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REMOTE SENSING FOR ENGINEERING SITE SELECTION

by

Jack N. Rinker and Robert E. Frost¹

ABSTRACT

For any significant construction, e.g., airstrip, bridge, dam, powerplant, industrial park, canal, etc., there is the first phase of site selection and evaluation. One goal of this phase is to obtain information about surficial materials (granular, cohesive, permeable, nonuniform, etc.), thickness of the soil mantle, nature of the bedrock, drainage, presence of unstable materials and conditions, presence of subsurface solution cavities, fractures, joints, faults, etc. Remote sensing techniques in the form of "manual" analysis of photo index sheets and Landsat for regional information, and of stereo aerial photography for local details, provides an economical and rapid means of obtaining this first assessment. An experienced team can quickly produce surficial geology/soils maps, drainage maps, land use/land cover maps, etc., highlight potential problem areas, select preferred sites and alternates, and indicate probable impacts on the environment of any given action. This image-derived information sets the basis for establishing a logical ground sampling program, and provides the framework for correlating a large variety of information. As yet, it is not possible to provide very much of this needed terrain information by digital, or automatic, image analysis procedures.

The manual analysis of stereo aerial photography represents the state-of-the-art for rapidly and economically obtaining reliable information about any given region of the earth in terms of its composition, properties, potential use, and probable response to stress. Whatever use of the terrain is envisioned in terms of building on it, tunneling through it, or extracting from it, certain pieces of information are needed before decisions can be made as to site selection, location of materials, performance prediction, and impact on other factors of the environment. These information needs tend to cluster about the fields of surficial geology, i.e., soils and rocks, and structure, and are usually in evidence by such questions as: what kinds of soils are present? are they permeable, granular, well sorted, poorly sorted? are they impermeable, plastic, cohesive? how thick is the soil mantle? what is the nature and attitude of the surface and subsurface rocks? are they highly fractured? are there local sources of sands and gravels? or, are there any indications of unstable materials or conditions, or potential hazards such as subsurface cavities? Answers to these questions, or at least information contributing to the answers, can come from several sources, including personal knowledge, field and laboratory work, maps and

¹U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia.

literature, and remote sensing. Each of these are part of the "tools of the trade" available to the engineer. As to which tool should be brought into play can sometimes be determined by the nature of the question. For example, to the question "What is the particle size distribution of this soil?" the answer can come from only a laboratory or field measurement; but to the question "Is the soil in this area permeable, and granular?" the answer can come also from an air photo analysis.

Air photos are but one of a varied assortment of remote sensing systems, some of which provide information about a specific property, such as the magnetic field, the gravitational field, or surface roughness. Others provide a measurement, such as a laser profilometer, or an ice thickness radar. And yet others provide some form of an image, such as an aerial camera, radar, Landsat, or a thermal imager. Some of these systems and their associated analytical procedures provide but one type of information, some provide a variety of information, some lend themselves to automation and digital techniques, and some do not. This paper is directed to the analysis of stereo aerial photography for several reasons. Foremost is the fact that stereo aerial photography has the highest information content in relation to the practical aspects of engineering use of the terrain. Next is the fact that there is sequential stereo photo coverage of most of the United States dating back to the late 1930's, and prints are available quickly and economically. Furthermore, very little equipment is needed for an analysis; at its simplest, a pocket stereoscope and a hand lens will meet all needs.

Conflicting opinions exist with reference to the state-of-the-art of image analysis in terms of manual versus machine procedures. In this instance, the term manual is used to denote a minimum of mechanical assistance, i.e., the analysis depends on the eye, mind, images, hand lens, and pocket stereoscope. The term machine is used to designate those procedures commonly referred to as automatic pattern recognition, digital analysis, and man/computer interactive analysis. As with most things, a point of view depends not only upon one's personality and background, but also on the task at hand. Most remote sensing and interpretation techniques tend to fall into one of two categories. These two categories are better thought of as representing extremes of a continuum, for there is not a sharp boundary between them; furthermore, many applications have elements of both. These categories can be loosely described as procedures associated with detecting, targeting, and monitoring on the one hand, and procedures associated with deductive and inductive reasoning on the other hand.

