N-33396

NASA TECHNICAL NOTE

NASA TN D-7730

NASA TN D-7730

EXTRACTING LAND USE INFORMATION FROM THE EARTH RESOURCES TECHNOLOGY SATELLITE DATA BY CONVENTIONAL INTERPRETATION METHODS

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

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TN D-7730		
4. Title and Subtitle EXTRACTING LAND USE INFORMATION FROM THE EARTH RESOURCES TECHNOLOGY SATELLITE DATA BY CONVENTIONAL INTERPRETATION METHODS		5. Report Date July 1974
		6. Performing Organization Code
7. Author(s) Paul L. Vegas		8. Performing Organization Report No. JSC S-395
9. Performing Organization Name and Address Lyndon B. Johnson Space Center Houston, Texas 77058		10. Work Unit No. 177-52-81-03-72
		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Note
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A procedure for obtaining land use data from satellite imagery by the use of conventional interpretation methods is presented. The satellite is described briefly, and the advantages of various scales and multispectral scanner bands are discussed. Methods for obtaining satellite imagery and the sources of this imagery are given. Equipment used in the study is described, and samples of land use maps derived from satellite imagery are included together with the land use classification system used. Accuracy percentages are cited and are compared to those of a previous experiment using small-scale aerial photography.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
· Satellite-Borne Imagery · Line Spectra · Data Acquisition · Multispectral Imagery · Wavelengths · Photointerpretation · Data Recording · Ground Truth · Spectral Emission · Earth Resources	STAR Subject Category: 13.

19. Security Classif. (of this report)	20. Security Classif. (of this page)
None	None

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EXTRACTING LAND USE INFORMATION FROM THE EARTH RESOURCES TECHNOLOGY SATELLITE DATA BY CONVENTIONAL INTERPRETATION METHODS

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SUMMARY

An experiment was performed by the NASA Lyndon B. Johnson Space Center Earth Resources Laboratory to determine the physical land use data that could be extracted from a single frame of Earth Resources Technology Satellite imagery by using various scales and bands when limited to general ground truth and to conventional photointerpretation methods and equipment. As new satellite data became available, the experiment was modified in an attempt to extract a maximum of data from the imagery by using sequential seasonal frames and more detailed ground truth and by making better use of individual bands and scales as a result of earlier experience. During the experiment, a procedure was developed for extracting selected data from available satellite imagery in a simple and cost-effective manner, with equipment and personnel available at local levels.

Harrison County, Mississippi, having a land area of 1515 square kilometers (585 square statute miles) and a population of 132 000, was chosen for the study. For more detailed land use delineation, townships 5, 6, and 7 south in range 10 west in Harrison County were selected. Multispectral scanner imagery in four bands covering the range of wavelengths from 0.5 to 1.1 micrometers was used. The 1:1,000,000-scale transparent film imagery of band 5 was enlarged to scales of 1:250,000, 1:120,000, 1:62,500, and 1:24,000, and the best color composite combination of bands 4, 5, and 7 was enlarged to scales of 1:250,000 and 1:120,000 for interpretation. After a thorough evaluation, the 1:24,000 scale was abandoned as being too vague in resolution for land use purposes or for use as a map base.

To evaluate the scales, three accuracy checks were made on each of the test townships. The first accuracy check was of total area, the second was of selected sample points, and the third was of 16.2-square-hectometer (40 acre) plots. For area computation, both the dot grid method and the planimeter were used.

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INTRODUCTION

The Earth Resources Technology Satellite (ERTS) Program was a major step in merging sophisticated space and remote-sensing technologies for monitoring and measuring the resources of the Earth. The basic program consists of two satellites, ERTS-A and ERTS-B. The ERTS-A vehicle (also designated ERTS-1) was orbited by NASA in July 1972, with ERTS-B planned to follow at a later date. As is implied by the name, these satellites are dedicated to gathering Earth data by using remote-sensing devices and to transmitting these raw data to strategically located ground communication stations that feed into a data processing center located at the NASA Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. Here, the data are converted into black and white or color images or into magnetic tapes to be used by various investigators or agencies. These images and tapes are distributed to specific investigators from GSFC and to most agencies and the general public from the U. S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center located in Sioux Falls, South Dakota.

In the past, satellite imagery of the Earth surface has been selective, unrepetitive, and used for limited scientific investigations. Much of the pre-ERTS imagery was obtained from hand-held cameras in the Apollo and Gemini Programs. The ERTS data have provided an entirely new baseline for such Earth surface investigations as geology, hydrology, geography, resource inventory, and land use planning and management. Because such data have never before been publicly available, the proper techniques for and the potentials of using the data have not yet been fully developed. The purpose of this report is to investigate the general quality, quantity, and accuracy of data extractable by manual interpretation for land classification purposes as well as to present a detailed methodology for extracting selected data from available ERTS imagery in a simple and cost-effective manner, with equipment and personnel available to the average potential user.

The experiment discussed in this report was initially an attempt to update existing 1:24,000-scale land use maps from a single frame of ERTS data (such as is available to the public) by using the basic skills and tools normally available at local levels in city, county, or regional planning offices. This effort proved infeasible, and the approach was modified to determine the physical land use data that could be extracted from a single ERTS frame by using various scales and bands and by limiting the experiment to general ground truth and to conventional drafting equipment. Later, as additional ERTS passes were made, these new data were evaluated, and the experiment was modified in an attempt to extract a maximum of data from the imagery by using sequential seasonal passes and more detailed ground truth and by making better use of individual bands and scales as a result of earlier experience. Three separate methods were used to evaluate scale and band accuracy as well as overall total accuracy.

The efforts expended are documented in this report with detailed descriptions, comments, comparisons, and evaluations so that a potential user will be able to accurately assess how he may best use the methods employed to extract data for his detailed needs. In another section of this report, a step-by-step procedure for choosing, acquiring, and using the ERTS imagery is presented. It is hoped that a careful reading of this report will provide the background necessary for anyone working in land use or photointerpretation to intelligently use the wealth of data provided by the Earth Resources Technology Satellite.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

This report is the result of the efforts of many persons; to recognize each individually would be difficult. Outstanding contributions were made by Lawrence W. Erickson, who performed all photointerpretation and from whose notes much information was extracted, and by Gary A. Shelton, who supported many facets of the investigation. Other participants included Paul S. Davis, acreage compilation and statistics; B. E. Arthur, Jr., acreage compilation; and Richard B. Sellers, acreage compilation. These personnel are employed by the Lockheed Electronics Corporation at the NASA Lyndon B. Johnson Space Center Earth Resources Laboratory (ERL), located at the Mississippi Test Facility.

DESCRIPTION OF THE ERTS

The ERTS-A vehicle was provided with two primary sensors. One was a return beam vidicon (RBV) system, which contained three cameras and was designed to obtain imagery in the 0.48- to 0.83-micrometer spectral range. Each image obtained was to cover an area of approximately 185 by 185 kilometers (100 by 100 nautical miles). The second primary sensor was a four-channel multispectral scanner (MSS). This sensor is a line-scanning device that uses an oscillating mirror to scan four spectral bands ranging in wavelength from 0.5 to 1.1 micrometers. The MSS is designed to scan a belt approximately 185 kilometers (100 nautical miles) wide at the normal satellite altitude. Thus, the ERTS sensors provide a swath of data, in a direction running generally from north-northeast to south-southwest and crossing the Equator at an angle of approximately 80°. The coverage over any given point is repeated at 18-day intervals. Both sensors are primarily designed for daylight operations.

In addition to the data obtained by the two primary sensors, the ERTS vehicles are also designed to collect and transmit data from remote, automatic data collection system (DCS) platforms selectively positioned on the surface of the Earth. Each DCS platform may collect data from as many as eight sensors for sampling local environmental conditions such as temperature, stream flow, soil moisture, snow depth, salinity, and atmospheric pollution. Data from any platform are available to users within 24 hours after being relayed to the satellite.

The RBV sensor operated for only a short time and was suspended because of technical difficulties in the satellite power source. The MSS, however, has been constantly transmitting, by radio link, data that are recorded on magnetic tapes and converted to photographic images encompassing scenes approximately 185 kilometers (100 nautical miles) square. The data collection system has also been operable and has performed well to date.

The satellite operates in a Sun-synchronous polar orbit at an altitude of approximately 915 kilometers (494 nautical miles), completing 14 orbits per 24-hour day. On each north to south pass, the satellite crosses the Equator at 9:42 a.m. local standard time. The apparent deviation in the satellite path from a true north-south direction is actually caused in part by the rotation of the Earth on its north-south axis under the satellite (fig. 1).

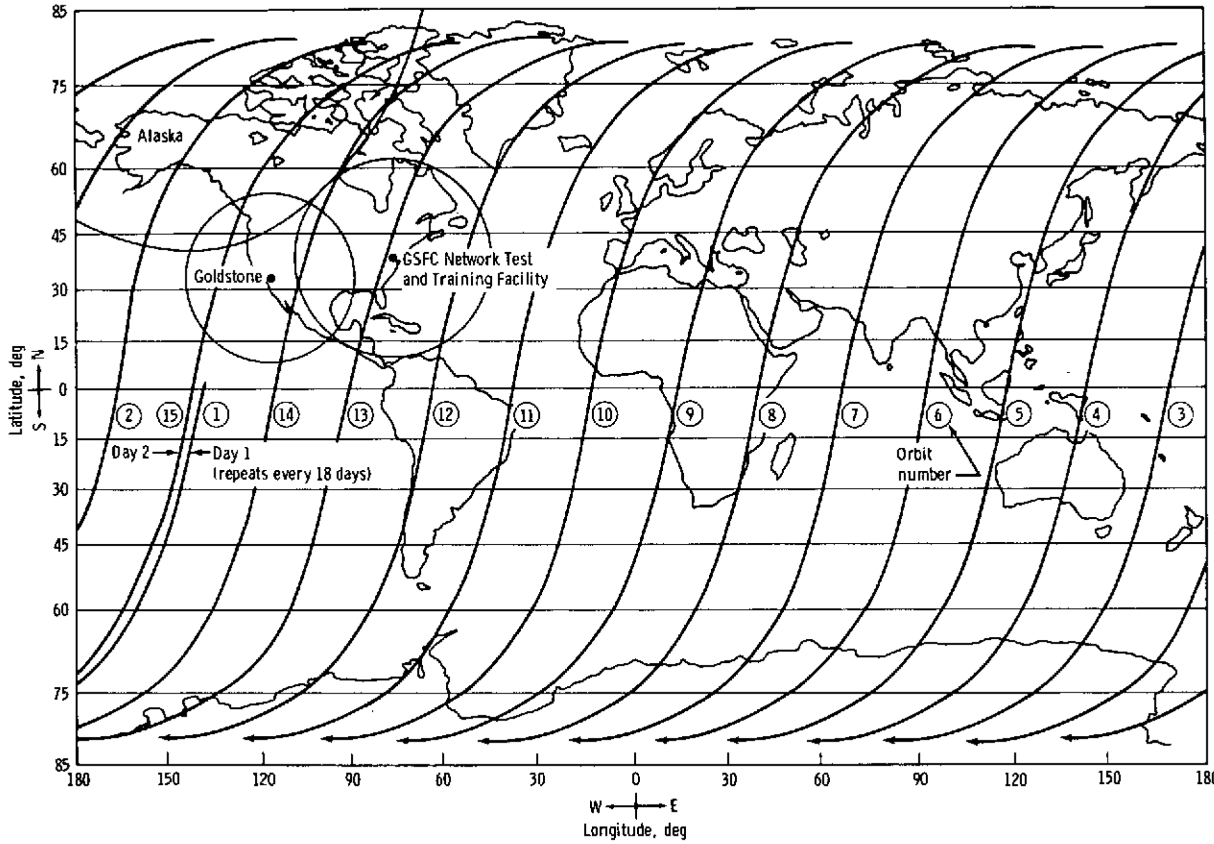


Figure 1. - Map of ERTS orbits.

LAND USE APPLICATIONS OF ERTS DATA

Upon completion of a project using small-scale photography to obtain land use information (ref. 1), it was decided to attempt a similar land use project using satellite data from ERTS-1 so that a comparison and an evaluation of the relative uses of satellite and high-altitude-aircraft imagery could be made, and to develop a procedure for using satellite imagery. The guidelines for the ERTS land use project were essentially the same as those for the high-altitude-aircraft, small-scale-photography project; the basic postulate was that a procedure developed for using satellite imagery to manually prepare land classification maps should not be so sophisticated as to be beyond the talent, the equipment, or the resources available in local or regional planning offices.

The area chosen for ERTS experimental applications was Harrison County, along the Gulf Coast, in the State of Mississippi. This county contains a land area of 1515 square kilometers (585 square statute miles), has a total population of approximately 132 000 inhabitants, includes the urban centers of Gulfport and Biloxi, and is part of a major Standard Metropolitan Statistical Area.

For more detailed work, and for attempting land use delineation at a more localized level, a three-township test area was also chosen. This smaller area, also in Harrison County, comprised a total of 272 square kilometers (105 square statute miles) and extended inland from the coastline at Gulfport, Mississippi. Specifically, townships 5, 6, and 7 south in range 10 west were selected. This area was chosen because it had been recently mapped, the land use had been classified under the previously mentioned small-scale-photography project, and the area covered a broad spectrum of land use (from dense urban - with residential, commercial, and industrial - to rural agriculture, rangeland, salt and fresh marshes, and hardwood and coniferous forests) representing a varied and fairly complete cross section of land use types and physiographic features common to the Gulf Coast region. Extensive ground-truth information was available for accuracy checks from experiments being performed in other disciplines by people working on various projects at the ERL.

The first available clear and usable ERTS imagery of the Gulf Coast test area was taken by ERTS-1 on August 7, 1972 (frame number 1015-16013). Because the ERTS-1 RBV equipment with its three channels was not operating, only the MSS imagery was available for investigatory purposes. This initial imagery was received in the color composite of all bands as well as in each individual band. The bands and wavelengths were as follows: band 4, 0.5 to 0.6 micrometer (green); band 5, 0.6 to 0.7 micrometer (red); band 6, 0.7 to 0.8 micrometer (near infrared); and band 7, 0.8 to 1.1 micrometers (infrared). Additional composites containing combinations of the four bands were produced in the ERL photographic laboratory.

The transparent film imagery received from GSFC was at a scale of 1:1,000,000 on a 22.86- by 22.86-centimeter (9 by 9 inch) format, and the 70-millimeter imagery, which is on an approximately 7.62- by 7.62-centimeter (3 by 3 inch) format, was at a scale of 1:3,369,000. An examination of the two scales proved that the 70-millimeter-film scale was too small to be usable with equipment normally available for stereoscopic use or for photointerpretation, and that to enlarge the 70-millimeter imagery to a scale of 1:24,000 would require a magnification factor of approximately 140, which was beyond the capacity of equipment commonly in use. For this reason, the 70-millimeter film is not discussed or considered further in this report. The 22.86-centimeter (9 inch) imagery at a scale of 1:1,000,000 was viewed on an Itek variable-width viewer, which allows viewing of imagery at 4, 12, 16, and 48 times the original scale. Using the 1:1,000,000 scale received, the viewer enlargement produced scales of 1:250,000 (4×), 1:83,000 (12×), 1:62,500 (16×), and 1:20,833 (48×). It had been previously determined that the desirable scales for experimental purposes were 1:250,000, 1:120,000, 1:62,500, and 1:24,000. These scales were chosen for the following reasons.

