P_2

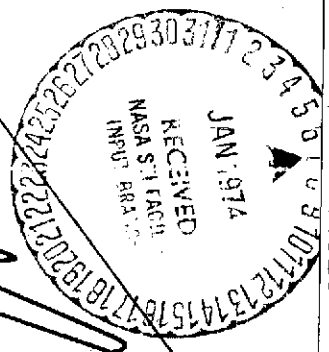**Project for the use of Remote Sensing
in Land Use Policy Formulation**

IMAGE INTERPRETATION
FOR A MULTI-LEVEL
LAND USE CLASSIFICATION
SYSTEM

MICHIGAN STATE UNIVERSITY

October 1973

ACKNOWLEDGEMENTS

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IMAGE INTERPRETATION FOR A MULTI-LEVEL LAND USE CLASSIFICATION SYSTEM

PREFACE

The purpose of this paper is to: 1) indicate the potential use of
three commonly used NASA remote sensors for developing and using a four-
level land use classification system and 2) give the reader some under-
standing of the techniques of image interpretation. Assuming the reader
has little or no knowledge of remote sensing, technical explanations
have been kept minimal. (Questions about the materials or techniques
described here may be referred to the Project for the Use of Remote
Sensing in Land Use Policy Formulation at Michigan State University.)

The paper was prepared as a guide to Western Michigan Planning
Commission. It suggests which remote sensors and imagery scales may
be most effectively employed to provide data on specific types of land
use. It is not intended to present an exhaustive analysis of each image
type, but to indicate some successful uses of the images and classifi-
cation system and the types of features that are visible to even an
untrained observer.

THE TYPES OF IMAGERY AVAILABLE FOR PHOTO INTERPRETATION

The design and execution of any project using remote sensing as an
information source requires some knowledge of the source information
content, and interpretability of specific images. In Michigan, the
prospective user of remote sensing can choose from at least three types
of imagery at four different scales; NASA Earth Resource Technology
Satellite (ERTS-1) imagery; NASA high-altitude Earth Resources Aircraft
Program Photography; medium-altitude Agricultural Stabilization and
Conservation Service (ASCS) and other public agency photography.

ERTS-1 SATELLITE IMAGERY

The ERTS-1 satellite (the "1" refers to the first in a series of
satellites) provides images of the Earth from an altitude of about
920 kilometers (572 miles). The satellite contains two types of remote
sensing equipment: 1) a return-beam vidicon (RBV) camera, which became
inoperative shortly after the launch: and 2) multi-spectral scanner
(MSS). The scanner does not take photographs but detects spectral
radiation from the surface of the Earth and records on magnetic tape
the amount of radiation detected. These data are then transmitted to
receiving stations on Earth and compiled as an image using an analog
printer, called an electron beam recorder. The recorder translates the
recorded amounts of radiation and prints small dots (or cells) in shades
of black and white at 4003 cells per 70 mm. (2-1/4") line, with 4312
lines per frame, to form an image (a frame is a 70 mm x 70 mm picture).

Data from the satellite can also be recorded on magnetic tape and proc-
essed by digital computers without actually forming an image.

The scanner produces images of the Earth's surface based on
radiation from four different segments or bands of the electromagnetic
spectrums lying within or close to the range of light visible to the
human eye. Each band of light -- green, red, near infrared, and inter-
mediate infrared -- accents different features of the Earth and thus
provides additional information.

The first sensing channel of the scanner (termed channel four by
NASA) senses green-yellow portions of visible light. Due to the short
wavelength of this light (.50-.60 micron wavelength), haze, water vapor,
and dust can interfere with the energy transmitted to the scanner. This
"atmospheric attenuation" makes the green light images more difficult to
interpret than the other three ERTS bands. Due to the ability of short
wavelength energy to penetrate several feet of water, however, band four
is excellent for viewing underwater features.

