Utilization of Photo Interpretation in the Highway Field

HAROLD RIB, Highway Research Engineer, U.S. Bureau of Public Roads

Many papers have been written in the past 20 to 25 years indicating the various possible applications of photo interpretation in the highway field. The purpose of this paper is to indicate to what extent these applications are being utilized by the various highway organizations. Summaries of the use of photo interpretation by major areas of photo interpretation and by stages of highway engineering are included. The paper also includes discussions on research under way and special applications of photo interpretation in the highway field, as well as the highway department's cooperative work with the Bureau of Public Roads utilizing Highway Planning and Research funds.

•THE VALUE of photo interpretation in the highway field has been discussed and demonstrated for over 20 years, yet its adoption by highway organizations has been slow. Only a limited number of highway organizations were utilizing photo interpretation extensively in their work before the enactment of the Federal-aid Highway Act of 1956. The enormous amount of work involved in the planning, design, and construction of the 41,000 mi of highways in the Interstate System, coupled with the shortage of engineering manpower available for this large undertaking, has resulted in a greater use of photo interpretation by the highway organizations. An analysis of a survey of highway organizations made in 1955-1956 (1) indicated that 33 highway organizations used photo interpretation in some phases of their work; however, only 10 indicated a fairly extensive use. Analyses of recent surveys (2, 3, 4) and projects of the highway organizations indicate that 50 are now employing photo interpretation in some phase of their work and 22 of these are using it fairly extensively.

The objectives of this paper are to (a) indicate the extent to which photo interpretation is currently being utilized by the highway organizations, (b) point out some of the special applications and research under way in photo interpretation by various highway organizations, and (c) indicate the type of work performed by the U.S. Bureau of Public Roads (BPR) and highway organizations cooperating with BPR utilizing the 1½ percent planning and research funds. No attempt is made to show how photo interpretation can be used in particular areas of highway engineering. This type of information can be found in the references to this paper especially in Refs. 2, 5, and 6.

The summarizations in this paper deal with 53 highway organizations: the 50 state highway departments, the District of Columbia Highway Department, the Puerto Rico Department of Public Works and BPR. In the summaries of the use of photo interpretation by the various highway organizations, only the number of highway organizations utilizing this is shown. A listing by individual organizations is not included, because a major portion of the information utilized in the summaries was obtained from answers to questionnaires, and the answers by the individual organizations to one of the questionnaires were confidential.

PHOTO INTERPRETATION IN THE HIGHWAY FIELD

Photo interpretation is used here in the broad sense employed by many highway engineers, i.e., to include all types of activities where qualitative information is

Paper sponsored by Committee on Photogrammetry and Aerial Surveys.

obtained from photographs. This is necessary since most of the information utilized in this paper is derived from questionnaires, and there is generally no reliable method whereby the various levels of photo interpretation—photo reading, photo analysis, and photo interpretation (5, p. 6; 6, p. 852)—can be differentiated.

There are numerous applications of photo interpretation in the highway field and various methods of summarizing the uses by the highway organizations. For this study, two types of summaries are made: (a) by the major areas of photo interpretation applicable to highway engineering, and (b) by the stages of highway engineering in which photo interpretation can be utilized.

The major areas of photo interpretation applicable to highway engineering include:

1. Location of construction materials (sand, gravel, borrow, clay);
2. Evaluation of soils and geology and preparation of engineering soil maps;
3. Evaluation of ground conditions affecting highway alignment, including topography (cut and fill, amount of bedrock and common excavation), soils (plastic, organic, erosive), drainage (seepage, flooding, high water table), landslides, and faults and earthquake zones;
4. Drainage studies and preparation of drainage maps;
5. Land-use studies;
6. Traffic surveys and analysis;
7. Planning subsurface exploration and surveying programs; and
8. Highway condition and inventory, and damage surveys.

Table 1 gives the summary by the major areas of photo interpretation in the highway field and indicates how many highway organizations are utilizing photo interpretation in these major areas. This summary is based on an analysis of several recent questionnaires (2, 3, 4), as well as on the author's knowledge of the activities of various highway organizations through their cooperative work with BPR.

