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NASA CR-150731

(NASA-CR-150731) A MANUAL FOR INEXPENSIVE METHODS OF ANALYZING AND UTILIZING REMOTE SENSOR DATA (Missouri Univ. -Rolla.) 32 p HC A03/MF A01 CSCL 05B G3/43 N78-28587 Unclas 27155

A MANUAL FOR INEXPENSIVE METHODS OF ANALYZING AND UTILIZING REMOTE SENSOR DATA

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July 1978

Prepared for

NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER
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INTRODUCTION

Purpose

This manual is intended to serve as a guide to the user of remote sensor materials. Contained are suggestions as to acquisition of photography, imagery and equipment, and use of simple analytical procedures for thematic map making and/or other data display. The procedures discussed are intended to be inexpensive and simple to implement for those who have had experience in photo interpretation.

Groups which have one or more of the following needs will find the contents of this manual useful:

1. Analysis of unique remote sensor data covering a small land area,
2. Analysis of general remote sensor data covering a large land area,
3. Information which must be easily updated seasonally or less frequently, and
4. A system of preparing remote sensor data products quickly, inexpensively and with minimal staff training.

Such groups might include planning agencies, crop data collecting/analysis agencies, contractors, tax assessors, teachers, city and county governmental agencies and engineers.

History of Remote Sensor Analysis

Remote sensor imagery historically has had many uses, with the most common method of analysis being visual interpretation aided with mechanical devices, (e.g. the use of plotting devices to produce topographic maps from stereo aerial photos). More recently, visual techniques have been used to identify and/or map desired terrain characteristics from aircraft and satellite imagery. The range of available imagery has widened during the past decade from the simple aerial photo to a wide spectrum of photo types, electronic sensor types capable of sensing either a unique data field or a wide range of data fields, and synoptic satellite imagery.

With the accumulation of this imagery, computer automated analysis procedures are being developed. To date, these systems for analysis are primarily oriented toward mapping land cover or surface characteristics from satellite imagery. However, many potential users of remote sensor data have needs which cannot be filled by computer-automated techniques of analysis. This manual has been prepared for those who need a guide to simple, inexpensive image analysis techniques.

Data Sources and Types (Relative Costs Included)

Remote sensor data appropriate for inexpensive analysis techniques can be divided into two categories depending primarily on the sensor system. Photography generally includes that data produced by actual exposure of film by an airborne camera. Photography is available as a print or transparency for either monoscopic or stereoscopic viewing. Scanner imagery, a second category, generally includes that data gathered by various kinds of electro-optical scanners and displayed either as a single band or composite photo-like image having a print or transparency format. Most composite displays have the appearance of a false color photograph and for visual analysis may be treated likewise. Photography and imagery may be procurred at a variety of scales.

The major source of both photography and imagery is the EROS Data Center, Sioux Falls, South Dakota 57198. Remote sensor data collected by U.S. agencies is indexed by Eros and is available to the user from this repository. Table I contains a summary of relevant characteristics with regard to the available materials. The potential user should first contact the Center, secure a "Geographic Search Form" and then request that a cost-free determination of available photography and/or imagery be made for the area in question. Subsequently, materials can be ordered from those listed, as available.

TABLE I

Examples of Remote Sensor Materials Available from EROS, Sioux Falls, S.D.

Photography	Sample Scales	Resolution (Smallest Observable Unit, Barney, 1977)	Approximate Cost*
Panchromatic (Black and White)	1:80,000 to 1:24,000	4-25'	Print: 9in x 9in $5.00 Trans: 9in x 9in $5-6.00
High Altitude Color Infrared	1:125,000	15-30'	Print: 9in x 9in $7.00 Trans: 9in x 9in $15.00
Imagery			
LANDSAT Single Band	1:3,369,000 1:1,000,000	Low Contrast Areas 300-700	B&W Trans: 2.2in x 2.2in $8-10.00 B&W Trans: 7.3in x 7.3in $10.00 Trans: $8.00
	1:250,000	Medium Contrast Areas 90-300'	B&W Print: 29.2in x 29.2in $20.00
LANDSAT Color Composite	1:1,000,000 1:250,000	High Contrast Color Features 45-90'	Trans: $12.00 Print $25.00 Print $50.00

*Costs taken from January 1977 order information, EROS Data Center

EQUIPMENT FOR LOW-COST ANALYSES

Stereoscope

Stereoscopes enable an interpreter to view an area in three dimensions--length, width and depth. Many stereoscopes are available ranging from simple, small pocket size, at a relative cost of $15.50, to mirror stereoscopes with a price variation of $68.90 to $185.00, plus a $20.00 case. If mirror stereoscopes are purchased, an additional magnifying lens system with 4x magnification can be attached at a cost of $195.00.

