(NASA-TN-D-7542) A DETAILED PROCEDURE FOR THE USE OF SMALL-SCALE PHOTOGRAPHY IN LAND USE CLASSIFICATION (NASA) 44 ~~45~~ p HC $3.25 CSCL 08B

N74-20978

Unclas
H1/13 35995

NASA TECHNICAL NOTE

NASA TN D-7542

NASA TN D-7542

A DETAILED PROCEDURE FOR THE USE OF SMALL-SCALE PHOTOGRAPHY IN LAND USE CLASSIFICATION

by Paul L. Vegas

Lyndon B. Johnson Space Center
Houston, Texas 77058

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MARCH 1974

1. Report No. D- 7542	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A DETAILED PROCEDURE FOR THE USE OF SMALL-SCALE PHOTOGRAPHY IN LAND USE CLASSIFICATION		5. Report Date APRIL - 1974
		6. Performing Organization Code
7. Author(s) Paul L. Vegas, JSC		8. Performing Organization Report No. JSC S-372
9. Performing Organization Name and Address Lyndon B. Johnson Space Center Houston, Texas 77058		10. Work Unit No. 160-75-85-03-72
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A procedure developed to produce accurate land use maps from available high-altitude, small-scale photography in a cost-effective manner is presented. An alternative procedure, for use when the capability for updating the resultant land use map is not required, also is presented. The technical approach is discussed in detail, and personnel and equipment needs are analyzed. Accuracy percentages are listed, and costs are cited. The experiment land use classification categories are explained, and a proposed national land use classification system is recommended.

17. Key Words (Suggested by Author(s))		18. Distribution Statement
·Aerial Photographs ·Photointerpretation ·Mapping ·Mosaic	·Earth Resources ·Ground Truth ·Infrared Imagery ·Stereoscopy	Cat. 13

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	43	$3.00

NASA — MSC

CONTENTS

TABLES

FIGURES

A DETAILED PROCEDURE FOR THE USE OF SMALL-SCALE PHOTOGRAPHY IN LAND USE CLASSIFICATION

By Paul L. Vegas*
Lyndon B. Johnson Space Center

SUMMARY

A procedure has been developed to produce accurate land use maps from available high-altitude, small-scale photography in a cost-effective manner. Land use classification maps were constructed from small-scale photographs by using 12 basic land use categories and 6 subcategories, or a total of 18 categories. For agencies not requiring land use maps that can be updated, an alternative procedure was developed. The basic and alternative procedures have been exercised over a six-county area and in demonstration projects conducted by two outside planning groups.

The most significant single feature of the procedure is the capability to produce a final product in a relatively short time, usually within 60 to 90 days after receipt of data. In addition, the procedure can be accomplished with the skills and types of personnel normally available on the staffs of local planning agencies. The personnel skills required are photointerpreters and draftsmen. The equipment required consists of standard light tables, 8- to 10-power stereoscopes, and standard drafting supplies. The photographic processing service and supplies can be provided by commercial firms in most large cities.

INTRODUCTION

For the past several years, the National Aeronautics and Space Administration (NASA) has conducted an Earth Observation Program as part of the Science and Applications Program. This effort has been directed toward the development of remote-sensing technology, which eventually will be used to monitor and measure the characteristics of the Earth from a satellite platform. As a precursor to satellites, extensive test work has been done with very-high-altitude aircraft, which were not available for such uses previously. The technology and application of small-scale, large-area-per-frame photography has received particular interest and study as a consequence. In the development of remote-sensing techniques and in the expansion of this

---

*Mississippi Test Facility, Bay St. Louis, Mississippi 39520.

technology, a large quantity of high-altitude (approximately 18 300 meters (60 000 feet)), small-scale (1:120,000) photographic data has been gathered over the United States. These data were gathered and used for specific experimental purposes by numerous investigators and agencies, and the photography currently is being made available to the public through the efforts of the NASA and the U.S. Geological Survey (USGS). A large volume of this high-altitude photography covering more than 1 300 000 square kilometers (500 000 square miles) of the United States is available to the public from the U.S. Department of the Interior, USGS EROS Data Center at Sioux Falls, South Dakota 57102. The cost is nominal: $7 for a single 22.86- by 22.86-centimeter (9 by 9 inch) color transparency, or $4 each for five or more frames.

Personnel of the NASA Lyndon B. Johnson Space Center Earth Resources Laboratory (ERL) at the Mississippi Test Facility (MTF) have conducted an experiment with the objective of developing procedures for the use of these data that are within the technical capabilities of most small governmental agencies and private companies, particularly regional planning or resource census groups. Because of the intensification and rapid change of land use, the growing population, and the depletion of natural resources within the United States, land use information has become critical for intelligent management and decisionmaking. This need was confirmed locally by meetings and discussions with various operating agencies in the Mississippi-Louisiana area.

Two other reasons were apparent for developing a procedure to use high-altitude, small-scale photography for obtaining land use information without ground survey teams. First, this is the logical step in going from low-altitude (approximately 4500 meters (15 000 feet) or less) imagery to the eventual high-altitude imagery expected from satellites in the Earth Resources Technology Satellite and Skylab Programs. Second, developing a technique for using these photographs would help encourage more widespread usage of the available data by public and private interests. To date, because of the scarcity of small-scale photography and the lack of public understanding of the advantages of such imagery, the use of such data has been limited. With the forthcoming satellite programs and the establishment of the USGS distribution center at Sioux Falls, it is expected that small-scale, high-altitude imagery will receive much more widespread usage in the near future.

In March 1971, with the help of the Gulf Regional Planning Commission (GRPC), a four-county planning agency in southern Mississippi, a map-update preliminary project was undertaken by ERL personnel. Seven areas along the Gulf Coast were chosen as test sites. These areas had been subjected to major land use changes since previous surveys had been made and were critical areas for the four-county planning agency. The NASA Earth Resources Program small-scale photography obtained on mission 150, flown in August 1970, was available. This photography was taken at an 18 300-meter (60 000 foot) altitude with a 15.24-centimeter (6 inch) focal-length camera, resulting in a photograph scale of 1:120,000. Because of the altitude, these photographs were relatively free of distortion, particularly in the center areas. The base maps of the areas being updated by the GRPC were of 1:24,000 scale. By enlarging the central areas of the NASA photography to the 1:24,000 scale, a 5× enlargement, it was shown that draftsmen could trace land use changes directly onto the base maps by using a light table. By using this system rather than transferring the information to base maps from a low-altitude photograph, the savings in time and money were substantial. In addition, low-altitude photography adds the problem of distortion. It was estimated that updating costs were cut by more than 60 percent by using a single distortion-free, small-scale photograph enlarged to scale rather than a series of low-altitude photographs. If the map was to be updated by a physical ground survey that had to be plotted point by point, the savings realized were even greater.

As a result of the success of the preliminary project, a decision was made to develop and evaluate a simple procedure by which large land areas could be economically categorized using high-altitude, small-scale photography. Initially, four counties in southern Mississippi were chosen as the basis for the experiment. These counties were Hancock, Harrison, Jackson, and Pearl River. The reasons for choosing this area were as follows.

1. Significant land use changes had occurred because of urbanization, industrialization, and a recent hurricane along with the ensuing regulatory efforts by code enforcement agencies. Existing land use information was relatively obsolete.

2. The area was convenient to the ERL at the MTF, and there was a basic need for current land use data for ERL experiments in other disciplines, such as forestry, hydrology, and agriculture.

3. The GRPC had been compiling data in the four-county area for approximately 10 years and had established a data base of records and costs of initial land use compilation as well as updating the information. This information would give an excellent measure of the accuracy, speed, and cost effectiveness of any new technique as compared to standard practices.

Later, to evaluate the procedure in a Standard Metropolitan Statistical Area, the experiment was expanded to include Hinds and Rankin Counties, which encompass the metropolitan Jackson area in central Mississippi.

An additional advantage of the areas chosen is that each has active planning agencies operating locally or regionally. These local agencies were eager to complete land use projects within their areas and agreed to evaluate the procedure using their own personnel, equipment, and funding. Hinds County was evaluated jointly by the Council of Governments, a regional planning agency, and the City of Jackson Planning Agency. Jackson County was adopted as a project by the GRPC. These efforts by area planning agencies, plus statistics of previous projects, gave excellent base data for evaluation of the procedure. Hancock County, because of its proximity to the MTF for field verification and its relatively elemental land use structure, was chosen as the pilot county for the study and was used to develop the procedure for the overall project.

In the following section of this report, a procedure demonstrating the use of high-altitude, small-scale photography in conjunction with conventional USGS maps to obtain an updated, accurate, cost-effective land use map is described in detail. The procedure is based on the completed study of Hancock, Harrison, Pearl River, and Rankin Counties by the ERL and of Jackson and Hinds Counties by local planning agencies using procedures developed by the ERL. The costs, the technical skills required, and the schedule were determined and evaluated and are presented in later sections of this report.

The purpose of this report is to provide a procedure that will be particularly useful to agencies or planning groups needing land use information, but working with limited resources of personnel and funding. The technical approach used in developing this procedure is discussed in detail in the section of this report entitled "Discussion of Procedures" and is based on the following.