The stages of highway engineering in which photo interpretation may be used are as follows:

1. Highway planning;
2. Traffic surveys;
3. Highway location surveys, including reconnaissance survey of areas to determine feasible routes, reconnaissance survey of alternatives to select route, prelimi-

TABLE 1

HIGHWAY ORGANIZATIONS UTILIZING PHOTO INTERPRETATION IN HIGHWAY FIELD BY MAJOR AREA OF USE

Major Areas of Use	No. of Organizations
Location of construction materials	32
Evaluation of soils and geology—preparation of engineering soil maps	42
Evaluation of ground conditions affecting highway alignment	36
Drainage studies—preparation of drainage maps	38
Land-use studies	38
Traffic surveys and analyses	11
Planning subsurface exploration and surveying programs	39
Road condition and inventory and damage surveys	15

nary survey of the selected route for design and preparation of construction plans, and location survey—staking of designed location on the ground;

4. Construction surveys;
5. Condition and inventory surveys; and
6. Maintenance surveys.

The number of highway organizations utilizing photo interpretation in the various stages of highway engineering is shown in Figure 1. The extent of use—slight, moderate or extensive—is also indicated. This summary is based on the answers by the highway organizations to the "Photographic Interpretation Surveys" portion of the 1962 Questionnaire on Use of Aerial Surveys (2).

An evaluation as to the extent of use of photo interpretation within each stage was accomplished by grouping the various items listed in each stage into the major areas of photo interpretation (land use, soils and geology, drainage, etc.). A weighted percentage was then determined based on the number of major areas of photo interpretation included within each stage and the possible degree of utilization of photo interpretation within each major area. The criteria on which the ratings of slight, moderate or extensive are based are as follows:

Slight—Utilized in up to one-third of the total possible uses in each stage;
Moderate—Utilized from one- to two-thirds of the total possible uses in each stage; and
Extensive—Utilized for more than two-thirds of the total possible uses in each stage.

The total number of responses on which the analysis is based is 50. In this number, BPR is considered as one organization; however, the degree of utilization by the

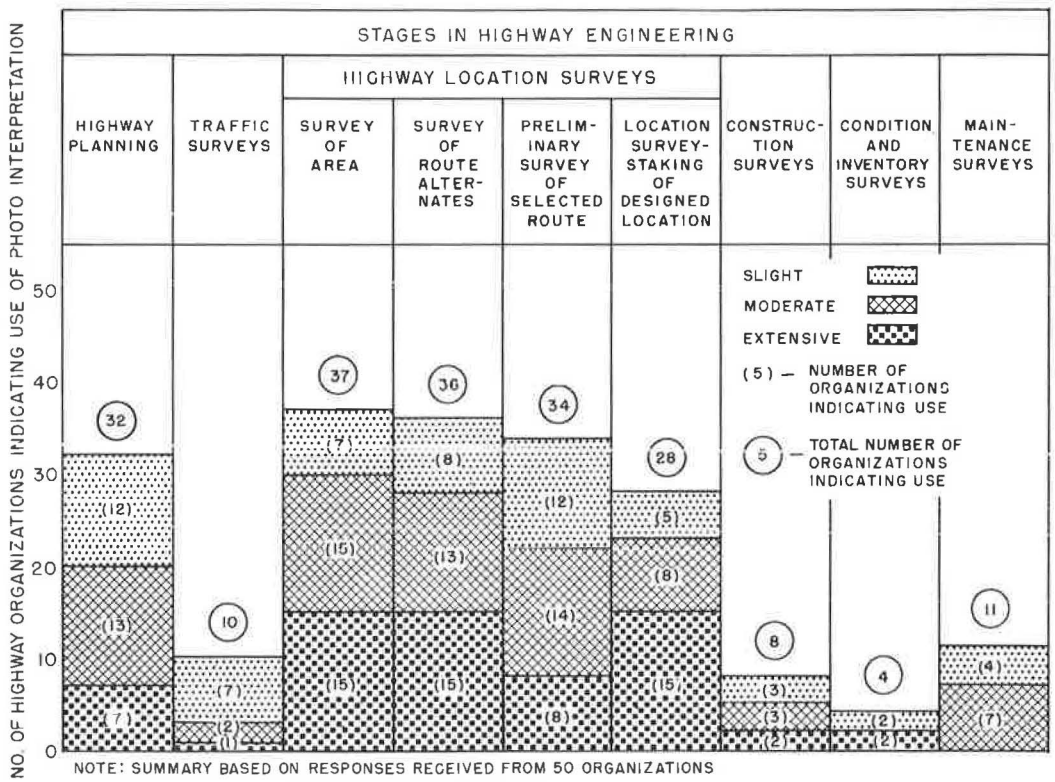


Figure 1. Highway organizations utilizing photo interpretation in the highway field, by stages in highway engineering.