1. The 1:250,000 scale is a standard USGS scale generally used for regional analysis, and universal coverage of the United States is available from the USGS at this scale.

2. The 1:120, 000 scale, although nonstandard, was the scale of the aerial photography used in the previously mentioned land use project (18 288-meter (60 000 foot) altitude, 15.24-centimeter (6 inch) focal length), and a comparison could be made at this scale of the quality and resolution of the two types of imagery.

3. The 1:62, 500 scale is standard for USGS mapping and would be the most logical scale to use if the 1:24, 000 scale could not be used.

4. The 1:24, 000 scale is the scale of the largest standard quadrangle map produced by the USGS, is used in most local planning and land use classification projects, and was the scale of the previously prepared land use classification.

A quick analysis of the ERTS transparencies on the Itek viewer revealed the following.

1. The 1:250, 000-scale enlargement retained acceptable detail in general but was too small to be compatible with the previously considered breakdown of land use with the township as a basic area. At the 1:250, 000 scale, each township was approximately 3.81 centimeters (1.5 inches) square on the imagery, making all but the grossest land use delineation impossible.

2. As previously mentioned, the 1:120, 000 scale is not a standard mapping scale nor could an approximation be produced on the Itek viewer. The closest scale available was 1:83, 000 (the 12× enlargement). At this scale, the color composite as well as individual bands became extremely grainy and began to lose definition. Although greater detail was discernible, it was not pleasing to the eye nor as smooth as 1:250, 000-scale data.

3. The 1:62, 500 scale (16× enlargement) was definitely at the limit of usefulness when viewed on the screen. Many features blurred, and only the linear features retained integrity.

4. The 1:20, 833-scale enlargement (48×) just fell apart. Only the strongest linear features such as a coastline or a new interstate highway were discernible.

Use of the Itek viewer saved much experimental photographic work in that it allowed the discarding of some scales and bands as unproductive for the purposes of this experiment. Bands 4, 5, and 7 were determined best for general land use, and band 5 alone produced the clearest map base for delineation purposes at all scales. The 12× enlargement, which produced a scale of approximately 1:83, 000, seemed the largest compatible scale producible on the viewer for interpretation.

On the basis of this preliminary visual review, positive Chronaflex enlargements of band 5 were produced in the photographic laboratory at scales of 1:250, 000, 1:120, 000, 1:62, 500, and 1:24, 000, and the best color composite combination of bands 4, 5, and 7 was enlarged to scales of 1:250, 000 and 1:120, 000 to be used for interpretation purposes. This procedure was done by masking out the desired area on he ERTS transparency with Chart-Pak tape and enlarging the masked portion to scale sing USGS maps for control. In all but the 1:24,000 and 1:62,500 sizes, the entire Iarrison County area was masked and enlarged because the scales were not conducive o working with the smaller township test areas. These scaled enlargements were then iewed on the light table for evaluation as a medium of depicting land use.

On the 1:250,000-scale photographic base, general land use categories were sep-rable. At this scale, such categories as urban, agriculture, forest, water, wetland, nd barren land were recognizable when they covered relatively large areas. Such ther categories as rights-of-way, specific agriculture, lakes, and borrow pits were ften discernible even if they comprised a relatively small area, say 1.22 to 1.62 square ectometers (3 to 4 acres). For these categories, either the sharp contrast in a spe-ific band or the linear physical features permitted easy separation.

Other categories, particularly small areas of mixed urban and agricultural use, ere more subtle and tended to blend into the general countryside. This subtlety is specially true of small urban centers having populations of less than 7000 and located n basically rural settings. These small urban centers could often be located, however, y checking the rights-of-way and their intersections.

Band 5 was generally the single best band for locating urban areas. At this scale 1:250,000), any delineation of land use other than in very generalized form is very dif-icult. For example, although approximately 10 categories were discernible by using arious combinations of bands, a township-sized area of 93 square kilometers 36 square statute miles) occupies approximately 3.81 centimeters (1.5 inches) square n the base, making any delineation and coding of the specific uses cumbersome.

On the 1:120,000-scale base, using 10× magnification on the original ERTS :1,000,000-scale imagery, the following land use classifications were definable in a ingle township area: residential, commercial, industrial, major transportation and tility rights-of-way, forest land, streams and waterways, bays and estuaries, open ater, nonforested wetlands (marshes), sand fill, sand beaches, and cleared or tripped areas. Although 12 different land use classifications were discernible, the ccuracy was not good, delineation was difficult, and many areas could not be classified ith any level of confidence. To delineate and label 12 categories in a 7.62-centimeter 3 inch) square, which comprised a 9.66-kilometer (6 statute mile) square township at his scale, proved cumbersome. A comparison of the RC-8, 18 288-meter (60 000 foot) ltitude color infrared imagery with the ERTS red band (which gave the most detail) at he same scale showed that most of the general physiographic information detectable on he RC-8 imagery was also available from ERTS; however, the detail available on the ircraft photography was not present in the satellite data.

In comparing land use delineation using ERTS MSS imagery to that using the high-ltitude-aircraft imagery, it was found that although major categories are reasonably ell defined from ERTS, a significant number of lesser features were incorrectly iden-ified or were unidentifiable. The basic difficulty with ERTS land use interpretation is lack of sharp detail, caused by the size of each resolution cell. Features tend to lend in and average.

The 1:62,500-scale enlargement was not nearly as pleasing to the eye as the :120,000-scale imagery. At this scale (1:62,500), the resolution-cell size began to be blotchy and the tones were blurred. The photointerpreters, all accustomed to the clear-cut patterns of photographic imagery, were taxed in trying to delineate and specify particular areas of interest on the enlargement. The initial reaction from the photointerpreters was that the 1:62,500 scale was the largest common scale compatible with the ERTS resolution, but that the 1:120,000 scale was easier to work with and would give better results.

The 1:24,000-scale enlargements proved useless as map bases and were a series of black and white blurs, with only the grossest patterns recognizable. After a thorough evaluation, it was decided to abandon the 1:24,000 scale as too vague in resolution for delineation of land use classifications or for use as a base and to concentrate on the development of a technique using a smaller scale.

A short discussion on the inherent characteristics of the two forms of imagery, photographic and scanner, should prove of interest to the potential user at this point. Essentially, a scanner is a revolving or oscillating mirror that views the target through a narrow slit. In the case of the ERTS, at an altitude of 915 kilometers (494 nautical miles), the size of the viewed area in an instant is an approximately circular cell 79 meters (260 feet) in diameter. The recording device in ERTS measures and records the intensity of the reflected or emitted light (signal) from the viewed area at calculated time intervals; this results in recording the signal from a string of overlapping circles along a scan line. The presence of more than one band on the scanner means that the signal emitted from each cell is recorded simultaneously in different areas of the spectrum for each band. In simpler terms, the light emitted from a cell may be recorded in the red area of the spectrum on one band and in the green or blue areas of the spectrum on the other bands simultaneously. The scanner may also record the intensity of emissions in areas of the spectrum not visible to the human eye, such as the near infrared or infrared areas. Although these measurements do not enable the viewer to actually see light emission or reflectivity in spectral areas invisible to the human eye, such measurements do indicate the intensity of the emission and, when plotted, can produce an image indicating the varying strength of each recorded cell emission in each band area being considered.

Because, in ERTS, each cell of 79 meters (260 feet) in diameter is recorded as a single signal or reading on each band, the reflection from the entire cell area is averaged for a reading in each band. Thus, if a cell of 79 meters (260 feet) in diameter falls on a division of forest and concrete, the reading of the light intensity of the cell will be recorded as an average and may bear no resemblance to either concrete or forest. Therefore, only cells that fall upon a uniform, homogeneous area will give representative readings. In essence, for ERTS data, any target area of less than 79 meters (260 feet) in diameter cannot give a true representation in its recorded signal but is averaged in with the adjacent cell area automatically. A 24-meter (80 foot) wide concrete bridge crossing a lake may appear to be visible in the image because it will tend to brighten each cell that encompasses it, forming a chain of brightened cells across a uniform dark background. Because of this phenomenon, linear features are more easily recognized. A street, road, highway, canal, utility line, or other linear feature less than 79 meters (260 feet) wide becomes a line the intensity of which varies with the adjacent areas averaged by the signal. Only by the use of spatial features such as adjacent land use, tributary streams, highway intersections, and continuity of adjacent patterns can the interpreter make an intelligent decision on many linear features.

Other land use boundaries, particularly when subtle or irregular, tend to merge into several averaged signals, which sometimes are difficult to delineate. For example, if, in urban delineation, a 2.03- to 4.05-square-hectometer (5 to 10 acre) shopping center appears in a basically residential area, unless there is a very strong differentiation in signal, it tends to blend and average into the overall image and is difficult to classify. The small blocks and the narrow streets are averaged with lawns, homes, and adjacent areas to give a mottled gray aspect. The contrast so prominent in urban areas on aerial color photography is averaged and blended in the ERTS imagery. Conversely, the small-scale photographic imagery, at an altitude of 18 288 meters (60 000 feet) with the lens and film normally used, has a resolution cell of 3 to 3.7 meters (10 to 12 feet). Even this size cell is much larger than photointerpreters are normally accustomed to working with.

Most of the aerial photography used in land use to date has been obtained at altitudes between 914 and 3658 meters (3000 and 12 000 feet), with a resolution of 0.3 to 0.9 meter (1 to 3 feet). The advantages of ERTS imagery are coverage, lack of scale distortion, and repeatability. The ERTS image covers more than 34 300 square kilometers (10 000 square nautical miles) as compared to 647.5 square kilometers (250 square statute miles) covered on the high-altitude aerial photography. Because of the higher altitude, the ERTS imagery presents no distortion or scale problem away from the center of the image as is normally found in aerial photography. Finally, the biggest advantage is to have a potential reflight with a frequency of 18 days (fig. 1). This feature allows a constant study of an area of interest and a monitoring of seasonal or physical changes. However, to take advantage of the potentialities of the satellite imagery, some reorientation will be required by most photointerpreters. Because of the low resolution, real boundaries between major land classification categories generally are poorly defined on the ERTS imagery, whereas the aircraft imagery permits clear definition of the subtlest variation between categories. This difference is significant because the interpreter relies heavily on such features as road and rail and on structure, patterns and size, shape, texture, and tone for identification. Even though a particular feature cannot be singularly identified in a photograph, the characteristics noted previously can be evaluated as clues to the function or predominant surface activity within an area. This interpretation is not usually possible with ERTS imagery except in very general categories over a large area.

To evaluate the potential accuracy of single-frame ERTS land use delineation, the 1:120,000 scale was chosen by the photointerpreter as the preferred scale after reviewing the various scales, and band 5 of the August 7, 1972, ERTS imagery was enlarged to this scale. The categories to be used were as defined by Level I of a proposed national classification system (ref. 2). These general categories were delineated to the best ability of a photointerpreter who had no previous experience with satellite scanner imagery but who had worked extensively with high-altitude-aircraft photography. The 1:1,000,000-scale ERTS original with all the bands and composites, as well as 1:250,000-scale enlargements, were used in a 10-power viewer. As previously noted, townships 5, 6, and 7 south of range 10 west were delineated, and the accuracy was checked against a previous study of land use over the same area that had proved 96 percent accurate on an overall acreage basis. In some cases, these acreages in the previous land use had to be aggregated to fit into the appropriate Level I categories. Using these data, updated and checked by additional aerial photographic imagery and ground truth, the accuracy of the ERTS delineation on the 1:120,000-scale base was checked and tabulated by two methods. The first consisted of a check by total area.

The total acreage in the test area in each Level I category was compiled by using the random dot grid method. The results are included in table I.

TABLE I.- ACCURACY CHECK BY TOTAL AREA[a]

Category[b]	Small-scale photography[c]				ERTS imagery			
	Dot count	Area		Percent of total area in category	Dot count	Area		Percent of total area in category
		hm^2	acres			hm^2	acres	
01 Urban and built-up land	1 336	2 860	7 067	10.6	1 523	3 399	8 400	12.7
02 Agricultural land	1 139	2 438	6 025	9.1	2 450	5 469	13 513	20.4
03 Rangeland	NA[d]	--	--	--	NA	--	--	--
04 Forest land	8 574	18 571	45 889	69.2	7 013	15 654	38 680	58.3
05 Water	949	2 032	5 020	7.6	832	1 857	4 589	6.9
06 Nonforested wetlands	390	835	2 063	3.1	121	270	667	1.0
07 Barren land	50	107	265	.4	87	194	480	.7
Totals	12 438	26 843	66 329	100.0	12 026	26 843	66 329	100.0

[a]Based on 1:120,000-scale enlargement of band 5; townships 5, 6, and 7 south of range 10 west; Harrison County, Mississippi; Level I land use.

[b]Land use categories from reference 2.

[c]Data from previous study; estimated accuracy 94 to 96 percent. (See ref. 1.)

[d]Not applicable.

To get an absolute accuracy check, several known ground-truth points in each category were chosen and these known points were evaluated one by one against the delineation by the photointerpreter. The results of this accuracy check are shown in table II. As can be seen from table II, the accuracy of the categories ranged from a high of 100 percent for water to a low of 42.6 percent for the urban area. The reasons for this deviation are explained later in this discussion.

At this point in the experiment, additional ERTS imagery of the test area became available. On October 18, 1972, an image with 75 percent cloud cover was produced that was much more interpretable in the cloud-free areas than was the August 7 imagery. On January 16 and February 3, 1973, excellent imagery was obtained. To estimate the problems of acquiring good imagery over certain areas, imagery obtained on ERTS flights from August 7, 1972, to May 4, 1973, was examined and graded. The percentage of cloud cover and the clarity and quality of the imagery for photointerpretation work during this period are shown in table III. As can be noted, during a 9-month period, only four passes over the test area produced relatively cloud-free data of quality good enough for land use interpretation.

Having completed the evaluation of the land use data obtainable from a single frame of ERTS imagery and having gained experience in using the bands and scales in the first experiment, the investigators decided to determine the improvement that could

TABLE II.- ACCURACY CHECK BY SAMPLE POINTS[a]

[Total area 26 843 hm^2 (66 329 acres)]

Category[b]	Total points checked	Total correct	Percent accuracy	Percent of test area in category	Percent of total area correctly classified
01 Urban and built-up land	55	24	42.6	10.6	4.52
02 Agricultural land	110	84	76.4	9.1	6.95
03 Rangeland	0	0	--	--	--
04 Forest land	120	96	80.0	69.2	55.36
05 Water	30	30	100.0	7.6	7.60
06 Nonforested wetland	20	12	60.0	3.1	1.86
07 Barren land	10	10	100.0	.4	.40
08 Tundra	0	0	--	--	--
09 Permanent snow and icefields	0	0	--	--	--
Totals	345	256	--	100.0	[c]76.69

[a]Based on 1:120,000-scale enlargement of band 5; townships 5, 6, and 7 south of range 10 west; Harrison County, Mississippi; Level I land use.