1. Use of available photography in 22.86-centimeter (9 inch) format with a scale of 1:120,000

2. Use of the township (approximately 9.6 by 9.6 kilometers (6 by 6 miles)) as a basic map unit

3. Selection of a scale of 1:24,000 to conform to current, widespread use

4. Maintenance of control by the use of simple techniques for transferring data from existing maps (for example, USGS quadrangle maps)

Detailed technical support for this effort was provided by Lockheed Electronics Co., Inc., under Contract NAS9-11584. Principal participants included Gary Shelton, Lawrence W. Erickson, Paul Davis, B. Edward Arthur, and George Hampton.

EXPERIMENTAL PROCEDURES

In this section, a procedure developed during the experiment for the preparation of updated land use maps is described in detail. The procedure is based on the availability of USGS or other maps at a scale of 1:62,500 or larger, or similar ground control.

An alternative method was developed for steps 6 to 8 of this basic procedure. Use of the alternate steps depends on the end result required and the facilities available. The alternative procedure and its advantages and disadvantages are discussed in the section of this report entitled "Alternative Procedure."

Step 1

In step 1, the process begins with the acquisition of a duplicate film positive, preferably color infrared, of a desired area at a scale of 1:120,000. This scale is the result of 18 300-meter (60 000 foot) altitude photography with a 15.24-centimeter (6 inch) focal-length camera. Each 22.86- by 22.86-centimeter (9 by 9 inch) frame at this scale covers approximately 25.7 kilometers (16 statute miles) per side, or a total of approximately 663 square kilometers (256 square miles) of land area on each frame. Because the average county in Mississippi covers approximately 1300 square kilometers (500 square miles), it can be seen that relatively few photographs can cover large land areas, even when the necessary photographic overlap is considered. For example, 15 frames of photography were used to cover Hancock County, which has approximately 1250 square kilometers (482 square miles) of surface area. This quantity is the result of the side and forward overlap as well as small portions of photographs required because of the irregular shape of the county. With low-altitude photography, 300 to 500 photographs normally would be used.

Step 2

If the area of interest requires more than one photograph, as is usually the situation, the photographs should be numbered and located on a map in step 2. Plotting the exact location of the first and last photograph of each flight line as well as each fifth photograph of each flight line on an existing map, preferably on a 1:62,500-scale USGS map, is sufficient to locate any photograph for reference purposes. Each photograph is located by physical features. If necessary, stereoscopy may be used but is not normally required. A rectangular template, scaled to cover the exact area of a 22.86- by 22.86-centimeter (9 by 9 inch) frame of photography on the map being used, is very useful to delineate the location of each control photograph on the map. During this step, the photographs can be screened for quality, cloud coverage, and physical defects. In this experiment, photography that was 90-percent cloud free was requested. With this amount of cloud cover, overlapping photography usually will give a clear view of all areas.

Step 3

In step 3, a county index sheet is made to show each township in its relative location. A scale of approximately 2.6 centimeters = 10.0 kilometers (1 inch = 6 miles) or smaller is suggested. At this stage, it is necessary to prepare individual township map sheets from existing USGS or base maps, preferably to a scale of 1:24,000, to use as a control for enlarging the photography. If a township falls on two or more of these map sheets, the sheets must be carefully mosaicked to produce the township area on a single sheet to a known scale. Should 1:24,000-scale USGS coverage of the area not be available, an extra step will be required in which the available base map, usually a USGS 1:62,500 scale, is separated into townships and each township then enlarged photographically to a scale of 1:24,000.

Step 4

Step 4 in the ERL process was the production of a black-and-white contact internegative from the 22.86- by 22.86-centimeter (9 by 9 inch) photography received. Should the photography received be black and white, this step would be omitted. However, as will be discussed in another section, the preferred film for photointerpretation was found to be color infrared, with color a second choice, and black and white the least desirable.

In this experiment, the color infrared duplicate positive was received. From this positive, the black-and-white contact internegative was produced by using Eastman Kodak 2402 panchromatic film with a continuous contact printer. A Log-E SP1070 printer is an excellent choice for this type of work. The internegatives were processed to a medium-high contrast in a continuous film processor to a gamma of approximately 1.5, using Eastman Kodak D-19 developer or equivalent. The Eastman Kodak Versamat film processor was used in this experiment. These steps normally can be done by any commercial photographic laboratory with standard equipment.

Step 5

Step 5 consists of locating the exact township boundary on the black-and-white internegative. Using the 1:24,000-scale township map that was prepared in step 3, the corners of the township are located as nearly as possible on the black-and-white internegative using physical features as reference points. This area then is masked out for enlargement. In this laboratory, Chart-Pak black-and-white, 0.6-centimeter (1/4 inch) wide tape was used, and the masked border was set approximately 0.6 centimeter (1/4 inch) back from the township lines to leave a trim area wide enough so that the adjoining sheets could be matched and the exact township lines could be delineated. The masked area then is sized to fit into the photoenlarger. In this case, the film was cut to a size of approximately 10 by 13 centimeters (4 by 5 inches), centering the masked township as nearly as practical.

Step 6

In step 6, the masked area of the black-and-white internegative is enlarged to 1:24,000 scale by using the township base map, which was prepared in step 3, as a scale reference. For the enlargement, a low-contrast, matte-surface film (DuPont Chronaflex PFm4) was used. The film was exposed at f/22 for 6 seconds, then processed in Eastman Kodak D-76 developer (concentration 2:1) at 293° K (68° F) for 3 minutes. When exposing the film, the negative should be reversed as necessary to produce the right image when reading through the film base. This procedure will allow any drafting work to be done on the side without emulsion. Three sheets of film, only one of which is processed at this time, are exposed during this step. Each film sheet is prepunched with a registration punch and alined on the enlarging easel on permanent registration pins so that the image is in exactly the same location with respect to the pinholes on each sheet.

The other two exposed but unprocessed sheets are labeled and stored for later use. If the township area on the 22.86- by 22.86-centimeter (9 by 9 inch) internegative falls on two or more frames of photography, the required areas of each frame are masked and enlarged separately to scale, and a film mosaic of the black-and-white enlargements is constructed. A black-and-white, scaled positive transparency then is made of the mosaicked enlargement, again with low contrast.

If 1:24,000-scale base maps are not available and the 1:62,500-scale USGS maps were not enlarged as described in step 3, it is possible to get a scaled enlargement at this point by measuring a distance on the 1:62,500-scale USGS map and enlarging the scale distance to 1:24,000 on the positive. If this procedure is followed, the longest possible measurement should be used to control the accuracy of the enlargement. This procedure would be particularly appropriate when only one or two photographs are to be enlarged, or when a small area is to be studied. In areas where no USGS maps made at appropriate scales are available, State highway department county roadmaps may be used very successfully for control.

Step 7

At this point (step 7), one black-and-white positive transparency enlarged to 1:24,000 scale and two prints that were exposed in step 6 but not processed have been produced. On the processed positive, using the USGS township maps from step 3 or any other available data, each section corner is located and marked as carefully as possible using physical features as references. Then, a sheet of Keuffel & Esser (K&E) scribe coat material is cut to overlay the enlarged positive, and both the enlarged positive and scribe overlay sheet are punched carefully for registration. The section corners are marked on the overlay, and the section lines are scribed between points. Any geographic names, highway numbers, or other data that are to be transferred to the photograph positive enlargement from the township maps also are scribed on the overlay.

Step 8

The exposed but undeveloped transparent film enlargements from step 6 are used in step 8. The enlargements are registered with the scribed grid overlay sheet, and composite photograph positives are produced. In this laboratory, an Agfa Gavert Dupliphot contact printer was used, but any vacuum printer would be adequate. The grid overlay on the scribe sheet from step 7 and the two preexposed enlargements from step 6 then are exposed at a light intensity of 0.7 for 0.5 second and processed in Eastman Kodak D-76 developer at 293° K (68° F) for 3 minutes. One of the two prints is a byproduct consisting of a 1:24,000-scale photomap of a township with grid lines and geographic names superimposed over the scaled aerial photograph, which can be reproduced for various uses. The second identical sheet will be used to delineate land use categories for the final product of this experiment.

Step 9

On the scaled, enlarged positive from step 8, it is possible to delineate land use areas in step 9. Most of the gross usage may be delineated directly from the enlargement. Where necessary, the original photography (preferably color infrared) is used at the 1:120,000 scale with manual 10× stereoscopic interpretation.

An 18-category breakdown of land use, which could be expanded or shortened depending on particular needs, was used in this study (appendix A). In any future projects, however, consideration should be given to the national land use breakdown proposed to the U.S. Department of the Interior by Anderson, Hardy, and Roach, at the National Land Use Conference sponsored by the USGS and the NASA in June 1971, and since modified. This proposal in modified form is available as USGS circular 671. (See ref. 1 and appendix B.)

The category symbols are portrayed directly on the enlarged, scaled transparency with heat-resisting, pressure-sensitive lettering (press-type). As was mentioned previously, because the emulsion side of the enlarged positive is delicate and cannot be erased, land use delineation and coding is always done on the uncoated side of the enlargement.

