Preparation of Engineering Soils and Drainage Survey Strip Maps from Aerial Photographs

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ABSTRACT

This paper reports the procedure for preparing engineering soil and drainage strip maps of proposed highways from aerial photographs. These maps are prepared from uncorrected aerial photographs at a scale of approximately three inches to the mile. An approximate scale is used, since ground control in conjunction with rectified airphotos would greatly increase the cost of preparing the strip maps.

The use of aerial photographs as an aid in highway engineering is rapidly increasing. Since many preliminary location surveys are made from airphotos, the advantage of identifying the soil and locating drainage structures from these same airphotos would greatly reduce the cost of preliminary surveys because objectionable sites could be avoided.

Strip maps of a highway location showing areal extent of soils and the probable profile development would benefit soils engineers in planning soil surveys and securing representative samples. These strip maps can be prepared economically from aerial photographs that are available at a nominal cost throughout the United States.

INTRODUCTION

The object of a soil and drainage survey of a proposed highway is to obtain information on soil conditions and watershed areas of drainage systems as they exist in the field so that a highway can be located and designed economically. There are several sources of information available to the engineer for a preliminary analysis of an area where a highway is proposed. In most instances, the information is of a specialized nature which was prepared for other than engineering purposes.
In some areas of Indiana, there are excellent geological maps available; but, since the geologist is interested mainly in the age, origin, and mineral composition of bedrock within an area, the information pertinent to surface and subsurface soils is somewhat lacking. To make effective use of geological maps, the engineer must be well versed in geological terminology, and the weathering of residual and transported materials together with their corresponding engineering significance.

Other maps that are of value to the engineer in obtaining a "picture" of soil conditions are those prepared by the United States Department of Agriculture in cooperation with various state agricultural experiment stations. These county soil surveys are excellent references in ascertaining the crop potentialities of a particular soil; but, to ascertain engineering significance of the special soil names—such as: Crosby, Brookston, and other members of a particular soil family—the engineer must have a special background in interpreting the classification of soils as used by the agriculturalist. Several states, including Indiana, have correlated engineering information with pedological units used in agricultural soil maps (2)*. The proficient use of such correlations in grouping the pedological units into soil groups with similar engineering significance aids in producing an accurate engineering soils map.

In Indiana, agricultural soil surveys and geological surveys are not available for all counties, and a method of mapping of soils and drainage from aerial photographs has been under investigation by the Joint Highway Research Project since about 1941. An extensive program of mapping engineering soils and drainage of the state on a county basis is currently in progress. The status of these programs is illustrated in Figures 1 and 2.

In the identification of soils from aerial photographs, certain characteristics of the soil are evident on the airphotos. Interpretation is based on the fact that patterns (materials) are repetitive in nature; that is, two materials derived from the same parent material at different locations but under similar conditions of age, topography, and climate will produce similar soils. (9).

The characteristics of a soil material shown on an aerial photograph collectively form the "pattern"; individually they are known as the "airphoto pattern elements" (1). Briefly, these elements are: landform, slope, vegetation, drainage pattern, gully cross-section and gradient, and photographic gray tones (1). Other elements of the airphoto pattern are: land use, field patterns, erosion control, engineering practice, and others of special significance to a particular soil type. Each

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* Numbers in parentheses refer to bibliography.
element seldom can be used alone in the identification of soils but when combined they produce an airphoto pattern that is characteristic of a particular soil, and an accurate prediction of the texture of the soil can be made. Detailed discussions of the airphoto method of soil and drainage analysis have been presented to the Road School on previous occasions, and the reader is referred to the various Road School
Figure 2. Status of engineering soils mapping program from aerial photographs.

Proceedings and miscellaneous publications (5, 6, 8, and 9) for a more thorough analysis than presented here.

Engineers of the state highway commission of Indiana requested the staff of the Joint Highway Research Project to develop procedures for preparing preliminary engineering soils and drainage strip maps.
from aerial photographs. Plans of several highway locations were fur­nished by the Commission, and these were used as a basis for develop­ing the strip maps from uncorrected aerial photographs of a scale of 1:20,000.