[b]Land use categories from reference 2.

[c]Overall average accuracy biased by area.

TABLE III. - EVALUATION OF ERTS-1 IMAGERY

[Harrison County, Mississippi]

Date	Image quality[a]	Percent cloud cover	Identification number
Aug. 7, 1972	Good	0	16013
Aug. 25, 1972	Good	50	16014
Sept. 12, 1972	Good	30	16014
Sept. 30, 1972	Good	100	16014
Oct. 18, 1972	Good	75	16020
Nov. 5, 1972	Good	100	16022
Nov. 23, 1972	Good	100	16023
Dec. 11, 1972	No data	--	--
Dec. 29, 1972	No data	--	--
Jan. 16, 1973	Good	0	16020
Feb. 3, 1973	Excellent	0	16023
Feb. 21, 1973	Poor	70	16022
Mar. 11, 1973	Good	70	16021
Mar. 29, 1973	Good	100	16021
Apr. 16, 1973	Good	100	16022
May 4, 1973	Good	0	16022

[a]Scale used refers to photographic quality of image and was rated poor, good, or excellent.

be made by using two sets of imagery: one summer, the other winter. Additional ground-truth data had been assembled, and the bands at various scales for both sets of imagery were to be combined and used in interpretation to determine whether overall improvement in accuracy was possible by using sequential imagery and to what degree improvement could be expected.

The two clearest winter passes over the test area occurred on January 16 and February 3, 1973. These passes were evaluated for scanner performance, image quality, ground detail, and interpretability. As received, both images were extremely dense, and some ground cover features were difficult to delineate in the darker portions of the image. Although essentially equal in quality to the January 16 image, the February 3 image was chosen for experimental purposes because it was sharper by contrast with the August 1972 image; the February and August images were taken almost exactly 6 months apart.

Band 5 of the February 3 imagery was enlarged to scales of 1:62,500, 1:120,000, and 1:250,000 for use as the map base, and a composite was produced of bands 4, 5, and 7 enlarged to a scale of 1:250,000 for interpretation purposes if desired. The same procedures used in the previous experiment were used for this phase. The interpreters used both sets (August 7, 1972, and February 3, 1973) of imagery in the various bands and scales.

Figure 2 is a reproduction of a color composite of the August 7, 1972, imagery as received from the EROS Data Center at a scale of 1:1,000,000. Figure 3 is band 5 of the February 3, 1973, imagery; band 5 was used as the map base for this project. This band was enlarged to scales of 1:62,500, 1:120,000, and 1:250,000 to serve as map bases for the test area. In figure 4, the Harrison County test area of 1515 square kilometers (585 square statute miles) and the urban test township of 93 square kilometers (approximately 36 square statute miles) are outlined on a 1:1,000,000-scale print.

It was found that viewing the same or different bands from the two sets of data in a stereoscopic viewer made possible a much improved interpretation. Not only was a false stereoscopic effect produced that aided perception, but the differences between the images were strongly emphasized. This effect is particularly useful for updating because using different sets in the stereoscopic viewer highlights any area of change or difference in the image and allows these areas to be noted and to be examined more closely. Using the categories established in reference 2, the Level I and II categories were defined in the three-township test area at each of the three map scales. To be consistent with earlier procedures, the 1:250,000 scale was completed first, followed by the 1:120,000 scale and, finally, the 1:62,500 scale. Table IV contains the land use categories definable on one or another of the three test scales with some degree of confidence by the interpreter. Although the additional experience of the photointerpreter with satellite imagery undoubtedly had some influence on the result, it is revealing to compare this list of 23 categories with the list of 6 categories delineated in the earlier attempt using a single frame of ERTS imagery. (See tables I and II.)

A discussion of each of the defined categories is included in this report as appendix A, in which comments on problem areas and a detailed recommendation on scale combinations for land use may be found. Table V is a summary of appendix A included for use by a photointerpreter working with satellite data for the first time.

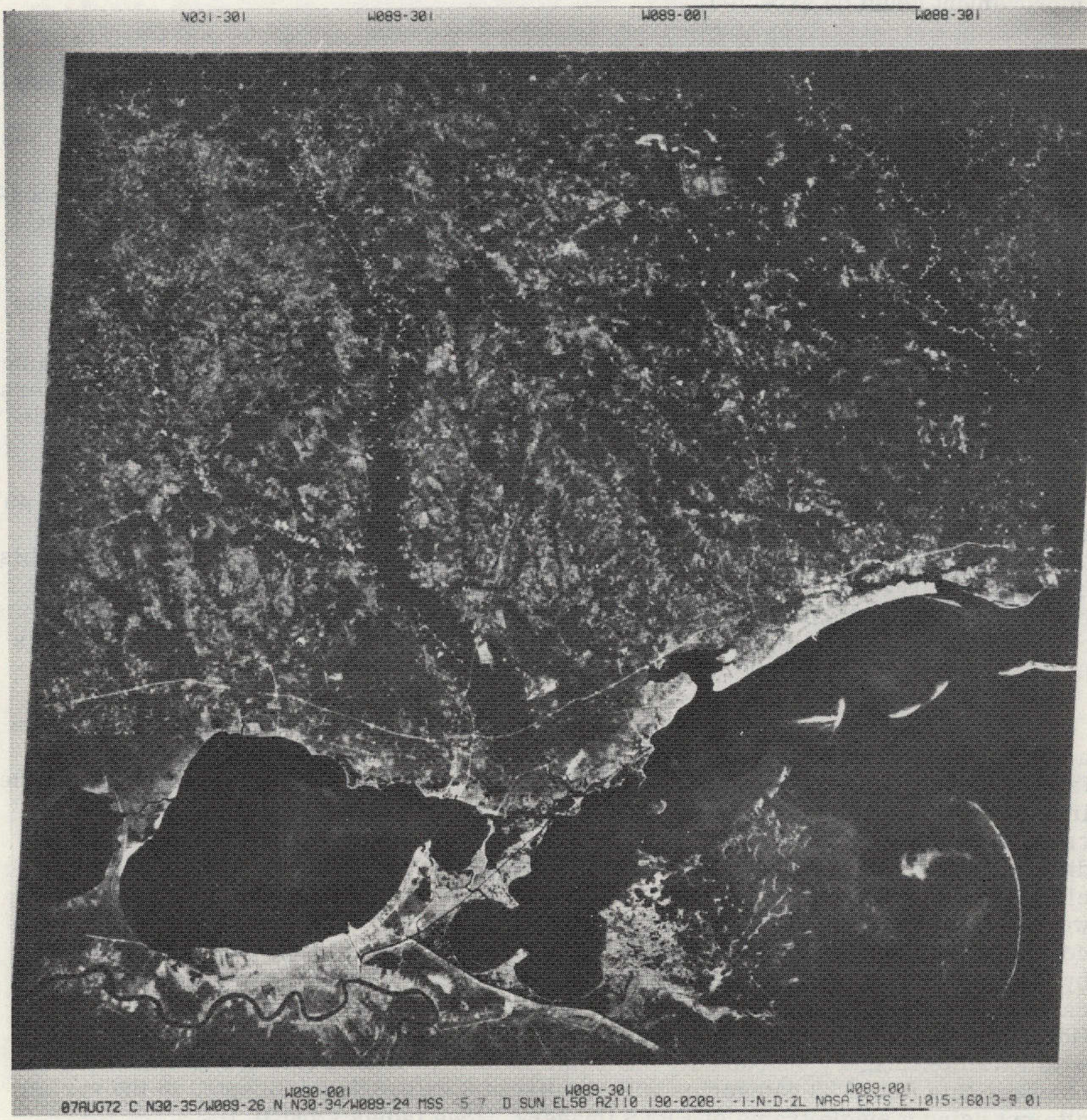


Figure 2. - Reproduction of typical ERTS color composite transparency.

Figure 3. - Reproduced transparency of ERTS band 5 at 1:1,000,000 scale, February 3 imagery.

Figure 4. - Band 5 of the ERTS showing Harrison County and the test township (T7S, R10W) at 1:1,000,000 scale, February 3 imagery.

TABLE IV.- CATEGORIES DISTINGUISHABLE FROM SEQUENTIAL SETS OF ERTS IMAGERY IN THE MISSISSIPPI GULF COAST AREA[a]

[Data from Aug. 7, 1972, and Feb. 3, 1973, ERTS-1]

Level I		Level II	
Code	Category	Code	Category
0100	Urban and built-up land	0101	Residential[b]
		0102	Commercial and services
		0103	Industrial
		0104	Extractive
		0105	Transportation, communications, and utilities
		0107	Strip and clustered settlement
		0108	Mixed
		0109	Open and other
0200	Agricultural land	0201	Cropland and pasture[c]
		0204	Other
0300	Rangeland		
0400	Forest land	0401	Deciduous[d]
		0402	Evergreen (coniferous)
		0403	Mixed
0500	Water	0501	Streams and waterways
		0502	Lakes
		0503	Reservoirs
		0504	Bays and estuaries
		0505	Other
0600	Nonforested wetland	0601	Vegetated
		0602	Bare (mudflats)
0700	Barren land	0702	Beaches
		0703	Sand other than beaches
		0705	Other

[a]Basic land use categories from reference 2.

[b]It should be noted that not all residential areas can be identified on ERTS-1 imagery without using extensive collateral data (ground truth, underflights, etc.). However, where residential areas exist in sufficient density or areal distribution, they can be identified. This definition is more applicable to an urban environment (units of 10 000 population and larger) than to isolated residential developments, which may be confused with other categories either because of the density and distribution of grass or because of tree cover or both. Small urban units (towns of less than 5000 population) may not be readily discernible without collateral data, especially in predominantly agricultural areas.

[c]Depending on the season and crops, certain reflectance characteristics reveal agricultural types, particularly on band 7. Although the August 7, 1972, imagery does not display significant image-density/crop-type correlation because the vegetation in general was universally lush, certain agricultural aspects were definable on the February 3, 1973, imagery. On the latter coverage, winter rye is quite evident, particularly when the visual integration interpretation technique is used. By proper registration and exposure of bands 4, 5, and 7, it is believed that a color composite correlated with ground truth could yield considerably more agricultural information. The land use categories could be modified in a number of ways to accommodate additional local agricultural conditions.

[d]Because swampland (forested) can be identified with considerable accuracy on the February 3, 1973, imagery and because the swamp is such a widespread and significant physiographic/vegetational condition in the Mississippi-Louisiana area, it may be worthy of a separate category.

TABLE V.- LAND USE IDENTIFICATION FROM ERTS-1 IMAGERY

Land use category	Best MSS band	Major identification characteristics
Residential	5 and color composite 4, 5, 7	Mottled gray surrounding central business district (CBD). Street patterns when visible.
Commercial and services	5 and color composite 4, 5, 7	Light tone in CBD, following major arteries; white/bluish in color composite
Industrial	5 and color composite 4, 5, 7	Regular boundaries, light tone, extensive structure/bare ground. Commonly separated from center of urban area.
Extractive	5 and color composite 4, 5, 7	Extensive light-toned spoil areas, road networks, isolated.
Transportation	5 and color composite 4, 5, 7	Light-toned, linear features.
Utilities	5 and color composite 4, 5, 7	Long, straight, fairly light features. Commonly do not conform to orientation of section lines.
Strip and clustered settlement	5 and color composite 4, 5, 7	Light tones or mottled areas along rights-of-way; isolated from other urban areas.
Mixed	5 and color composite 4, 5, 7	Mottled white to gray areas not uniform enough to allow for separate classification.
Open and other	5 and 7 and color composite 4, 5, 7,	Dark tone within urban area.

TABLE V.- LAND USE IDENTIFICATION FROM ERTS-1 IMAGERY - Continued

Land use category	Best MSS band	Major identification characteristics
Golf course/cultivated grass	7	Light tones with "fingered" appearance within urban or forested area.
Cropland and pasture	5 and 7 and color comsite 4, 5, 7	Light tone (pink to red on color composite). Extensive land area occupied. Boundaries conform to section lines. Orientation; contoured boundaries adjacent to bottom lands.
Rye grass	7	Extremely light tone.
Deciduous forest	5 and color composite 4, 5, 7	Dark red (uniform texture) conforming to the stream patterns in bottom land. Very dark tone on black and white (B&W) image.
Coniferous forest	5 and color composite 4, 5, 7	Lighter red/pink, mottled appearance in upland areas. Mottled dark gray on B&W image. Conforms to drainage patterns but usually separated from the bottom land by the deciduous forest.
Mixed forest	Color composite 4, 5, 7	Combination of mottled red/pink in lowland areas. (Reliable delineation difficult.)
All water areas	7 and color composite 4, 5, 7	Black tone on band 7 B&W image. Varying shades of blue on color composite depending upon suspended materials.
Nonforested wetland	7	Dark-gray tone between black water and light-gray land. Coastal.

TABLE V.- LAND USE IDENTIFICATION FROM ERTS-1 IMAGERY - Concluded

Land use category	Best MSS band	Major identification characteristics
Beaches	4 and 5 and color composite 4, 5, 7	White strip at coastline.
Sand other than beaches	4 and 5 and color composite 4, 5, 7	White tone inland from beach not associated with industrial or extractive areas.

If limited to a single pass, such as was the case in the first portion of this experiment, optically combining sets of bands reduces the problem of scan-line/ground-detail confusion and permits greater ease and accuracy of interpretation. Analysis by color composites indicates that this method is considerably better than interpretation of a single band.

In conclusion, it can be definitely stated that visual integration of like bands from different passes yields significantly improved image interpretability. The actual percentage of improvement possible by using sequential imagery rather than a single frame is hard to assess; however, in the test areas, improvements of 12 to 18 percent in accuracy were demonstrated.

Each of the three township test areas was delineated at each of the scales on the base prepared from band 5. To provide some concept of the scales and the detail discernible, scaled prints are shown in figures 5 to 7. These prints were produced from band 5 but are not nearly as clear as is the actual Chronaflex base. Figure 8 is a print of band 5 enlarged to 1:24,000 scale and is included to demonstrate the problems caused by overenlargement. Figure 9 was produced using the same film and under the identical conditions used to produce figure 7. The greatly increased density of the February imagery (fig. 7) is demonstrated. The setting used is too dark to display the February image to best effect. Reproductions of the land use maps of the urban test area (township 7 south, range 10 west) are shown in figures 10, 11, and 12 at the three test scales of 1:250,000, 1:120,000, and 1:62,500, respectively. The delineations shown on these figures were made by using the August and February sequential imagery. The land use delineated earlier using the August 7 single pass is shown in figure 13. A comparison of figures 12 and 13 demonstrates the improvement obtainable by using the August and February data rather than the August data alone.