Step 10

In step 10, the enlarged positive transparency, complete with grid, geographic names, and land usage, is ready for reproduction. A 55- by 70-centimeter (22 by 28 inch) clear-Mylar format with the township on the enlarged film-positive display is used. The township on the enlarged transparency at 1:24,000 scale normally occupies a space approximately 41 by 41 centimeters (16 by 16 inches) on the left side of the format. On the right side of the sheet is a small index county map with the township and range lines displayed. This location map is at a scale of approximately 2.6 centimeters = 10.0 kilometers (1 inch = 6 miles). The township displayed on this particular sheet is shown cross hatched on the county map. The mean declination, the scale, the legend, and the title are displayed on the right side of the sheet. The initial sheet is made in format with the particular township identification and the declination left blank, and transparent master positive copies are reproduced corresponding to the number of townships in the county. To make the individual township map for reproduction purposes, it is only necessary to tape the desired enlarged photographic land use map on the sheet, cross hatch the appropriate township on the small locator map, label the section and township, and show the magnetic declination. Either blue or black line prints may be produced by the Ozalid Dry Print method from the final format. The black line print, at essentially no difference in cost, has proved to be more legible and to produce a tone of greater depth and quality than the blue line print and, thus, is recommended for this type of work. A further discussion of types and quality of prints is included in the section entitled "Discussion of Procedures."

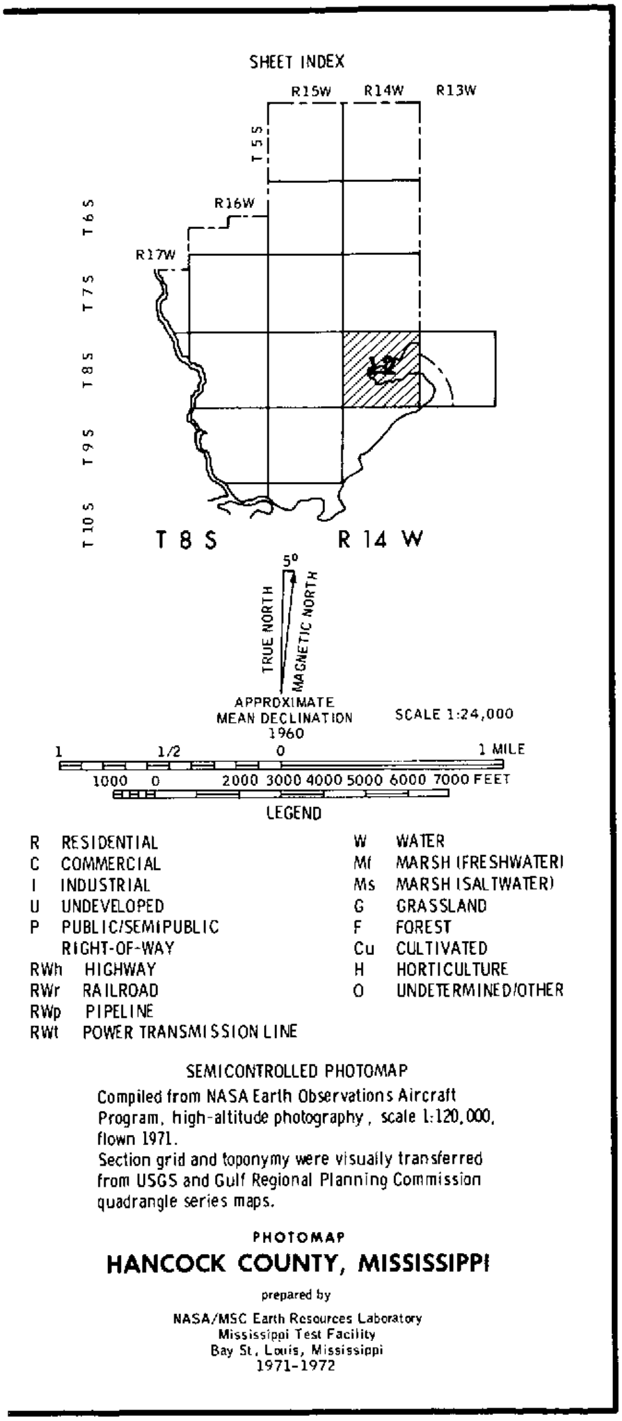
Step 11

Although the final map product was produced in the preceding step, an optional effort (step 11) is required to transfer the data from the map to a statistical form. The areal land use is measured by category in each section and could be aggregated for township, county, or state statistics. To compile the land use breakdown in acres for each section, the dot grid system is used. This method of computing areas uses a random dot grid. The number of dots in a particular area multiplied by a constant gives an approximation of the area. The plastic dot grid scale is available from most drafting equipment suppliers.

Figure 1 is a reproduction of a duplicate positive (22.86 by 22.86 centimeters (9 by 9 inches)) color infrared photograph as received from the NASA or the USGS, and figure 2 is a reduced copy of the final product of this procedure, a township land use map in the final format.

Figure 1.- Aerial, color infrared photograph of a portion of Hancock County, Mississippi, taken from an altitude of 18 300 meters (60 000 feet) with a 15.24-centimeter (6 inch) focal-length camera (scale of original, 1:120,000).

Figure 2. - Reduction of township land use photomap of a portion of Hancock County, Mississippi (township 8 south, range 14 west), constructed from a film positive of the imagery shown in figure 1 (scale of original, 1:24,000).



ALTERNATIVE PROCEDURE

For the use of an agency desiring the most economical product or wishing to develop land use maps of a specific area without the consideration of future updating, an alternative procedure, which varies somewhat from the steps described in the section entitled "Experimental Procedures," has been developed. In this section, the alternate procedure is discussed and each divergence from the basic procedure is explained.

Steps 1 to 5

Steps 1 to 5 are identical to the procedures previously explained.

Step 6

The same photographic procedure previously described for step 6 is used, but, instead of exposing three film sheets in registration, a single enlargement is made of each township. Care should be taken in the enlargement to keep the emulsion side on the bottom of the film base so that drafting is done on the side away from the emulsion.

Step 7

In this alternate procedure, no scribe sheet is produced in step 7. Using the single enlargement from step 6, the township boundaries, section lines, geographic names, and other pertinent information are placed directly on the enlargement with a plastic-base ink (such as Pelikan T-17). Mechanical or freehand lettering may be used, depending on the quality desired.

Step 8

If a photomap byproduct of the area is required, a sepia or Mylar positive master may be made of the enlargement at this point (step 8) with the information inked on the enlargement. This byproduct will be a photomap with section lines, numbers, geographic names, and any other information required and placed on the enlargement.

Steps 9 to 11

Steps 9 to 11 are identical to the steps of the basic procedure.

Use of Alternate Procedure

An additional consideration that may dictate use of the alternative method is the fact that some commercial photographic centers may refuse to handle, or charge prohibitive costs for working with, the three enlargements in registration. The storing of the exposed but unprocessed registered enlargements and other work required in steps 6 to 8 may not be part of the service normally available in some commercial photographic centers.

The major disadvantage of this alternative method is that use of the method does not produce the scribe coat sheet. In any future update, instead of using the scribe sheet to transfer the base information to the new photographic enlargement, all information including section lines, numbers, geographic names, and so forth will have to be located and inked on the updated photography, at additional drafting costs.

Another variation of the alternative method would be to delineate the land use on a clear-Mylar overlay. In this method, either photomaps or land use photomaps are produced from the same base and additional overlays (such as topography) can be used if available.

DISCUSSION OF PROCEDURES

In this section, a supplementary discussion of the technical procedure detailed in the section entitled "Experimental Procedures" is presented to aid in the use of the techniques developed as well as to suggest possible alternate procedures for use in specific applications.

In the acquisition of the high-altitude photography from the USGS EROS Data Center, as described in step 1 of the basic procedure, the latest photography of a particular site normally should be requested. Many test areas have been photographed more than once, and a choice of scale, type of film, and season may be available. For land use, general delineation, and clarity, color infrared is the preferred film. This preference is attributable primarily to the vegetation enhancement and haze penetration characteristics of color infrared. Color and black-and-white film are second and third choices, respectively, from the photointerpretation viewpoint. If data are being gathered specifically for application of this procedure, the ideal data base would be both color infrared and black-and-white infrared. The color infrared is used for interpretation, and a black-and-white infrared negative is used instead of the black-and-white internegative specified in step 4 of the procedure.

The photography used in developing this procedure as well as most of the photography generally available from the files had 60 percent forward overlap and 30 percent side overlap. This overlap was found to be adequate, although an increase in side overlap would reduce the amount of mosaic work that has to be done in step 6. For large area projects in which a photographic flight is conducted specifically for this type of land use classification, the flight lines should be flown along alternate township lines. For a larger area, the flight lines should be flown approximately 19 kilometers (12 statute miles) on center with 60 percent forward overlap. With this spacing, at 18 300 meters (60 000 feet) altitude, a sidelap of approximately 5.5 kilometers (3.4 statute miles), or approximately 22 percent, results. This sidelap allows masking of a single photograph for two townships without mosaicking, uses the center 80 percent of the photography, and provides enough overlap for stereoscopic interpretation. However, when using this minimum sidelap, flight lines must be flown to within a 3.2-kilometer (2 mile) accuracy.