The purpose of this paper is to illustrate the application of the airphoto method to preliminary engineering soils and drainage surveys of proposed highways. The procedure that was used in preparing the survey strip maps will be presented, and the results of the several sur­veys that have been completed will be reported.

PREPARATION OF DRAINAGE STRIP MAP

The procedure for preparing a drainage survey strip map may be outlined as follows:

1. Assemble an airphoto mosaic and mark the section corners.
2. Conduct a detailed stereoscopic examination and mark the drain­age of all watersheds between terminal points of the highway location.
3. Transfer the drainage lines from the airphotos to a paper base map.
4. Trace the paper base map on the final cloth map.
5. Indicate all federal, state and county roads on the cloth map.

The methods of assembling the airphoto mosaic, marking of section corners, and marking of gully systems on the airphotos are similiar to methods described by Parvis (11, 12). A discussion of the methods will not be presented in this paper.

The drainage information marked on the airphotos is traced directly on a paper base map drawn to an approximate scale of three inches equal one mile. Section corners marked on the airphotos are used as control points. Since accurate ground control in conjunction with the airphotos is needed to make exact maps, the maps are now made to an approximate scale only. The use of ground control would greatly increase the cost of producing the strip maps. At times, some error is involved by assuming that all sections are exactly three inches square on the airphotos, but the error will be small if corrections are made by proportioning the section on the airphoto to the corresponding sec­tion on the paper base map.

In transferring the drainage information, the gully systems are traced directly from the airphotos to the base map. Only those sections near the center of the photograph are transferred as distortion increases with distance from the center of the photograph. Since overlap between alternate prints is approximately 20 per cent in the vertical direction,
LEGEND

CITIES AND INCORPORATED TOWNS

UNINCORPORATED CITY ADDITIONS

STATE CAPITAL

COUNTY SEATS

OTHER TOWNS AND VILLAGES

U.S. AND STATE HIGHWAYS

PAVED HIGHWAYS

BITUMINOUS ROADS

COUNTY ROADS

STATE LINE

COUNTY LINE

CONGRESSIONAL TOWNSHIP CORNERS

SECTION LINES

TOWNSHIP LINES

APPROXIMATE ELEVATIONS

MAJOR STREAMS

PERENNIAL STREAMS

INTERMITTENT DRAINAGE WAYS

LAKES AND PONDS

Figure 3. Legend that accompanies drainage strip maps.
only about two square miles of a possible six are transferred from a 7"x9" airphoto print.

The paper base map is then traced directly onto the final cloth map. All federal, state, and county roads are indicated with appropriate symbols as shown in Figure 3. This is done as a convenience for the

**Figure 4.** Illustration of detailed drainage strip map of highway location in Marion County, Indiana.
field parties so that they may orientate themselves when making field checks of drainage systems and soil borders.

When detailed county drainage maps are available (see Figure 1), the area surveyed is approximately one mile wide on each side of the highway location. For example, Figure 4, shows the completed drainage strip map of proposed State Road 100. Small watershed areas can be computed from this strip map, but it is necessary to use the Marion County drainage map for the study of large systems. If detailed county drainage maps are not available, a much larger area must be presented on the drainage strip map. This map must contain all watersheds that affect the highway, although the entire drainage system need not be transferred if a large drainage system crosses the highway, as it may

Figure 5. Illustration of completed drainage strip map of a highway location. the dotted lines outline watersheds. Areas may be computed by planimetering.
be computed from the airphoto mosaic. In a study of a road in Gibson County the county drainage map was not available and a survey of approximately 2½ miles on each side of the highway was made (see Figure 5).

The dotted lines on Figure 5 outline the watershed areas that are applicable to the design of drainage structures required for the project. Only about a third of West Fork Pigeon Creek watershed was transferred, but the area which was computed from the airphoto mosaic measured 13,195 acres. Some time could have been saved in transferring if only those areas adjacent to the highway were needed; but, if a change in location should be forthcoming, the larger areas would be applicable.