TABLE I

ELECTROMAGNETIC SPECTRUM
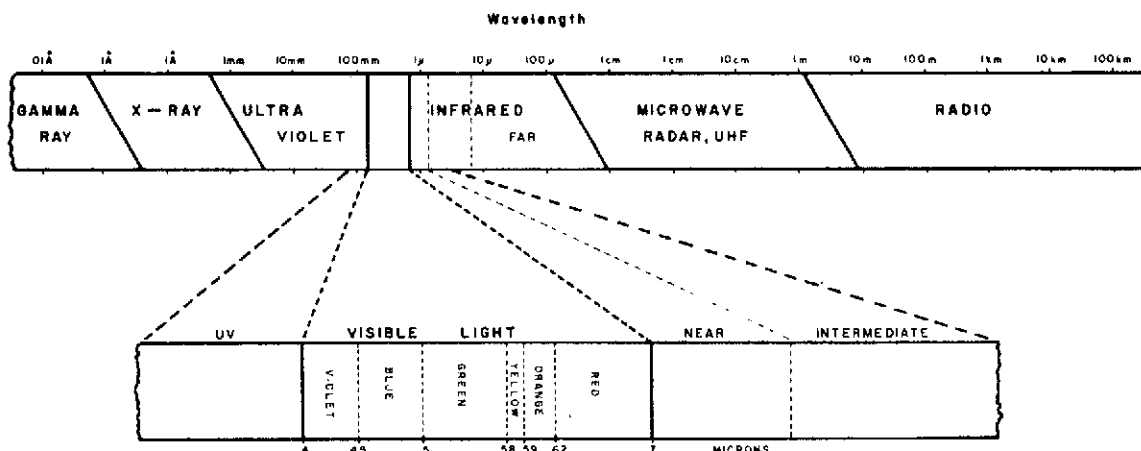
Wavelength

Channel five detects energy located in the red portion (.60-.70
micron wavelength) of visible light. Since the wavelength detected in
channel five is longer than in channel four, atmospheric attenuation
is not as much a problem in this channel. Underwater features are less
easily seen, however, due to the lesser water penetration ability of
the longer wavelength light.

Channels six and seven detect energy in the infrared portions of
the spectrum. Both channels are similar and because the differences
between them are not great, they will be discussed together. The energy
detected in these channels is not visible to the human eye, and is

accordingly, somewhat different from the light we are familiar with.[1] It might be noted, incidentally, that these infrared channels of the scanner do not detect emitted heat. The thermal infrared part of the spectrum has a much longer wavelength. However, the bands of energy detected by channels six and seven of the scanner detect light of longer wavelengths than can be seen by the human eye, (but shorter than that of thermal or heat energy), and these longer wavelengths reduce atmospheric attenuation to such a low degree that haze is virtually eliminated from the images. However, light detected in these channels will not penetrate clouds; and images obscured by clouds cannot be detected. Also, due to the long wavelength, there is virtually no water penetration. Thus rivers, lakes, and ponds appear black, as no energy is reflected from the water. Shorelines show up in stark contrast to the water bodies.

When interpreting imagery, it is important to consider the change in tone between the images produced by visible light and those produced by the infrared portions of the spectrum. As seen in Figure 2, non-water areas appear considerably lighter in the infrared range than in the red or green light images. This is due to the very large amounts of normally undetected infrared radiation reflected from the landscape. Although vegetation reflects large amounts of "green" energy in the visible light portion of the spectrum, it reflects more than twice as much "invisible" infrared energy. Thus, much more energy is detected by the scanner in the infrared portion of the spectrum than in the green portion, causing a lighter image in the infrared scene. Figure 2 shows imagery produced from four different scanner channels recorded over the Lansing-Grand Rapids region of Michigan on August 25, 1972, by the ERTS-1 satellite.

The images from the four separate channels of the scanner, which are normally printed in black and white, can be combined to form a composite color image if so desired for interpretation or display. This is done by combining the images from scanner channels four, five, and either six or seven, each printed in a different color (yellow, red, and blue).

ERTS imagery normally comes to the user at a scale of 1:1,000,000 in a 10" x 10" image depicting an area about 115 miles square. Enlargements of these images are possible, but the detail on interpretability does not substantially increase.