Aside from cost, the following comparisons can be made between pocket and mirror stereoscopes. Pocket stereoscopes are generally more durable, may be used in small work areas, and do not require extra lighting Due to their size, photos must be overlapped, making over-lay mapping somewhat difficult. Mirror stereoscopes are larger, requiring more working space and better lighting, although overlay mapping is very convenient, due to the wider photo spacing. The field of view is generally larger with a mirror stereoscope than with a pocket stereoscope.

Light Tables

A light table might be described as a backlighted, frosted glass writing surface. Such a table must provide light for viewing transparencies or photos at a temperature which will not damage the materials or the operator.

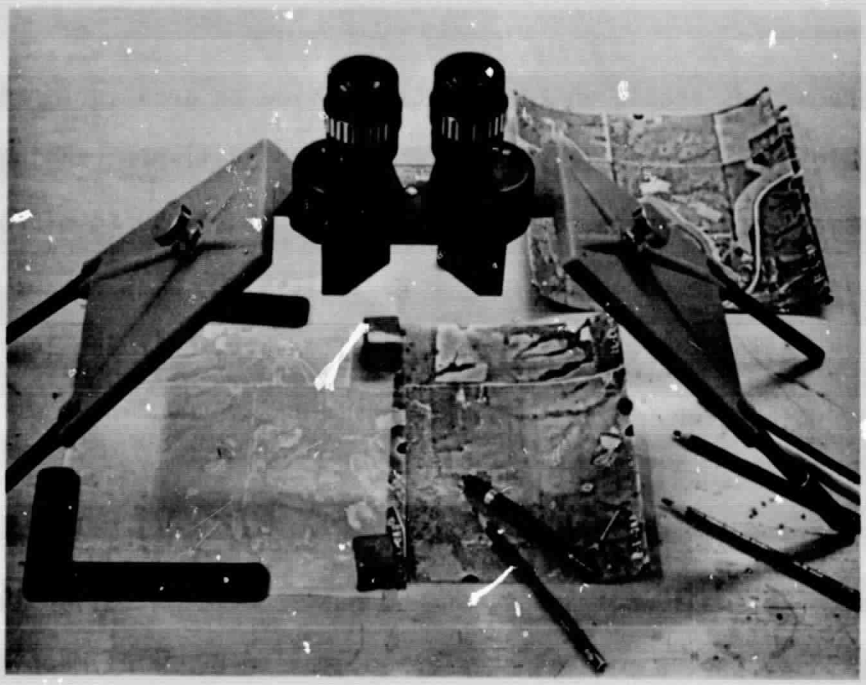


Figure 1. Mirror Stereoscope Shown in this photo is a mirror stereoscope in place over a stereo pair of photos. The overlay on the left photo is set to receive the map data interpreted as the photos are viewed in stereo. An overlay map made in this manner is to a scale equal to the scale of the photo.

This equipment may be purchased from suppliers or built in a local shop. Typical cost for an 11 in. x 18 3/4 in. table using two 15-watt fluorescent lamps is $69.75. The same table using one lamp is $49 25. Larger models are available at greater cost.

Additive and Subtractive Color Devices

These devices enable an interpreter to enhance specific features of multispectral LANDSAT imagery. The most inexpensive of these systems is a Diazo Processor. Current price for automatic hardware necessary for Diazo processing is $550.00. However, a heat lamp and ammonia jar will suffice. In addition, film and chemicals must be purchased.

A more versatile and elaborate system consists of an additive color viewer at a typical cost of approximately $10,000-$30,000. An additive color viewer provides for the optical superposition of up to four LANDSAT transparencies produced from each of four LANDSAT multispectral channels. An inexpensive additive color system can be devised by bore sighting several 35 millimeter slide projectors onto a screen. However geometric distortion is a significant problem.