Bureau is based on an average of the answers received from four of the Bureau's regional offices.

ANALYSIS OF SUMMARIES AND CONCLUSIONS INDICATED

It is generally considered that the greatest value of photo interpretation in the highway field is in the early stages of highway location, that is, highway planning, reconnaissance survey of area and preliminary survey of alternate routes. The reason for this is that several of the environmental factors controlling the economics of highway location, such as topography, soils, land use and availability of materials, can be evaluated by photo interpretation and the information thus developed can be utilized to arrive at the best and most economical solution. An analysis of Figure 1 indicates that in these stages, 32 to 37, or approximately 65 to 75 percent, of the responding highway organizations utilize photo interpretation in their work; however, only 7 to 15 organizations or approximately 15 to 30 percent of the responding highway organizations make extensive use of photo interpretation in these stages.

Photo interpretation is also of great value in the preliminary survey of a selected route for evaluating the environmental factors as well as for planning a soil survey program to obtain information for the final design of the highway. As indicated in Figure 1, 34 of the highway organizations, or 68 percent of those responding, utilize photo interpretation in this stage. However, only 8 organizations, or 16 percent of the responding organizations, utilize the method extensively.

Considerable use is also being made of photo interpretation in location surveying and staking of the designed location. Twenty-eight of the highway organizations indicated the utilization of photo interpretation in this stage, and more than half of these indicated a fairly extensive use.

The application of photo interpretation in the remaining stages, traffic surveys, construction surveys, condition and inventory surveys, and maintenance surveys, is very limited. Comparatively few highway organizations are experimenting with or developing procedures or techniques for the use of photo interpretation in these stages. Some examples of the use of photo interpretation in some of these stages have been given (7, 8, 9).

An analysis of Table 1 indicates that photo interpretation is utilized by up to 42 of the 53 highway organizations for the determination of one or more of the environmental factors that control the economics of highway location (i.e., ground conditions, soils, availability of materials, land use, etc.), as well as for drainage studies and planning field exploration and surveying programs. However, it is evident from Table 1 and Figure 1 that there is a limited number of highway organizations utilizing photo interpretation in the areas of traffic surveys, road condition and inventory studies and damage surveys.

Although Figure 1 and Table 1 indicate that, in the majority of the stages of highway location and major areas of photo interpretation, one-half to three-fourths of the highway organizations are utilizing photo interpretation in their work, only one-fourth to one-half of these are using it extensively. Most important in determining the extent of its use by a highway organization are the presence of photo interpreters on the staff of the organization and the knowledge, background, and experience of these interpreters. It is interesting to note that, in a questionnaire published in 1962 (3), only 12 highway organizations indicated they had photo interpreters on their staff (BPR not included in this summary); however, from the author's contacts with the state highway departments, it is estimated that today between 20 and 25 highway organizations have photo interpreters. This may well be the reason for the lack of extensive use of photo interpretation by most of the highway organizations.

The need for more trained photo interpreters has been recognized for many years by the highway organizations. Several have sent personnel to the special short courses on photo interpretation given by several universities (e.g., Cornell and Purdue). In addition, BPR has given short courses. Also, many universities are increasingly emphasizing photo interpretation. In a survey of university engineering schools made in 1962 (10), 29 out of the 96 answering indicated they planned to increase their emphasis on photo interpretation.

In summary, based on an overall study of the information available and known to the author, the use of photo interpretation by the 53 highway organizations is as follows:

1. Fifty, or 94 percent, utilize photo interpretation;
2. Three, or 6 percent, indicated no use;
3. Fourteen, or 26 percent, use photo interpretation to a slight extent;
4. Fourteen, or 26 percent, use photo interpretation to a moderate extent;
5. Twenty-two, or 42 percent, utilize photo interpretation extensively;
6. Only two have indicated a use of photo interpretation in all stages of highway engineering.