HIGH-ALTITUDE PHOTOGRAPHY

A large portion of Michigan is covered by aerial photography

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[1] Generally, humans see in the violet (.40 microns) to the red (.70 microns) portion of the spectrum, normally termed visible light. Some people, however, can see into a small portion of either the ultra violet or infrared areas. These exceptions are not being considered in this paper.

ERTS-1 COVERAGE OF
LANSING - GRAND RAPIDS AREA

BAND 4
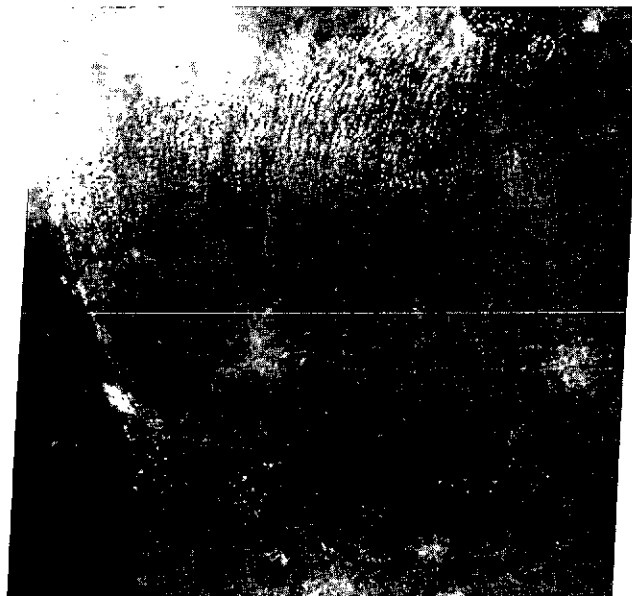
BAND 5

BAND 6

FIGURE 2

BAND 7
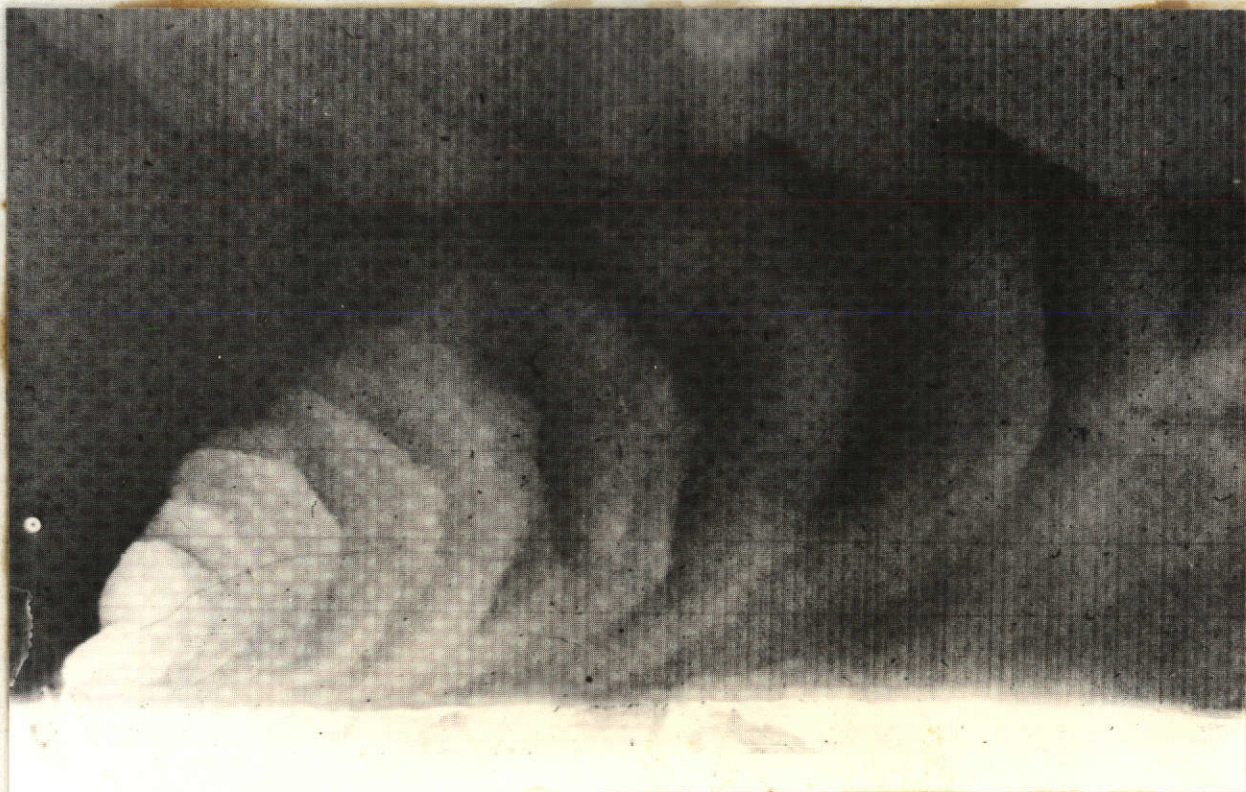
Figure 4.   "Front-laden" plume, dominated by a
series of concentric sharp temperature
gradients or fronts.