In areas where drainage systems are undeveloped or almost lacking, the drainage strip map has been combined with the engineering soils strip map; however, this has been found to be unsatisfactory in the presentation of both drainage information and soils information. Therefore, the practice is not recommended. Some of the illustrations in this report show the ineffectiveness of the combined maps (see Figures 8 and 11).

**Preparation of Soils Strip Map**

The procedure for preparing a soil survey strip map may be outlined as follows:

1. Review literature.
2. Mark general soil borders on airphoto mosaic.
3. Conduct a detailed stereoscopic examination and mark soil borders of an area approximately one mile wide on each side of the proposed location.
4. Transfer the soil borders from the airphotos onto a paper base map.
5. Trace the paper base map on the final cloth map.
6. Indicate typical soil profiles that may be encountered within a soil area.

The first step in the investigation of any given site is the gathering and study of available information on surface and subsurface conditions, and an investigation of the performance of other highways in the vicinity of the proposed project. The available information may take the form of geological surveys, agricultural soil surveys or combinations of both. Studies prepared from aerial photographs listed in the bibliography are of special value since pavement performance has been correlated with soil or rock types identified by the airphoto method. These
studies are also advantageous in obtaining familiarity with the airphoto technique. The important element of a literature survey is the development of an understanding of the factors which produced that particular soil or rock and an idea of the behavior of the material in its natural state.

When an understanding is obtained of the mode of formation of the material within an area, the interpreter may then proceed to mark on the mosaic the general soil borders. To obtain a complete picture,

**Figure 6.** Illustration of an airphoto mosaic of Laporte County, Indiana, showing general engineering soil borders. A detailed stereoscopic study is made of the enclosed area of the mosaic.
the mosaic should cover a relatively large area. The general soil borders usually outline the major landform units, and most of these units can be separated without extensive stereoscopic study. Where particular airphoto pattern elements are easily discernible, a brief stereoscopic examination may be sufficient to determine the soil texture represented by the identified landform. Figure 6 is an illustration of general soil borders marked on an airphoto mosaic consisting of approximately half the southern part of Laporte County, Indiana. Here the general soil borders outline the landform units of outwash plain, lakebed, muck depressions, organic-sand-outwash plain, and alluvial valley. This overall view is essential for the stereoscopic study that is made of the enclosed area shown in the figure.

The detailed stereoscopic examination is made to refine as much as possible the general soil borders and to determine all variations within each soil area where problems will be encountered. In this examination, each airphoto pattern element must be thoroughly analyzed so that an accurate prediction of soil texture can be made. Often the accurate determination may not be made directly from the airphotos, but the questionable area may be outlined and indicated so that the field party may investigate the site in the field. Figure 7 illustrates the northern portion of the enclosed area shown in Figure 6. This illustration shows refinements in soil borders in the outwash and muck areas, and the addition of several flat areas of sand within the organic sand outwash. Notice the contrast in photographic gray tones between the muck, organic sand outwash, and outwash. The area surveyed is one mile wide on each side of a proposed highway. This width provides the engineer with a broad picture of the soils adjacent to the highway in case a change in location should be proposed.

Steps four and five of the procedure are similar to the steps presented in the section on drainage. The same scale of base map and cloth map is used, and the method of transferring by land sections is employed. Soil symbols used on the soil strip maps are intended to show the mode of formation, drainage conditions, and soil texture. For example, horizontal lines indicate poorly-drained materials, and dots or small circles indicate well-drained sands or gravels.

The final step in the preparation of a preliminary soils strip map is to prepare the typical soil profiles that may be encountered within a particular soil area (2, 16). The use of soil profiles gives a three-dimensional view of a soil area. The most effective method of presenting the typical soil profiles is by illustrating the profile directly on the strip map with the corresponding profile number indicated within
A portion of Figure 6. This strip, one mile wide on each side of the proposed highway, is studied in detail with the aid of a stereoscope; all soil areas where a change in material or engineering problem is presented are outlined. The distance between the heavy crosses is approximately one mile.
a soil area where such development can be expected. Figure 8 illustrates the completed highway strip map prepared from the airphotos shown in Figures 6 and 7. In this instance, a combination drainage strip map and soil strip map is presented. This area is drained artificially and the ditches follow the roads or appear as straight lines that are nearing soils strip map which accompanies the drainage strip map shown in Figure 4. The soils in this area are of glacial origin, and
difficult to separate from soil symbols. Figure 9 illustrates an engi-
there are landform features of kames and eskers that offer possible
sources of constructional material for the proposed highway. In com­
paring this figure with Figure 8, it is obvious that the drainage strip
map and soils strip map should be prepared separately.
Illustrated in Figure 10 is the legend used to identify soil num­
bers within the horizons of the typical soil profiles presented on soil

