Procedures of Applying Air Photo Interpretation in the Location of Ground Water

DR. ROBERT H. L. HOWE, *P.E.*
B.S., B.S.C.E., M.S., M.C.E., Ph.D.
West Lafayette, Ind.

ABSTRACT: *This paper discusses a new phase of air photo application. The technique of air photo interpretation has been used and tested in the location of ground water bearing formations. A procedure for the application of this technique has been developed and improved. It includes the following steps in terms of order: (1) air photo mosaic assembling, (2) study and identification of ground materials, (3) study of surface drainage patterns and system, (4) study of land forms, land uses, and other ground features, (5) interpretation of ground water conditions with the aid of literature, and (6) preparation of a ground water map for the area investigated.*

INTRODUCTION

THE technique of air photo interpretation has been employed successfully in many fields of engineering. Based on published reports, air photo interpretation and study have been used for: soil survey and mapping (1), agricultural and engineering material analysis (2, 3), geologic investigation (4, 5), drainage study (6, 7), land use survey (8), hydrographic research (9, 10), and mineral exploration (11, 12), etc.

The application of air photo interpretation to the location of ground water is a new attempt to coordinate the air photo interpretation technique with sciences such as geology, climatology, hydrology, stratigraphy, and other technical data that may furnish information concerning the physical conditions of an area. An initial procedure developed by the author engaged in a research project of Indiana Department of Conservation in cooperation with Purdue University (13) had been tested in the study of ground water conditions of eight countries in Indiana. These eight counties represent eleven sub-physiographical and geological areas of the State. This paper is a report of the improved procedure of the one previously published in the Journal of American Water Works Association (14).

PROCEDURES

The air photo interpretation for locating ground water involves scientific procedures, much like the medical practitioners' interpretation of the chest X-ray picture. Through the procedures developed, the air photo analyst with proper training may thus be able to see air photos and find things that can provide valuable information concerning ground water potentiality of an area.

Fundamentally, the availability of ground water of an area depends to a considerable extent upon the *terrain characteristics*, most of which can be evaluated from air photos: The patterns of each "wrinkle" of the earth, the shapes of gullies, the patterns of streams and their tributaries, the tonality of shading of the photograph of an area, and other recognizable features photographed all provide valuable information for the interpreter-engineer-analyst who is able to evaluate and analyse the data obtained on the air photos. The *vegetation* that is observed may be of important value in interpreting the kind of surface materials or the topographic condition. Tonality or shading tones of the vegetation on air photos may provide considerable information about the texture or moisture content of the soil.

The *use of the land* is a guide to the in-

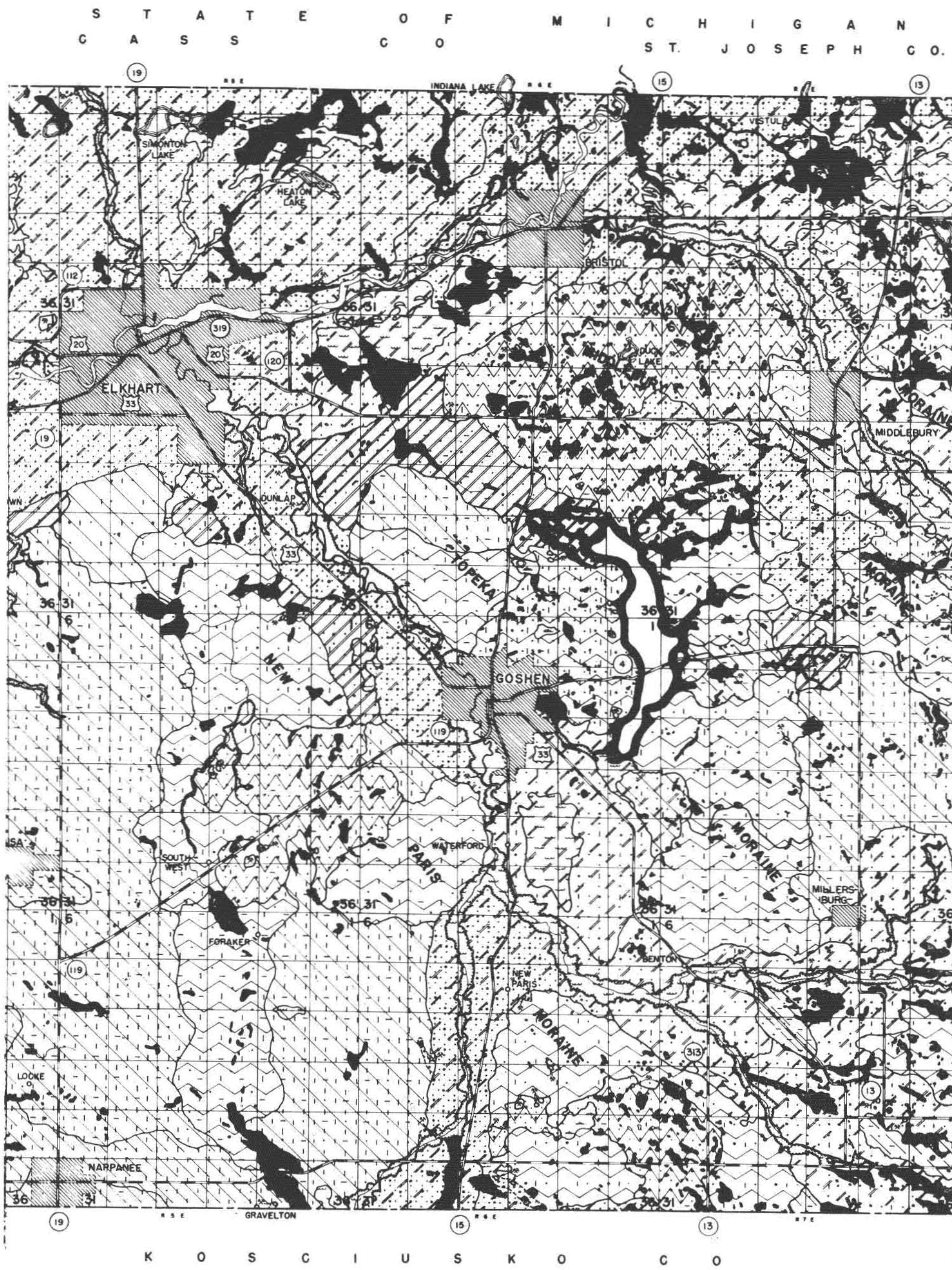

FIG. 1. Engineering soils map Elkhart County, Ind. prepared from 1940 AAA aerial photographs.

terpreter in determining soil types. The farming methods employed on flood plains will show definite differences to those of upland areas.