RESEARCH AND SPECIAL STUDIES

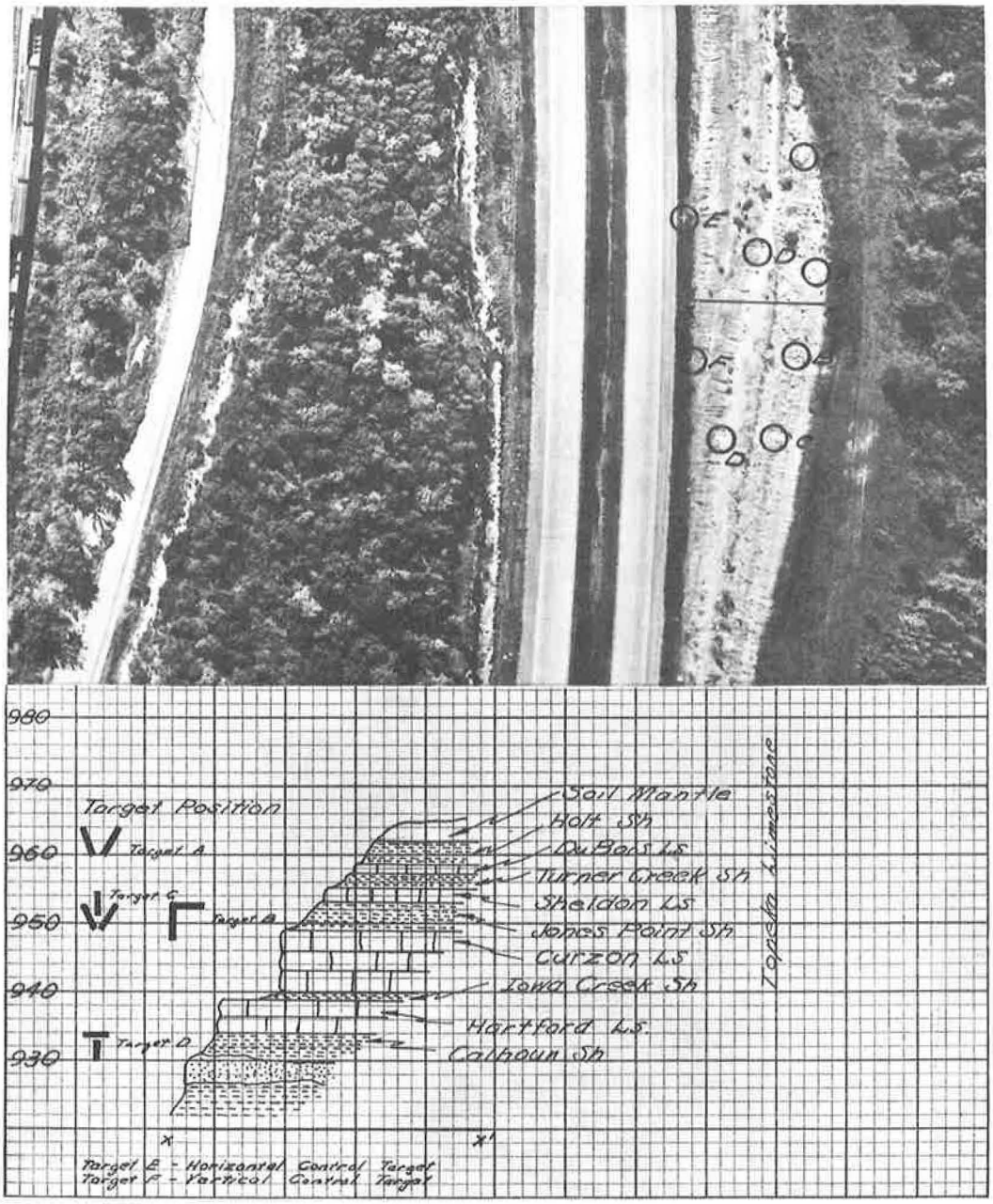
In all phases of photo interpretation as applied to the highway field, information is obtained in practically all cases by the stereoscopic examination of black-and-white panchromatic aerial photographs or from the study of mosaics prepared from the black-and-white aerial photographs. However, within recent years, several highway organizations have been investigating the use of other types of photography, i.e., black-and-white infrared, color, and color infrared.

