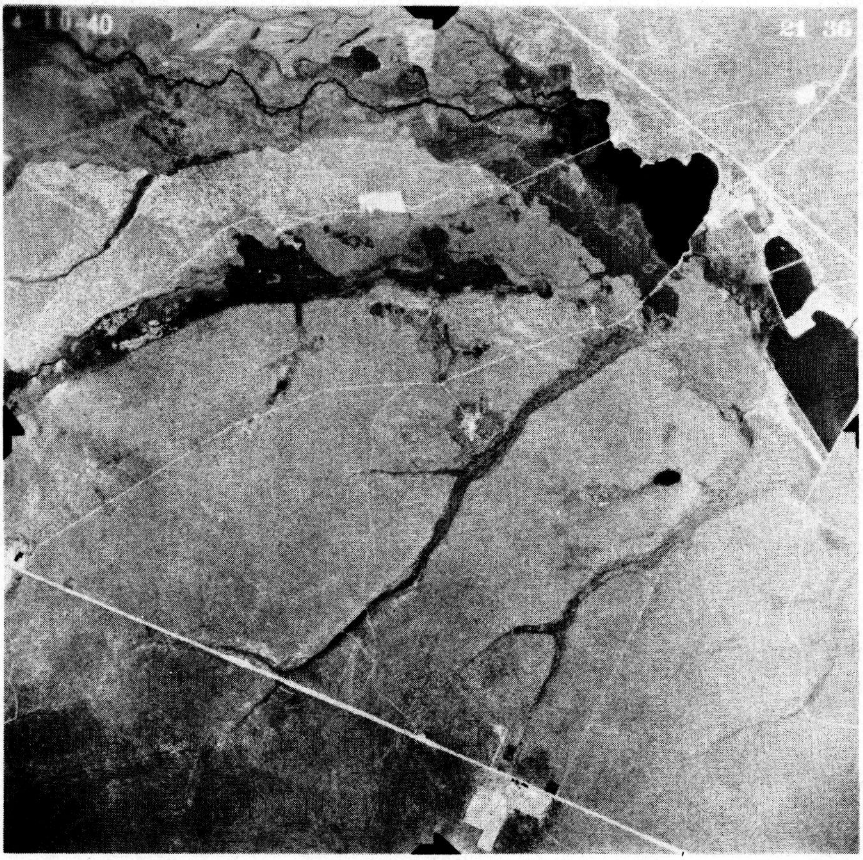

Figure 12. Example of tone contrast. Darker alluvial channel separates silty-sand area in lower portion of photo from a more granular area in upper portion. Cedar growth evident in poorly drained areas.

The material usually appears as reworked remnants of old alluvial mantles of rather complicated origin. It usually occupies the slightly elevated positions or higher river terraces. Assorted, relatively homogeneous, it is composed primarily of quartz gravel and sand with occasional large quantities of weathered chert. The depth to the underlying formation is variable, ranging from a thick, extensive deposit to a thin local capping on some of the smaller hills.

A significant engineering soil profile contrast is lacking and the map unit is generally correlated with certain types of the Sassafras and Lakewood Agronomic Soil Series. Predominantly coarse textures prevail with AASHO designations including A-1-a, A-1-b, and A-2-4.

This material is well drained, due to its slightly elevated position and its granular nature. The ground-water table is usually below 10 ft. and few drainage paths occur in the area.

Highway alignment problems will be at a minimum with cuts and fills usually not exceeding 6 ft. This is an excellent material both for use in embankments and as a source of borrow. Pavement support will be exceptionally good.

M-3 ig

Marine sediments composed of un-

consolidated, stratified materials deposited during the Tertiary period and identified as either the Kirkwood sand or Cohansey sand formations.

No prominent land form is associated with this map unit. It is usually found in areas of extremely level to undulating ground surfaces. The material is composed of assorted, homogeneous, quartz