Photographic Processes

Photographic equipment consisting of a camera, copy stand, and standard dark room equipment and supplies might be used for enhancement or enlargement of specific terrain features. For example, a typical application is to photograph a small section of an existing image or photograph with contrasting filters and display this at a larger scale providing for more detailed observation. Costs for such processes must be determined individually for each application.

Microviewer

A microviewer is a device which is designed to view either microfilm or microfiche. This device can be used to view small areas of film transparencies and 35 millimeter slides at large magnification (16 to 20x) depending upon the particular machine. Costs for such a device vary greatly, from less than $100 to several thousand dollars.

Transfer Devices

These pieces of equipment are used to plot or re-plot data at a scale different from the scale of the original photo, image or map. The Bausch and Lomb Zoom Transfer Scope and Map-O-Graph are commonly available instruments. Approximate cost of a Zoom Transfer Scope is $5,000 while that for the Map-O-Graph is $3,000.

Drafting-Cartographic Equipment and Supplies

Standard drafting equipment, including at least a technical fountain pen set and lettering set, along with suitable tables, is an acceptable arrangement with which remote sensor data might be interpreted. Certainly a well equipped drafting room is adequate.

Supplies needed include ink and acetate which has both maximum light transmission and a surface upon which pencil and ink might be used. Again, the usual well supplied drafting room, in addition to a supply of acetate,

Figure 2. Microviewer In this photo the microviewer has projected on its screen a 1:120,000 scale color infrared transparency.

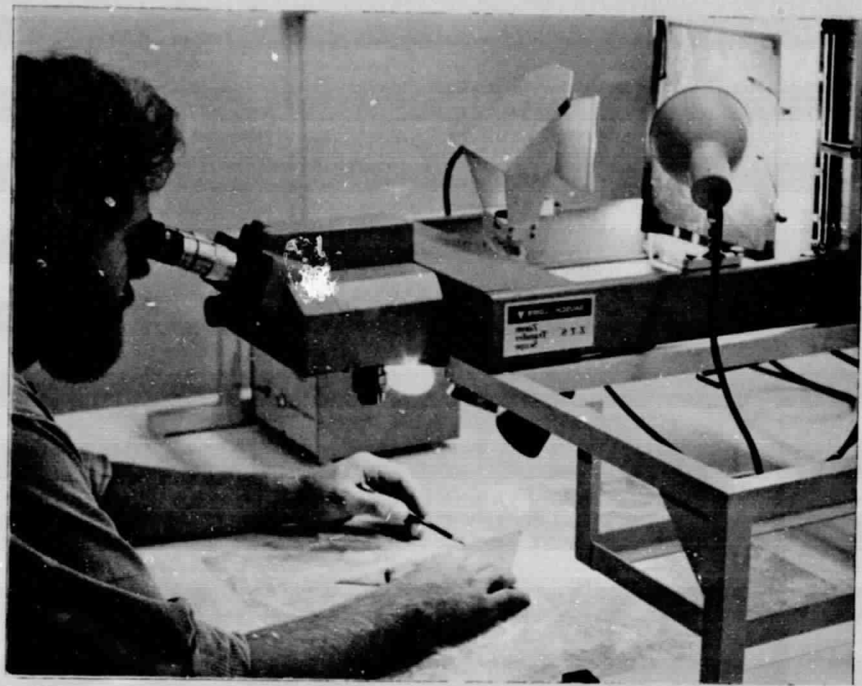
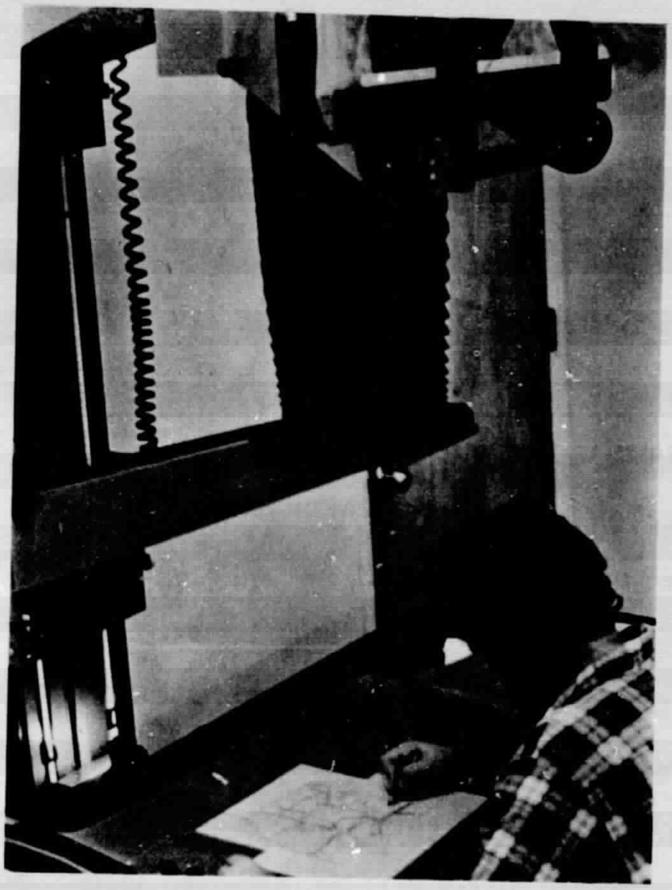