Several organizations, including BPR Indiana, Kansas, Michigan, Montana, Ohio, Virginia and Wyoming, have been investigating the use of color aerial photography for photo interpretation purposes. The use of color photography as reported in the Bureau's projects (11, 12) has proved so successful that the Region 9 office in Denver now uses color aerial photography for photo interpretation purposes for practically all of their projects in national forests and parks.

Research in the value of color photography is being performed by the Ohio Department of Highways and Ohio State University under a cooperative agreement with BPR. In this project, the university is evaluating various film-filter-scale combinations to determine the usefulness of photo interpretation in obtaining design information for the highway engineer. Areas under study are landslide-susceptible terrain and organic or soft subsoil areas. Multisensor photography (panchromatic, infrared, color, and color infrared) are being evaluated at scales of 1/9,600, 1/4,800 and 1/2,400. In addition, various filter combinations are being studied. Preliminary reports on this project (13, 14) have indicated that for organic soils, the best differentation of surface moisture conditions occurred on panchromatic film with no filters, and for landslide areas color photography was best for differentiating the type of rock outcrops and for determining details in the shadows. The report also indicated that a scale of 1/9,600 was satisfactory in both landslide and organic area, but for evaluating items such as depth of organic layers and for differentiating types of rock, a scale of 1/4,800 was preferable.

Interesting research projects utilizing photo interpretation techniques are also being conducted by the State Highway Commission of Kansas. Some typical uses, as well as special uses, of photo interpretation of black and white aerial photographs have been reported (8). Some of the special projects discussed are (a) the use of special targeting techniques in conjunction with photo interpretation for the identification of geologic formations and evaluation of the use of these geologic materials in highway construction; (b) the study of channel changes over a period of years to try to evaluate the effect of a highway on channel changes or the effect of channel changes on an existing or proposed highway; and (c) a bridge deck condition survey. The meander patterns of streams are also being studied in an attempt to correlate the meander angle (function of degree of curvature of the stream meander) as seen on the photograph and the type of material the stream is cutting through. Some examples of the work done by State Highway Commission of Kansas are shown in Figures 2 and 3.

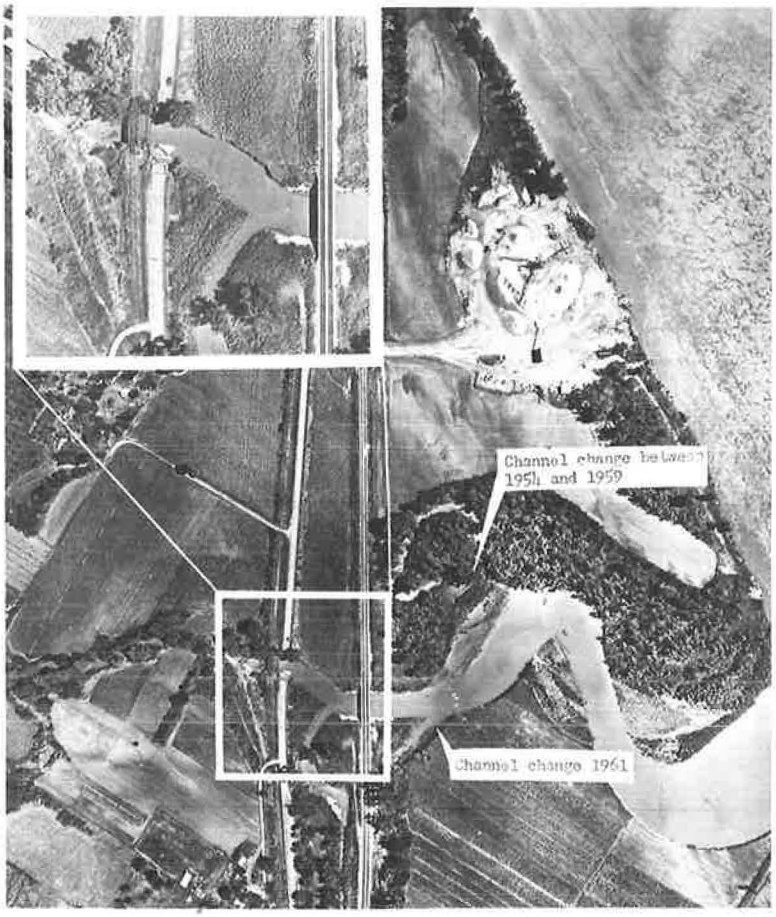
Figure 2 shows an example of a geologic exposure that has been targeted so the thickness, strike, dip and extent of the various geologic formations can be determined and mapped. This geologic information may then be used in the design of rock slopes, estimation of the quantity of rock that will be encountered during construction, and the determination of the possibility of slides and other maintenance problems that may be encountered in existing facilities.