Targeting, detecting, and monitoring techniques require that the target, whatever it is, have some characteristic that is different from its background and which, hopefully, cannot be confused with any other object in the field of view. These differences can be based on such things as shape, size, arrangement, surface texture, color, spectral absorption and reflection, temperature, etc. Applications that tend to fall into this category include: detecting discrete objects such as roads, airports, dams, vehicles, number of lakes per area, etc.; detecting changes in patterns; detecting and mapping flood boundaries, flood

and storm damage, insect damage, and diseased crops; and estimating values such as crop yield, percent of tree cover, etc. Many of these tasks, or parts of them, lend themselves to machine analysis, and, in some instances, it would be the only sensible way to go about the job.

Deductive and inductive reasoning procedures produce information that is broader in scope, and more complex in content, than that derived by the use of targeting and detection techniques. These procedures are directed towards gaining as much understanding as possible about the area in question, including the nature of the materials in terms of composition and properties, the characteristics of the vegetation, the climatic factors, and the nature of man's activities, if present. These types of information form what can be called an environmental data base which can then be interpreted with respect to such problems as resources inventory (including ground water), regional planning, site selection and evaluation, and prediction of environmental impact as the result of any given action. This procedure of analysis relies upon the inductive and deductive evaluation of various lines of convergent evidence derived from the visual examination of image patterns, preferably in the form of stereo aerial photography. In general this method does not lend itself to machine procedures. It is mostly a manual task and the burden of the work falls on the individual. The quality of the product depends more on the characteristics of the individual than it does on the remote sensor system. In detection oriented tasks, many of the procedures are more dependent on the system than on the individual.

Certainly there is more than one way of analyzing stereo aerial photography, or other imagery. The procedure that we used is based on the published and unpublished notes of Robert E. Frost, many of which were developed and used at the School of Civil Engineering of Purdue University during the late 1940's and early 1950's (Frost, et al, 1953).² At that time, the procedure was directed towards the photo interpretation of soils and rocks for engineering purposes, and still retains much of that perspective. Over the years, it has been tested and evaluated in many areas of the world, by field research projects, and by direct application tasks such as engineering and geologic problems ranging from locating engineering materials through site selection for roads, canals, airports, etc., to large scale applications such as the layout of Thule Air Base, or the environmental data base prepared over much of Wisconsin for the Navy Project Sanguine. In addition, this photo analysis procedure has formed the basis for a series of intensive short courses that has been presented within the U.S. to some forty groups, composed mostly of U.S. Army Corps of Engineers' personnel, some U.S. Air Force personnel, and a few from other agencies. Similar material has been presented also to Latin American engineers and scientists via a series of courses sponsored by the Inter American Geodetic Survey of the Defense Mapping Agency.

²Frost, R. E., J. G. Johnstone, O. W. Mintzer, M. Parvis, P. Montano, R. D. Miles, and J. R. Shepard. 1953. A Manual on the Airphoto Interpretation of Soils and Rocks for Engineering Purposes. School of Civil Engineering and Engineering Mechanics, Purdue University, West Lafayette, Indiana.

This method of photo analysis relies on associating numerous threads of converging evidence, and requires a thorough understanding of the origin and relation of landscape features, as well as the relation of these features to their aerial formed images. In practice the procedure is divided into two phases, the regional analysis and the local analysis. For the regional analysis, relatively small scale imagery is used, such as Landsat images, or photo index sheets. The purpose of the regional analysis is to establish the broad frame of environmental conditions that are contained within, as well as around, the area of interest. In this part of the analysis general decisions are made as to boundaries separating economic pursuits, vegetation classes, landform units, and soil characteristics. For the local analysis, effort is focused on the landscape pattern units via larger scale stereo imagery, which provides the detail needed to fill in the regional information, and to make decisions as to types and conditions of materials. A number of photo scales are available, e.g., 1:20,000, 1:40,000, 1:60,000, and 1:120,000. In recent years, the tendency has been to take aerial photography at the smaller scales, especially 1:40,000 and 1:60,000. Where available, the larger scale of 1:20,000 is usually preferable. It is a very good compromise in terms of the amount of photography needed to cover an area, and the size of pattern detail that must be seen. Much of the fine structure such as gully cross section, and subtle changes in gully gradient or concavity of slopes, is not readily seen in the smaller scales. In some instances, color photography is also available, either as normal color or false color. Although such is certainly usable, color photography is not needed for a general photo analysis, and does not contribute enough additional capability to justify the greatly increased cost. For certain detection tasks however, such as vegetation mapping, locating diseased vegetation, or locating wetlands boundaries, it can be more useful than panchromatic photography.