The *topography* of the area, showing the size and location of hills and valleys as well as uplands and lowlands, is often indicative of soil types and geologic formations.

Drainage features exhibit very definite characteristics in certain types of soils and subsurface formations, as referred to: (1) the appearance of the cross section of a

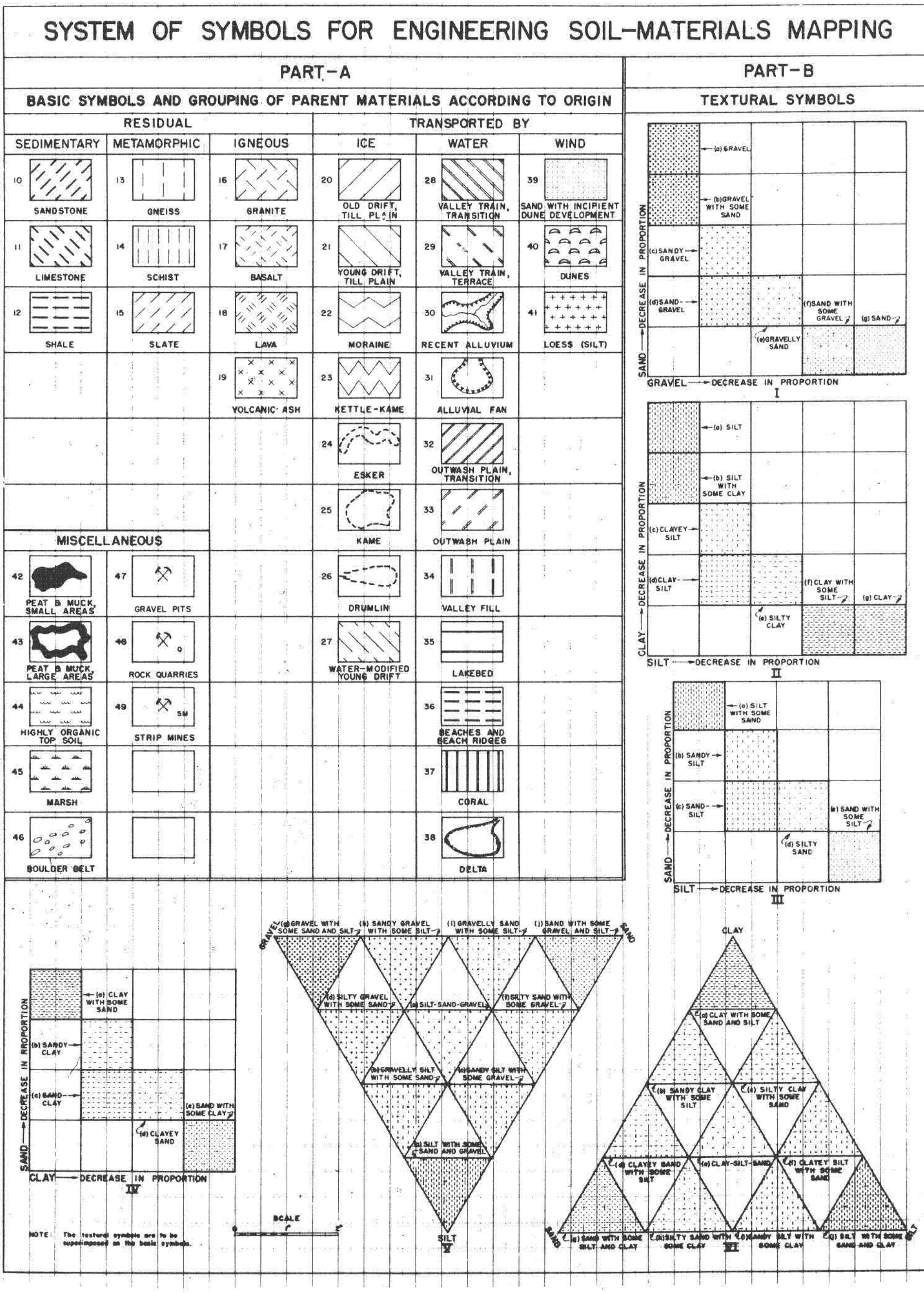

FIG. 2. Symbols for engineering soils map (Fig. 1).

gully, (2) the gradient of the gully, and (3) the pattern of the drainage features. All of these can help to identify types of soils and even the condition of subsurface deposits.

Special ground features, such as kames and eskers, terraces, alluvial plains, lake beds, gravel pits, and quarries, are recognizable on air photos and represent certain types of surface and subsurface materials.