Figure 5.   "Meandering" plume exhibiting a
meandering instability of the upwind
edge.
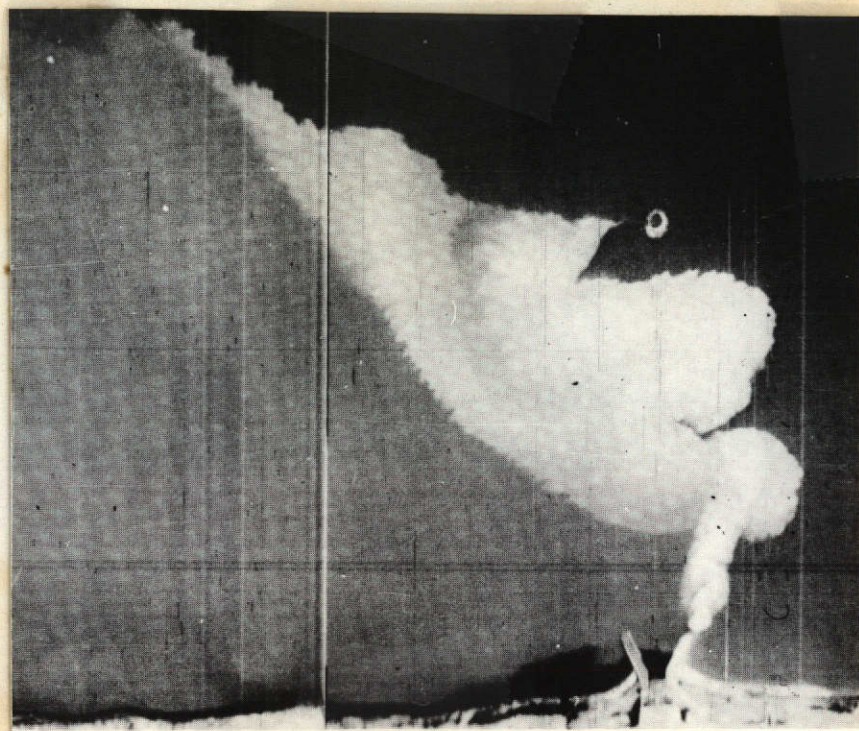
Figure 6.   A plume falling into none of the other categories, probably associated with a wind change.