As a full discussion, with appropriate illustrations, of the details of stereo photo analysis cannot be covered, this paper will present but a general outline of the procedure and its associated logic. Reduced to the simplest of terms, the principles for this procedure of image analysis can be expressed as follows:

1. An air photo is a pictorial representation of the various features within the landscape.
2. A pattern is composed of elements that serve as indicators of materials, conditions, and events that are related to the physical, biological, cultural, and climatic components of the landscape.
3. Similar materials and conditions in similar environments produce similar patterns, and unlike materials and conditions produce unlike patterns.
4. The type, quantity, and quality of information that can be obtained by photo analysis is proportional to the background, knowledge, experience, skill, and interest of the analyst.

The foundation of this method rests in principle 3, i.e., similar materials and conditions in similar environments produce similar patterns, and unlike materials and conditions produce unlike patterns. There are many patterns to be evaluated and most of them can only be evaluated by stereo viewing. Based upon the statement in principle 3 one can reason that if the patterns are uniform across an image, then the materials and conditions, whatever they might be, will be uniform throughout that area. If any pattern element changes, e.g., gully cross section, gradient, soil tones, hill shape, vegetation texture, etc., then either the materials, or the conditions, or both, must have changed. In some cases specific pattern elements are uniquely related to the identity of a material, or to a given condition. Many of the pattern elements must also be evaluated in relation to climate and season as these can cause considerable modification. The analysis of any given pattern involves at least three steps: identification, description, and signification. The latter is the more important step, and, without doubt, it is the most difficult, requiring more in terms of knowledge, experience, and judgment than do either of the other two steps. Identification is the act of recognizing any given pattern and either tracing out its domain or otherwise using it during the analysis. By definition, the pattern must be different beyond that boundary; therefore, there must be a corresponding change in materials, or conditions, or both, as that boundary is crossed. Depending on the pattern being considered, the boundary might enscribe a group of items of the same shape, a surface of uniform tone and texture, a drainage net of uniform spacing and arrangement, or some other identifiable property. The boundary denotes the location of a change, it does not give information about the contents within. The next step is to describe in detail the characteristics of the subject pattern in terms of size, shape, spacing, arrangement, symmetry, etc. The description is then evaluated in terms of its significance. Each pattern element signifies, or suggests, something about the nature of the material in terms of its composition, its characteristics, or its condition. There are of course, many patterns yet unknown, as well as many patterns that are not understood. There are many different pattern elements within an air photo, and in order to apply the stated principles in an effective manner, one must follow some sort of a systematic procedure to ensure that all elements are considered. The scheme that we use classifies the pattern elements into the following categories: landform, drainage (plan and elevation), erosion, deposition, vegetation, cultural, photo tones and texture, and special. Each of these factors provides some information as to the nature of the materials either in terms of composition, or in terms of conditions, and it is this sequence of classes that forms the basis for what we call a systematic procedure for the analysis of natural features by use of air photos. The pattern sets of landform, drainage, erosion, etc., are so basic to this procedure of analysis that a brief description as to how and why they are important is in order.

Landform. This pattern refers to the shape, size, and orientation of any given surface feature and its location within and relation to the surrounding area. It is the most important pattern element because it is so closely associated with the origin of the material and the subsequent erosional history. An understanding of landforms and their origin makes it possible to bound areas of similar materials and predict their composition, textures, and physical characteristics. In this

part of the photo analysis, areas are outlined in which the terrain elements within are uniform in shape, size, spacing, arrangement, and orientation. Wherever any aspect of landform changes, there is the basis for a boundary denoting some change in materials or conditions, or both. An area might contain but one item or one shape, for example, a plain, or it might contain a collection of shapes, such as a group of similar hills. There will be as many materials, or conditions, or combinations of both, as there are landform units. For example, if one has bounded five different landform units, then one can say that the area of study contains at least five different materials, or conditions. Each bounded area must be described in terms of shape, size, spacing, arrangement, symmetry, dip, slope, angularity, roundedness, etc., and evaluated with reference to the significance of these observations. For example, sharp angularity in the hill shapes (or mountains) suggests a hard resistant material, whereas soft, gently rounded slopes suggest the presence of a soft material. Climate modifies these aspects and must be taken into consideration. A clay shale can have gently rounded slopes in a moist temperate region, and rugged precipitous slopes in an arid region subjected to seasonal rains and flash flooding. Profiles should be drawn along several transects through the stereo field of view. Upon completion of the analysis the profiles can be converted into predicted cross sections. The complexities of landform classification found in most texts is beyond the needs of air photo analysis. Regardless of how complicated the shape, it can be assigned into one of four general categories: mountains and hills, plains, basins, escarpments.