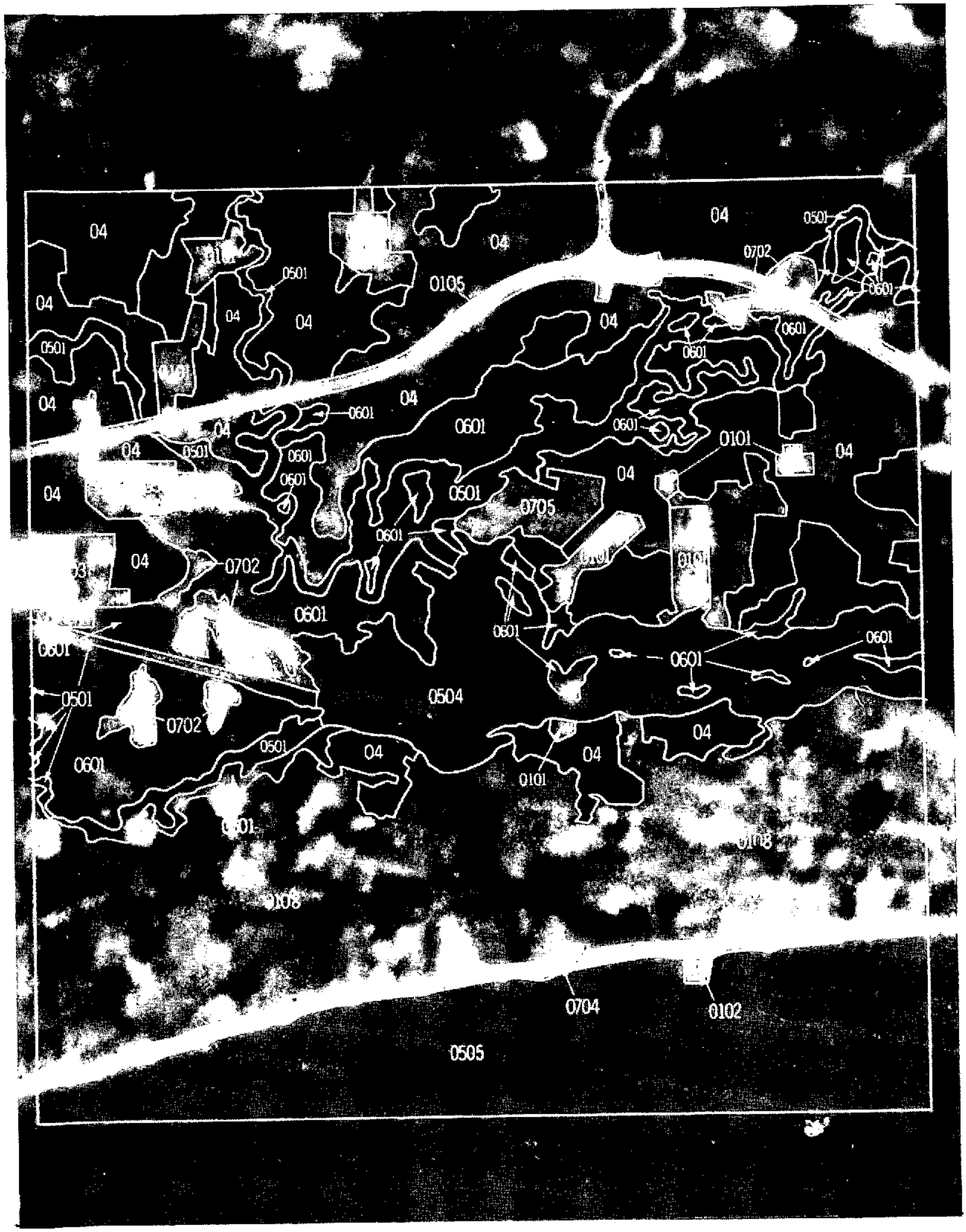


Figure 13. - Test township band 5 with land use at 1:62, 500 scale, August 7 imagery.

Figure 5. - Test township band 5 at 1:250,000 scale, February 3 imagery.

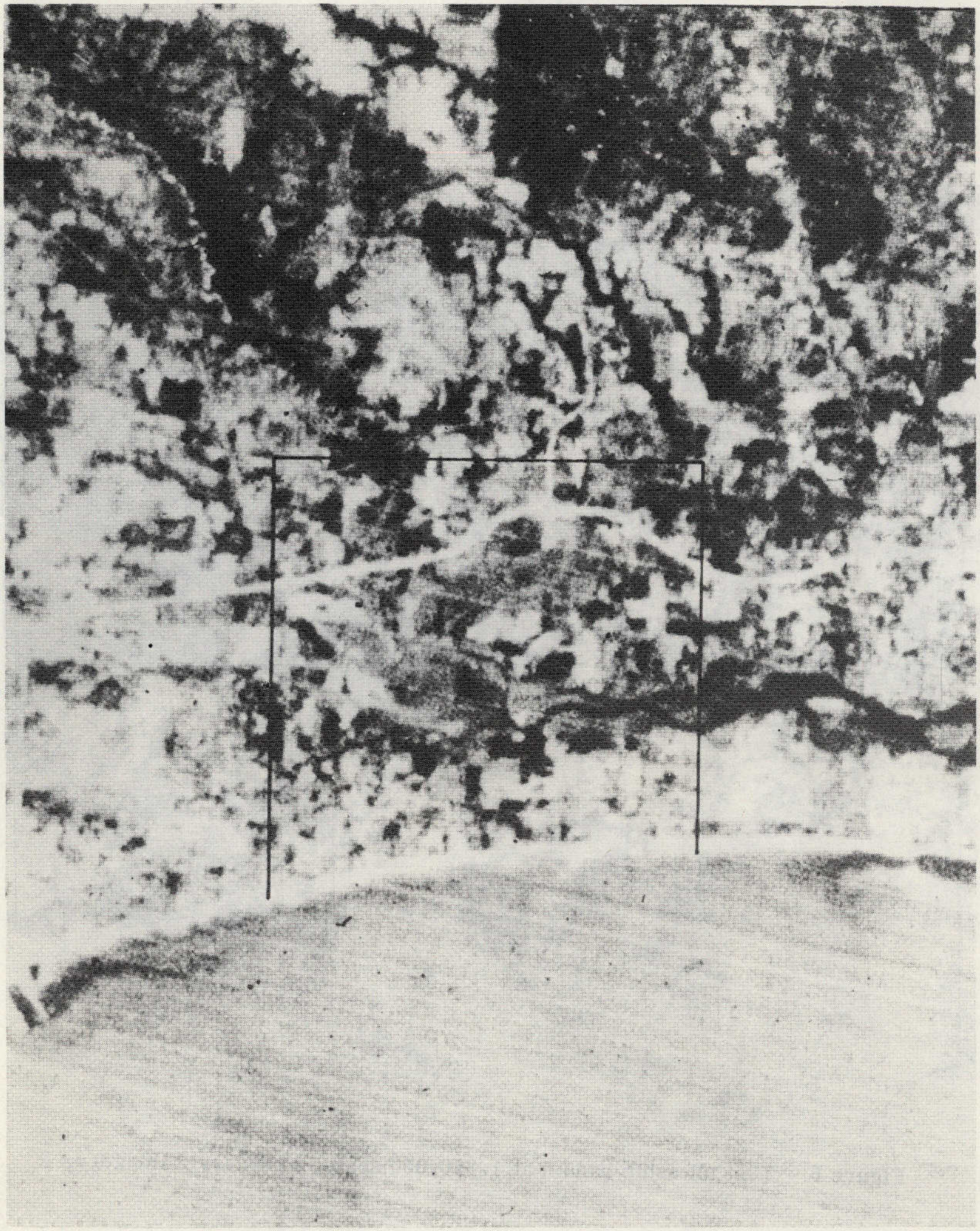


Figure 6. - Test township band 5 at 1:120, 000 scale, February 3 imagery.

Figure 7. - Test township band 5 at 1:62,500 scale, February 3 imagery.

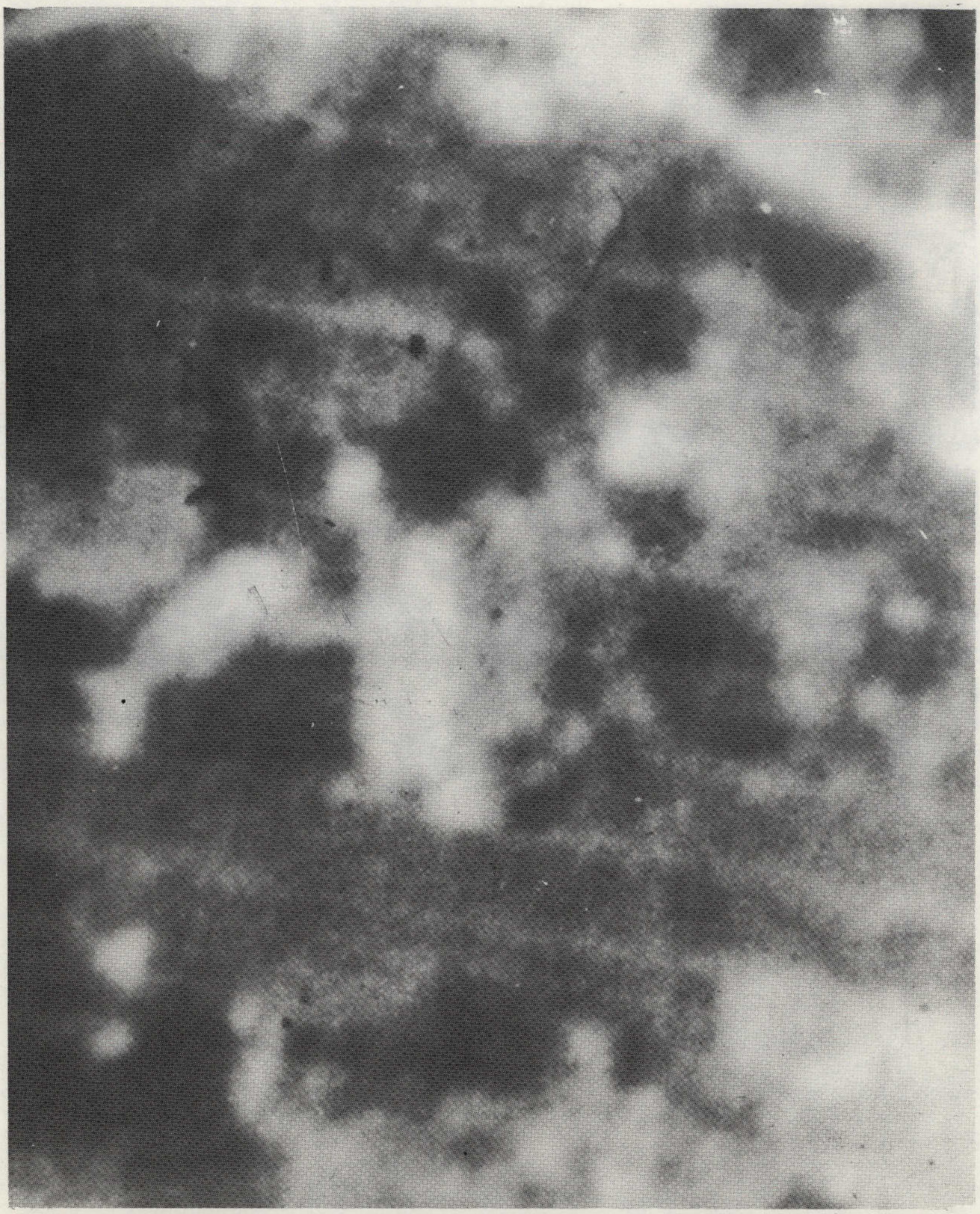


Figure 8. - Test township band 5 at 1:24,000 scale, August 7 imagery.

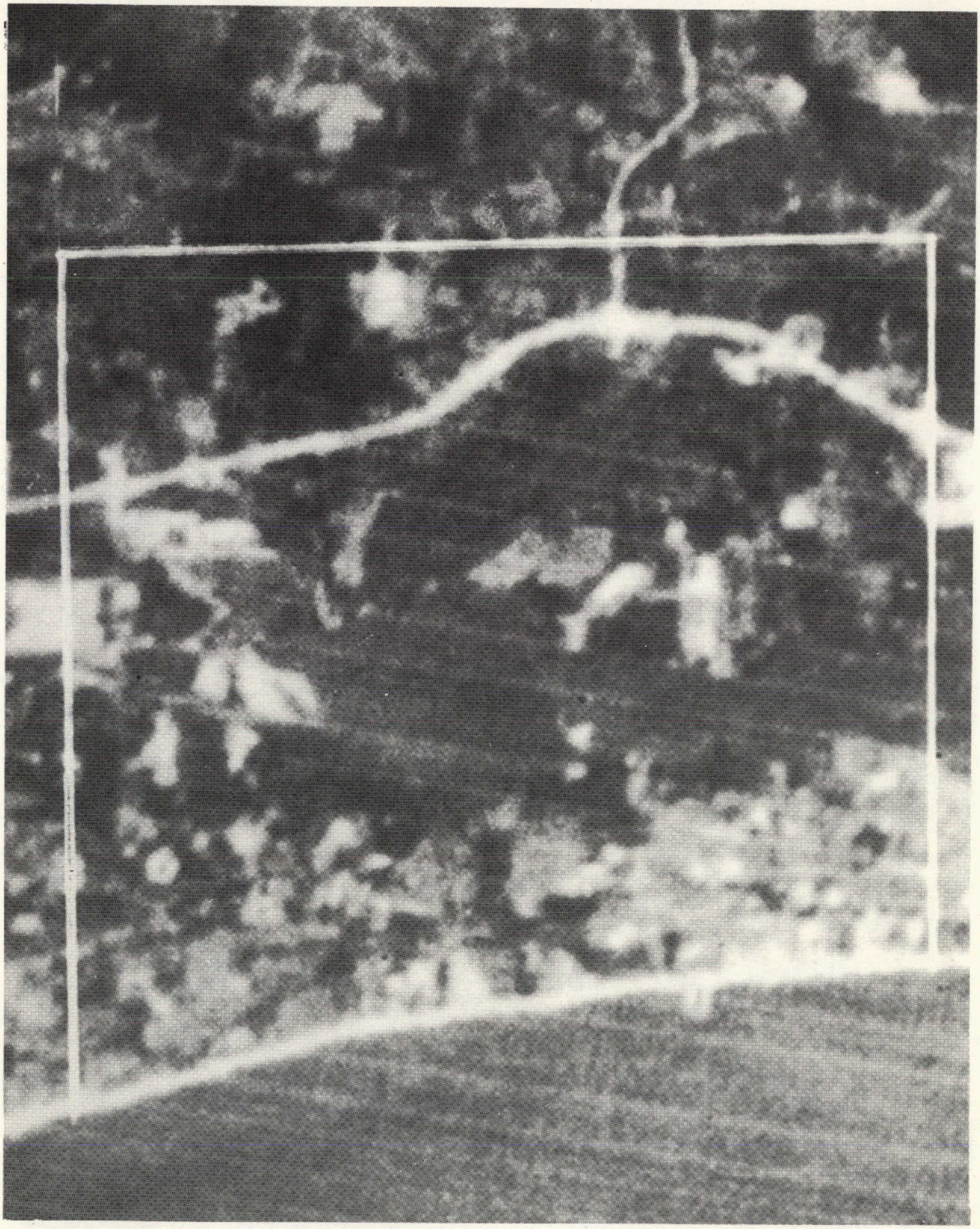


Figure 9. - Test township band 5 at 1:62,500 scale, August 7 imagery.