A spring flight over rural areas makes cultivated areas easily definable. Winter gives an excellent contrast of deciduous and nondeciduous tree types, provides a better indication of standing water under heavy overgrowth, and will indicate with great accuracy which pasture areas are natural grasslands and which are cultivated. It appears that a midwinter (January or February) or a spring (April or May) flight would be most informative as to general land use in the Gulf Coast region. The summer and early fall vegetation is so universally lush, particularly in the southeastern United States, that delineation of rural agricultural land use becomes more difficult. This is particularly true if a general agriculture classification is desired rather than a crop classification.

Before discussing the location of each photograph on a flight map, some explanation of the NASA aerial photography may be in order. Each frame received will bear a frame number, usually four digits, and an image of a clock that depicts Greenwich mean time. Usually, a bubble within a bull's-eye is added to show the camera vertical alinement. These three items appear on the leading edge of each photograph. Several cameras operating on the same flight will register the same time sequence, but the frame numbers normally bear no relationship to each other.

For step 3, after consultation with various planning and potential user agencies, it was decided to map and compile all data by township. The 9.6-kilometer (6 mile) square area that normally comprises a township is the basis for land measurement throughout the United States and lends itself ideally to use as a basic data unit. Townships are delineated on large-scale USGS maps, are usually clearly outlined on the imagery by roads and fence lines, and may be broken down into subareas such as sections, quarter sections, or sixteenth sections, each of which is definable easily and can be located physically.

In areas for which no 1:24,000- or 1:62,500-scale USGS (standard quadrangle) maps were available for scale control, county highway maps were used to calculate control points, which were drawn to scaled distances on drafting vellum. The photography then was enlarged to coincide with these control points. The USGS Mapping Service should also be consulted for new data in any area to be worked. (See appendix C for a complete list of USGS offices and areas served.) Preliminary mapping not generally released for public dissemination was available over many areas of the State of Mississippi that had not been mapped by the USGS previously.

In handling the material in the office, it was found that using a large manila envelope for each township was the best method for data use and storage. Each envelope was numbered with its range and township, respectively, and all pertinent data from original positive photography to area compilation were kept intact and readily available. A form sheet with the various steps of the procedure and hours used was kept on the face of the envelope so that the work completed and the hours expended were always displayed.

In step 4, the use of a Log-E SP1070 contact printer was mentioned. Use of this printer will improve the overall quality of the black-and-white internegative by giving a more even tone across the image, but it is not necessary to the overall success of a project. In cooperative experimental projects with local planning agencies, the Log-E printer was not used and the final product was not affected measurably.

When preparing the film for enlargement in step 5, care should be taken to minimize cutting of the film. With some enlargers, it is not necessary to cut the film. Sandwiching the film between panes of clear glass when enlarging will at times improve the product as well as protect the film.

For step 6 of the basic procedure, it should be noted that the photographs as received from the NASA or the USGS at times will have a slight tip or tilt. If the complete township falls on a single frame, the slight resulting distortion may be negligible. The distortion becomes critical when the township must be mosaicked from two photoenlargements. When this situation occurs, a distance appearing on each photograph near the match line must be chosen and the photographs must be enlarged separately to the scale that will make this distance identical on both enlargements. When spliced, both photographs then will have identical scales along the match line. Tip or tilt in images can be corrected by adjusting the film table while enlarging.

In step 7 of the basic procedure, when making the scribe sheet with the grid lines and geographic names, two methods are possible. If the photoenlargement corresponds exactly to the township area as shown on the USGS 1:24,000-scale township map, it is possible to locate the section corners on the scribe sheet by overlaying it directly with the USGS township map. If any discrepancy between the enlarged photograph and the USGS township map exists, it is best to locate the section corners from points of physical reference on the USGS map and transpose them to the enlarged photograph by using these reference points. A serious problem may be encountered in attempting to locate section lines and corners in areas of urban sprawl. The USGS maps are often not current enough to include new landmarks in areas where urban development such as subdivisions or industry has overrun once rural areas. Often, no recognizable features from which the section corners may be located remain in an area. In these instances, it may be necessary to use records normally available in county archives, such as street dedication plats and subdivision plans, from which section corners may be established on the updated photography. Another caution required when preparing the scribe sheet is the necessity for establishing north before lettering so that the orientation of the lettering is toward the proper side of the final product.

One of the principal advantages of the scribe sheet is that it allows future photography to be made into an updated photomap by superimposing the scribe sheet in registration over the new photography that has been enlarged to the same scale. Whenever updated photography is available, land use maps may be produced with a minimum of cost and effort by using the scribe sheet and updating the land use as necessary.

It should also be mentioned that it is possible to produce a neater, clearer, more even product by transposing information with the scribe sheet rather than by inking directly onto the enlargement base. However, if significant tip and tilt are present in the photography, the value of the scribe sheet is questionable because it may not be usable for the updating procedure.

The photomap with the superimposed grid system that was a byproduct of step 8 in the basic procedure is an up-to-date photomap with geographic names, section lines, and current information. The forest tree lines are clearly shown and are up to date. In some instances, even tree types are distinguishable. Those interested in agriculture are able to use the map to ascertain the location of crops grown and the acreage. The maps also are useful in hydrology for determining stream meandering, especially when compared to older maps.

In step 9, when delineating land use, experience proved that the best sequence to use for avoiding errors and reducing erasures was as follows.

1. Waterways and shorelines

2. Rights-of-way

3. Urban land uses

4. Forests

5. Agricultural and pastoral features

6. Undeveloped categories

Photointerpreters who are not familiar with conditions in an area will increase accuracy and speed if allowed time for familiarization with ground conditions compared to prints of photography. This statement is particularly true when unique conditions exist in an area, such as salt marsh, swampy areas, and peculiar cultivation. Wheneven possible, use of photointerpreters from the study area is decidedly advantageous.

All photointerpreters who are working on a given project must be given standards for decisions and checked carefully for uniformity. Again, it might be pertinent at this point to reemphasize the fact that a national land use classification system has been proposed (ref. 1), and any future projects should consider adoption of such a scheme to fit land use information into the national program. (See appendix B for proposed national land use categories.)

If USGS 1:24,000-scale maps of the township are available, copies of the overlay plates for these areas with topography, hydrography, cultural features, and so forth can be obtained at $10 for the first overlay and $1 for each additional overlay from the U.S. Geological Survey. (See appendix C.) These plates may be superimposed over the grid photomap for various map requirements and uses. If the USGS map is not current, the only useful plate usually is the topography, which normally does not change appreciably within the time frame discussed. When updating or obtaining information on land use of any area, it is well worthwhile to contact a USGS office to ascertain the status of the USGS effort in the locale. Often, advanced material is available or new mapping is being done in the area.

In reproducing the final product, several copying systems were tried and evaluated. In general, the black line seemed to offer better tonal qualities and detail than did the blue line when using the Ozalid Dry Print method of reproducing copies. The cost of the paper for either color is essentially equal. However, acquiring good black line paper presents a problem in some areas because of the relatively small quantity used and the short shelf life.

Brown, sepia-tone color gave a better quality product than did either the blue line or black line, but the reproduction cost was approximately double that of the blue or black line (\$1.29/m^2 (\$0.12/ft^2) compared to \$0.65/m^2 (\$0.06/ft^2)). A problem presented by any of the reproduction methods discussed previously is the tendency for the reproduction to fade badly when exposed to sunlight.

It is possible also to use the negative rather than the positive enlargement to produce the land use final product on the negative enlargement. The general procedure is the same, but the enlargement negative is used for the map base. If the negative is used, a photographic paper print may be made on Kodak Adtype paper. This method of reproduction compares favorably in quality with the sepia, costs approximately twice as much (\$2.69/m^2 (\$0.25/ft^2)), but offers much greater resistance to fading than any previous method because it produces essentially a permanent print.

The negative final product also may be used to reproduce blueprint copies that compare favorably in quality with the blue or black line Ozalid process, at approximately the same cost, and that resist fading somewhat better than do the black or blue line prints. The detail and contrast on blueprints usually are as good as those on blue or black line prints.

From the preceding discussion, it is obvious that each agency producing land use reproductions must evaluate the reproduction equipment and paper stock available, must evaluate the quality, permanence, and resolution needed, and must balance these factors against the cost.

To update the land use information as new photography becomes available is a relatively simple and inexpensive procedure. If the basic procedure is followed with the scribe sheet produced, it is necessary only to enlarge the new photography to scale and superimpose the scribe sheet photographically to obtain a photomap base upon which the new land use information may be delineated. If the alternative method is used and no scribe sheet produced, again, the photography must be enlarged to scale and the section and township lines plus any other desired information traced onto the updated photograph. This second method is much more time consuming and gives a product inferior to that produced by use of the scribe sheet. In either case, the updating can be done with a photographic cost of less than \$12 per township.

In compiling the areal data for each land use category at the grid section level, several techniques for measurement were tested. The planimeter was tried, as was the dot grid. Using the dot grid for determining acreage classifications proved to be a surprisingly accurate, fast, and economical method of providing statistical data from maps. The planimeter, an almost universal method for calculating areas, proved no more accurate and took three to four times as many hours for the same effort. Also, the level of talent required to operate the dot grid is substantially lower than that required for the planimeter. Part-time students produced excellent results with the dot grid. A statistical analysis of dot grid and planimeter results over three townships revealed a difference between the two measurements of ±1 percent. The dot grid, however, was consistently three to four times faster than the planimeter and resulted in an overall accuracy exceeding 97 percent over measured areas.