Drainage-Plan. This refers to all drainageways, including standing water as well as the channels that water would follow if it fell on the surface. This pattern is next in importance after landform and provides information about soil permeability, areal homogeneity, ease of erosion, ground slope, relative depth of soil mantle, presence and type of rock, and dip of beds. Aside from forms of control such as caused by bedding, jointing, and fractures, drainage is a function of soil permeability and slope. Surface drainage patterns do not develop on highly permeable materials such as sand. In materials that are not wholly permeable, such as clays and silty clays, the water, or at least part of it, runs over the surface and scours out a drainage pattern. In general the finer the drainage net, i.e., the closer the gullies are spaced, the less the permeability and the finer the texture of the material. In this part of the stereo photo analysis all drainageways, low spots, standing water, etc., are traced out on the overlay material and the resulting pattern is evaluated in terms of homogeneity, arrangement, spacing, and geometry (angularity, type of intersections, etc.). Wherever one of these characteristics changes, there is a basis for a boundary denoting a change in materials, or conditions, or both. Supposing, as in the landform overlay, the drainage pattern overlay has been removed from the photos, placed on white paper, and five different patterns have been identified and bounded. This in itself sets the basis for considering that the area in question has at least five different materials, or conditions; which supports a similar conclusion derived under landform. One could of course, come up with more drainage patterns than landform patterns. There does not have to be a one to one correspondence. Going back to the stereo images and examining the

area in question, one might now note some subtle variation in slope, or shape, that was not noticed during the landform analysis.

Drainage-Elevation. This pattern refers to the shapes of the gullies in cross section and in gradient. It is an important pattern element because soil textures and profile features can be interpreted directly from a detailed study of gully systems and gully characteristics. These features are closely associated with specific soil types and are not duplicated in unlike materials. In general, there are three basic gully cross section shapes that correspond to the textural groups of granular soils, silty soils, and clayey soils. In granular soils, erosion will develop gullies with a sharp V-shaped cross section and with a short, steep gradient. In silts, the gully cross-sections tend to have steep sides and flat bottoms, or vertical sides and flat bottoms, as a function of wind deposits vs. water deposits. Nongranular, cohesive, and plastic soils, i.e., the clays, develop a gully whose cross section has a broad, softly rounded saucer shape, and whose gradient is gentle and extends well back into the upland. In this part of the stereo photo analysis the gully cross sections and gradient are carefully examined and sketched. Wherever there is a change in a gradient or in cross section, there is a basis for a boundary denoting a corresponding change in materials, or conditions, or both.

Erosion. The patterns of erosion provide information about the nature of the materials, conditions, and climate. Each mechanism of erosion leaves a telltale pattern of shape or tone. In this part of the stereo analysis one looks for indicators of the mechanism of erosion, describes them, and assesses their significance. For example, the occurrence of blowouts on a surface is suggestive of the presence of a granular or sandy material; the presence of sinkholes, a form of chemical erosion, is suggestive of limestone; the intensity of water erosional patterns suggests something about the nature of the resistance of the material to erosion. In general, these patterns are related to: water, wind, gravity, ice, chemical, thermal, and man induced.

Deposition. Material that is eroded away must be deposited elsewhere, and the resulting patterns are controlled by the nature of the material, conditions, and climate. Some depositional formations are large enough to be classified as landform patterns, e.g., large deltas, fans, terraces, dunes, etc. Even so their patterns are indicative of composition. This part of the analysis serves as a checkpoint to review the imagery for indicators of deposition and assess their significance, e.g., examining gully mouths to see if fans are present, which, if found, would indicate that there must be a source of granular material someplace. In general, depositional patterns are caused by the following mechanisms: water, wind, gravity, ice, and man induced.