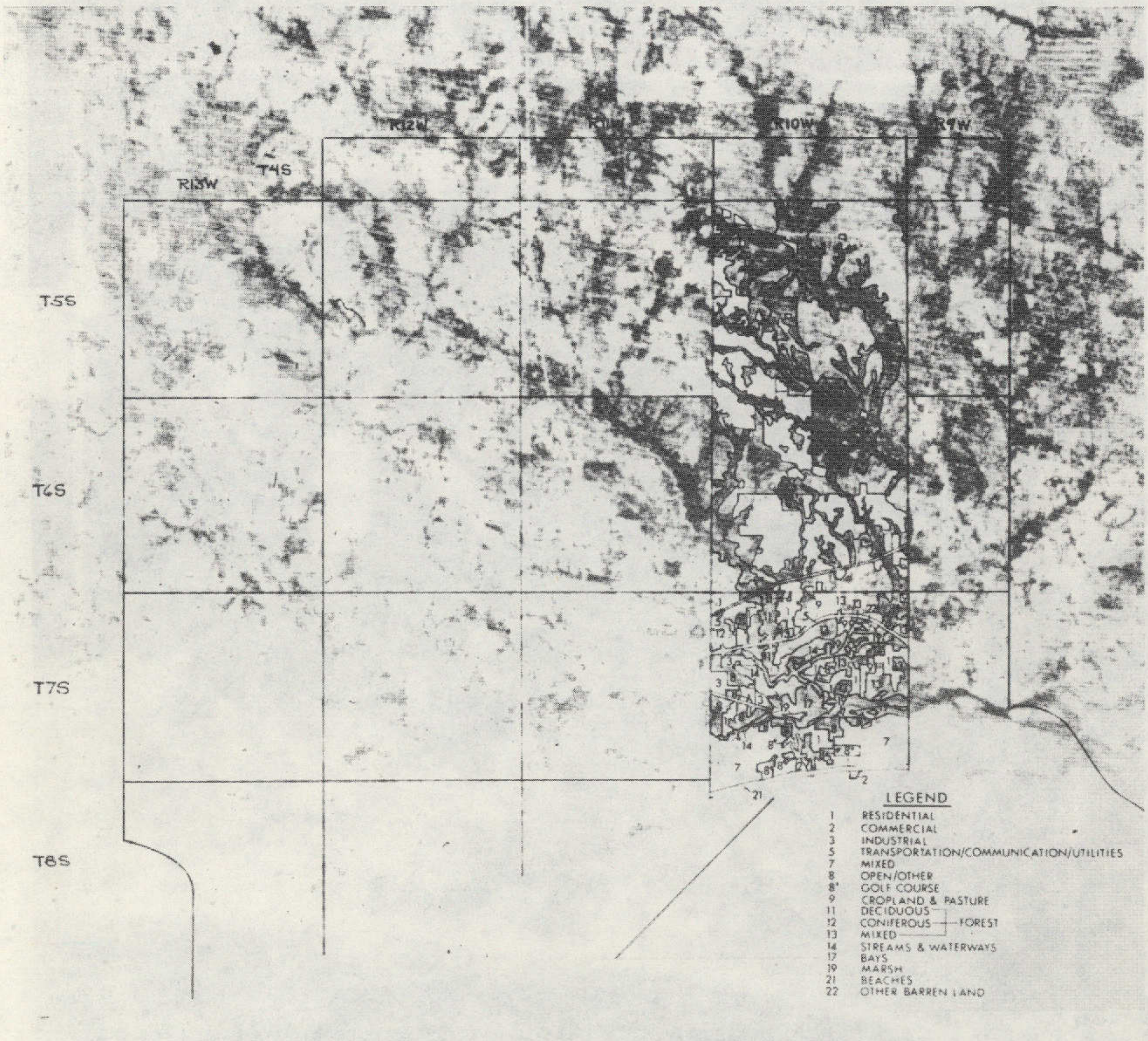


Figure 10. - Test township band 5 with land use at 1:250,000 scale, August/February imagery.

Figure 11. - Test township band 5 with land use at 1:120,000 scale, August/February imagery.

Figure 12. - Test township band 5 with land use at 1:62,500 scale, August/February imagery.

Figure 13. - Test township band 5 with land use at 1:62,500 scale, August 7 imagery.

To evaluate the scales, three accuracy checks were made on each of the test townships. Township 7 south, range 10 west is a relatively urbanized area along the coast; township 6 south, range 10 west is an area of intermediate development; and township 5 south, range 10 west is a completely rural area composed of forests and agriculture.

In the first accuracy check, a comparison was made of the total area classified by category in each township. This check is more useful as an indicator of economic activity within an area than of accuracy on an absolute scale, because errors of omission and commission tend to cancel each other to some degree. In test A, the three townships were graded by the percentage of area that fell into each category. The basis for comparison was an area compilation produced by using high-altitude photography and ground truth that, in a previous experiment, had proved 94 to 96 percent accurate on a total area basis. The results of this test are shown in table VI(a).

The second check of the test areas (test B) was designed to indicate accuracy on an absolute scale. In this evaluation, several points of known ground truth were assembled for each category, and the points were located on the ERTS land use map and graded for correctness. Again, all three townships at the three scales were graded. A summary of this evaluation appears in table VI(b), in which it can be seen that the accuracy of ERTS land use delineation is inversely proportional to the fracturing of the acreage within a given area. The more urbanized area had a low of 46.5 percent of the points correct at one scale, whereas accuracy in the rural area ranged as high as 90.0 percent. It should be noted that, in this test, the ground-truth points were not selected with regard to the ERTS resolution cell but were random points that had been defined for various studies. Many test points, particularly in the urban area, were impossible to define on the ERTS image.

In the third accuracy evaluation, shown as test C in table VI(c), each 16.2-square-hectometer (40 acre) area was considered individually. In each of the test townships, the entire 9.66- by 9.66-kilometer (6 by 6 statute mile) area was divided into 16.2-square-hectometer (40 acre) test plots on a section by section basis. The central point of each 16.2-square-hectometer (40 acre) test plot was classified using ground-truth data and the aircraft imagery. The ERTS classification on each of the three test scales at each point was then compared to the control. As can be seen, the accuracy ranged from a low of 72 percent correct on township 7 south, range 10 west, which is predominately urban, to a high of 99 percent correct on township 5 south, range 10 west, which is extremely rural.

TABLE VI. - ACCURACY OF ERTS LAND USE OVER TEST AREAS[a]

(a) Test A, evaluation by total area

Township	Total area		Scale								
			1:62,500			1:120,000			1:250,000		
			Area correct		Percent correct	Area correct		Percent correct	Area correct		Percent correct
	hm^2	acres	hm^2	acres[b]		hm^2	acres[b]		hm^2	acres[b]	
T7S, R10W (urbanized)[c]	8429	20 829	5629	13 910	66.8	5673	14 017	67.3	5374	13 280	63.8
T6S, R10W (intermediate)	8905	22 005	7220	17 840	81.1	7722	19 080	86.7	6633	16 390	74.5
T5S, R10W (rural)[d]	9508	23 495	7956	19 660	83.7	8025	19 830	84.4	7912	19 550	83.2

(b) Test B, evaluation by selected sample points

Township	No. of points	Scale					
		1:62,500		1:120,000		1:250,000	
		No. correct	Percent correct	No. correct	Percent correct	No. correct	Percent correct
T7S, R10W (urbanized)[c]	520	325	62.5	242	46.5	248	47.7
T6S, R10W (intermediate)	310	247	79.7	240	77.4	231	74.5
T5S, R10W (rural)[d]	252	227	90.0	215	85.3	222	88.1

(c) Test C, evaluation by center points of 16.2-hm^2 (40 acre) plots

Township	No. of points	Scale					
		1:62,500		1:120,000		1:250,000	
		No. correct	Percent correct	No. correct	Percent correct	No. correct	Percent correct
T7S, R10W (urbanized)[c]	576	437	76	458	80	416	72
T6S, R10W (intermediate)	576	497	86	489	85	461	80
T5S, R10W (rural)[d]	575	570	99	560	97	560	97

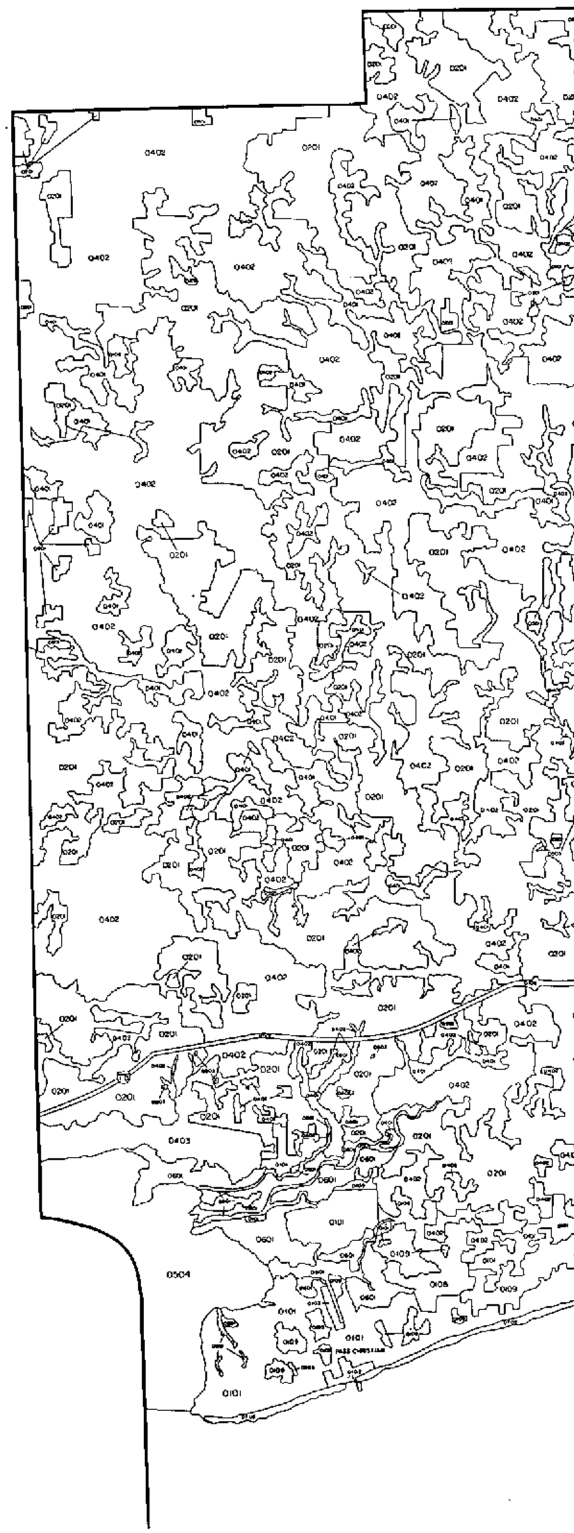
[a]Overclassification not penalized; otherwise, scores would have averaged somewhat lower.
[b]Number of acres in agreement with previous land use acreage compilation, which was 94 to 96 percent accurate.
[c]The urbanized township was 34.7 percent urban, 25.4 percent water, 25.1 percent forest, and 14.2 percent other.
[d]The rural township was 78.2 percent forest, 21.0 percent agriculture, and 0.8 percent other.

A noteworthy point that can be demonstrated by the accuracy tests of table VI is that the general accuracy declines slightly as the scale increases. Thus, the 1:62,500 scale generally proved more accurate than the 1:120,000 scale, which, in turn, was more accurate than the 1:250,000 scale. The differences in accuracy between the scales, as might be expected, were greatest in the urban areas and less noticeable in the rural areas.

To estimate the effort required to produce an ERTS land use map of an area, Harrison County was mapped in its entirety at the most accurate test scale of 1:62,500 (fig. 14). The effort required to produce this product was 108 man-hours for the photointerpretation and drafting and approximately 28 man-hours for the preparation of the base, enlargement and scaling, format, and so forth, or a total of approximately 136 man-hours. This value compares very favorably with the 640 man-hours spent to produce a similar product of the same area from high-altitude, small-scale photography at a scale of 1:24,000. Although the accuracy of the ERTS map is not comparable to that produced by the high-altitude, small-scale photography for detailed urban or local planning, it is sufficient for use in regional work; the ERTS map would be particularly useful in resource planning and management of rural areas.

A STEP-BY-STEP PROCEDURE FOR POTENTIAL ERTS USERS

To enable practical use of ERTS data in any of the methods described in this report, the following step-by-step process by which the imagery is obtained, prepared, photographically processed, and used is presented. Although this section of the report is complete within itself, the preceding section should be consulted as necessary to obtain more detailed information on specific areas of interest.



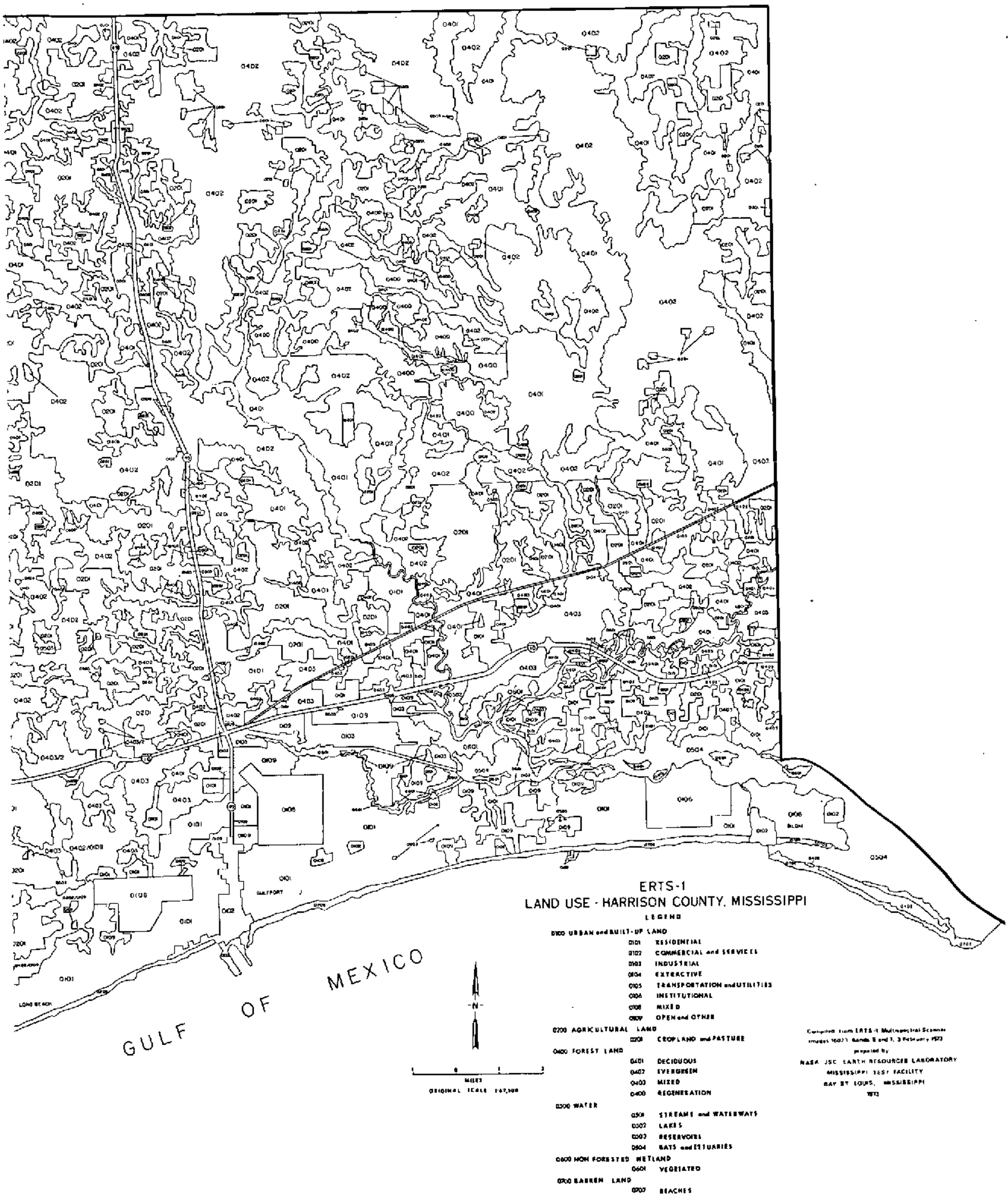


Figure 14. - Land use map of Harrison County, Mississippi, prepared from ERTS-1 imagery.