A few exceptions to the exolusive use of the dot grid overlay for obtaining specific area measurements were made.

1. An engineering scale, graduated into 23.6 units/cm (60 units/in.), is used to measure the perimeter to obtain the area of each section.

2. The areas of rights-of-way also are determined by using an engineering scale.

3. The area occupied by individual residences normally is assumed to be

a. Approximately 4000 square meters (1 acre) if located in a rural area (low-density housing)

b. Approximately 1000 square meters (1/4 acre) if located in a subdivision (medium-density housing)

PERSONNEL, EQUIPMENT, SCHEDULE, AND COST EFFECTIVENESS

In this section, the types of personnel and equipment required, the work schedules developed, and the cost effectiveness of this technique compared to the costs of conventional land use mapping and updating procedures are discussed. The initial concept of this experiment was to develop a technique that, once the imagery is available, would require equipment and personnel normally available to the average city or county planning agency.

Personnel

The personnel assigned to the ERL task consisted of a full-time senior photointerpreter-draftsman and a full-time draftsman. Initially, the draftsman was responsible for masking the areas on the photographs, for mosaicking the enlargements when required, for preparing the final format, for locating the township and section corners, and for doing the scribing work and the area compilation. The photointerpreter was used full time in classifying land use areas. Because the photointerpretation was a more time-consuming task than the drafting, the draftsman also was used to do the more general photointerpretation. Within 2 weeks of the inception of the experiment, either man was capable of performing any of the steps in the procedure. Later, an assistant draftsman was introduced to the procedure and he also proved capable of full production after a learning period of approximately 2 weeks. The manpower used normally would be dictated by availability of personnel and schedule requirements. The optimum economic effort probably would be achieved by two photointerpreters and one draftsman, dividing the tasks as necessary for maintaining production. Under normal conditions, the team could average three to four townships per week. The city and regional planning groups participating in the experiment used normal office and drafting personnel, who proved capable of producing an excellent and useful product at a minimum cost with a minimum training cycle.

Equipment

Because of the availability of special equipment at the ERL, the temptation to use such equipment in this experiment was strong. However, trying to keep the equipment simple was an integral part of the experiment. Two light tables were used, one for each man working on photointerpretation. When handling large areas, it is convenient, but not mandatory, to have light tables that will accommodate rolls of film. If the photography is separated into single frames, any standard light table will be adequate.

A large quantity of land use data as well as boundaries between water and land may be traceable directly onto the scaled enlargement. Much of the remaining land use information can be determined visually from the color infrared transparency or from the scaled enlargement. However, for optimum accuracy, it is recommended that a stereoscopic viewer with at least a 10× magnification be available. A Bausch & Lomb 240 zoom stereoscope was available at the laboratory and was used part of the time, but the savings in time and the improvement in accuracy when compared to a simple 10× stereoscopic viewer were negligible.

To demarcate land usage and for all lettering or drafting, the side of the photoenlargement without emulsion is used. As was previously mentioned, the image is reversed during the enlarging cycle to read correctly when looking through the base. This procedure was followed to avoid erasing on the more delicate emulsion side of the imagery. The pens used for delineating areas were standard Rapidograph ink pens; point numbers 00, 0, 1, 2-1/2, and 3 were used. Erasing was accomplished by using a damp cotton swab. For removal of dry ink, using an eraser or scratching with a small blade is effective. The land use letters and symbols were heat-resistant press-type.

One of the participating planning groups elected to ink in the categories with Leroy templates rather than to use press-type. Any ink used should be of a plastic-base type such as Pelikan T-17. Inking letters was found to be somewhat tedious, but ink has the advantage of being more permanent because the press-type, with age and the heat of reproduction, tends to loosen and fall off the print. The problem of flaking press-type was avoided to a large extent by making a Mylar master positive of each township as it was completed. This master positive was used for mass reproduction, and the original was stored in a flat file. For delineating land use areas, standard curves and straightedges were used when applicable, but the majority of land use was delineated manually.

The scribe coat used was the standard K&E scribe coat, which is available from most distributors of drafting supplies. To scribe the township and grid lines, number the sections, and scribe the appropriate geographic names, a standard Leroy lettering set with scribing points was used. A trimming knife and 0.317-centimeter (1/8 inch) wide black and black-and-white Chart-Pak tape were used to outline the township on the black-and-white internegative and to set the finished, scaled enlargement in the final format for reproduction.

Schedule

Experience from the procedure developed while working with the Mississippi counties proved that the drafting, photointerpretation, and statistical effort will average 30 to 45 hours per township-sized sheet. Table I includes an average breakdown of man-hours required per township sheet completed in the counties worked, with no supervisory or administrative time included.

TABLE I. - TIME REQUIRED FOR COUNTY MAPPING

County	Masking and scribing, hr	Photointerpretation, hr	Acreage compilation, hr	Average township total, hr	County area, km^2 (mi^2)	Total (county) man-hr
Hancock	[a]6.5	20.3	4.8	31.6	1248 (482)	856
Harrison	3.6	25.5	9.1	38.2	1515 (585)	840
Pearl River	3.2	21.3	8.0	32.5	2145 (828)	813
Rankin	3.2	21.1	6.1	30.4	2020 (780)	763
Hinds	[b]3.6	25.5	4.2	33.3	2269 (876)	872

[a]Hancock County value is high because of learning curve.

[b]A scribe sheet was not used for Hinds County; instead, the information was inked as described in step 7 of the alternate procedure.

The work on Hinds County was done by the Council of Governments and the City of Jackson Planning Agency in a cooperative experiment with the ERL. Jackson County was part of the overall experiment, but the evaluation was not completed by the GRPC early enough to include the data in this report. Table I, however, does not present a true picture because a county normally contains partial townships, which do not take as long to process. Using only complete townships in each county, each of which contains approximately 93 square kilometers (36 square miles), the total average time per township would be approximately as shown in table II.

TABLE II. - TIME REQUIRED FOR TOWNSHIP MAPPING

County	Masking and scribing, hr	Photointer-pretation, hr	Acreage compilation, hr	Average (township) man-hr[a]
Hancock	6.4	23.4	5.1	34.9
Harrison	3.6	30.6	10.6	44.8
Pearl River	3.2	23.3	8.8	35.3
Rankin	3.2	24.6	7.1	34.9
Hinds (not scribed)	3.6	29.1	5.1	37.8

[a]Based on full-size townships (93 square kilometers (36 square miles)).

The selected counties range from heavily populated counties such as Hinds and Harrison with populations of 209 513 and 131 268, respectively, to rural counties such as Hancock and Pearl River with populations of 16 566 and 27 440, respectively. Surprisingly, population and intense land use were not the most important factors in determining the time required to complete an area. Large blocks of residential or commercial use were no more difficult to delineate and measure than were large areas of agricultural fields or forests. The areas that required additional photointerpretation and compilation time per township sheet were usually semiurban areas with a large variety of land uses, in plots of small acreage. Small agricultural plots, small pastures, and scattered residences with clusters of commercial, industrial, public, rights-of-way, and other mixed land uses in small blocks in an area were by far the most time consuming to separate into categories and were subject to a relatively high number of errors of classification. Classification-error probability for a given area is related directly to the number of parcels to be classified within that area.

The time in man-hours used on each township in a typical two-county area of Mississippi is displayed graphically in figure 3. Hancock County contains 1248 square kilometers (482 square miles), has a population of 16 500, and, with the exception of approximately 39 square kilometers (15 square miles), is rural. Excluding the time in the learning and experience portion of the Hancock County graph (the first four townships), the county would have averaged approximately 22 hours per township, or a total of approximately 375 hours for the county. One rural township was completed in 10 hours. Conversely, the adjacent county of Harrison contains 1515 square kilometers (585 square miles), has a population of 134 582, and is predominantly urban, suburban, and industrial. For one township in this county that consists of intensified and varied land use in small parcels, 80 man-hours were required to complete the effort. Thus, the working hours per township ranged from a low of 10 hours on some rural townships to almost 80 hours in some suburban townships. The graph (fig. 3) is a good indication of the number of man-hours that should be required by a standard planning group with

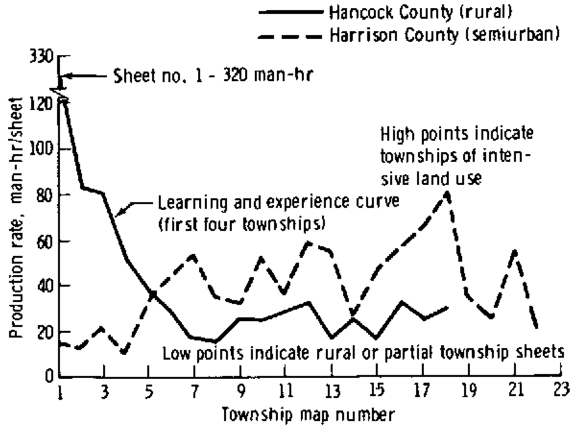


Figure 3.- Plot of man-hours expended on the development of township sheets for Hancock and Harrison Counties, Mississippi.

the normal talent available in such an organization and with no previous experience in small-scale photography. Photographic time was not considered, as this time normally will be handled under a separate contract and included in total cost. The hours shown include all drafting, photointerpretation, and area compilation. From figure 3, after adjustment for time lost in technique development and experience, it may be concluded that land use classification of an average Mississippi county with an area of approximately 1300 square kilometers (500 square miles) and a population of 20 000 would require approximately 600 man-hours. It is estimated that a small, rural county could be classified in as few as 450 man-hours, whereas classification of a large, heavily urbanized county of complex land use could require nearly 900 man-hours to complete, allowing a small experience loss in each instance. To establish some criteria for estimating timespans involved in the project effort, three men were assigned essentially full time and one man part time to four counties from December 10, 1971, until July 30, 1972. The effort, however, included acreage compilation and accuracy samplings, which were optional. Hinds County was classified by a joint effort of local planning agencies with two people assigned full time for 2-1/2 months and two part time for 4 months. The two full-time people were junior draftsmen.