Vegetation. The results derived from an analysis of vegetation patterns can be used to provide information about the vegetation itself in terms of type, density, vigor, average stem diameter, etc., or to provide information about other terrain characteristics and climate. Air photo scales suitable for engineering soils evaluation and environmental data base preparation, i.e., in the 1:20,000 scale range, are too small for use in species identification. Vegetation types or large

pure stands however can be identified, and boundaries established between groups. These boundaries are frequently associated with changes in soil texture, soil moisture, topography, and orientation, and give supportive information to factor boundaries established in earlier phases of the analysis. Knowledge of landform and soil within an area can frequently set the basis for a fairly accurate prediction of the species distribution. The vegetation patterns can also provide some information about climate. Under certain conditions, usually in subhumid and arid regions, a vegetation type or species can be a unique indicator to such things as the depth of the soil mantle, or the soil type. Although there are several ways of classifying vegetation, some of them task oriented, a first order break down based solely on photo patterns usually includes: closed canopy forest, open forest, brush, grassland, mixed, wetlands, barren.

Cultural. As in the case of vegetation, the analysis of cultural patterns can be done for two reasons: to derive information about the culture itself, or to use the cultural patterns to derive information about other factors. As an example of the first, the economic characteristics of a given society can be deduced through an analysis of the cultural patterns. As an example of the second, a pattern of cultivated fields, such as the alternating tones of fallow farming, can provide clues as to soil texture and the general climate. Because cultural information serves many different uses, it is not possible to provide a single satisfactory classification scheme. In many applications this type of information becomes part of a land cover/land use overlay, or map. In other applications this factor is ignored, except for those cultural patterns that provide information about the composition, or condition, of surficial materials, e.g., quarries, borrow pits, drainage tiles, etc. Based solely on photo patterns, one can identify and map the following first order cultural patterns, and many of their second order parts: transportation and communication, built-up areas (areas with structures), agriculture and livestock, recreation, and special.

Photo Tones and Texture. These patterns can provide information about specific materials or conditions, as well as provide information to support conclusions developed during the analysis of other factors. In most cases these patterns are associated with areas of relatively bare or exposed soil and rock, or with an area of uniform vegetation cover. Although photo tones and texture are important sources of information, care must be taken in evaluating them, especially those of soils, because climate and season greatly influence the development and the detectivity of these patterns. With respect to soils, the tones and textural patterns can provide information about identity, origin, uniformity, horizon development, moisture relations, etc. As an example, in panchromatic photography silt has a bright uniform photo tone and a silky texture. Soils of the Wisconsin glacial till show an intricate mottling of light gray and dark gray tones that are related to soil texture and moisture conditions. With respect to exposed rocks, tone and texture can provide supportive information as to type. In igneous rocks, for example, the basic groups such as basalt and gabbro have dark photo tones. The acidic rocks such as granite tend to have lighter tones. With respect to vegetation, tone and texture can provide

information about composition or vegetation type.

Special. This category includes items that do not easily fit under other factor headings, or items that, though discussed under other factors, are sufficiently direct indicators of identities and conditions that they warrant additional evaluation. This part of the analysis serves as one more check point to carefully examine the imagery for clues to support previous findings or to suggest new relations or identities. These patterns frequently depend on some inherent quality of the material, or on some inherent nature of an action. Typical patterns include: joints, fractures, and faults; soil slumps, landslides, mudflows, and tears; special landforms such as barchane dunes, cones, drumlins, etc.; and some patterns of drainage, erosion, and tones. As an example, windblown silt deposits have an internal vertical structure that accounts for several patterns that serve as direct indicators of the presence of such a material. These include the pinnate drainage pattern, flat-bottomed steep-sided gullies, terracettes and pinnacles on gully walls, and vertical-faced road cuts. The pinnate, gully cross section, and road cut patterns would be evaluated under their respective sections. The terracettes and pinnacles, too small to be considered as landforms, would probably be discussed under this section. As another example, slumps and tears in an otherwise smooth valley wall would be indicative of instability and potential engineering problems.

That summarizes the important characteristics of each of the pattern groups. Each of the pattern elements provide some information about the nature and condition of the resident materials, with each group serving as a check on deductions from other groups. Eventually, after much detailed examination of the stereo photos, debate, and modification of boundaries, a set of boundaries, cross sections, profiles, and supporting discussion emerges that the analysis team agrees to let stand as their results. The statements of significance for each pattern group are reviewed and, for each bounded area, a statement is prepared that discusses the contents of that area in terms of its composition and condition, i.e., origin, rocks, soils, structure, fractures, vegetation, land use/land cover, and any special features. This collection of statements and overlays forms an environmental data base for the area in question which is then interpreted with respect to the problem at hand, e.g., selection of a construction site and an alternate.