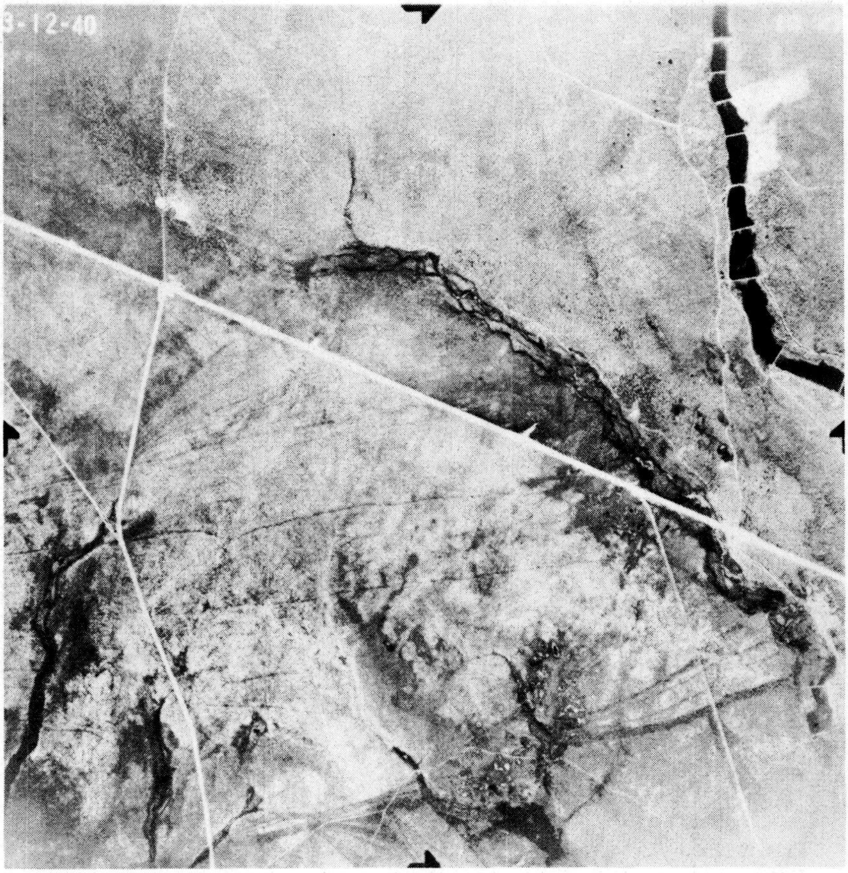

Figure 13. Contact between normal pine growth and stunted pine barrens. Major highway through center of photograph separates these two types of vegetation.

sand with the northern section becoming exceedingly micaceous.

Irregularities, such as 1- to 3-in. lenses of clay, seams of gravel, and pockets of clayey sand or clayey gravel, are present but generally they are local in nature.

There is a pronounced pedologic (14) soil profile development associated with this map unit. It is an excellent example of a podsol with as much as 2 ft. of leached topsoil present, correlated with certain types of the Lakewood, Sassafras, Leon, Norfolk, and St. Johns Agronomic Soil Series. This profile development is not of engineering significance for classifications of A-3 predominate throughout the various horizons. The soil is primarily a medium to coarse sand, extremely loose and permeable, with a minimum of fines.

The overall levelness of the ground surface and low sealevel elevations associated with this map unit results in a variable depth to ground-water table. Most often an imperfect to good (ig) designation best describes prevailing conditions. However, at lower elevations of even a few feet, the depth to the ground-water table will noticeably decrease.

There will be no engineering problems associated with alignment, cuts, or fills due to the level nature of the ground sur-

face. However, for use in embankment construction or as a source of borrow material, this soil presents a problem. Due to its uniform grain size, there will be difficulties experienced in compacting this soil; consequently low densities will prevail.

Figure 14. Cranberry farms. The orderly arrangement of these farms gives very distinct pattern evident in upper portion of photo. This area is poorly drained and system of dikes is in operation to control water supply.

<u>MX-2 ig</u>

Primarily marine deposition, composed of unconsolidated, stratified materials deposited during the Tertiary period and usually correlated with the Cohansey sand formation.

The overall land form appears dissected and hummocky, but large level areas do occur. The letter "X" in the map unit signifies that a variable condition is present in the area. It refers to the erratic manner in which soil textures outcrop and to their variable aerial extent. The material is a sand or gravel but in addition contains varying amounts of clay. Usually there is enough clay content to affect the soil classification, becoming A-2-6 and A-2-7 for some depth.

Soil profile development, while technically present, is mostly obscured by stratification. The typical profile consists of 2 or 3 ft. of intermixed sand and gravel (A-2-4 or A-1-b), overlying either clayey sand or clayey gravel (A-2-6 or A-2-7). This map unit is associated with certain types of the Lakewood, Norfolk, and Sassafras Agronomic Soil Series.

The drainage symbol usually employed in MX-2 areas is "ig," imperfect to good, but due to the variable nature of the land form, all types of drainage are encountered.