Cost Effectiveness

The cost figures that will be shown are the result of experiments with five of six counties involved in the project. The sixth county, Jackson, was omitted from this report because classification was not complete at the time of publication. Four counties were classified by ERL personnel operating under standardized conditions in the laboratory at the MTF. The fifth county was classified by independent regional or city planning agencies in cooperation with the ERL, using the procedures described in this report. The approximate total costs of the counties completed are contained in table III.

From table III, it is obvious that the variation in total cost per county was relatively small. In a preliminary report, based on a single rural county, costs were anticipated to range from $4000 to more than $10 000 per county over the State of Mississippi. On the basis of five completed counties, and two partially complete, which covered the largest, most densely populated areas and both Standard Metropolitan Statistical Areas of Mississippi, the average cost per county must be revised to a minimum of approximately $5000 for a small, undeveloped county such as Benton, with a land area of 1067 square kilometers (412 square miles) and a population of less than 7000, to a maximum of approximately $7600 for a large, heavily populated county of

TABLE III. - COSTS FOR FIVE-COUNTY STUDY AREA

Parameter	County				
	Hancock	Harrison	Pearl River	Hinds	Rankin
Total area, km^2 (mi^2)	1248 (482)	1515 (585)	2145 (828)	2269 (876)	2020 (780)
Total man-hr	856	840	813	872	763
Number of township sheets	18	22	25	30	25
Labor cost at \$7.50/hr[a], dollars	6420	6300	6098	6540	5723
Cost of materials and supplies at \$6.50/sheet[b], dollars . . .	117	143	163	195	163
Photographic costs at \$20.50/township[c], dollars	369	451	513	615	513
Imagery cost, from USGS[d], dollars	96	108	156	172	140
Total direct cost per county, dollars	[e]7002	7002	6930	7522	6539

[a]Estimated labor cost based on high average for type of personnel employed in southeastern United States, including direct labor cost plus approximately 40 percent for indirect cost.

[b]Materials costs are average retail costs of materials acquired in southeastern United States.

[c]Photographic costs are from actual contracts with commercial photography shops in southeastern United States (usually based on square footage). The listed cost covers three township enlargements of approximately 41 by 41 centimeters (16 by 16 inches) plus a black-and-white internegative produced from the original color infrared photography. The contract cost was \$29.60/m^2 (\$2.75/ft^2) of enlargement.

[d]Total is based on \$4 per photograph for 18 300-meter (60 000 foot) altitude color infrared imagery for the number of photographs estimated to be necessary to cover each county.

[e]Not representative because procedure development was charged to this county.

intensive land use such as Hinds, with an area of 2269 square kilometers (876 square miles) and a population of more than 200 000.

For comparison to the preceding costs, data were gathered on a similar type of project completed in 1968 by the GRPC in the coastal area of Mississippi, covering many of the same counties. Costs of the 1968 four-county (Hancock, Harrison, Jackson, and Pearl River) project were as follows.

1. The total cost for 3657-meter (12 000 foot) altitude coverage with black-and-white aerial photography of Hancock, Harrison, Jackson, and Pearl River Counties, with atlas sheets and three copies of the photography boxed and indexed to the atlas sheets, plus an uncontrolled aerial mosaic of three of the counties, was \$31 770. This cost was for photography only and did not include any mapping or land use.

2. To categorize land use in Hancock, Harrison, Jackson, and Pearl River Counties, the planning agency expended the efforts shown in table IV.

TABLE IV. - COST OF LAND USE CATEGORIZATION FOR 1968 GRPC MAPPING PROJECT

Activity	Expense
Field work required to gather land use data on aerial photographs, man-hr	4 000
Acreage compilation from photographs, man-hr	2 000
Transfer of land use data to base-map overlay, man-hr . . .	2 800
Approximate four-county total, man-hr	8 800
Estimated cost at $7.50/man-hr, dollars	66 100

3. To obtain base maps from the photography listed in item 1, an additional contract was let for 1:24,000-scale maps to be made from the purchased photographs for the four-county area. Total cost of the four-county mapping contract was $17 495.

4. An additional effort was made by the planning agency to edit, check, and correct the mapping at a cost of $6750.

A summary of the total approximate cost to obtain 1:24,000-scale land use maps of the four counties by standard methods is as shown in table V.

TABLE V. - TOTAL COST FOR 1968 GRPC MAPPING PROJECT

Item	Cost
Aerial photography	$ 31 770
Land use, drafting, and acreage compilation	66 100
Base-map contract	17 495
Checking, editing, and correcting maps	6 750
Total approximate cost	$122 115

For control, USGS 1:24,000-scale maps were available over approximately three-fourths of the four-county area. In the area not covered by this scale, USGS 1:62,500-scale maps were used. This same USGS control was used in the 1972 ERL project over the same areas.

To obtain land use maps (with base-map byproduct) of the identical four-county area by using the procedures described in this report, the total costs were as shown in table VI.

TABLE VI. - TOTAL COST FOR 1972 ERL MAPPING PROCEDURE

Item	Cost
Photography contract (for enlargements and contact prints)	$ 1 813
Labor	24 818
Materials and supplies	573
Imagery from USGS	480
Total approximate cost	[a]$27 684

[a]Cost figures on Jackson County were incomplete at the time of publication of this report, but the total was estimated on the basis of costs and progress to date. Jackson County is being classified by the GRPC in cooperation with the ERL.

The preceding costs are calculated on the basis of classifying the area county by county, or respecting political boundaries. Where a township is split by a county boundary, the area appears on two sheets with the area in each county separated from the total. As a result, a duplication of imagery, photography, and drafting effort is required. This duplication could be avoided if the four counties were treated as an area. The land areas were separated into counties to get a true cost comparison to the GRPC four-county project of 1968. One obvious disparity in the comparison is, of course, the cost of the imagery: $31 770 to the GRPC in the 1968 contract as compared to the cost of USGS high-altitude, small-scale imagery of $480. It should be noted that even if the cost of the photography is removed from each total, the photointerpretation of small-scale photography enlarged to scale will cost approximately $27 204 as opposed to the cost for standard techniques using low-altitude photography of approximately $90 345.

Although the cost figure of $7.50/hr for labor was estimated, it is considered a current average with normal benefits and overhead. However, in the case of field survey teams, summer students often are employed at a substantial cost saving, which narrows the difference. Employment of students for all field data acquisition and area compilation could reduce the $90 345 figure by approximately $27 000 to a total of $63 345. Even at this minimal figure, the cost of using the ERL procedure ($27 204) represents a saving of $36 141 if no photograph acquisition costs are considered. In attempting a comparison of the cost of this technique to that of other methods for achieving similar results, it is apparent that in addition to being cost effective, this technique also has the advantages of (1) producing as a byproduct an updated, accurate, 1:24,000-scale base photomap with grid lines and geographic names; (2) being more accurate than mapping to the same scale from low-altitude photography; (3) producing a map within 90 days of receiving the photography (which was at least five times as fast as normal); and (4) having a built-in capability for quick, inexpensive updating as future imagery becomes available.

The principal disadvantage of the ERL procedure is the present limited coverage of the photography. Also, because future coverage of most areas is unpredictable, there is no method at present of scheduling updates. With the advent of the satellite, which provides repetitive coverage of all areas, it may be possible to update the land use inventory on any desired timetable. Research currently is being conducted toward developing techniques and procedures for using satellite data for this purpose; if these efforts prove fruitful, the problems of scheduled updating will no longer exist.

ACCURACY

The accuracy of land use delineated within a three-county coastal area of Mississippi was evaluated by stratified area sampling. The locations sampled were in areas in which extensive ground-truth work was conducted in July 1971 in support of various ERL experiments, and data were furnished by the GRPC from windshield surveys throughout the area.

A total of 322 points of known land use covering all categories was located and compared with the classifications made at the corresponding points on the township land use sheets. The accuracy is shown in table VII. If it is considered that the photointerpreter was not familiar with the area under discussion and that the photography was made from an altitude of 18 300 meters (60 000 feet), the percentage of accuracy is impressive. The overall percentage of accuracy compares favorably in most cases to ground or windshield surveys, which usually are limited by vehicular accessibility and usually are less accurate in rural areas.