At this point, the analysis team should go into the field to sample and examine the study area. For the most part the data base contains general information rather than the specific quantitative information needed for many of the engineering decisions. But, the team goes into the field with a thorough knowledge of the area in terms of its origin, its parts, the relation of the parts to each other, and the contents of the parts. They know exactly where to go to sample, where to drill, where the potential problem areas are, where sands and gravels are located (if present), etc. They do not, however, have specifics. For example, they might know exactly where to go to get granular material; but, only field samples can tell them how well sorted it is, or its particle size distribution. Or, they might be confident that a particular massive limestone bed contains a significant number of

large, subsurface, solution cavities; although they could not with certainty point to the spots on the surface over them. They would know that in that area a rather close drilling net would have to be established before making decisions about site location. Thus, the air photo analysis serves as an excellent data base to evaluate an area, and to guide the team in its decision making.

The duration of a photo analysis depends on the complexity of the study area, the competence and experience of the analysts, the type of information desired, and the format in which the information is to be expressed. An experienced team of three to five members can produce an environmental data base and preliminary interpretations with draft overlay maps and text in a work period of 16 to 24 hours. Usually, the factor overlay maps are keyed to the uncontrolled photomosaics of the study area, a procedure that is adequate for most needs. If requirements dictate that the information be transferred to some controlled grid, such as a 7½-minute quadrangle sheet, then more time will be needed. That, however, is an issue separate from the analysis.

Even though the area of interest is relatively small, the area of the photo analysis should be extended considerably beyond its borders in order to better recognize regional trends, as well as the possible impacts of construction on the overall area. The following schedule is for one 4- by 8-foot board, which is as large a size as can be handled conveniently. A project might require several such boards to cover the region of interest. A photo scale of 1:20,000 provides a photo work area of about 14 by 18 miles on a 4- by 8-foot board. The time required for each step is given in approximate man-days. Doubling the manpower does not necessarily reduce the time requirements for a given factor because it usually engenders more discussion and argument, which is to the good, for that produces more information.

1. Using every other photo from the flight lines, an uncontrolled photomosaic is made by stapling the photos to a 4- by 8-foot Cellotex board, or equivalent. The remaining alternate photos are used to provide stereo viewing throughout the mosaic. The pattern mismatch between photos, due to off-axis distortion or scale changes, can be distributed either to optimize features of interest, or uniformly dispersed throughout the area. If future work is anticipated, the photomosaic should be copied at 1:1 and contact prints made on a stable base material.

Trim photos, assemble mosaic, and set up for copying . . . ½-1 day

2. Using stereoscopes and hand lenses, the photomosaic is studied and discussed among the team until each analyst is familiar with the general characteristics of the area and their relations to each other. Unusual features, or avenues for investigation, are noted for future consideration.

Preliminary study ½ day

3. Cover the mosaic with stable base transparent acetate material to serve as a marking surface. A fresh sheet of overlay can be used for each factor. For an environmental data base oriented towards surficial

geology and soils, the minimum of factor overlays are landform, drainage, and lineaments (fractures, joints, and faults). For a complete data base the factors of vegetation and land use must also be done. For the latter two factors the most recent photography should be used and it may be necessary to schedule photo flights in order to get current coverage. For the factors of soils, geology, drainage, etc., the older photography is adequate, and frequently preferable, because the background clutter of cultural development can obscure soil, drainage, and landform boundaries. As work proceeds, the photomosaic and derived factor overlays are photo reduced and copies made on transparent as well as on paper stock. A convenient format is 20" x 24". If copies of quarto size are needed for the report, that reduction can be done at the same time. If the factor transparencies are color coded, i.e., blue for drainage, red for landform, etc., the comparison step is easier.

(1) Landform. Using the stereo image, trace out all areas that have internal homogeneity with reference to shape, e.g., plains, terraces, valleys, areas of similar type hills, areas of similar slope on compound hills. These boundaries indicate the interfaces between different materials and/or conditions. While looking for and tracing these boundaries, note and mark such clues as the presence of bedding planes, dip and strike, indicators of instability such as slides and tears, angularity or gentleness of slopes and hills, erosion patterns, and unique features.