Step I — Definition of the Study Area

The first effort by a user (Step I) should be to define the physical geographic area to be studied. The easiest manner in which this definition can be accomplished is to delineate the study area on standard USGS 1:250,000-scale maps. These maps are available from any mapping distribution center or drafting supply center; the names and addresses of suppliers are usually available in the classified section of the local telephone directory. If the area falls on two or more such maps, the maps may be trimmed and mosaicked to define the entire study area. If mosaicking is required, the latitude and longitude lines should be matched as carefully as possible because they will be used later to define the area more precisely on the ERTS image.

Step II — Access to EROS Data Browse and Order Centers

All unclassified imagery from USGS, NASA, and other Federal agencies has been made available to the public through the Department of the Interior. These products are available for the cost of reproduction. The distribution center and central files are located in the USGS EROS Data Center, 10th Street and Dakota Avenue, Sioux Falls, South Dakota 57198, telephone 605-339-2270. In addition to the EROS Data Center, browse files and order centers have also been established by the Department of the Interior for public use at the locations listed in appendix B. Should a browse file be located within reasonable distance of a user, it is well worth spending some time in becoming familiar with the system and its potential (Step II). Each browse location has complete files of the available ERTS imagery, which may be scanned for cloud cover, clarity, seasonal differences, and a multitude of variances over any given area. The browse centers are user oriented, and the staff will assist the individual in obtaining the best imagery to suit his needs. They respond to inquiries by telephone, letter, or personal visit.

Step III — Familiarization With Nomenclature and Numbering Systems

Before beginning a search and deciding on a selection from available imagery, the user should have some idea of the numbering system used and the information printed on each image for control and identification purposes (Step III). This information is contained as a line of characters across the bottom of the image. The explanation can best be followed on an actual ERTS image (e.g., fig. 2).

Beginning at the left, under latitude and longitude, the first set of information is the abbreviated date and year; for example, "07 Aug. 72." This notation is followed by the letter "C," then by a latitude and longitude designation. This designated point is the center of the image and is the latitude and longitude point one would obtain by connecting the corner registration marks on the image by diagonals. These registration marks are discussed in more detail subsequently.

Following this first set of coordinates is a second set, which defines the exact location of the satellite when it was scanning the center line of the image. This location may vary by several minutes from the center of the image and is of no interest to the user unless it is so different as to introduce a tip or tilt effect into the image. This effect may be ignored as long as the satellite operates normally.

The next notation indicates which sensor produced the image and the bands used. This notation might read "MSS 457," which would mean that the image produced came from a composite of bands 4, 5, and 7 of the multispectral scanner, or "MSS 7," which would indicate that the image was produced from MSS band 7 alone.

Following the band designation will be either a "D" or an "R." A "D" indicates that the material on the image was transmitted directly in real time to a ground station. An "R" indicates that the information was stored on tape and "dumped" electronically to a ground station. The mode of transmission is normally of no consequence in land use work.

The next series of characters gives the Sun elevation and azimuth to the nearest degree with respect to the center of the image. This notation might read "Sun EL58AZ110," which would indicate that the Sun elevation was 58° and that the Sun azimuth angle measured clockwise from true north was 110°. Although the highest Sun angle would normally produce the most interpretable imagery, these data are usually of little interest for land use purposes.

Following the Sun azimuth is a three-digit number, which gives the spacecraft heading to the nearest degree measured clockwise from the north. This value would be the orbital path plus or minus any yaw in the axis of the spacecraft from the path. Because the imagery is always taken from north to south by the spacecraft, the difference of this reading from 180° will indicate the skew angle of the image, or the angle of the axis of the image in relation to the longitude lines.

Following the azimuth of the satellite, there is a dash, then a four-digit number that represents the revolution of the satellite from north to south during which the image was made. This count begins with launch and increases by 14 each 24-hour day.

Next is found a series of characters that represent the code number of the ground station from which the image was received; then an "N" or an "A" to indicate whether the image was processed normally or abnormally; followed by a "1" or a "2" to indicate the signaling mode from the satellite to the ground station. This notation is followed by either an "H" or an "L" to indicate a high- or low-gain setting of bands 4 and 5 if they are included in the image. The next notation, "NASA ERTS," indicates the agency and project responsible for producing the image. None of the data between the band identification and "NASA ERTS" has any bearing on the work covered by this report other than for internal identification purposes.

The last set of characters following "NASA ERTS" is a frame identification number; the "E-1" represents ERTS-A, and the following numbers represent the time in days, hours, minutes, seconds, and tenths of seconds relative to launch. This identification number should be used in all requests for data or in identifying the image for other purposes. Provision of the frame identification number and the band number or numbers is sufficient for complete identification of any image. The date, although not necessary, is normally included as a check or cross reference.

Step IV — Selection of Imagery

The computerized imagery storage and retrieval system, with terminals at each browse location, is based on a geographical system including the standard grid systems supplemented by such information as date and scale. The staff will convert individual inquiries into searches of the computer-based system. They will also assist in ordering reproductions. Visitors to a center may consult the browse files to evaluate the frames of a particular area of interest (Step IV) before placing a purchase order.

The user may ask for imagery that includes a particular map grid coordinate (obtained from the 1:250,000-scale USGS map) and may indicate that only those available frames with less than a given amount of cloud cover are acceptable. Cloud cover is normally expressed by percentage. Imagery with 10 percent or less cloud cover is considered essentially cloud free and is recommended for land use purposes.

Once the area of interest has been established, the type of imagery chosen will be dictated by the desired product and equipment of the user. If an image is desired for familiarization purposes, the latest cloud-free image (usually requested as 10 percent maximum cloud cover) should be ordered; that is, a color composite of bands 4, 5, and 7 in the form of either a transparency or a print (or both) is recommended.

For the most detailed data extraction, such as that described in this report, it is recommended that two sets of images of the study area, preferably a winter set and a summer set, be chosen. A transparency of a color composite of bands 4, 5, and 7 and an individual transparency of each of those bands (a total of four transparencies) are recommended for each chosen date. The 22.86- by 22.86-centimeter (9 by 9 inch) enlargements at a 1:1,000,000 scale are recommended for enlargement, photointerpretation, and land use purposes. If a large area is under study and if the final product is to be presented at a scale of 1:250,000, imagery in print form available at that scale should be ordered for use as a reference and for scale control when enlarging the transparencies.

Once a user is familiar with the ERTS schedule, it is easy to check cloud cover and general atmospheric conditions in a specific area at the time of an overflight to anticipate whether good imagery on a particular pass can be expected. An ERTS calendar with each overflight day marked is a handy reminder for a user to keep track of the imagery over his area. A delay of usually 3 to 4 weeks can normally be expected from the date of the ERTS pass until the imagery becomes available through the distribution system.

Step V — Ordering of ERTS Imagery

An ERTS order form and the accompanying instructions for its completion are shown in figures 15 and 16, respectively. As noted on the form, a location may be designated by a center-point longitude and latitude, by a center point and radius, or by the corners of a closed traverse having as many as eight sides. These control data can be obtained from the 1:250,000-scale USGS map of the study area.

ERTS INQUIRY/ORDER FORM

(please print or type)

Data to be furnished by:

EROS DATA CENTER

Sioux Falls, SD 57198

Commercial: 605-339-2270

FTS : 605-336-2381

Date ____________________

Total $ ____________________

NAME : ____________________

ADDRESS: ____________________

PHONE:

Commercial ____________________

FTS ____________________

AREA(S) OF INTEREST

If you have a map available with geographic or UTM coordinates, please provide the geographic location by one of the following:

_________ Latitude and longitude of a point (if you are interested in a small area)*

_________ Latitude and longitude of the center and radius in miles (if you are interested in a larger, generally circular area)

_________ Latitude and longitude of up to eight corners of a polygon (if you are interested in an irregular area)

*You may describe a specific area by geographic name if the coordinates are unknown. i.e., I am interested in a 10 mile radius circle centered on the city of Atlanta, Georgia. Explain on the reverse of this form.

DATA DESIRED (System Corrected Images-Bulk) Black and White

Circle the desired band(s) on each sensor -- Return Beam Vidicon — Bands 1 2 3

Multispectral Scanner — Bands 1 2 3 4

Circle the percentage of maximum cloud cover acceptable 10 20 30 40 50 60 70 80 90

WHEN YOU PLACE THE ORDER, WE WILL FURNISH THE LATEST PHOTOGRAPH(S) OBTAINED OVER YOUR AREA OF INTEREST UNLESS YOU SPECIFY OTHERWISE.

SIZE	SCALE	PRINTS UNIT PRICE**	UNITS	PRICE	TRANSPARENCIES UNIT PRICE**	UNITS	PRICE
Contact (70mm)	1:3,369,000	$1.25			$2.50		
Enlargement (9 x 9)	1:1,000,000	1.75			3.00		
Enlargement (18 x 18)	1:500,000	3.50			---		
Enlargement (40 x 40)	1:250,000	9.00			---		
Microfilm (16mm) 100 ft. roll	---	---			15.00		
Totals	---	(enter in line A below)			(enter in line B below)		

** For more than 25 photographs of one frame in an order there is a reduction in unit price. This reduced price may be obtained from the Data Center.

__ I wish to order a color composite, if available (DO NOT SEND MONEY UNTIL NOTIFIED OF AVAILABILITY BY THE DATA CENTER)

__ I wish to order Scene Corrected Images (Precision) (DO NOT SEND MONEY UNTIL NOTIFIED OF AVAILABILITY BY THE DATA CENTER)

__ I wish to place a standing order for repetitive cover (You will be contacted by the Data Center to arrange details). (DO NOT SEND MONEY FOR A STANDING ORDER)

PRINTING INSTRUCTIONS

Check whether product should be:

1. _____ Undodged (Reproductions will normally be dodged electronically or manually to achieve a uniform density over the image area. Check this item if you plan to use the image for radiometric analysis, in which case the density distribution in the original material will be preserved.)

2. Print to:

_____ Accentuate highlighted areas

_____ Normal

_____ Accentuate shadowed areas

3. Special requirements:

PRICE CALCULATION

A. Total from A (above) $_____

B. Total from B (above) + $_____

C. Total cost of reproductions (A + B) $_____

Plus Cost of Shipping

D. _____ Regular Mail $ 0.00

E. _____ Air Mail ($2 + 1% of line C) $_____

F. Total price of order (C + D + E) $_____

Payment Made By:

_____ Purchase Order No. _____

_____ Check No. _____

_____ Government Account No. _____

EDCIIM FORM 5
AUGUST 7, 1972

Figure 15. - The ERTS inquiry/order form.

ORDERING ERTS IMAGES FROM THE EROS DATA CENTER

Placing an Order

You may place an order with the Data Center for reproductions of the System Corrected Images (bulk) by completing this form. Your cooperation in following these steps will be appreciated:

1. Please print or type all of the information on the form.
2. Give your complete address, including ZIP Code.
3. Give a telephone number where you can be reached during normal business hours. Enter the number in the blank marked "commercial" if the telephone given is not a Federal Telecommunications System number.
4. Indicate the photo identification code for the frame(s) you desire.
5. Select and check the RBV or MSS spectral bands desired. Each band checked is, of course, a separate photograph; therefore, if you check four different bands, you will receive four separate frames of photography.
6. Determine the size of the reproductions desired and enter in the Product Type Desired column. Note that there are separate entries for paper prints and transparencies. Be sure to enter the information from the appropriate column.
7. Complete any special printing instructions you may wish to give in the square at the lower left of the form. If you do not have any special printing instructions, our laboratory personnel will use their own judgment in attempting to make the best print possible. Film transparencies are reproduced to match the gray scale of the master film.
8. Multiply the number of units by the unit price and enter in the total price column. If you desire reproductions at several different sizes, indicate accordingly, using a new line for each product type.
9. Add the total price columns and carry the grand totals to the price computation area at the lower right of the form. Submit payment by check, money order, or purchase order payable to the U.S. Geological Survey in the CORRECT amount.
10. The mail charges are as follows:

Surface	Charges
U.S., Canada, and Mexico	None
Other Areas	$1 + 1% of Line D
Air Mail	
U.S., Canada, and Mexico	$1 + 1% of Line D
Other Areas	$2 + 2% of Line D

11. If you wish to order Scene Corrected Images (precision), indicate in space provided. You will be notified whether precision data are available over your area of interest, if requested.

If you have any questions regarding the above information or about the EROS Data Center in general, we invite your telephone call to:

605-339-2270 from private or commercial telephones
605-336-2381 from Federal Telecommunications System telephones

Figure 16. - Instructions for ordering ERTS imagery from the USGS EROS Data Center.

In ordering (Step V), when referring to band numbers of ERTS imagery, the user should be aware that two systems of numbering bands are commonly used; the use of two systems can result in some confusion if not understood. The RBV sensor was originally assigned bands 1, 2, and 3, whereas the MSS was assigned bands 4, 5, 6, and 7. These numbers, as explained later, appear on the imagery and are used for discussion purposes in this report. However, in ordering imagery or in discussions with the browse center personnel, the bands will normally be referred to as RBV bands 1, 2, and 3 and MSS bands 1, 2, 3, and 4. Confusion can be avoided by remembering that any set of bands containing a number larger than 3 is automatically considered to be from the MSS. Any band number from 1 to 3 should be checked for a prefix of either RBV or MSS; MSS bands 1, 2, 3, and 4 are equivalent to bands 4, 5, 6, and 7 without a prefix. As previously stated, for land use purposes, the recommended permissible cloud cover is 10 percent; this value should be marked on the request. For normal land use requirements, the product should be ordered "dodged" and "normal" on the order form under "Printing Instructions." If no light table is available to the user, a color composite print may be substituted for the composite transparency, but a slight loss of interpretable information may result.