Figure 9. This is an engineering soils map which accompanies the drainage
strip map illustrated in Figure 4. The soils in this area are of glacial origin
and deposited in the form of a low moraine. The parent material is predomi­
nantly silt with sand and/or gravel or PRA-A4 soil. The variations illus­
trated in typical profiles 1-4 are produced by variations in slope of the moraine.
On the steeper slopes (4-16% or greater), Profile No. 1 can be expected, while
on gentle slopes (0-4%), Profile No. 2 is typical. The “B” Horizon of both these
profiles present engineering problems because of their plastic nature. Profiles
3 and 4 are those developed within the depressions of the moraine. Profile
No. 5 is typical of the development in the several kames and eskers which dot
the area. These landforms are excellent sources of borrow material.
**CHART II — LEGEND AND CLASSIFICATION FOR ENGINEERING SOIL IDENTIFICATION**

<table>
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<tr>
<th>SOIL NO.</th>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
<th>B.P.R. (1)</th>
<th>C. AGG.</th>
<th>G. SAND</th>
<th>F. SAND</th>
<th>SILT (%)</th>
<th>CLAY (%)</th>
<th>LIQUID LIMIT</th>
<th>PLASTICITY INDEX</th>
<th>MAX DRY WT (LBS PER CUB FT)</th>
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1 & BUREAU OF PUBLIC ROADS, NOW PUBLIC ROADS ADMINISTRATION.

Figure 10. Legend and classification for engineering soil identification. This legend is used in conjunction with all typical profiles indicated on engineering soils strip maps.
No. 2 will be a PRA—A5 or A6 soil that is about 90 per cent of silt size or smaller. It will have a very high liquid limit and be plastic over a wide range of water content. It will be highly compressible under continuous application of load. Its dry density will be about 90 lbs./cu. ft. Where this soil is encountered, it will present problems in construction and performance.

Figure 11. Illustration of a combination engineering soils and drainage strip map of State Road 23, St. Joseph County, Indiana. The legend in Figure 3 is applicable to the drainage and cultural features of the strip map. For identifying soil texture or Public Roads classification, see Figure 10. The watershed area of State Ditch should be computed from the county drainage map prepared from airphotos. There is considerable constructional material available within the area surveyed, and engineering problems should be relatively few.
Figure 11 illustrates a combination engineering soils and drainage strip map of State Road 23, St. Joseph County, Indiana. All watershed areas except State Ditch may be computed directly from the map by planimetering. The watershed area of State Ditch should be computed from the county drainage map prepared from airphotos. Profiles No. 1 and 2 will be encountered in the moraine. Profile No. 3 illustrates the typical muck development in the area, and Profile No. 4 is typical of sand dunes. In the sand-gravel outwash plain, Profiles 5, 6, or 7 may be encountered, but No. 6 is more typical of outwash. The alluvial soils will develop somewhat similarly to Profile No. 12.

Figure 12 shows the great detail that can be obtained from airphotos in sand and muck areas. The numerous muck areas will present considerable problems; also, the highly organic topsoil mapped will be troublesome.
considerable problems, also the highly organic topsoil will be troublesome. The sand dunes shown on the map could be used for borrow material, but near this area there are kames that offer better construction material.

**Uses of Strip Maps Prepared from Aerial Photographs**

Engineering soils and drainage strip maps are of value to both location and soils departments in long-range planning of highway projects. The maps could be prepared in the winter time after the approximate terminal points of a proposed highway have been selected. They would be available to the various departments when they are needed most—that is, as soon as possible after the project is scheduled for detailed location surveys.