Landform overlay 1 day

(2) Drainage. In the stereo image, trace out all water bodies, water courses, and places where water would stand or flow if water fell on the surface. While doing this, carefully note the erosion patterns and any changes in them (gully cross section, stream gradient, nature of stream junctures, etc.) for these are also indicators of changes in materials and/or conditions. Also note any indicators of instability such as bank erosion, slides, etc. When complete, the drainage overlay is removed from the mosaic, and evaluated as an isolated factor pattern. If materials and conditions are the same throughout the area, the drainage pattern will be uniform in its composition. If the pattern changes in terms of density, fineness, angularity, tributary intersection, etc., a change in materials and/or conditions can be inferred. If the pattern does vary, then those areas that are internally uniform in pattern arrangement are identified and bounded.

Drainage map, overlay and analysis. . . 3 days

(3) Lineations. This factor includes all natural line-like features such as fractures, faults, joints, portions of streambeds, bedding, dikes, etc., that can be traced by use of a hand lens, stereoscope, or distant viewing. All reduced versions of the photomosaic (20" x 24" and 8" x 10") are used as well as the original mosaic board. Most of the features will appear as a discontinuity because of obscuration by overburden, vegetation, or the confusing clutter of other pattern detail. In limestone areas, the factors of drainage and lineations provide the basis for predicting subsurface conditions with respect to cavern and channel development.

Lineation map 1 day

(4) Land cover/land use. This factor contains general vegetation information such as wetlands, cropland, orchards, pasture, woods, etc. If more specific details are needed such as vegetation types, density, canopy closure, etc., a separate vegetation factor can be prepared. However, the general land use category is suitable for most needs. In this factor the lines of transportation (roads, railroads, pipelines, power lines, etc.) are traced out and the various uses of land elements are bounded and identified. The classification is usually specified by the user but includes such items as agricultural land (pasture, orchards, crops, woodlots, etc.), urban areas (residential, industrial), recreational areas, wildlife and natural areas, etc. In addition, such features as quarries, mines, the presence of agricultural drain tile, irrigation ditches, etc., are noted. These are not only part of land use, but serve also as special indicators for materials and conditions.

Land use map 1-3 days

(5) Data Base Preparation and Interpretation. The combined overlays are examined and boundaries common to all members are assumed to be valid interfaces between different materials and/or conditions, and these are transferred to a new overlay base. All of these, as well as areas of boundary disagreement, must be repeatedly checked with the stereo photos until acceptable boundary conditions have been established. Many of the boundaries will be obvious enough that they can be traced out directly from the mosaic. Each bounded area is identified and described in terms of its material composition and physical properties, and expressed in such terms as poorly drained soils, organic soils, expansive clays, sand, gravels, easily eroded soils, unstable slopes, etc. Bedrock characteristics are described and, where possible, the depth of the soil mantle is estimated. These data are then interpreted with respect to specific problems such as site selection, location of materials, development of an area, or preparation of environmental impact statements.

Data base preparation, interpretation, report . . 2-3 days

Approximately 12 man-days, exclusive of field work, are needed to accomplish the above tasks and produce a written report (text and overlays) that reviews the area in detail, selects a site and an alternate, notes the presence or absence of needed materials, discusses potential construction problems, and lists the probable consequences of construction in terms of environmental impact statements. An experienced and knowledgeable multidiscipline team of three to five members can usually complete such a report in two to three working days, i.e., 16 to 24 hours of concentrated effort. There isn't any other procedure that can produce as much useful information in such a short time, at such a low cost, and with readily available materials.

Air photo analysis is the most rapid and reliable procedure for studying the terrain, and for gleaning from that study the needed general information about the composition and properties of that piece of the earth. As for all remote sensing techniques, air photo analysis is but a tool; and, as with all tools, the results depend mostly on the

user. A set of knives in the hands of a master carver can bring forth an exquisite piece that eventually finds its home in a museum. The same knives in the hands of another can bring forth nothing but a pathetic array of knicks, notches, and splinters. And so it is with an air photo analysis. The air photos are tools; they do not provide information directly. Information can be extracted from them, as a function of the skill, and knowledge of the analyst.