Step VI -- Orientation and Preparation of Imagery

Once the imagery has been received, the user should familiarize himself with the product for most efficient use of the imagery. First, in each corner of the frame outside the image area are crosses (registration marks) that allow the user to superimpose various bands easily and quickly with accurate registration by alinement of the crossmarks. Because the superimposition of different bands sometimes results in fuzzy delineation lines on the image, these registration marks are quite useful. Along the edges of the image, on all four sides, are latitude and longitude designations with a small tick mark following each number. The connecting of like tick marks will superimpose a standard latitude and longitude grid on the image. Remember that these lines do not run north and south or east and west on the image because the ERTS path is on a skew angle with the north-south axis of the Earth, as explained previously. Because of this skew, latitude marks may occasionally appear on the north or south edges of the image, and longitude marks on the east and west edges. In connecting these points, pairs should be located without regard to the sides on which they appear. By locating the latitude and longitude lines corresponding to the study area on the 1:250,000-scale USGS map, any area of the image may be defined on the USGS map. This procedure will allow any point on the map to be located on the ERTS imagery and any point on the ERTS imagery to be located on the map to within 0.81 kilometer (0.5 statute mile) or less. For a more exact location, discernible features on ERTS imagery may be located on the map and a point defined by a simple triangulation from nearby locatable points.

At this point (Step VI), the user has the area of interest defined on the ERTS imagery. Should land use delineation be the ultimate goal, the user must decide on an appropriate scale. If a large geographical area is to be considered, such as several counties or a portion of a state, and if the desired product is a gross delineation, the 1:250,000 scale may prove appropriate. For finer, more detailed work and for developing the imagery to a more refined product, as was described earlier in this report, a scale of 1:62,500 is recommended. In either choice, the procedure will remain essentially standard. The study area on the proposed ERTS map base (band 5 recommended) and on either the 1:250,000-scale or the 1:62,500-scale USGS map (depending on the choice of scale) are carefully outlined. For enlargement, control points appearing on both the base and the map should be carefully chosen; these should be sharply identifiable points such as road intersections or other easily identifiable features that appear on the USGS map and on the proposed base. These points (at least four, preferably more) should be chosen along the outer boundaries to ensure spatial accuracy across the entire image. To facilitate locating when scaling the enlargement, these control points may be circled on the USGS map.

Should USGS maps or other accurate maps to the desired scale not be available of a specific area, the enlargement can still be controlled if exact distances between discernible points on the image are known. These known distances (which should contain north-south as well as east-west controls) can be converted to linear distances at the desired final scale, and these scaled distances can be used to control the enlargement.

Step VII — Enlargement of the Map Base to Scale

Once the imagery has been received, the test area delineated on the ERTS positive, and enlargement control points established by use of USGS maps or of alternate methods, the user is prepared to enlarge the base to his desired scale (Step VII). This step can be done by any commercial photographic studio with a suitable enlarger capable of producing a 4× enlargement for the 1:250,000 scale and a 16× enlargement for the 1:62,500 scale. The quality of enlargement equipment varies greatly, as does the cost, and the product will reflect the quality of the lens used for enlarging. A Schneider Componon lens (used on this project) or its equivalent is recommended. If the enlargement equipment poses a local problem, contact the nearest aerial mapping firm for the names of suitable photographic firms; the imagery can be mailed after a telephone call to explain the needs of the user and to confirm the capability of the firm chosen. In any discussion of the photographic work, the user should be aware of and emphasize the following points.

1. In Step II, it may not have been possible to order a negative of band 5 for enlargement purposes. At times, only the positive transparency is available. If a positive transparency is received, a contact internegative must be made; this is easily done by using Eastman Kodak fine-grain positive film number 7302. The instructions on the film are quite complete for exposure and processing. A contrast somewhere between medium (normal) and low seemed to give the best product in the ERL experiment. For the enlargement, a low-contrast, matte-surface film (Du Pont Chronaflex PFm4) should be used to ensure a suitable drafting surface.

2. When using the Chronaflex film for enlargement, an exposure of 6 seconds at f/22 was generally adequate. The film was 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 to produce the proper image for reading through the film base. Use of this procedure will allow any drafting work to be done on the side without emulsion or image and will allow erasing and other options that would not be possible if working directly on the emulsion (print) side of the material.

3. When enlarging the image, the negative is enlarged to fit the chosen points on the control map as closely as possible. Once the scale is correct, focusing should be done on the center area of the enlargement for best results.

If a particularly clear negative is available and if a continuing study is being done of an area with a series of updatings expected, it is usually expedient to make several enlargements from the extremely good negative for use in updating land use with later imagery that may not produce as clear a base. In general, the winter imagery of the Gulf South area seems clearer and produces better bases than does the summer imagery.

Alternate Step VII — Making of Overlay Plates

An option (Alternate Step VII) that is recommended if an area is under continuing study is the preparation of an overlay or a scribe sheet containing geographic names, location information, political boundaries, highway and road designations, and any other data that would be desirable on all enlargements of a study area. Once this overlay sheet has been prepared, it may be superimposed photographically over all desired imagery at the time of enlargement. To do this, a sheet of Keuffel and Esser scribe coat material is cut to overlay the study area on the USGS control map, and the map, the scribe sheet, and the ERTS imagery are carefully registered. Any data on the control map or additional user information considered desirable for transfer to the image can then be cut into the scribe sheet in the proper location. The data on this scribe overlay are then superimposed photographically over any film map base that is to the same scale to essentially provide a Chronaflex film base photomap containing the scribed information upon which to denote land use. Leroy lettering sets are normally used with scribe points to do this type work.

Another available source of overlay data that should be investigated by the user is the U.S. Geological Survey. If USGS maps at the desired scale (1:62,500 or 1:250,000) are available, copies of the overlay plates for these maps 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, Box 133, Rolla, Missouri 65401. These plates may be photographically superimposed over the photo-enlargement in place of, or in conjunction with, the scribe sheet described previously for various map requirements and uses. If the USGS map is outdated, the only useful plate may be the topography, which normally does not change appreciably within the time frame discussed. The cultural overlay, if current, is extremely useful. When updating or obtaining information on land use of any area, it is well worthwhile to contact the USGS office in Rolla, Missouri, to ascertain the status of the USGS mapping effort in the locale. Often, advanced material is available or new mapping is being done in a particular area. Use of this overlay system provides for a quick, inexpensive update and produces a neat, professional product.

Step VIII — Delineation of Land Uses

From the enlarged, scaled base prepared in the preceding step, it is possible to delineate land use directly on the base in Step VIII. Any available ground-truth data such as windshield surveys and low-altitude imagery should be assembled to improve accuracy. If, as recommended, the image was placed on the back side of the enlargement (emulsion side down), the land use categories may be inked directly on the base. Wet ink may be erased by using damp cotton swabs; dry ink may be eradicated by using an eraser or by scratching with a sharp blade without affecting the image.

The pens used for delineating areas were standard Rapidograph lettering pens, point numbers 00, 0, 1, 2-1/2, and 3. The land use letters and symbols used were heat-resistant Presstype. For anyone doing an extensive amount of land use delineation, it is probably worthwhile to order special sheets of Presstype containing only the desired symbols. This procedure will save both time and money and avoid the accumulation of masses of Presstype sheets with only one or two characters used. The special sheets of Presstype with custom symbols used in this experiment were ordered from Jaggers, Chiles, and Stovall, Inc., Box 5393, Dallas, Texas 75222. Many other drafting supply centers furnish a similar service. Any pressure-sensitive lettering used should be of the heat-resisting type to avoid the risk of having these letters stripped off during a reproduction process.

The ink used on the film base should be of a plastic-base type such as Pelikan T-17. Although inking of category symbols was found to be somewhat tedious and did not produce as neat a final product, ink has the advantage of being more permanent because even heat-resistant Presstype, with age and the heat of reproduction, tends to loosen and flake off the print. The problem of flaking Presstype can be avoided to a large extent by making a Mylar master positive of each final reproducible product. This master positive, produced by the Ozalid Dry Print process on clear Mylar, can then be used for mass reproduction and the original stored in a flat file. For delineating land use areas, standard curves and straightedges should be used for line drawing when applicable, but a majority of land uses, particularly in areas of intense land use, will require freehand delineation. The use of standard drafting tools, supplemented by cotton swabs and an artist's knife and blades for erasing, will facilitate the operation. Any light table with sufficient lighted area to accommodate the enlargement as well as the 22.86-centimeter (9 inch) originals from which the interpretation is done will prove adequate for the work. An 8- or 10-power stereoscopic viewer should be available for interpretation work. Although only partial overlays of ERTS imagery occur, limiting true stereoscopic use, the capability of the stereoscopic viewer in overlaying seasonal imagery and multiple bands is essential for delineating many land uses. Table V of this report will prove quite helpful as a reference for the interpreter.

The categories delineated are the option of each preparing agency, but, for a standard of consistency, it is recommended that USGS Circular 671 (ref. 2) be used. This circular gives national standard recommended first- and second-level categories; any identifiable third level or beyond may be categorized by the user's needs. The circular is free, on request, from the U.S. Department of the Interior, U.S. Geological Survey, Washington, D.C. 20242.

Step IX — Preparation of the Final Product

Once the land use delineation has been completed and the symbols and lettering placed on the scaled enlargement, the product is ready to be put in reproducible form (Step IX). A blue line or black line paper print may be made directly from the positive, but a more professional presentation is recommended. Using clear drafting Mylar, a format that will greatly enhance the final product is easily prepared.

Once the size of the display area on the positive enlargement has been determined, a total sheet layout having a legend, a title block, a scale, a north arrow and declination, a general location of the area, and any other data desired can be prepared for reproduction on clear drafting Mylar. The image can be set and actually framed with 1.27-centimeter (0.5 inch) Chart-Pak tape of solid color in a display window on the format. To update the product later, all that is necessary is to change the image in the display window and the date.

Step X — Reproduction

For reproducing the final product (Step X), several systems were tried and evaluated. In general, the black line prints seemed to offer better tonal qualities and detail than did the blue line prints when using the Ozalid Dry Print method for reproducing copies from the positive map base. The cost of the paper for either color is essentially equal. However, the acquisition of good black line paper is a problem at times because of the relatively small quantity used in some localities and because of the short shelf life of the product.

Brown, sepia-tone color gave a better quality product than did either the blue line or the 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 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 in Step VII to produce the land use final product. 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 reproduced from the negative 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. This method of reproduction is not practical if large quantities of copies are required. The negative final product also may be used to reproduce blueprint copies that compare favorably in quality with the blue or black line prints mentioned previously at approximately the same cost (\$0.65/m^2 (\$0.06/ft^2)) 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. Whether the final product is on positive or negative is of little consequence because the opposite can easily be produced at this point by contact print using the Kodak fine-grain film as discussed in Step VII.

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

Step XI — Updating of Land Use

To update the land use information as new imagery becomes available (Step XI) is a relatively simple and inexpensive procedure. If the basic procedure is followed with the scribe sheet or overlays produced, it is necessary only to enlarge the new imagery to scale and superimpose the desired overlays and scribe sheet photographically; this procedure gives a photomap base on which the new land use information may be delineated. If no scribe sheet or overlays were produced, again, the photography must be enlarged to scale and the control and geographic data inked directly on the base before delineating the land use. This second method is more time consuming, gives a product inferior to that produced by use of the scribe sheet, and is recommended only if the project is a one-time effort without proposed future update. In updating, the use of sequential imagery in a stereoscopic viewer to facilitate locating changes is recommended. A review of the discussion on updating of land use contained in the preceding section of this report will prove beneficial at the time of updating.

Step XII — Area or Acreage Computation

Normally, upon completion of the land use classifications of an area, the need will exist for a compilation of acreage in various categories (Step XII) to enable meaningful comparisons to be made. In compiling acreages over the test areas in this and similar experiments, several techniques for measurement were tested. The planimeter was tried, as was the dot grid. The dot grid technique, described earlier in this report, consists of using a clear Mylar sheet with a grid, each square of which contains random dots. To determine any irregular area, the number of grid squares totally within the area are counted, then the dots in the partly enclosed squares are counted. Using a multiplication factor determined by the scale, the area is then easily computed. Dot grid sheets are available from most drafting supply houses. The dot grid method for determining acreage classifications proved to be a surprisingly accurate, fast, and economical means of extracting 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 in a previous experiment revealed an accuracy 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 overall accuracy exceeding 97 percent over measured areas.

An exception to the exclusive use of the dot grid overlay for obtaining specific area measurements was made in the case of rights-of-way and narrow linear features. An engineering scale, graduated into 23.62 units/cm (60 units/in.) is used to measure the perimeter to obtain the area of each such feature. In the case of rights-of-way, an arbitrary width may be assigned. The resolution of ERTS is incapable of truly representing such narrow linear features, and accurate dot counting or planimetering is impossible.

CONCLUDING REMARKS

Investigations concluded to date have established that the following assumptions may be made when using ERTS imagery for land classification by conventional manual interpretation.

1. All applicable Level I and many Level II types of land uses are discernible on ERTS imagery and can be delineated to a reasonable accuracy by manual photointerpretation methods.

2. Sequential imagery, particularly of opposite seasons, is extremely useful and will significantly improve the overall obtainable accuracy by as much as 12 to 18 percent. Use of sequential imagery in a stereoscopic viewer is an extremely effective tool for verifying land use or for investigating areas of change.

3. The accuracy that may be expected from ERTS data will vary inversely with the intensity or the fracturing of land use in a given area. The accuracy varies from a low in urban areas of diverse use to a high in largely agricultural or forested areas. In using ERTS imagery for agricultural and forestry purposes, Level II categories are often as easy to obtain as Level I categories, particularly when sequential imagery is available. This definition is possible because with the multiple bands of the scanner, not only is a category definable but shades and tones within that category allow subdelineations to be made easily.

Over large rural areas, which comprise the majority of land area of the United States, ERTS imagery is extremely effective in determining land use for use in resource control, management, and planning. A procedure was developed within this report by which ERTS imagery may be obtained, processed, and used for producing land classification maps to scales of 1:62,500 and 1:250,000. Recommendations for updating these products and for extracting statistical data from them for resource evaluation and management needs have also been discussed. 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 ERTS imagery and of the procedure presented in this report.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, April 30, 1974
177-52-81-03-72

REFERENCES

1. Vegas, Paul L.: A Detailed Procedure for the Use of Small-Scale Photography in Land Use Classification. NASA TN D-7542, 1973.

2. Anderson, James R.; Hardy, Ernest E.; and Roach, John T.: A Land-Use Classification System for Use With Remote-Sensor Data. Cir. 671, U.S. Geological Survey, 1972.

APPENDIX A

LAND USE CATEGORIES IDENTIFIABLE FROM EARTH RESOURCES TECHNOLOGY SATELLITE IMAGERY

The following categories from a proposed national land use classification system (ref. 2) are identifiable from Earth Resources Technology Satellite (ERTS) imagery by using multiple bands and sequential imagery. The best bands for identification are recommended, and some category and identification discrepancies or difficulties are included in a discussion of each category.

CATEGORY 0100 — URBAN AND BUILT-UP LAND

For identifying "urban and built-up land" usage (category 0100), band 5 and a color composite of bands 4, 5, and 7 should be used. Larger urban areas (those with a population greater than 10 000) may be identified fairly consistently using bands 4 and 5 and, in those with heavy building concentrations, band 7. Band 5 and color composites provide the best imagery for interpretation of urban areas.