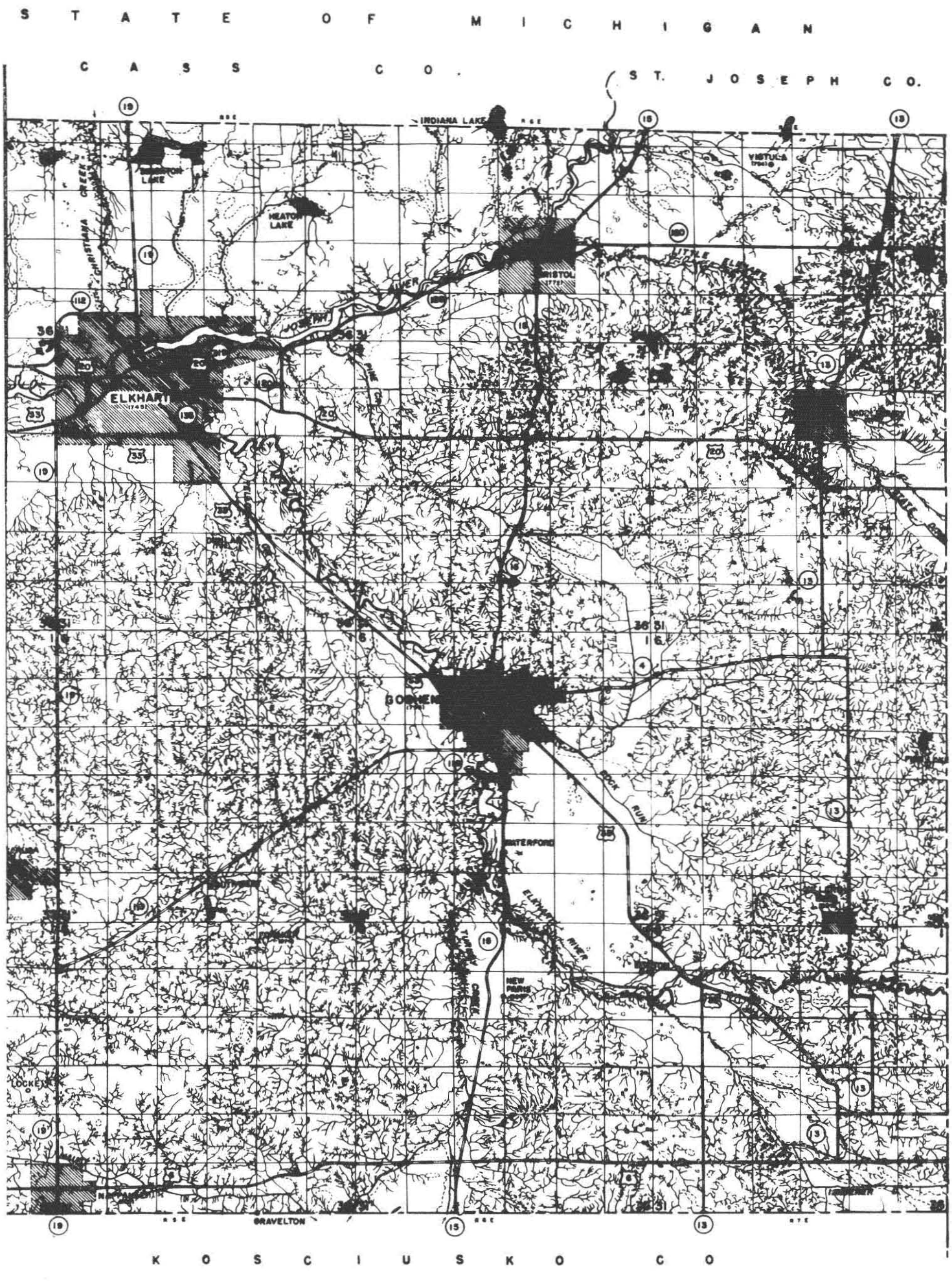

FIG. 3. Drainage map (Elkhart County, Ind.) prepared from 1939 AAA aerial photographs by Joint Highway Research Project at Purdue University 1950.

Certain recognizable features on air photos such as those mentioned above can be used to identify kinds and conditions of soils and ground deposits. Information obtained from air photo studies will then provide the basic data for the interpretation and location of ground water in an area.

A simple yet systematic procedure has been developed and improved. The order

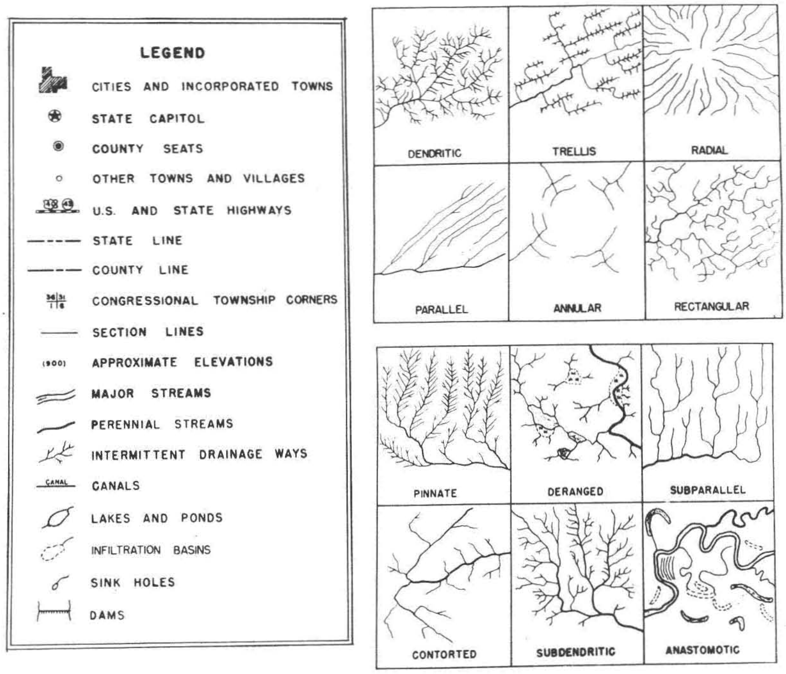

FIG. 4. Symbols for drainage map (Fig. 3).

of this procedure must be followed in order to produce reasonably accurate results:

1. ASSEMBLING THE MOSAIC of air photos of the area to be studied (using 1:20,000 air photos).

2. STUDY OF THE SURFACE MATERIALS of the area by detailed stereo-observation.
   a. *Outlining the major soil groups* on the air photos by stereovision of the en-entire area. This will result in the separation of the soil areas into groups of different depositional origin or developing origin such as: glacial, fluvio-glacial, fluvial, residual, the demarcation of the peat and muck channels, etc.
   b. *Separating the major soil group* into sub-groups of different types of texture formations, if any may exist.
   c. *Studying the texture of different soils* for further investigation of their water bearing properties (by their topographic, photographic, erosional and hydrological characteristics, etc.).
   d. *Transferring the different soil areas* outlined to a prepared base map which indicates the geographic location of the area, and thus to form a soils map showing the distribution of soils and ground deposits. (Figure 1) The symbols are explained in Figure 2.
   e. *Interpreting the origin, texture, and importance* of surface and subsurface materials with the aid of available literature.

3. STUDY OF SURFACE DRAINAGE.
   a. *Marking all the drainage lines* on individual contact prints by stereovision.
   b. *Transferring the marked drainage lines* to a prepared base map thereby making a drainage map (Figure 3). The symbols are explained in Figure 4.
   c. *Interpreting the relation* between the drainage system and patterns and the conditions and characteristics of the surface and sub-surface formations of the area.

4. STUDY OF THE LAND FORM, LAND USES, AND OTHER SPECIAL GROUND FEATURES.
   a. *Obtaining the information of land use*

for the possible correlation between the surface and subsurface conditions as reflected by the existing structures.

b. *Obtaining the information of land form* which is indicative of the topographic and physiographic conditions and is important in predicting the ground water level with respect to the surrounding areas.

c. *Observing special ground features* and marking their locations, such as ponds, flooded gravel pits, quarries, lakes, ditches, dams, and other man-made structures which may aid in the interpretation of ground conditions.

5. INTERPRETATION OF GROUND WATER CONDITIONS.

a. *Outlining on air photos* the areas likely to possess water bearing formations as justified from the results of studies of surface and subsurface materials, drainage characteristics, and other ground features which furnish the basis to interpret as to whether a formation is water-bearing or not in conjunction with the principles of hydrology, soil science, and geology.

b. *Studying available literature and records* showing the existing conditions of ground water in the area (or in an area of similar nature). This will help to verify the result of air photo interpretation.

c. *Checking the result of interpretation* by field investigation and by low altitude aerial inspection (Figure 5). This will help to obtain further necessary information for the ground water condition of an area in doubt.

d. *Preparing a ground water map* (Figure 6) with data and information obtained as a result of the air photo study and interpretation.