The maps would aid the location engineers in determining the best route on the basis of soils and drainage of a given area. Large watershed areas could be avoided; and, when this is not feasible, an accurate determination of watershed areas can be made. These watershed areas can be used in standard design formulas for drainage structures. Also, the engineer may be able to avoid bad soil areas. If this is not possible, the areal extent of these soils can be determined from the strip map and the location placed to reduce construction problems.

The maps would aid the soils engineers in briefing field parties on the types of soils to be encountered, the probable variations in soil profile development, and areal extent of the soil types. It is possible to direct field parties to locations where detailed soils information is needed. Since the soil areas are mapped on the basis of similar engineering problems, the number of sample locations may be reduced by spotting auger holes to secure representative samples. Figure 9 shows several locations for obtaining representative samples along a highway location. Samples obtained at these locations should give an accurate picture of the true horizon development throughout the area.

Engineering soils strip maps will be of value in correlating pavement performance with soil types. The performance in each soil area can be indicated on the map; and, in future years, these studies can be used in the design of new pavements in similar soil areas. The scale, one inch equals approximately 1,760 feet, is rather small for a performance survey; but, by a suitable projection system, it is possible to construct the maps at a much larger scale. It is hoped that in the near future an economical projection system can be developed to produce maps of a scale of one inch equals 500 feet. This development
would greatly improve the mapping of detail that is obtainable from aerial photographs.

A definite advantage of using aerial photographs in highway engineering would be in having trained interpreters make a preliminary soil and drainage survey as possible routes are analyzed on the air-photos. Routes crossing objectionable soils could be disregarded, and also those requiring numerous drainage structures. The direct use of preliminary surveys in this manner would greatly reduce the cost of locating a proposed highway.

**Cost of Preparing Engineering Soils and Drainage Strip Maps**

Preliminary engineering soils and drainage surveys of proposed highways can be prepared in a reasonably short period of time. Table 1 presents the time distribution and total number of hours required in the constructions of the maps of State Road 100 in Marion County,

**TABLE 1**

<table>
<thead>
<tr>
<th>TIME DISTRIBUTION DATA FOR PREPARING PRELIMINARY ENGINEERING SOILS STRIP AND DRAINAGE STRIP MAPS PROPOSED STATE ROAD 100, MARION COUNTY</th>
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Indiana, illustrated in Figures 4 and 9. The survey covers a length of approximately 10 miles. The total time required to prepare two complete maps was 235 hours. This time includes time of staff members and part-time student help. Of this total time, 58 per cent, or 136 hours, was supervisory or staff member time, and 42 per cent, or 99 hours, was student time.

Approximately 70 per cent of staff member time was spent in analyzing engineering soils within the area; the other 30 per cent was acting in a supervisory capacity of student labor and checking drainage systems on the aerial photographs. Sixty-seven per cent of student time was spent in the preparation of base maps and drafting of final maps. Thirty-two per cent of the total time was spent in preparing the drainage map, and 40 per cent was devoted to preparing the engineering soils map. On the basis of length of highway surveyed, a total of 23½ man hours per lineal mile was devoted to preparing soil and drainage survey strip maps from aerial photographs.

CONCLUSIONS

From the several preliminary engineering soils and drainage strip maps that have been prepared by using airphotos, certain conclusions have been reached:

1. Preliminary engineering soils and drainage surveys having a high degree of accuracy can be prepared from aerial photographs.
2. The use of available uncorrected aerial photographs is justified as the cost increases directly with amount of control used.
3. Separate drainage strip maps and engineering soil strip maps should be prepared.
4. These maps have engineering value:
   a. As an aid in location of a proposed highway.
   b. As an aid in determining watershed areas used in standard design formulas.
   c. As a planning medium for field surveys.
   d. As a permanent record on which to document pavement performance.
   e. As a means in determining areal extent and texture of soils.

It is believed that a highway department will benefit from preliminary surveys performed from aerial photographs.

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All airphotos used in this report automatically carry the following credit line: "Photographed for Field Service Branch—PMA—U.S.D.A."

BIBLIOGRAPHY