Except in the more hummocky areas,

TABLE 3

Representative Soil-Test Data

Map Unit	Agronomic Name and Slope	Horizon	Depth to Bottom Inches	Test Results: Sieve Analysis, Cumulative Percent Passing ¾	4	10	40	200	Hyd. Anal. Silt %	Clay %	Physical L. L. %	P. I. %	Proctor Max. D. p. c. f.	Opt. M. C. %	H. R. B. Designation Sub-Grade Group	Group Index
AM-12 ge	Sassafras 0-1°	A	8	98	82	77	50	27	*	*	26	5	*	*	A-2-4	0
		B	34	96	89	71	29	11	*	*	16	3	*	*	A-1-b	0
		C	108	94	80	61	15	6	*	*	16	5	121	10	A-1-b	0
		-	180H	86	30	22	9	1	*	*	NL	NP	119	13	A-1-a	0
AM-12 ge	Sassafras 0°	A	6	*	*	*	*	*	*	*	*	*	*	*	*	*
		B	36	98	71	62	27	8	*	*	NL	NP	*	*	A-1-b	0
		C	72	97	53	44	23	4	*	*	NL	NP	*	*	A-1-a	0
		-	120H	99	62	43	18	1	*	*	NL	NP	*	*	A-1-a	0
M-3 ig	Lakewood 0°	A	16	100	100	96	58	4	*	*	NL	NP	*	*	A-3	0
		B	24	100	100	94	51	5	*	*	NL	NP	114	10	A-3	0
		C	46H	100	97	85	51	4	*	*	NL	NP	117	10	A-3	0
M-3 ig	St. Johns 1°	A_1	3	*	*	*	*	*	*	*	*	*	*	*	*	*
		A_2	25	100	100	100	75	7	*	*	NL	NP	*	*	A-3	0
		B	38	100	100	100	71	4	*	*	NL	NP	109	13	A-3	0
		C	54H	100	100	100	73	7	*	*	NL	NP	112	11	A-3	0
MX-2 ig	Lakewood 2-3°	A	8	100	99	98	83	7	*	*	NL	NP	*	*	A-3	0
		B	34	100	93	77	31	6	*	*	NL	NP	123	11	A-1-b	0
		C	43	100	96	82	43	16	1	16	30	12	126	10	A-2-6	1
		-	45	*	*	*	*	*	*	*	*	*	*	*	*	*
		-	64H	100	100	100	61	22	1	22	30	13	118	14	A-2-6	1
MX-2 ig	Sassafras 0°	A	4	100	99	95	74	47	*	*	40	10	*	*	A-4	1
		B	12	99	86	70	41	18	*	*	18	4	*	*	A-1-b	0
		C	30	99	93	78	49	12	*	*	NL	NP	*	*	A-1-b	0
		-	60H	100	99	97	63	21	*	*	28	12	*	*	A-2-6	1

* Values usually unnecessary.
H Depth to bottom of hole.
NL Non-liquid; sample not susceptible to liquid limit test procedure.
NP Non-plastic; plasticity index zero or cannot be determined.

Figure 15. A bypass and rutting on forest road. This rutted sandy soil in left hand portion of photograph will discourage further traffic. Automobile is leaving newly formed bypass at right.

road alignment can proceed in all directions. The maximum height of cuts and fills is approximately 6 to 8 ft. For use in embankments, as a source of borrow, and as pavement support, it is largely a matter of field inspection by a soils engineer to determine its suitability. In areas containing appreciable amounts of clayey material, caution should be exercised.

Figure 16. Long radial lines. The dark streaks prominent throughout, especially noticeable in upper-right corner. Lines continue irrespective of existing topography and alluvial channels.

This map unit outlines areas in which clayey sand and clayey gravel are most apt to be encountered. This material is very erratic both in depth and aerial extent, and it is difficult to interpret the exact boundaries. This is a generalized map unit and should be treated as such.

CONCLUSION

Application of the previously outlined airphoto interpreting guides in the coastal plain differs sharply from that in a residual or glaciated area. In the coastal plain, emphasis must be placed on tone differences, drainage patterns, and vegetative cover, while in residual and glaciated areas, land form, erosion, and gully characteristics should usually be given first consideration. The stressing of these guides, heretofore considered as of secondary importance, may seem to complicate further the task of interpretation. Nevertheless, by strict adherence to a study of all the guides, it is possible to interpret the soil conditions present and to produce an engineering soil map of considerable detail in a coastal-plain area.

Such a map as that prepared for Ocean County, contains more than a dozen soil classifications, or as designated, "map-units." In an area with this number of significantly different soil units, a high-

way engineer could make good use of a guide or map delineating the existing soil boundaries. The time, energy, and money expended in the development of such a helpful instrument would be worthwhile.

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EDWARD A. HENDERSON, Soils Engineer, New Jersey Highway Authority — The authors have presented in the paper a worthwhile contribution to the science of preparing engineering soil maps by airphoto interpretation.