The Significance of the Ground Water Map

The ground water map which can be produced through air photo study and interpretation will show the distribution and locations of areas found and identified to have different ground water-bearing conditions. These are determined from the characteristics of surface and subsurface materials, drainage conditions, and other ground features which furnish the basic

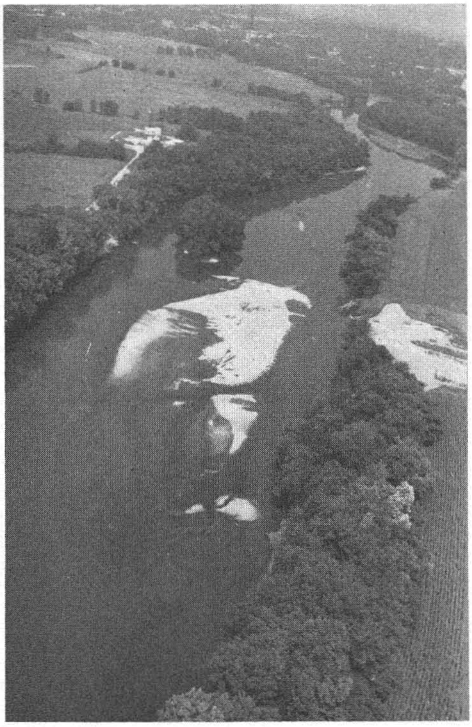

FIG. 5. Air photo taken at low altitude for checking water-bearing formations.

information for prediction, interpretation, and subsequently location of ground water formations of an area.

The ground water map may provide information of areas that are likely to be the appropriate place for ground water prospecting and on the other hand, exclude the areas that are not promising for obtaining ground water supplies.

With the accuracy of the ground water map verified, the ground water map may be used for suggesting the location of test-well sites. Consequently the cost of prospecting for ground water may be greatly reduced. This is of great importance to many industrial developments because the ground water map, when used with other maps, may furnish to the industries valuable information for the selection of new plant sites if ground water supplies are essential to them.

Technically speaking, the investigation of ground water conditions by air photo interpretation is not only systematic but also time-saving and economical. For example, the time required and equipment involved in the study of an area of 400 square miles are much less those of other

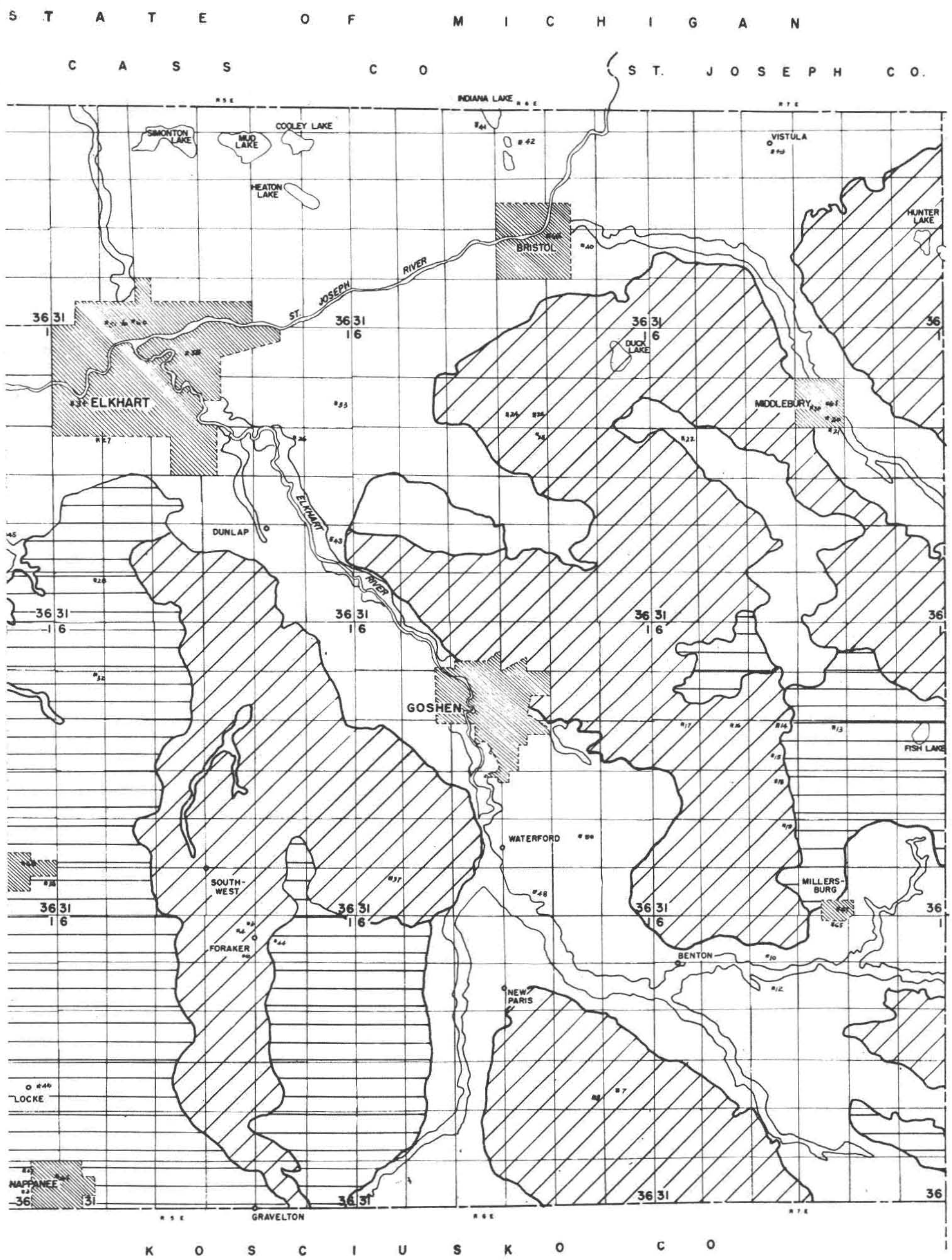

FIG. 6. Ground water region map (Elkhart County, Ind.) prepared from 1938 AAA aerial photographs by Indiana Department of Conservation Project at Purdue University 1952.