Figure 2.   Streamflow gauging station. Type "HL" flume with supporting structures. Site location is shown in Figure 1.
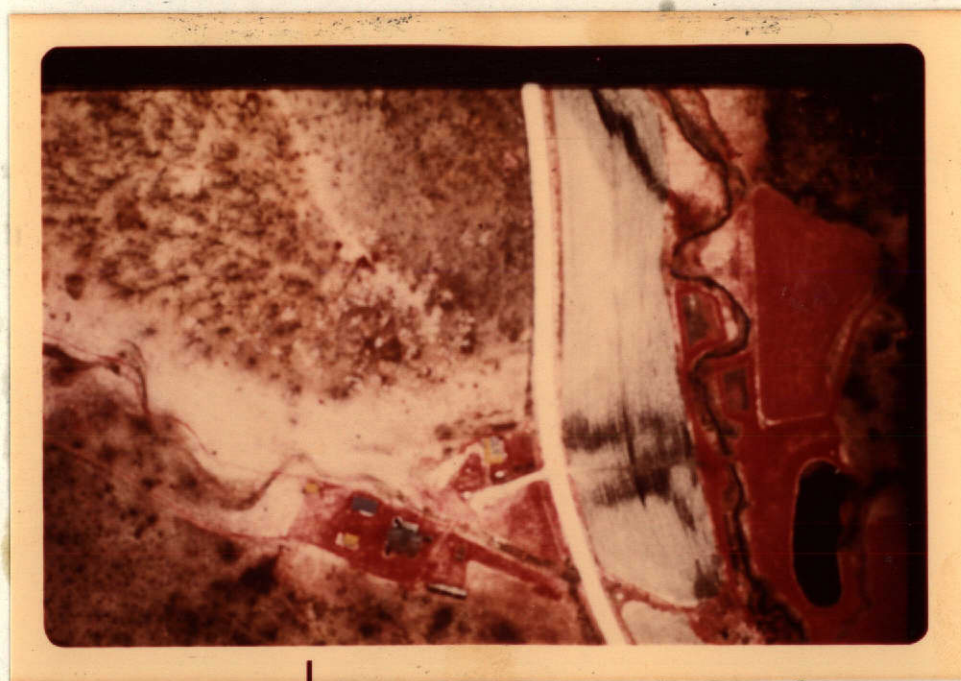
Figure 3.   Probable source area is shown in dark gray between the road and stream. Site location of this area is marked 2 in Figure 1.
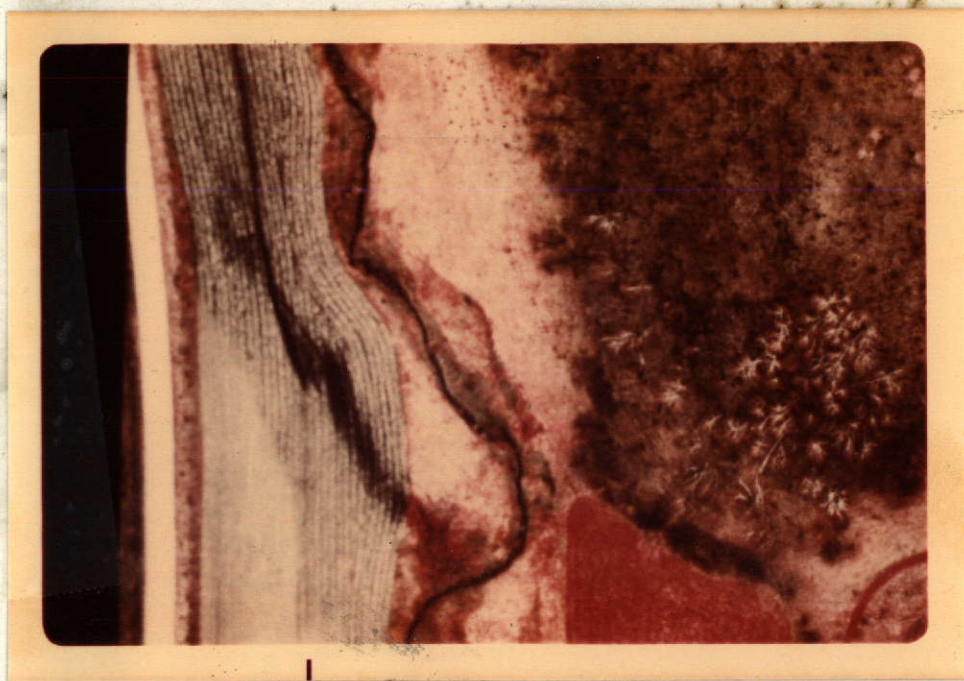
Figure 4.   Probable source area shown in dark gray
to the left of the stream. The hydraulic
connection to the stream too is seen.