If the errors in classification are examined more closely, it is obvious that most errors are explainable. For instance, in the commercial classification (which shows the lowest accuracy), all examples miscategorized were in downtown areas. The interpreter categorized the areas within the central business district entirely as commercial. As in most urban complexes, many residences or other allied land uses are found within the central business district. When looking down upon the rooftops of a commercial district that is partly residential, industrial, or public, it is difficult to separate the usage. The same difficulty is encountered with small commercial enterprises such as

TABLE VII. - ACCURACY OF LAND USE DELINEATION[a]

[Classification by photointerpreter]

Category	Sample points	Classification												Accuracy, percent
		R	C	I	P	ROW	W	M	G	F	Cu	H	O	
Residential (R)	48	45	2	--	--	--	--	--	--	1	--	--	--	94+
Commercial (C)	30	14	16	--	--	--	--	--	--	--	--	--	--	53+
Industrial (I)	11	--	--	11	--	--	--	--	--	--	--	--	--	100
Public, semipublic (P)	21	6	2	--	12	--	--	--	1	--	--	--	--	57+
Right-of-way (ROW)	27	--	--	--	--	27	--	--	--	--	--	--	--	100
Water (W)	30	--	--	--	--	--	30	--	--	--	--	--	--	100
Marsh (M)	24	--	--	--	--	--	1	17	2	4	--	--	--	70+
Grassland (G)	28	--	--	--	--	--	--	1	24	2	1	--	--	86
Forests (F)	59	--	--	--	--	--	--	1	--	58	--	--	--	98+
Cultivated (Cu)	29	--	--	--	--	--	--	2	6	--	20	--	1	68+
Horticulture (H)	14	--	--	--	--	--	--	--	--	1	--	13	--	92+
Other (O)	1	--	--	--	--	--	--	--	--	--	--	--	1	100
Total	322								Overall average					84+

[a]The accuracy check was made by sampling points rather than acreage or areas. For example, residential, which comprised 15 percent of the points sampled, comprises only 2.6 percent of the land area. Commercial, the lowest accuracy classification with 53 percent correct, comprised 9 percent of the samples but occupies less than 1 percent of the acreage in the areas sampled. Acreage accuracy from these areas consistently averaged 92- to 96-percent correct.

barbershops or beauty shops within a residential area. When the commercial area was large and undiluted (for example, strip highway development or cluster shopping-center-type enterprises), the photointerpretation was usually 100-percent correct.

The public and semipublic categories often were difficult to separate, particularly in the residential areas. Small churches, public buildings, and neighborhood parks often were categorized as residential.

The only other categories that fell below 86 percent were the cultivated and the marsh. As was previously mentioned, the date of the flight (September 30) was a poor time of the season for separation of these categories. It was relatively difficult to separate permanent pasture or grassland from cultivated grassland and borderline marshland from grassland. Because these land use categories are so closely allied, however, the error is not serious in most cases. An interpreter who is more familiar with the area should be appreciably more accurate on these particular categories. It should be realized that, even from ground level, 4 to 6 percent of the land use is categorized arbitrarily and could fall into two or more uses; that is, forests and grassland in areas of other predominant usage, grasslands along marsh area, and so forth. It is obvious from the results, however, that if a heavily urbanized area is to be studied in detail, it will be necessary to supplement any aerial photography with ground-level investigation, especially in commercial or fringe commercial districts where land use information is required on a door-to-door basis. These same problems exist with all photography regardless of altitude. In a larger urban commercial area, the classification problem still would exist on the fringes of the central business district, but the overall percentage of accuracy would be improved.

Although 16 percent of the sampled points were incorrect, it must be noted that many of these points were in the urban area. This fact heavily biases the statistics in that the total urban acreage of the areas sampled averaged slightly more than 3 percent of the total area, whereas the urban samples comprised 33 percent of the sample points. If the total acreage is considered instead of point sampling, an accuracy of 92 to 96 percent was normal, with the higher accuracy in the more rural, undeveloped sections.

APPLICATIONS

Upon completion of the project within the four-county area by the ERL, 25 land use map atlases of each county were prepared for limited distribution to solicit comments from potential user agencies. The copies were distributed to the following.

1. County agents (state)
2. U.S. Department of Agriculture Soil Conservation Service (national)
3. Civil defense groups (state)
4. Sheriffs (county)
5. Tax assessors (county)
6. Local and regional planning groups
7. County engineers
8. Chambers of commerce (county)
9. Port and harbor commissions (county)
10. Area foresters

11. Research and development centers (state)

12. Game, fish, and conservation departments

13. Air and water pollution control boards

14. County boards of health

A letter was sent to each recipient asking for comments on usefulness, accuracy, possible improvements, and so forth. Although few replies had been received at the time of publication of this report, the information on usage was gratifying. Some of the more interesting applications for the product are as follows.

1. County assessors have added substantially to the tax rolls by finding residences and improvements not listed previously. In Hancock County, 16 untaxed residences were found in less than 1 hour of study in rural areas.

2. The updated maps were used to delineate future land use from trends established since previous studies were made. The land use maps will play a major role in a proposed zoning system being developed for the coastal area of Mississippi to guarantee optimum use of land.

3. Proposed greenbelts and recreational areas have been located from trends established by current land use.

4. Transportation needs, present and future, have been studied, and future transportation corridors have been located on the basis of present and expected future land use.

5. In at least one county, all 1972 schoolbus routes were planned and plotted on an overlay of the land use maps. No other mapping was available with current data, such as new subdivisions, residences, and street extensions.

6. Based on recent trends revealed by the land use maps, a study on census and land use projections through the year 2000 was completed in the Standard Metropolitan Statistical Areas.

7. The product was used to identify existing and potential growth areas for the Housing and Urban Systems Engineering Program in Harrison and Jackson Counties. This is a federally sponsored and funded plan for a regional utility network.

8. Several small communities are using the data available to implement the U.S. Department of Housing and Urban Development 701 plans.

9. A ground-water-pollution study was made in Hinds County by using land use data from the atlas. Similar studies are planned in other areas.

10. Forest patrolling, firefighting, and fire-containment plans were aided in the coastal area.

11. Sheriffs and civil defense groups use the maps daily in their business.

12. County agents have used overlays of the agricultural areas to compute crop acreages and agricultural crop classifications.

CONCLUDING REMARKS

It has been shown that land use classification maps with an average accuracy of more than 84 percent by point sampling and of 92 to 96 percent by acreage can be constructed from small-scale, high-altitude photographs using the procedure presented in this report. The total cost of producing land use maps by this procedure is approximately $7000 per county averaging 1554 square kilometers (600 square miles), or approximately 25 percent of the usual cost for producing a similar product by standard procedures. Other facts are not so obvious; most of them relate to the basic difference between this and other similar photointerpretation experiments: the use of small-scale, high-altitude photography. The area covered by a single frame (663 square kilometers (256 square miles)) is almost equivalent to storing data on microfilm. Large areas are covered by relatively few frames. The lack of distortion, even on the edges of the 26-kilometer (16 mile) square areas, is surprising even to experienced photointerpreters, who have learned to distrust scale away from the center of a photograph. Ordinarily, it is expected that to get such coverage and lack of distortion, resolution would be sacrificed. However, by the data obtained in this experiment, it was proved that very little is sacrificed in resolution or accuracy and that this sacrifice was far offset by the advantages of the small-scale imagery.

The land use classification over urban areas was particularly interesting because it presented exactly the same problems of interpretation and error encountered when working with 600-meter (2000 foot) altitude photography. It is, to a large extent, guesswork to try to determine the use of a structure from a view of a rooftop. The identical problem exists whether the observer is standing on the rooftop or in a satellite several hundred miles overhead. Because of the problems of urban areas, the high intensity of land use and population, it is obvious that for some time in the future, there will be a definite need for surveys on a building-by-building, floor-by-floor basis in areas of concentrated land use such as central business districts. Much of the urban planning work, however, such as traffic analysis studies, map updating, utility studies, annexation studies, and subdivision regulations, can make excellent use of the small-scale-photography potential.

Over large rural areas, which comprise the majority of the land area of the United States, the small-scale photography is extremely effective in determining land use, which can be used in resource control, management, and planning.

As a result of this experiment, it is believed that land use studies of rural, undeveloped, or underdeveloped areas could profit immediately from the use of small-scale, high-altitude photography and of the procedure presented in this report. The natural resources, including the land itself, are easily categorized by using small-scale photography and a stereoscopic viewer to standard accuracy requirements for this type of work. Obvious natural resources such as forests, water, agricultural lands, watersheds, and grassland are easily definable and measurable. With the techniques defined in this report, land use, particularly in rural areas, may be defined, mapped, and updated at minimum cost, with maximum accuracy, and with equipment and personnel available in most local planning or governmental agencies.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, November 1, 1973
160-75-85-03-72

REFERENCE

1. Anderson, J. R.; Hardy, E. E.; and Roach, J. T.: A Land-Use Classification System for Use With Remote-Sensor Data. U.S. Geol. Survey Cir. 671, 1972.