Explanation

Area	Ground Water Condition
Unshaded	Good to excellent: (wells expected to be able to supply domestic and industrial demands)
Diagonally shaded	Fair: (wells expected to be able to supply domestic demands)
Horizontally shaded	Poor or uncertain: (only small quantities of yield from wells)

TABLE 1

TIME REQUIREMENT FOR THE LOCATION OF GROUND WATER BY AIR PHOTO INTERPRETATION THROUGH THE PROCEDURE DEVELOPED

Item	*Time Required (man-hours)*
Literature search	30
Air photo markings:	
Setting up mosaic	8
Drainage study	100
Study of ground materials and land forms	100
Ground water study	40
Transferring and map preparation	
Drainage	60
Soils	60
Ground water	30
Laboratory checking	30
Field checking	
Ground tests	24
Low altitude flight investigation	8
Drafting	
Soils and ground materials map	80
Drainage map	80
Ground water map	40
Writing report	40
Total	740

methods. Table 1 gives the average timekeeping for the study of an average Indiana county having an area of 400 square miles.

The total of 740 man-hours indicated in Table 1 may be explained as the amount of time required for one trained air photo engineer-analyst and one assistant draftsman to complete a project of the size mentioned. However, it does not include the time required for stenographic work. In plain language, when a project is properly organized and coordinated with available air photos and a schedule is arranged, the investigation of an area of approximately 400 square miles can be completed in about ten (10) weeks time. The speed attained is therefore of importance to ground water prospectors.

AIR PHOTO PATTERNS FOR GROUND WATER LOCATION

The investigation of the ground water conditions and locations of an area is made possible by following three basic principles:

(1) The existence (or absence) of porous and granular water-bearing formations that can be identified on air photos.

(2) The existence (or absence) of favorable ground water conditions in an area of similar topographic and geologic nature, that has been investigated.

(3) The existence of favorable ground conditions such as location and elevation which are important to the ground water storage and movement.

With the aid of air photo analysis data, typical air photo patterns for the identification and location of possible water-bearing ground formations can be recognized. In the following, seven typical air photo patterns for the identification of water bearing deposits, produced through the study of eight counties in Indiana, may be of interest to those living in the Midwest:

AIR PHOTO PATTERN FOR THE ALLUVIAL PLAIN AND TERRACE AREA (FIGURE 7)

This pattern is illustrated on the stereopair which shows a typical alluvial plain and a terrace area associated with a major stream. The stream may affect the ground water condition of the area hydrologically, such as the re-charge of ground water at high stream flow. The photo tonality and the sparse surface drainage reflect the presence of granular, water-bearing materials. As a result of the natural development, the elevation of such areas is much lower than that of the upland nearby and therefore the ground water table may be close to the ground. Generally, the wider the alluvial plain the larger the volume of porous materials and the better ground water condition can be expected to exist (Photos used: BFV-8-70 and 71, Tippecanoe County, Indiana).

AIR PHOTO PATTERN FOR THE OUTWASH PLAIN (FIGURE 8)

This pattern is illustrated on the steropair which shows an outwash plain developed by water action. The water worked marks and typical photo tonality of the outwash soils and the sparse surface drainage indicate the presence of granular, water-bearing deposits. The elevation of such an outwash plain is generally very low in comparison with the nearby up-

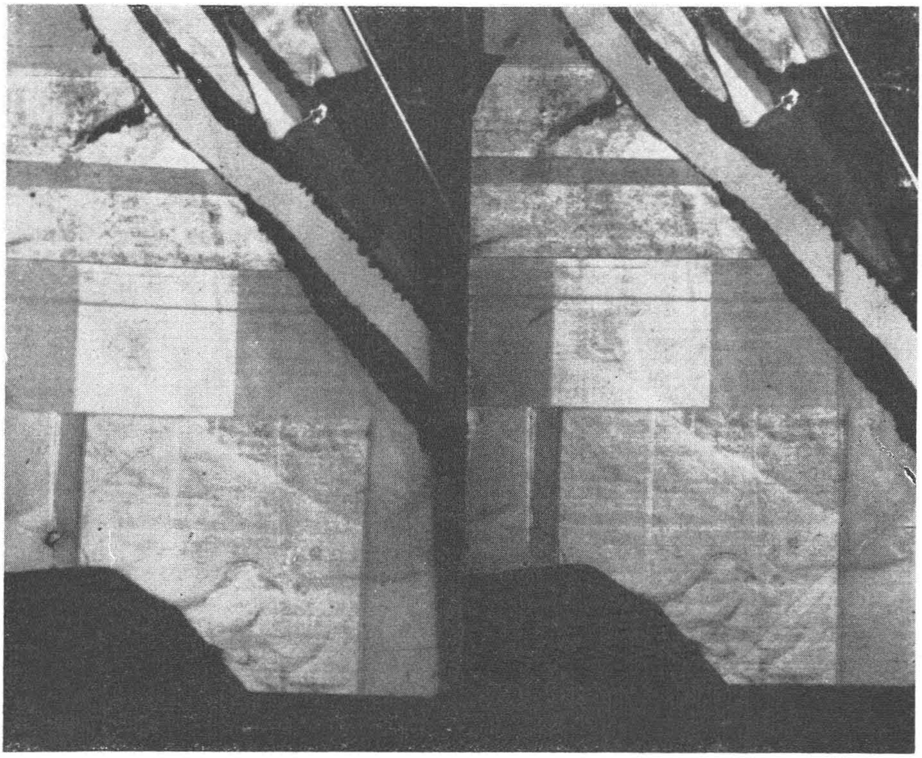

FIG. 7. Alluvial plain and terrace area.