COURTESY STATE HIGHWAY COMMISSION OF KANSAS

Figure 2. Example of targeting of specific geologic formations for determination and mapping of thickness, strike, dip and extent of various geologic formations.

An example of the use of photo interpretation for the evaluation of channel changes over a 21-year period and the effect of the channel changes on an existing road is shown in Figure 3. Aerial photographs taken at five different times during this period were studied to ascertain the stream activities. From photo interpretation and the evaluation of the stream gradient, it could be determined that the collapse of the highway

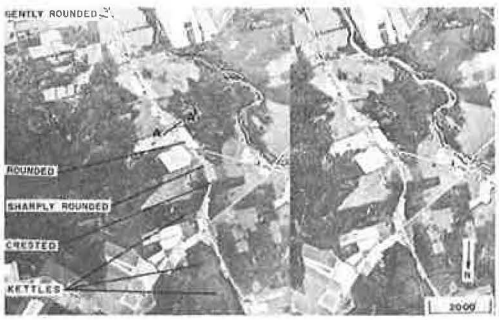


COURTESY STATE HIGHWAY COMMISSION OF KANSAS

Figure 3. Use of interpretation of five sets of photographs taken over 21-year period to determine reason for collapse of highway bridge.

bridge was caused by the increased erosive action of the stream within recent years due to channel changes occurring in this period.

The Maine State Highway Commission and the University of Maine under a cooperative agreement with BPR have recently completed two research projects on the use of photo interpretation techniques for obtaining information of value to highway engineers. In the first study, various features, such as size, orientation, elevation and type of vegetative growth, were evaluated to determine if reliable estimates could be made on the depth of peat by photo interpretation techniques. A statistical analysis made on data obtained from 174 sites indicated that none of the features studied were statistically reliable for predicting the depth of peat, although general trends were noted (15). In the second study certain features of eskers discernible by photo interpretation techniques such as longitudinal slope configuration, transverse shape, and height were evaluated to determine if some relation existed between these features and the grain size of the materials in the esker at a given point. Results indicated that the combination of longitudinal slope configuration and transverse shape were very valuable in predicting locations of gravelly materials, and for the areas checked, the prediction of gravelly materials was correct in 70 percent of the cases (16). Figure 4 is a stereogram showing a 2-mi section of an esker indicating four of the seven basic transverse shapes evaluated in this study (gently rounded, rounded, sharply rounded and crested).



COURTESY MAINE STATE HIGHWAY COMMISSION

Figure 4. Stereogram showing 2-mile section of esker and several shape configurations analyzed to correlate shape with grain size of materials encountered.

In addition, this study also developed criteria for defining the limits of excessive overburden on esker flanks so that a photo interpreter could determine realistic boundaries for material volume estimates.

PHOTO INTERPRETATION AND THE BUREAU OF PUBLIC ROADS

Throughout the years, BPR has been one of the leading proponents of the use of photo interpretation in the highway field. For over 15 years, BPR has been promoting the use of photo interpretation through education and research and has been encouraging the highway organizations to use Highway Planning and Research funds available to them for research in this area.