Figure 5.   Probable source area shown in dark gray
between road and stream. Site location
is marked 3 on the map in Figure 1.

obtained by NASA-sponsored RB-57 high-altitude aircraft (Figure 3 and 4, the RB-57 coverage maps of Michigan).[2] This twin-engine jet aircraft carries numerous high-quality photographic systems and normally conducts photo missions at about 60,000 feet altitude. Two of the RB-57 camera systems provide 10" x 10" photographs at scales of 1:60,000 (or about 1" on the photo to a mile on the ground (there are 63,360 inches in a mile)) and 1:120,000. As another, more familiar, indication of scale, four frames (or photo images) of the 1:120,000 scale imagery provide coverage of virtually all of Eaton County, while it would take about 16 frames from the 1:60,000 scale imagery. RB-57 high-altitude photography is usually of high quality with excellent resolution (i.e., a sharp, clear photo in which small objects can be identified).

The cameras usually carry either conventional color film or color infrared (false color) film. Conventional color film shows the landscape as it would be seen by human eye from the aircraft. Since colors are shown as they appear to the eye, interpretation is eased. However, atmospheric attenuation is a serious problem when 60,000 feet of haze, dust, and ground smoke must be penetrated, particularly near the urban areas, the ground is frequently obscured.

Color infrared (CIR) film detects in part the infrared portion of the spectrum, eliminating much of the atmospheric attenuation which interferes with conventional color film. At times, this film may detect objects obscured to the human eye by haze or smog. Color infrared film is referred to as false color film or color reversal film. In the chemistry of this film and its processing, infrared energy detected is printed as red, red light is printed as green, and green is printed as blue. Blue and violet light are eliminated from the photographic print by using a yellow (minus blue) filter on the camera to filter out those colors. Figure 5 shows two false color photographs of Muskegon, Michigan. In the top photograph, only a small amount of blue light was filtered out by using a light yellow filter. In the bottom paragraph, a medium or dark yellow filter was used, filtering out more blue light.

In the bottom photograph of Figure 5, the red areas are vegetation; the dark red is wooded; and the light or brighter red is grass. Golf course fairways such as those above and to the right on the land mass near the white plume, are usually readily identifiable. The urban areas show up as gray-green, sand dunes as white, and water as black. The upper photograph of Figure 5 is similar, but appears more blue and green throughout.

A photo interpreter must allow for a little time to get used to the unconventional color scheme in CIR film. Once this is done, however, it is often much easier to interpret land use features. This

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[2] For a list of high-altitude imagery collected, refer to Users Guide to High Altitude Imagery of Michigan, Michigan State University.