APPENDIX A

LAND USE CLASSIFICATION USED IN THE SIX-COUNTY EXPERIMENTAL PROGRAM

The following are the land use categories that were delineated in this experimental program. Each land use category is defined, with a discussion of problems or peculiarities encountered in defining each area. In addition, several subcategories were used and are recommended for use as appropriate. It should be mentioned that this particular classification was in use by the Gulf Regional Planning Commission and was adopted for this experiment so that true cost comparisons to a 1968 program that had a similar classification could be developed.

RESIDENTIAL

The residential (R) classification is characterized by intensive occupancy of an area by residential facilities. In rural areas, the immediate area adjoining the residence and used in conjunction with the residence was considered residential.

In some areas, usually adjoining urban development, such categories as new subdivisions or housing developments in which the land has been dedicated to residential use but is not yet occupied are found. For planning purposes, a subcategory called undeveloped residential (UR) was used to denote such situations.

COMMERCIAL

The commercial (C) classification is characterized by land area that is in commercial use such as central business districts, shopping centers, and strip developments along primary traffic arteries. In rural areas, the building and adjacent land used in support of the operation was delineated.

Currently, no category to delineate areas dedicated to commercial use or under commercial development exists. A subcategory, undeveloped commercial (UC), should be added to cover such situations.

INDUSTRIAL

The industrial (I) classification pertains generally to land that is in light and heavy industrial use as well as to dedicated industrial parks. In this category, again, the major problem area was classifying a vicinity that had been zoned or defined as industrial, as in an industrial park area, but was being used actively for other purposes such as forests or grazing. In this study, only area that was actually in industrial use or that had industrial buildings under construction at the time of the overflight was classified as industrial. The dedicated but undeveloped industrial areas were classified as undeveloped industrial (UI).

UNDEVELOPED

The undeveloped (U) classification generally applies to area not dedicated to any specific land use under other categories of definition. This category could be expanded logically to include land dedicated to a particular use, but not actually functioning in that category at the time of a survey. The categories undeveloped residential (UR), undeveloped commercial (UC), and undeveloped industrial (UI) were mentioned previously as such examples. In the rural areas, undeveloped grassland (UG) for natural pasture that is not being tended or used and undeveloped forest (UF) for borderline forest areas should be considered as categories. Acreage that falls into no other specific area is categorized as undeveloped other (UO) or other (O), depending on the location and proximity to urban areas.

PUBLIC AND SEMIPUBLIC

The public and semipublic (P) classification is applicable to land dedicated to such uses as recreation, education, military bases, cemeteries, public utilities, and flood control. In this category, the most controversial areas are the large recreational facilities or military bases that are public or semipublic in themselves but often are so large that, within their boundaries, they can be broken down into the full spectrum of land uses. In this experiment, if the facility was so large as to have evident areas within its boundary committed to a particular land use, these areas were defined as to their usage.

RIGHT-OF-WAY

The right-of-way (ROW) classification includes any land dedicated for use specifically as right-of-way. It was necessary to break this usage into the following subcategories for clarity.

1. Highway right-of-way (RWh) includes all Federal, State, and local lands dedicated or delineated for use by public road traffic.

2. Railroad right-of-way (RWr) includes all railroad rights-of-way and facilities such as terminals.

3. Pipeline right-of-way (RWp) includes those areas set aside for use as pipeline rights-of-way. This category would include pumping substations and so forth but not the plant or origin, which normally would fall under the industrial classification.

4. The category power transmission lines (RWt) includes land dedicated to use of electrical transmission facilities. This category would include substations but not power transmission plants.

WATER

The water (W) classification applies to all areas normally inundated permanently by water.

WETLANDS

The category wetlands includes all low areas permanently or frequently saturated with either freshwater or saltwater. The two classifications are freshwater marsh (Mf) and salt marsh (Ms). There was some discussion on this category as to whether it should be expanded to cover the tree-covered lowlands (swamps). It was decided that these areas, if tree covered, were forests and, when covered by brush or other aquatic vegetation, could be classified as freshwater marsh. If, for any specific need, the forest-covered lowlands should be required as a separate category, the differentiation of such areas would not be difficult usually.

GRASSLAND

The category grassland (G) includes lands dedicated to pastoral usage but not cultivated for such use. Natural grassland or grazing area and permanent pasture fall into this category. This category was the most difficult to define. It was particularly difficult because of the time of the year of the photographic flight (September 30). Most crops were harvested, and, except for winter pasture, new land was not being tilled. The area had suffered from a lack of moisture, and, in some cases, it was difficult to separate permanent overgrazed pasture and grasslands from cultivated pasture and harvested crop areas, especially when some crops such as soybeans are often not cultivated in rows and are impossible to distinguish from pasture after harvesting.

Grassland within areas generally dedicated to urban usage was classified as undeveloped grassland (UG). This classification lets the usage be known while still maintaining the integrity of the urban pattern.

FOREST

By Earth Resources Laboratory definition, the forest (F) category consists of areas with tree cover of approximately 20 percent or greater. This category encompasses forest plantations, natural woodlands, and forest brushlands. In some areas, the delineation between forest and grasslands was quite arbitrary because land was in joint usage. When the tree cover approximated 20 percent, the area was considered forest. In urban areas, the forests often occupied areas that were an integral part of the urban activity; that is, residential, commercial, or industrial. These areas were denoted as undeveloped forests but were statistically categorized as urban to maintain the integrity of the urban area.

CULTIVATED

The cultivated (Cu) category was used to denote areas under cultivation. Row crops, specialty farms, cultivated hay, and cultivated pastures fall into this category. Two areas are difficult to delineate in this category. One occurs when cultivation has ceased but, for several years thereafter, the row patterns are apparent. Until the row pattern is obscured by new growth, the area may be interpreted wrongly. The second problem occurs in the delineation between activated pasture and grasslands. It is often difficult to separate a lush natural grassland from a cultivated pasture. Usually, the tone of a cultivated pasture is much more uniform than that of a grassland, which is usually somewhat mottled in appearance, but this difference may not always be apparent.

HORTICULTURE

The horticulture (H) category is used to denote areas covered by a geometric pattern of trees. Fruit orchards, pecan groves, or tung areas fall into this usage. Horticulture is an easily defined land use category with no particular delineation problems. It should be realized that the geometric planting pattern defines the area. Random tree plantings, or spaced plantings along boundary lines, do not come under this classification.

APPENDIX B

PROPOSED MODIFIED LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Prepared by James R. Anderson*

The following land use classification system is an October 1973 revision of a system previously published in a U.S. Geological Survey circular (ref. 1).

Level I		Level II	
Code	Category	Code	Category
1	Urban and built-up land	1	Residential
		2	Commercial and services (including institutional)
		3	Industrial
		4	Extractive (excluding strip mining, quarries, gravel pits, etc.)
		5	Transportation, communications, and utilities
		6	Mixed (including strip and clustered settlement)
		7	Open and other
2	Agricultural land	1	Cropland and pasture
		2	Orchards, groves, vineyards, and ornamental horticultural areas
		3	Confined feeding operations
		4	Other
3	Forest land	1	Deciduous
		2	Evergreen (coniferous and other)
		3	Mixed

*Chief Geographer, U.S. Geological Survey.

Level I		Level II	
Code	Category	Code	Category
4	Wetland	1	Forested
		2	Nonforested
5	Rangeland	1	Herbaceous range
		2	Shrub-brushland range
		3	Mixed
6	Water	1	Streams
		2	Lakes
		3	Reservoirs
		4	Bays and estuaries
		5	Other
7	Tundra	--	(a)
8	Permanent snow, icefields, and glaciers	--	(a)
9	Barren land	1	Salt flats
		2	Beaches (including mudflats)
		3	Sandy areas other than beaches
		4	Bare exposed rock
		5	Strip mines, quarries, and gravel pits
		6	Transitional areas
		7	Other

[a] Proposed Level II categories are currently under study in Alaska and will be reported separately.

APPENDIX C

U.S. GEOLOGICAL SURVEY REGIONAL OFFICES AND AREAS SERVED

The following list of U.S. Geological Survey (USGS) regional offices includes addresses, telephone numbers, and states serviced by each.

Regional office			Areas served
Title	Address	Telephone	
USGS Eastern Mapping Center	1109 N. Highland Street Arlington, Virginia 22210	703-557-0927	Alabama Connecticut Delaware District of Columbia Florida Georgia Indiana Kentucky Maine Maryland Massachusetts New Hampshire New Jersey New York North Carolina Ohio Pennsylvania Rhode Island South Carolina Tennessee Vermont

Regional office			Areas served
Title	Address	Telephone	
USGS Eastern Mapping Center	1109 N. Highland Street Arlington, Virginia 22210	703-557-0927	Virginia West Virginia
USGS Western Mapping Center	345 Middlefield Road Menlo Park, California 94025	415-323-8111	Arizona California Hawaii Idaho Nevada Oregon Washington
USGS Mid Continent Mapping Center	Post Office Box 133 Rolla, Missouri 65401	314-364-3680	Arkansas Illinois Iowa Kansas Louisiana Michigan Minnesota Mississippi Missouri Nebraska North Dakota Oklahoma South Dakota Wisconsin
USGS Rocky Mountain Mapping Center	Denver Federal Center Building 25 Denver, Colorado 80225	303-234-2326	Alaska Colorado Montana New Mexico Texas Utah Wyoming