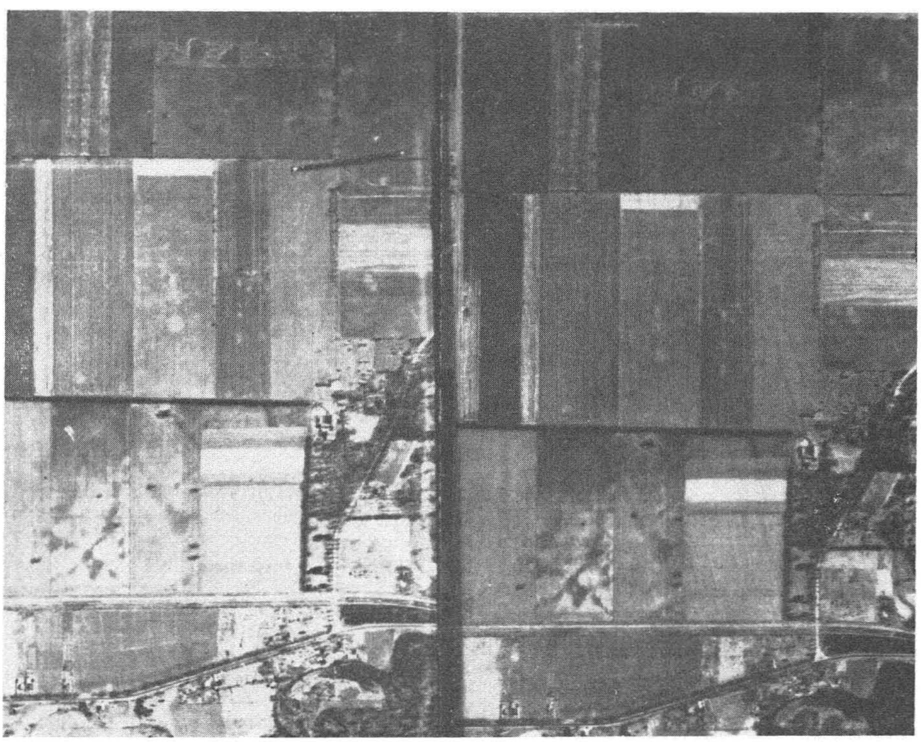

FIG. 8. Outwash plain.

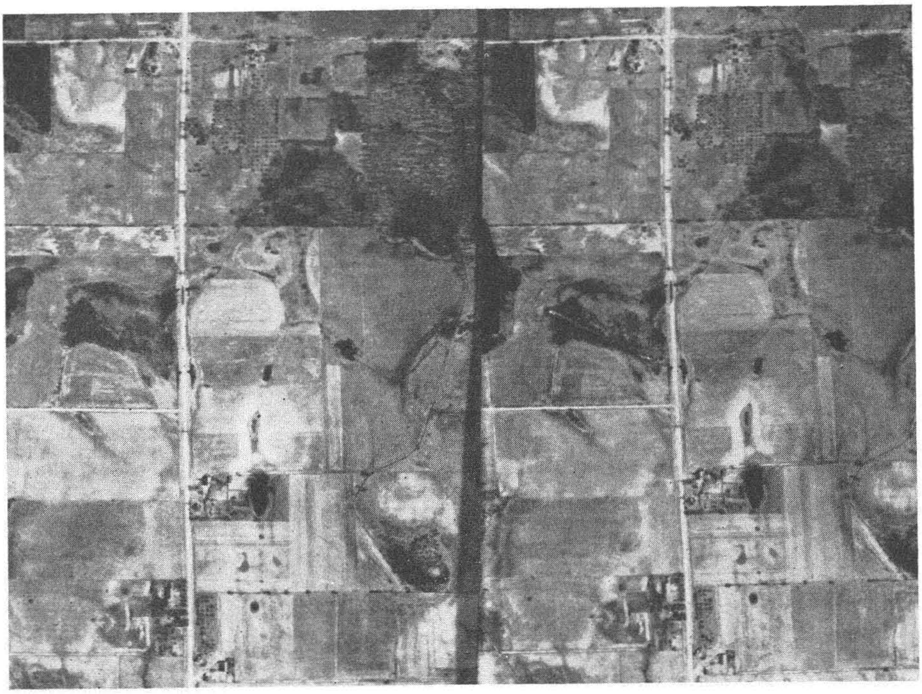

FIG. 9. Kettle-Kame morainal area.

land; a high water table may frequently be anticipated (Photos used: BFB-4 -3 and 4, Elkhart County, Indiana)

AIR PHOTO PATTERN FOR THE KETTLE-KAME MORAINAL AREA (FIGURE 9)

This pattern is illustrated on the stereo-pair which shows the kettle-kame moraines which have granular and water-bearing materials of glacial and fluvial origin. The light and dark photo tonalities, and the absence of a natural surface drainage system except the ponds and basins, frequently indicate the existence of porous, permeable and probably water-bearing materials (Photos used: BFB-4-35 and 36, Elkhart County, Indiana).

AIR PHOTO PATTERN FOR SANDY LAKE BEDS (FIGURE 10)

This pattern is shown on the stereo-pair which illustrate a sandy lake bed having abundant granular and water-bearing deposits as indicated by the scattering dark and light photo tonality, the absence of natural drainage, the flatness of the ground and the many man-made ditches for drainage improvement. Occasionally, sand ridges are present in such areas (Photos used: BFP-3-18 and 19. Porter County, Indiana).

AIR PHOTO PATTERN FOR RE-SORTED TILL PLAINS (FIGURE 11)

This pattern is illustrated in the stereo-pair which shows a re-sorted till plain which may be made up of granular, porous, and water bearing formations as indicated by the water-worked scars on the ground surface, the lack of natural drainage line, and the slightly depressed land situation (Photos used: BWM-2-35 and 36, Tipton County, Indiana).

AIR PHOTO PATTERN FOR FILLED VALLEYS (FIGURE 12)

This pattern is shown on the stereo-pair which illustrates a filled stream valley which generally has abundant granular and water-bearing materials. This is indicated by the depressed land form, channel-like topography, light photo tonality, numer-

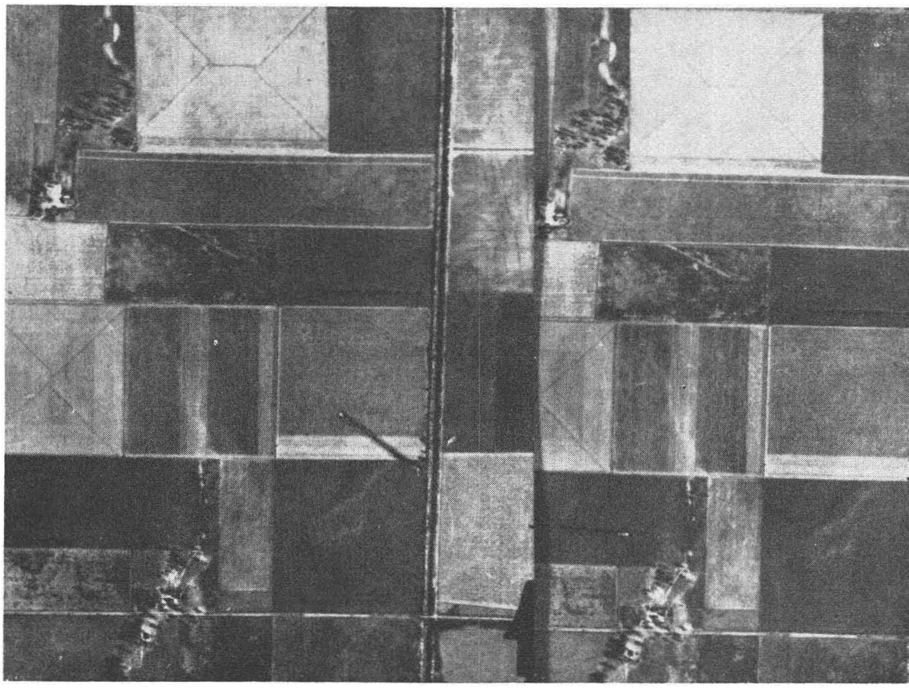

FIG. 10. Sandy lake bed.