Figure 3. Bausch and Lomb Zoom Transfer Scope The photo interpreter in this picture is interpreting data from the aerial photo on the stage, upper left, and recording the data on the map beneath his hands. The map being constructed is an overlay to the base map of desired scale. The Zoom Transfer Scope enables the interpreter to "zoom" the photo to base map scale and to superimpose the photo onto the base map for recording data on an overlay to the base map.



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OF POOR QUALITY

Figure 4. Map-O-Graph A map placed on the stage of this instrument, upper portion, can be projected onto the drawing surface at scales either smaller or larger than the original.

is adequate. Special supplies such as Diazo materials are required, should such special processes be used.

DATA ANALYSIS TECHNIQUES

Stereo Photo Interpretation

For stereo viewing-interpretation, the most convenient and time efficient technique is a simple overlay procedure. Locate over one photograph a sheet of acetate upon which features are to be delineated. Locate the stereo matched photograph such that both can be viewed in stereo. A series of photos might be used to cover a larger area. This results in a data display at the photographic scale, which can be adjusted to the desired scale with transfer or photographic equipment.

Delineation of features requires some knowledge of characteristic signatures and patterns, which will be discussed later. However, some general knowledge of the area in question is useful and will facilitate interpretation. The development of a simple photo/imagery key for the area, with some field checking and ground truth, will prove very worthwhile if done before a project is started. With these steps, a high degree of accuracy can be anticipated.

TYPICAL PATTERNS

Photo-Tone and Texture

The tone of the area on a photograph refers to the color or shade of gray displayed. Texture, while being a function of the scale of the photograph, refers to the relative size of resolution elements and/or objects on the photograph. Where possible a photo key to relate tone and textural characteristics of the study area to those of the photography is recommended. However, some general relationships might be assumed.

Uniform light tones represent barren rock or coarse textured soils without a vegetative cover. Dark tones represent moist areas or organic soils. Grasslands differ from forested areas, with forested areas usually of darker tones. Water bodies and muck areas exhibit the darkest--nearly black--tones.

By analysis of the scale-texture relationship many interpretations may be made with use of the textural characteristics of the photography. It must be kept in mind that the larger the scale of the photography, the more coarse textured it will appear. Types of vegetation might be identified by textural characteristics. From the texture of the land surface, many interpretations as to drainage, rock type, soil type, etc. can be made. Urban areas can be identified on small scale photography by the textural aspects of the land cover. Coarse texture areas are usually industrial sites whereas fine textured areas are usually residential.

On larger scale photography, such areas are identified by means of the individual targets. Flood plains may be identified by the general homogeneity of both tone and texture. Uplands, on the other hand, exhibit more irregularity of both tone and texture.

Photo-Landcover-Land Use

With the use of overlays, land cover can be accurately mapped at almost any scale. Stereo viewing provides the advantage of interpretability of morphology. Tonal variation aids in the interpretation of types of vegetation. Other signature patterns can be developed as the study of the area progresses. An example of target association would be the fact that swimming pools normally indicate motels as compared with other similar commercial development. Industrial storage areas, parking lots and buildings generally are more compact whereas open parking patterns and building density help to distinguish residential and commercial areas. The morphology of a forest can be interpreted readily as related to the kinds and distribution of trees present.