Category 0101 — Residential

For identifying "residential" usage (category 0101), band 5 and a color composite of bands 4, 5, and 7 should be used. Residential areas, although very frequently confused with agricultural areas or unidentifiable as a result of tree cover, are usually recognized by a mottled gray tone surrounding the lighter gray to white tone of an urban core or a predominantly commercial area. It should be noted that not all residential areas can be identified accurately on ERTS imagery without extensive collateral data (ground truth, underflights, etc.). Spatial relationships, distribution, and shape are more significant in the identification of residential areas (as well as all other urban categories) than other traditional identification criteria.

Category 0102 — Commercial and Services

For identifying "commercial and services" usage (category 0102), band 5 and a color composite of bands 4, 5, and 7 should be used. As noted previously, most commercial areas of significant areal distribution to be identified will display a light-gray tone on the band 5 imagery and a white to bluish color on the color composite image. A significant aid to identification is the pattern of most large commercial areas: larger shopping districts or strip commercial development will obviously follow major urban highway arteries; the central business district will usually exhibit a general street pattern or, in areas where blocks are irregularly shaped, the overall pattern of streets will be noted. This pattern, together with tone or color, will allow for reasonable reliability in identification of larger commercial districts. Business districts in small towns or outlying commercial areas are more frequently unidentifiable or confused with the predominant surrounding land use.

Category 0103 — Industrial

For identifying "industrial" usage (category 0103), band 5 and a color composite of bands 4, 5, and 7 should be used. Industrial areas commonly are fairly large; contain extensive areas of open storage; and are surrounded by fairly large areas of bare soil, spoil, or cleared land that often yields a considerably different signature from that of the surrounding area. Most industrial areas also have fairly significant boundaries and are supplied by large water, rail, or road systems that aid in identification.

Category 0104 — Extractive

For identifying "extractive" usage (category 0104), band 5 and a color composite of bands 4, 5, and 7 should be used. Most criteria for industrial identification are applicable to extractive activity as well; however, in Harrison County, the only significant extractive industry is sand and gravel that either is too small to be identified or is confused with other categories such as new residential/commercial development, bare soil in agricultural areas, or water when borrow pits are flooded. Both industrial and extractive areas display a light tone on the imagery.

Category 0105 — Transportation, Communications, and Utilities

For identifying "transportation, communications, and utilities" usage (category 0105), band 5 and a color composite of bands 4, 5, and 7 should be used.

Transportation. - Major highways are identifiable on band 5 as light-toned, linear features. In urban areas, there is no requirement to identify transportation routes because they are integrated with the predominant urban category. Railroads are frequently unidentifiable because of the limited width of easement or the similarity in tone to surrounding land.

Communications. - Communications transmitting facilities are not identifiable on ERTS imagery.

Utilities. - Large electrical generating plants are commonly confused with industrial units because the identification criteria and ground features on ERTS imagery are the same as those of industrial areas. Power and gas transmission rights-of-way are identifiable when they cross a forested or other densely vegetated area; they appear as relatively straight, lighter toned narrow strips on the image.

Category 0107 — Strip and Clustered Settlement

For identifying "strip and clustered settlement" usage (category 0107), band 5 and a color composite of bands 4, 5, and 7 should be used. Although no areas within this category were delineated in the three townships mapped, investigations in nearby areas revealed distinctive strip settlements readily identifiable as a result of the sharp contrast between the built-up areas and the surrounding forest or marsh. As with other urban categories, identification in a predominantly agricultural area would be difficult because of tone similarities. Color composites yield more information for agricultural-urban separation than does the black and white imagery. In areas where fields are plowed or fallow, the distinction between settlement and agriculture is not easily recognizable without collateral information.

Category 0108 — Mixed

For identifying "mixed" usage (category 0108), band 5 and a color composite of bands 4, 5, and 7 should be used. Where the various subcategories of urban and built-up land are not large or concentrated enough to be separately identified, the mixed classification is used. Unfortunately, the appearance on the imagery of this type of usage is similar to that of residential; therefore, the categories are frequently confused. It appears that, for small towns having populations less than 10 000 in which the areal extent of the urban unit is so small as to make separate delineations impractical or categories unidentifiable and in which residences commonly occupy a significant portion of the urban core, "mixed" would be the most reliable classification.

Category 0109 — Open and Other

For identifying "open and other" usage (category 0109), bands 5 and 7 and a color composite of bands 4, 5, and 7 should be used. This category includes undeveloped forest or grassland within urban areas as well as all parks and golf courses. Forest land and grassland are identifiable in an urban area because of the significantly darker tone, especially of forested areas. It should be noted that golf courses are identifiable only on band 7 imagery, where they are visible as very light features within the gray urban tone. Freeways appear as long, randomly oriented strips.

Older, well-established residential areas are frequently misidentified as forest areas because the heavy tree cover yields the same spectral signature as a forested area. Areas not identifiable on ERTS imagery because of tone and shape inconsistent with predominant land uses or unique spatial relationships are classified as "open and other."

Summary

In summary, the low resolution of the ERTS imagery often prevents recognition of secondary features leading to positive identification of urban or built-up units beyond Level I with the exception of isolated highways and railroads and some large, isolated industrial sites identifiable because of location relative to waterways, rail yards, or other industrial indicators. Because most of the interpretation is based on image tone, a number of residential areas and some agricultural areas were identified as barren land. In addition, some agricultural areas were identified as residential based on the tone resembling that of known residential units. An excellent example of this misidentification is that a large land (residential) development in an area of sparse tree cover may be wrongly classified as agricultural, whereas agricultural land adjacent to known urban centers will usually be misclassified as urban residential.

CATEGORY 0200 — AGRICULTURAL LAND

For identifying "agricultural land" usage (category 0200), bands 5 and 7 and a color composite of bands 4, 5, and 7 should be used. Cropland and pasture are identifiable by their light tone, fairly predominant boundaries conforming to the section lines, relatively uniform texture, and contoured boundaries adjacent to stream bottom lands. Band 5 provided the best imagery for agriculture-forest separation.

Although not separately identified in the accuracy calculations, areas of winter rye were easily identified on band 7 imagery because the high infrared reflectance of the crop produced a very light tone. Delineations were made on the Chronaflex photographic base of band 5 or made on band 7 and transferred to the band 5 base. Near the urban areas, some confusion between agricultural and residential use is apparent because of similarities in tone and texture in the adjacent land use types.

On the color composite, most cropland and pasture are recognizable by the criteria noted previously as well as by a light-pink to bright-reddish color during productive seasons. Individual fields were not normally resolvable within the Harrison County area studied where most fields tend to be less than 16.2 square hectometers (40 acres) in area. Again, the real boundary between an agricultural unit and some other adjacent land use type is poorly defined on ERTS imagery, whereas the aircraft imagery permits reasonably accurate determination. The slight, if any, change in tone from a nonagricultural to an agricultural area resulted in some misinterpretation when using the ERTS imagery. Large segments of agriculture were identified incorrectly as forests, particularly when using a single frame of the August data on which lush crops eliminate sharp division from adjacent forest areas. Winter crops, such as rye grass, stand in sharp contrast on the winter imagery and are easily identified. However, even when using a single frame of imagery for examining large areas, a generalized agricultural identification may be made over a geographic region indicating agriculture of one form or another as the major economic activity. Sets of imagery that highlight the seasonal changes of agricultural lands are particularly useful in correctly identifying agriculture. Even sets of imagery obtained 3 or 4 months apart will help delineate agricultural areas when used with a stereoscopic viewer.

CATEGORY 0300 — RANGELAND

For identifying "rangeland" usage (category 0300), bands 5 and 7 and a color composite of bands 4, 5, and 7 should be used. Using the classification defined in reference 2, there is no rangeland in the southeastern United States. Improved pasture would be classified as agriculture, and there is no appropriate category for unimproved grazing land such as that prevalent in most of the Southeast. These limitations notwithstanding, grasslands and open grassy areas such as golf courses were definable when using the recommended bands.

CATEGORY 0400 — FOREST LAND

For identifying "forest land" usage (category 0400), band 5 and a color composite of bands 4, 5, and 7 should be used. Forested areas are recognizable by their very dark tone on band 5. In contrast to urban and agricultural areas, forests are considerably darker and, if sufficiently large, pose no identification problems. On the color composites, the predominant dark-red color of the forested areas and the dendritic pattern conforming to the drainage systems provide the best identification keys.

Deciduous and coniferous forests were separated solely on the basis of spatial distribution and tone. Deciduous forests revealed a darker tone near the stream bottoms, whereas coniferous stands usually exhibited lighter, less uniform tone and texture in upland areas. The winter data were particularly useful when contrasted in a stereoscopic viewer with summer imagery. The areas displaying the sharpest tonal differences between seasons could then be confidently delineated as deciduous. Conversely, because of the similarity in tone to a well-established residential area, a forested area within an urban area cannot be reliably identified.

The "mixed" category was used to identify forested areas near the coast where a combination of tones and textures indicated the probability of small stands of both deciduous and coniferous trees or a generalized mixture of the two. An area of known regeneration in townships 5 and 6 south, range 10 west was identified under a separate Level II forest land category. Without collateral information, this fairly extensive area at the stage of growth exhibited would undoubtedly, because of its shape and tone, be classified as cropland and pasture.

CATEGORY 0500 — WATER

For identifying "water" usage (category 0500), band 7 and a color composite of bands 4, 5, and 7 should be used. Water areas of sufficient size to be resolved by the ERTS multispectral scanner are the most easily identifiable feature of all land use categories when using band 7. Water areas appear black in contrast to the light gray of the land. On color composites, the brilliant blue of clear water contrasts sharply with the generally pink to red or white of dryland. Turbid water reduces this contrast and will blend in and be harder to accurately identify. The various Level II classifications were delineated using standard geographic criteria and depend on spatial relationships for identification.

Although positive identification cannot be extended to small tributary streams as with aircraft imagery, the drainage patterns are clearly indicated by vegetation patterns. Lakes, ponds, and reservoirs smaller than 4.05 square hectometers (10 acres) are hard to discern if not surrounded by a contrasting background and, at times, may appear as an error or as noise in the signal data. By using sequential imagery in a stereoscopic viewer, the level of confidence and accuracy in delineating small water bodies will be increased.

CATEGORY 0600 — NONFORESTED WETLAND

For identifying "nonforested wetland" usage (category 0600), band 7 should be used. Because no recognizable mudflats were present in the area, vegetated (marsh) wetland was the only category delineated. Vegetated wetlands are easily identified on band 7 by a fairly uniform dark tone between areas of "black" open water and light-gray dryland. The spatial characteristics of the area between water and dryland and tone are the prime identification aids. Although marsh is easily recognized on color composites, the vigor of the vegetation often produces the characteristic red coloring, which may lead to false identification as dryland vegetation. The black and white band 7 eliminates the possibility of this misidentification because the darker tone of the water visible between the vegetation dominates the marsh areas. In areas of periodic inundation with dense growth, some misidentification resulted. In general, however, extensive wetlands can be identified with acceptable accuracy.

CATEGORY 0700 — BARREN LAND

For identifying "barren land" usage (category 0700), bands 4 and 5 and a color composite of bands 4, 5, and 7 should be used. The categories "beaches" and "sand other than beaches" were identified by spatial criteria and by the pure white tone visible on bands 4 and 5 and on the color composite. Although the category "sand other than beaches" should be reserved for dune areas, bare sand areas near Interstate Highway 10 that could not reasonably be classified under transportation or industrial usage were included under this Level II category.

As previously cited in the discussion on the category "urban and built-up land," some industrial and residential areas were mistakenly identified as barren land. Given the resolution limitations of the ERTS scanner, frequent misidentifications will be made in cross-interpreting barren land, newly developed residential areas, industrial areas, and recently harvested agricultural areas. Beaches pose no significant identification problem and can be delineated with a high degree of accuracy simply because of the spatial relationship, the contrast, and the distinctive tone at the land/water interface. Beaches are particularly definable in river bottoms, where the sharp contrast to the surroundings makes identification relatively simple. White sand beaches of 1.22 to 2.03 square hectometers (3 to 5 acres) in size can sometimes be detected by close observation along major drainage patterns, particularly if in a linear configuration, when viewed on a sequential basis.

APPENDIX B

DEPARTMENT OF THE INTERIOR

BROWSE FILES AND ORDER CENTERS

In the following table, browse files and order centers established by the U.S. Department of the Interior are listed alphabetically by state or territory.

State or territory	Title and address	Telephone number
Alaska	USGS Public Inquiries Office 108 Skyline Building 508 Second Avenue Anchorage, Alaska 99501	415-323-8111
Arizona	USGS Water Resources Division Room 5107, Federal Building 230 North First Avenue Phoenix, Arizona 85025	602-261-3188
	USGS Library 601 East Cedar Avenue Flagstaff, Arizona 86001	602-774-1330
California	USGS Public Inquiries Office Room 7638, Federal Building 300 N. Los Angeles Street Los Angeles, California 90012	213-688-2850
Canal Zone	Inter-American Geodetic Survey Headquarters Building Fort Clayton, Canal Zone	117-1201, Panama Routine 833-227
Colorado	USGS Regional Topographic Engineer Room 2404, Building 25 Denver Federal Center Denver, Colorado 80225	303-234-2351
District of Columbia	USGS Map Information Office Room B-310, GSA Building 18th and F Streets, NW Washington, D.C. 20242	202-343-2611

State or territory	Title and address	Telephone number
District of Columbia	USGS CARETS Information Center Room 837, 1717 H Street NW Washington, D.C. 20242	202-343-5985
	USGS EROS Program Library Room 827, 1717 H Street NW Washington, D.C. 20242	202-343-7500
Florida	State Topographic Engineer Florida Dept. of Transportation State Topographic Office Lafayette Building Koger Office Center Tallahassee, Florida 32304	904-599-6212
Maryland	Goddard Space Flight Center Browse Facility Room 204 Greenbelt, Maryland 20771	--
Massachusetts	U.S. Geological Survey 5th Floor, 80 Broad Street Boston, Massachusetts 02110	617-223-7202
Mississippi	U.S. Geological Survey Room G-210, Building 1100 Mississippi Test Facility Bay St. Louis, Mississippi 39520	601-688-3472
Missouri	USGS Topographic Division 961 Pine Street Rolla, Missouri 65401	314-364-3680
New York	USGS Water Resources Division Room 343, Post Office and Court House Building Albany, New York 12201	518-472-3107
Oregon	Director, Portland Service Center U.S. Bureau of Land Management 710 NE Holladay Portland, Oregon 97203	503-234-4100

State or territory	Title and address	Telephone number
South Dakota	USGS EROS Data Center 10th Street and Dakota Avenue Sioux Falls, South Dakota 57198	605-339-2270 605-336-2381 (Federal Telecommunications System)
Tennessee	Chief, Maps and Surveys Branch Tennessee Valley Authority 200 Haney Building 311 Broad Street Chattanooga, Tennessee 37401	615-755-2133
Washington	USGS Public Inquiries Office Room 678, U. S. Court House Building West 920 Riverside Avenue Spokane, Washington 99201	509-456-2524

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