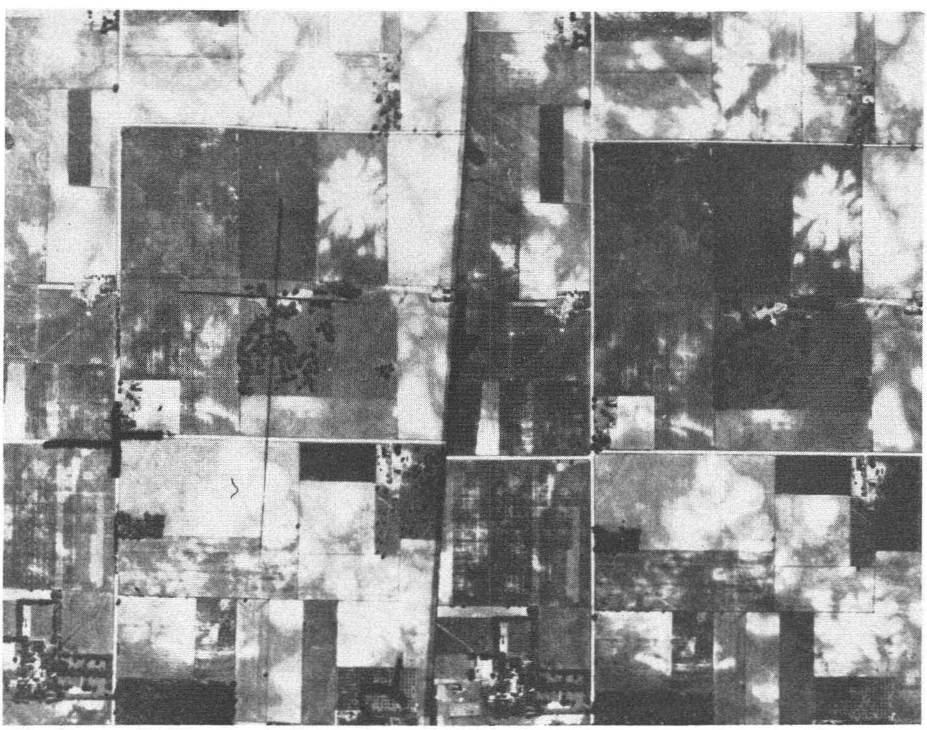

FIG. 11. Re-sorted till plain.

FIG. 12. Filled Valley.

ous gravel pits, lack of natural drainage lines, a chain of ponds, and the tributary-like gullies on both sides of the "valley" (Photos used: BFV-7-9 and 10, Tippecanoe County, Indiana).

AIR PHOTO PATTERN FOR GLACIAL SLUICEWAYS (FIGURE 13)

This pattern is illustrated on the stereo-pair which shows the typical glacial sluiceway having the light and dark photo tonality, some infiltration holes (basins), and the current streaks resulting from the development of the sluiceway. The flat and somewhat depressed topography associated with granular materials having a high water table is typical of the sluiceway area (Photos used: RC-8-801 and 802, Owen County, Indiana).

The stereo-pairs indicated in the figures show the typical patterns of the areas identified which are likely to possess a good ground water potentiality. The identification and location of any of these patterns on the air photos of an area, therefore, may suggest the possibility of obtaining a good water supply if the environmental conditions are also favorable. On the other hand, the absence of any of these patterns in an area in the similar geologic classification as Indiana may suggest going to other areas to locate ground water.

Other patterns of ground water areas can also be recognized on the air photos of other territories of the United States. If extensive air photo study and research can be conducted by thoroughly trained air photo engineer-analysts, there are no grounds for not believing that reasonably accurate ground water map can be produced for any area desired.

GROUND WATER INVENTORY THROUGH AIR PHOTO INTERPRETATION AND STUDY

In addition to the development of a ground water map, the air photo interpretation and study may assist in the derivation of an inventory of ground water resource or potentiality of an area. When the area of water-bearing formation is

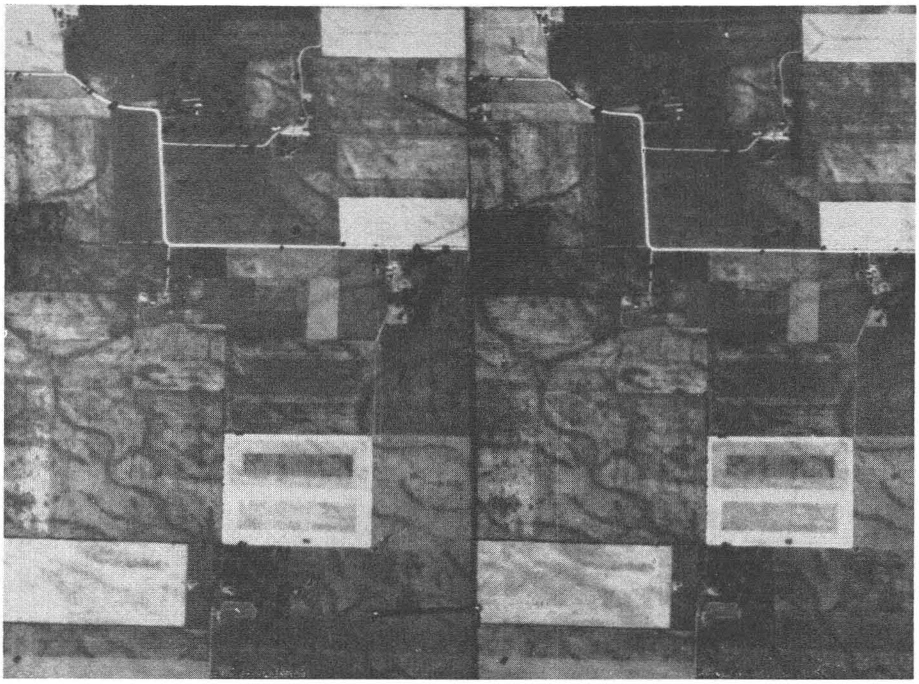

FIG. 13. Glacial sluiceway.

carefully identified and defined, it is possible to determine the thickness of the formation. With the aid of technical data of soil science and hydrology, followed by physical tests of the area, the approximate ground water storage of a formation can be estimated. This is naturally of great interest to water prospectors, industrialists, as well as to national economists and defense planners. Table 2 is presented to show the ground water inventory of Elkhart County, Indiana as a result of study through air photo interpretation.