Photo-Drainage

Elements of form in undeveloped areas are the key to the natural drainage patterns. Natural drainage, unless controlled by specific geologic conditions usually is not of a regular geometric design. On the other hand manmade alterations frequently are of regular geometric design. An interpretation of soil texture, geologic condition and land use can be made from an analysis of drainage density and pattern. Where possible, comparison of photos taken at widely spaced time intervals (three to five years or more) will also provide a key to the development of the drainage and to the effects of man's activity.

Photo-Erosional Form

Interpretations of erosional form can be made by evaluating both landform and tone and texture of the photo. The land morphology, as observed in a stereo view, provides the major identifying factors of the erosional form. However, the tone provides a basis for determination of the degree of vegetative cover present. Erosional form and tone might also be used to estimate the relative age of the land form. For example, newly formed slopes which are devoid of vegetation and dry are usually light toned. Well vegetated areas appear darker, as do wet areas. Photo texture provides an evaluation of the types of earth materials being modified by erosion.

Monoscopic Image Interpretation - LANDSAT Multispectral Scanner (MSS)

LANDSAT data is acquired at a small scale. Therefore the display of data taken from imagery is synoptic as compared with aerial photography. This characteristic should not be considered as a limiting factor to imagery use. Regional land use and geologic trends are enhanced, and repeated coverage allows for the analysis of temporal change. Each MSS band has advantages for analysis of spectral reflectances. Table II summarizes these characteristics.

Techniques for data display from imagery are many, with overlay maps being very easily made. Interpretation from several different MSS bands can be recorded on one overlay, thus providing a composite of data from a study area. As with stereo photo interpretation, scale modifications can be made easily.

LANDSAT MSS-Tone and Texture

Tone and textural signatures of black and white LANDSAT displays are very similar to those of photography. Light areas tend to imply bare soil, rock or man-made inert features such as pavement. In cases where these types of tones are associated with coarse textural patterns that have geometric regularity, transportation or other man-made features might be inferred. Darker areas indicate the presence of more dense vegetation, with the darkest implying wet lands and/or water bodies. Intermediate toned areas may be interpreted as residential areas or grass land/crop areas, depending upon their geometric composition and surroundings.

The tone and texture of a color composite usually provides a more easily interpreted format. Dark blue colors indicate water or very wet soils. Reds represent intense low growing plant life with mottled red-brown-dark brown colors representing forest. Bare soil, rock and inert substances appear very light to white.

TABLE II

SPECTRAL SENSING CHARACTERISTICS OF LANDSAT

Note: From Hudson and Elifrits, 1976, Table I, page 3.

BAND	SPECTRAL RANGE (wavelength)	SPECTRAL RANGE (color)	GENERAL LAND USE APPLICATIONS
4	.5-.6 micrometers	Green	Greatest potential for water penetration. Some contrast between vegetation and soil.
5	.6-.7 micrometers	Lower Red	Best for showing topographic and overall land use recognition, especially cultural features, such as roads and cities. Geologic and surficial soil features enhanced.
6	.7-.8 micrometers	Upper Red to Lower Infrared	Tonal contrasts reflect various land use practices; also give good land-water contrast.
7	.8-1.1 micrometers	Near Infrared	Best for land-water discrimination.

LANDSAT MSS-Land Use-Land Cover

LANDSAT and similar small scale imagery provide excellent sources of synoptic data for land use mapping at U.S.G.S. Classification levels I and II. Many of the signatures mentioned previously can be used directly as examples of land use or land cover mapping guides. For a level I land use map an overlay interpreted from a 1:250,000 scale LANDSAT color composite is very easily produced at a high degree of accuracy. Knowledge of the layout, size and shape of man-made features is of great value in making such interpretations.

LANDSAT-MSS-Drainage-Erosional Form

Patterns of drainage are readily observable on the MSS color composite. Topographic features are evident and make regional drainage systems easily interpreted. For detailed study, MSS band 7 provides a good water land discrimination whereas MSS band 5 provides the best display of topographic relationships.

ENHANCEMENT TECHNIQUES

The following procedures are intended to provide an interpreter with methods by which specific features of photography or imagery might be enhanced. Scale adjustment, tonal contrast and image masking can all be used to facilitate visual interpretation.

Additive Color Techniques

Additive color viewers enable an interpreter to view various MSS band transparencies in any desired combination of superposition. By inserting either negative or positive transparencies in the machine and using variable light intensity and a different color filter for each band, a desired spectral response can be enhanced.