In 1946, the Bureau entered into a cooperative agreement with the New Jersey State Highway Department for development of engineering soil maps for the state. Work on this project was performed by Rutgers University under contract with the state highway department, and photo interpretation was used extensively for the development of the engineering soils maps. Rhode Island completed a similar project in 1956 using photo interpretation extensively. Cooperative work with Maine State Highway Commission was first initiated in 1948 for the development of engineering soils and materials maps using photo interpretation techniques. This work is still under way, but is mainly utilized for highway location studies. In addition, as previously indicated, techniques have been investigated for increasing the amount of information that can be derived by photo interpretation. At present there are 19 states in which photo interpretation techniques are being utilized using the 1½ percent Planning and Research funds. Some of these projects are (a) materials mapping on a strip, county or state basis; (b) engineering soils mapping on a strip, county or state basis; (c) evaluation of terrain investigation techniques; and (d) special projects, such as the engineering classification of geological materials. Two procedures manuals for performing material studies have been developed under the cooperative program (17, 18).

In addition to promoting the use of photo interpretation by the state highway departments, the Materials Division of BPR has conducted or participated in 14 schools of a 1- to 2-week duration to train highway personnel in the techniques and applications of photo interpretation.

REFERENCES

1. Time-Saving Methods in Highway Engineering. Highway Research Board, 1955-56.
2. Committee on Photogrammetry and Aerial Surveys: Results of 1962 Questionnaire on Use of Aerial Surveys. Highway Research News No. 6, June 1963. 50 pp.
3. Subsurface Exploration: Organization, Equipment, Policies and Practices. Highway Research Board Bull. 316, pp. 1-11, 1962.
4. Huffine, W. B. Highway Department Usage of Advanced Techniques. Amer. Highways, pp. 14-20, April 1961.
5. Manual of Photographic Interpretation. Amer. Soc. of Photogrammetry, 1960.
6. Lueder, D. R. Aerial Photographic Interpretation—Principles and Applications. New York, McGraw-Hill, 1959.
7. Aerial Photography in Right-of-Way Acquisition: A Symposium. Highway Research Board Bull. 354, pp. 51-84, 1962.
8. Stallard, A. H., and Anshutz, G. Use of the Kelsh Plotter in Geo-Engineering and Allied Investigations in Kansas. Highway Research Record No. 19, pp. 53-107, 1963.

9. Wagner, F. A., Jr., and May, A. Use of Aerial Photography in Freeway Traffic Operations Studies. Highway Research Record No. 19, pp. 24-34, 1963.
10. ARBA Committee on Highway Engineering Curricula—Education Division. Results of the Highway Engineering Curricula Study—A Survey of the Highway Industry and Engineering Colleges in the United States. ARBA Tech. Bull. 251, 1962.
11. Chaves, J. R., Schuster, R. L., and Warren, R. J. A Preliminary Evaluation of Color Aerial Photography in Materials Surveys. Highway Research Board Proc., Vol. 41, pp. 611-620, 1962.
12. Chaves, J. R., and Schuster, R. L. Use of Aerial Color Photography in Materials Surveys. Highway Research Record No. 63, pp. 1-9, 1964.
13. Lape, L. H., and Ory, T. R. Aerial Film-Filter-Scale Experiments in Soils Engineering. Presented at 30th Ann. Mtg. Amer. Soc. of Photogrammetry, Washington, D. C., March 1964.
14. Ohio State University. Terrain Investigation Techniques for Highway Engineers—Research Project EE-196B, Report Summary. Prepared for Ohio Department of Highways and U.S. Bureau of Public Roads, 1964 (unpublished).
15. Kennedy, R. A. The Relationship of Maximum Peat Depth to Some Environmental Factors in Bogs and Swamps in Maine. M. S. Thesis, Univ. of Maine, prepared for Maine State Highway Commission and U.S. Bureau of Public Roads, Aug. 1963 (unpublished).
16. Stoeckeler, E. G. Criteria for Predicting Soil Types in Eskers. Maine State Highway Commission, Soil Mech. Ser. Tech. Paper 64-1, Jan. 1964 (unpublished).
17. Procedures for Location of Granular Materials. Colorado Dept. of Highways, 1962.
18. Procedure Manual for Statewide Materials Location Surveys. Wyoming State Highway Dept., 1963.