DISCUSSION

The procedure of applying air photo interpretation for locating ground water as presented in this paper is new, and naturally it is still in the stage of further improvement through additional research and study. As water utilization of the nation is increasing rapidly, the need of developing new water resources is urgent. As recently reported in newspapers, the current consumption of *ground water in the United States is about 25 billion gallons per day* and this is expected to increase tremendously in the near future. It is hoped by the author that this developed procedure may serve to help in solving some water resource problems. To this end, the author extends invitation to researchers, and all who are interested in further knowing this new application of air photo interpretation in connection with ground water location and evaluation, for comments and discussion.

REFERENCES

1. Bushnell, T. M.: "Aerial Photography and Soil Survey." *Proc. Am. Soil Survey Assn.* 10: 23, 1929.
2. Bushnell, T. M.: "A New Technique in Soil Mapping." *Proc. Am. Soil Survey Assn.* 13: 74, 1932.
3. *Manual on the Airphoto Interpretation of Engineering Soils.* Purdue Airphoto Interpretation Laboratory, Purdue University, Lafayette, Indiana, 1950.
4. Frost, R. E.: "The Use of Air Photos in Soil Studies." Purdue Airphoto Interpretation Laboratory, Purdue Univ., 1949.
5. Smith, H. T. U.: *Aerial Photographs and Their Applications.* Appleton-century-Crofts, New York, 1943.
6. Parvis, M.: "Development of Drainage Maps from Aerial Photographs." Purdue

TABLE 2

GROUND WATER INVENTORY OF ELKHART COUNTY, INDIANA AS PRODUCED FROM AIR PHOTO STUDY AND INTERPRETATION

Formation	*Origin*	*Location*	*Photo tonality*	*Drainage pattern*
Moraines	Glacial	Central, east, south and southeast	Light	Haphazard or deranged
Kettle-kames, kames and eskers	Glacial	Central, south and southeast	Light on tops and dark in nearby areas	Deranged
Re-sorted till plains	Glacial and glacio-fluvial	Scattered	Dark	Sub-dendritic
Till plains	Glacial	South, west, and east	Varied	Dendritic and rectilinear
Outwash terrace deposits and alluvium	Fluvial	Northwest, central, south, and east	Light and/or dark	Undeveloped
Muck areas	Fluvial	Scattered	Dark	Basins
Sand	Aeolian	North, east	Light	Undeveloped

TABLE 2

PART 2

Formation	*Gully cross-section*	*Land form*	*Special features*	*Materials and (textures)*	*Land use*	*Ground water conditions*
Moraines	V-shaped with short gradient	Rugged, hilly	Knolls, depressions, and muck basins	Silt, clay, sand and some gravel (fine to medium)	Gravel pits, farming	Fair
Kettle-kames, kames and eskers	V-shaped with short gradient	Rugged	Ridges, muck basins	Silty clay, with sands and gravels (medium to coarse)	Gravel pits	Fair
Re-sorted till plains	V-shaped with short gradient	Level	Current scars	Sandy silt and sands (fine to medium)	Farming	Uncertain
Till plains	Saucer-shaped with long gradient	Flat to rolling	Flatness, mottled areas	Clay, silt, sand and gravels, boulders (varied)	Farming	Uncertain
Outwash terrace deposits and alluvium	V-shaped to U-shaped with short gradient	Flat	Flatness associated with stream current scars	Silts, sands and gravels (coarse)	Gravel pits, farming	Good to excellent
Muck areas	——	Depressed	Depression and channels	Peat, muck, silty sand and gravel (varied)	Farming or undeveloped	Uncertain
Sand	——	Rugged	Dunes	Sands (medium)	Undeveloped	Poor

Airphoto Interpretation Laboratory, Purdue Univ., 1949.

7. Matthes, G. H.: "Aerial Photography as an Aid in Map Making, With Special Reference to Water Survey." *Trans. ASCE*, 86: 1521, 1923.
8. Miller, C. E., *et al.*: "The Use of Aerial Photographs in the Michigan Land Economic Survey." *Proc. Am. Soil Survey Assn.* 13: 82–85, 1932.
9. Moore, J. B.: "Determination of Depths to Extinction Coefficient of Shallow Water by Air Photographs." *Philosophical Trans.* Series A 240, 1947.
10. Howe, R. H. L.: "Aerial Photographic Interpretation of Ground Water Conditions

of Farmersburg Area, Sullivan County, Indiana." Research project report, Purdue Univ., 1951 (unpublished).

11. Levings, W. S.: "Aerogeology in Mineral Exploration." *Colorado School of Mines Quarterly*, Vol. 39, 1944.
12. Herzog, G. W.: "The Uses of Aerial Photogrammetry in the Petroleum Industry." PHOTOGRAMMETRIC ENGINEERING, 6: 3, 1940.
13. Howe, R. H. L.: "Prediction of Ground Water Conditions by Air Photo Interpretation." Ph.D. Thesis, Purdue Univ. 1955.
14. Howe, R. H. L., Wilke, H. R., and Bloodgood, D. E.: "Application of Air Photo Interpretation in the Location of Ground Water." *JAWWA*, vol. 48, No. 11, 1956.

ACKNOWLEDGMENTS

The author is indebted to his former professors and friends: R. E. Frost, D. E. Bloodgood, H. R. Wilke, and M. Parvis of Purdue University, for their valuable assistance and advice in the initial stage of the development of this procedure. He also thanks the Indiana Department of Conservation, Division of Water Resources for the funds made available for the initial research in 1950 to 1952. Also, he is grateful to T. W. Norcross, Editor of PHOTOGRAMMETRIC ENGINEERING and C. E. Palmer, Secretary of the American Society of Photogrammetry, for their interest and for request to have this paper published.

SHADED RELIEF EDITION OF GRAND TETON NATIONAL PARK MAP PUBLISHED

A new shaded relief edition of the Grand Teton National Park topographic map has been published by the Geological Survey and is available for public purchase.

The map is scaled at 1:62,500 with contour intervals at 50 feet. Travelers and park visitors are expected to favor this new shaded relief overprint which brings out the hills and valleys of this rugged, mountainous area in striking fashion. The previously issued contour edition, without shading, has proved its appeal to engineers, geologists and others accustomed to reading this type of map.

The reverse side of both editions contains information, diagrams, panoramic views, a generalized west-east cross section through the Alpine portion of the Teton Range and Jackson Hole, and a short account of the geology, geography, flora and fauna of the area.