Responses which tend to interfere with interpretation might be masked or removed from view. From this enhanced view of the area being studied, a map or other desired display can be constructed. By readjustment of light and/or color, other features may then be enhanced and this data added to the display. A map prepared from cumulative thematic displays can be made directly from the viewing screen.

Subtractive Color Techniques (Diazo Process)

The Diazo process provides for an inexpensive method of making copies of MSS band positive and negative transparencies. These copies may be made in a variety of colors. By selecting the MSS band which contains the best response of the desired feature, use of the Diazo process enables the interpreter to enhance this feature. A composite of several Diazo copies viewed over a light table enables the interpreter to effect about the same result as with the additive color viewer. The spectral response of a selected MSS band might be adjusted by adding more copies of the band or removing copies of other bands from the composite. A thematic map can be interpreted onto a direct overlay.

Image Enlargement

By photocopy and enlargement, isolated sections of imagery may be more easily studied. Care must be taken with regard to change of scale and color reproduction. However, standard photographic procedures using copy stands for copy of large areas or close-up lenses for copy of small areas, prove adequate for most work. Likewise standard filters, films, and processing are adequate. However, before the enlarged print or transparency is used for thematic mapping it should be checked for geometric accuracy.

APPLICATIONS

Land Use-Land Resource Mapping

Inexpensive land use maps can be prepared from LANDSAT imagery and photography. Hudson et. al. (1976) describe such procedures. Once a map is completed, field checked and accepted, updating the information on a regular basis might be easily accomplished at a very low cost.

Engineering Soils Mapping

Analysis of topography, drainage and vegetation provide a format by which properties of soils can be interpreted. Water quality from the standpoint of stream turbidity serves as an indicator of erosion and sediment yield. Areas which display the effects of wind erosion imply fine grained, noncohesive soils. Areas of dense vegetation imply that the possibility of large amounts of organic debris exist, if the terrain permits such buildups.

Geologic Mapping

Vegetative cover and drainage patterns serve as clues to the rock type present at the surface. Also spectral and/or photographic signatures which can be keyed to specific rock types in individual areas might be used to map outcrop patterns. Topographic forms also serve as indicators of the geologic materials present.

Water Resource Mapping

Watershed boundaries can be mapped. Topographic relationships, drainage pattern as well as ground cover, provide a basis for analyzing runoff versus infiltration. Stream patterns provide clues as to the relationship between groundwater and surface water. Quality of surface water might be assessed with repeated photography or imagery of surface water bodies.

Environmental Assessment

Many characteristics of the environment may be measured with inexpensive techniques, using LANDSAT imagery or photographic coverage of an area. Natural resource recovery such as timber cutting or surface mining can be monitored. A number of E. P. A. programs have been established to evaluate water quality using remote sensor data. Sanitary landfilling operation and urban growth are easily studied, as well as the growth of transportation networks.

Crop and Vegetation Mapping

Crop reporting using remote sensor data has been practiced for some time. However, the measurements have been mainly for production or weather-related information. In addition, the types of vegetation, degree of land cover, healthiness of vegetation, etc., might be easily measured. These basic data can in turn be used as a tool for other interpretations. Effects of conversion of timber land to pasture land can be monitored. This might be followed by study of the subsequent effects of grazing, over grazing, and erosion.

SUMMARY

Limitations placed upon the potential remote sensor data user, in terms of man hours and space availability or budget may tend to limit experimentation with this technology. Computer-automated methods of interpretation generally require staff training, special computer adaptations, and individualized system development. These factors also may preclude the use of remote sensor data.

The inexpensive techniques discussed in this report provide a method by which remote sensor technology can be utilized by practically anyone desiring to collect land resource information in an efficient economical way.

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APPENDIX I

Suggested Equipment and Supplies Needed for Setting Up a Photo/Imagery Interpretation Laboratory

Equipment: (minimum for initial study)

Stereo viewer
Light table
Drafting equipment
Transfer device - optional

Supplies:

Acetate and/or tracing paper (clear acetate, if available)
Pencils, drawing and colored
Technical fountain pens
Ink - compatable with acetate
Base Maps

Space Requirement:

An average size office with maximum table surface or counter working surface should be adequate. Good lighting with an adjustable control is helpful.

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