The outer Atlantic Coastal Plain area, in New Jersey is commonly considered locally as being all sand. The authors have shown that significant differences of soil types do exist and complete engineering soil maps of the area will be of use to highway engineers in delineating the different areas.

One specific thing of special interest is contained in Figure 5 of the paper. The geologic map shows areas designated Qps — Pennsauken Formation. It is known that this formation is one of the sources of the so-called South Jersey gravel. To locate the gravel deposits in the flat wooded terrain using the available small-scale geologic maps is next to impossible. Furthermore, the geologic map gives no indication of the thickness of the gravel deposits. In Figure 5 of the paper, the sources of gravel are shown on the engineering soil map by the general map unit AM (Alluvial mantle). These areas are shown in more detail than on the geologic maps, and the finished engineering soil maps will be on a fairly large scale. In areas mapped as AM, a relatively thick

gravel deposit can be expected; whereas in areas mapped $\frac{AM}{M}$, only a relatively shallow gravel layer underlain by sand can be expected. The presently known sources of gravel in this area are being rapidly depleted and the engineering soil maps will furnish a tool for use in a systematic method of locating new sources.

As pointed out by the authors, the Joint Highway Research Project at Rutgers University is preparing individual engineering soil maps and reports of each of the 21 counties in New Jersey. The importance of making available these maps is recognized by the cooperating agencies, inasmuch as other research activities have been subordinated until completion of this task. The general techniques used in developing the maps and reports are as described in this paper.

The above-mentioned engineering soil maps and reports have been used to a considerable extent in New Jersey in connection with highway location and design. Borings and soil sampling along highway alignments have shown that the delineation of soil types is remarkably accurate. The following are major ways in which the engineering soil maps have been used:

1. Area Familiarization. A study of the maps and a reconnaissance in the field using the map as a guide at the beginning of a soil survey gives a good concept of soil conditions. This is important in planning all future phases of soil studies and is something that would normally not be achieved until the completion of a survey based only on borings, soil sampling, and testing.

2. Alignment and Profile Selection. The maps furnish sufficient soils information for all preliminary selection with the exception of major stream and swamp crossings. Where several alignments are being considered, the soil or foundation problems of each are evaluated and used in determining final selection. At major stream and swamp crossings borings are necessary to determine depth to adequate bearing strata.

3. Establishing Boring Programs. The maps and reports enable the setting up of a program of borings, sampling and testing concentrated in areas where specific problems exist. The soil surveys are always made to secure certain information such as the presence of rock and ground water, type of subgrade soil, etc. To make borings at definite intervals along an alignment to determine this information is costly and time consuming and unless the interval between borings is small, critical areas may be missed. With the advance knowledge available as to general soil conditions, the soil survey can be made with assurance that the detailed information needed will be obtained at a minimum cost and, more important, that it will be obtained in time for its use in the early stages of highway design.

4. Pavement Design. The present practice of various large organizations is to consider some test value of the subgrade soils as one factor in arriving at a pavement thickness. The time, money, or facilities are not normally available to smaller organizations for the purpose of making a comprehensive study of soil values and applying it to pavement design. However, within given areas, local engineers can determine the design and performance of existing pavements. Having the soil maps of the area, the performance of pavement types and thicknesses can be correlated with soil areas. From this a pavement can be selected based on a consideration of the important element of soil conditions. Those sponsoring the making of engineering soil maps of New Jersey hope for great use of the maps in this manner.

The engineering soil maps and reports published by the Joint Highway Research Project at Rutgers University were recently used by the New Jersey Highway Authority in establishing flexible-pavement thicknesses for the Garden State Parkway, now under construction. This parkway will run in a general north-south direction for the length of the state. In the complex soil areas of Middlesex and Monmouth counties, finished maps were not available, but a strip map was prepared by the Joint Highway Research Project for the use of the New Jersey Highway Authority.

The Garden State Parkway alignment was found to traverse a glaciated area, the inner Atlantic Coastal Plain area (many clay soils) and the outer Atlantic Coastal Plain area (sandy soils). In each of these areas a definite flexible pavement thickness (surface, base and subbase) was established for the entire length of the area. Within an area, variable thicknesses up to 24 in. of selected borrow beneath the subbase were established for clay soil por-

tions. Up to this point, all soil conditions considered for pavement design were based on the Rutgers maps and reports. In critical areas, a limited number of borings were made and the thickness of selected borrow modified in some cases. Some further modifications in thickness and extent of the selected borrow only are anticipated during construction to meet field conditions.

For the pavement design of a toll facility of the magnitude of the Garden State Parkway, where time is of the utmost importance, the use of the available engineering soil maps was of great value. Time was definitely not available to make an extensive soil survey by borings, sampling and testing.