RB-57 HIGH ALTITUDE
PHOTOGRAPHIC COVERAGE
OF MICHIGAN
1969-1972

EMMET

CHEBOYGAN   PRESQUE ISLE

CHARLEVOIX

MONTMORENCY

ANTRIM   OTSEGO   ALPENA

LEELANAU

GRAND
TRAVERSE
BENZIE   KALKASKA   CRAWFORD   OSCODA   ALCONA

MANISTEE   WEXFORD   MISSAUKEE   ROSCOMMON   OGEMAW   IOSCO

ARENAC

MASON   LAKE   OSCEOLA   CLARE   GLADWIN

HURON

OCEANA   NEWAYGO   MECOSTA   ISABELLA   MIDLAND   BAY

MUSKEGON   TUSCOLA   SANILAC

KENT   MONTCALM   GRATIOT   SAGINAW

GENESEE   LAPEER   ST CLAIR

OTTAWA   IONIA   CLINTON   SHIAWASSEE

MACOMB

ALLEGAN   BARRY   EATON   INGHAM   LIVINGSTON   OAKLAND

VAN BUREN   KALAMAZOO   CALHOUN   JACKSON   WASHTENAW   WAYNE

BERRIEN   CASS   ST. JOSEPH   BRANCH   HILLSDALE   LENAWEE   MONROE

0   50 miles

FIGURE 3

-6-

RB-57 HIGH ALTITUDE

PHOTOGRAPHIC COVERAGE

OF MICHIGAN

1969-1972

KEWEENAW

HOUGHTON

ONTONAGON

BARAGA

MARQUETTE

GOGEBIC

IRON

DICKINSON

ALGER

LUCE

SCHOOLCRAFT

CHIPPEWA

MACKINAC

DELTA

MENOMINEE

0   50 miles
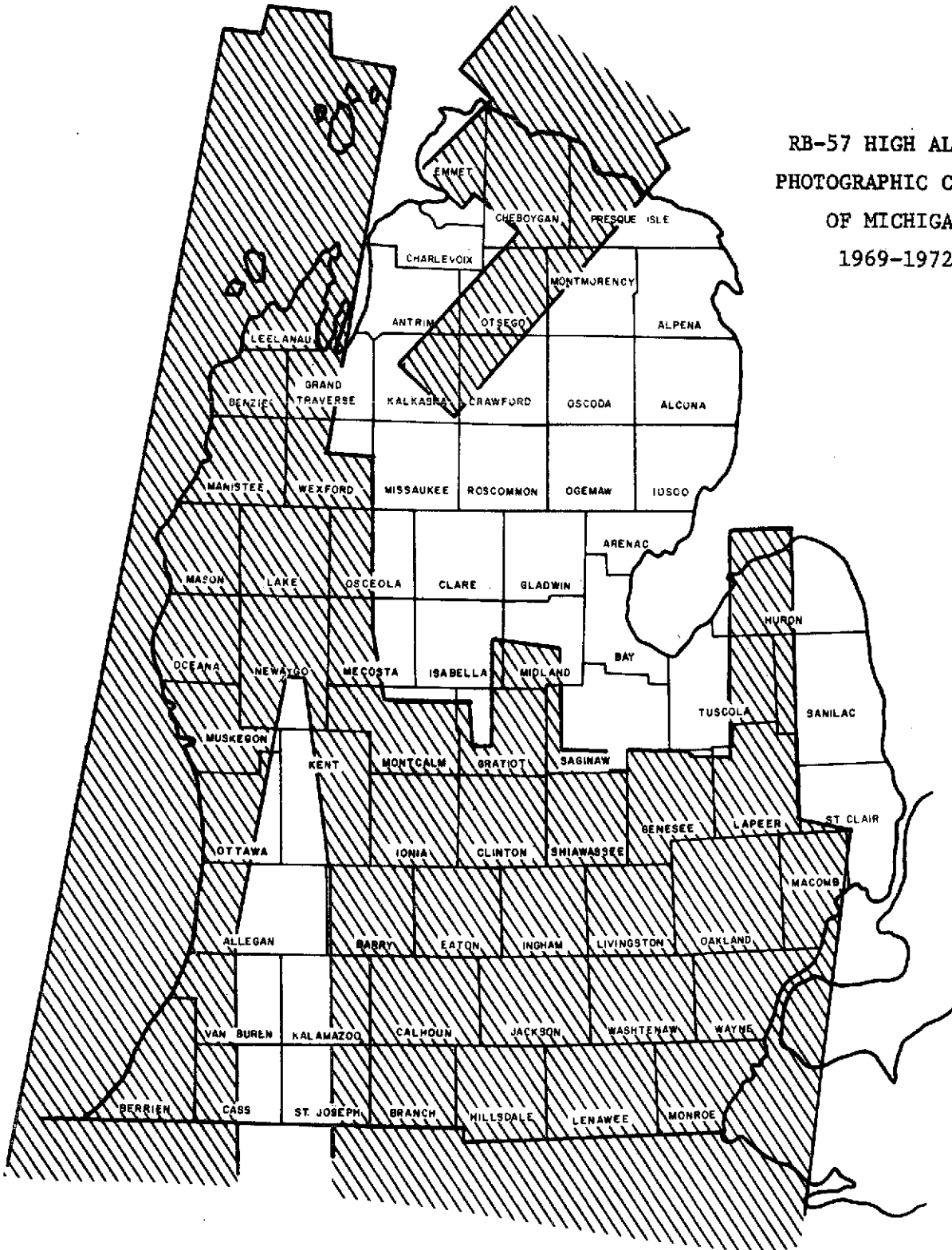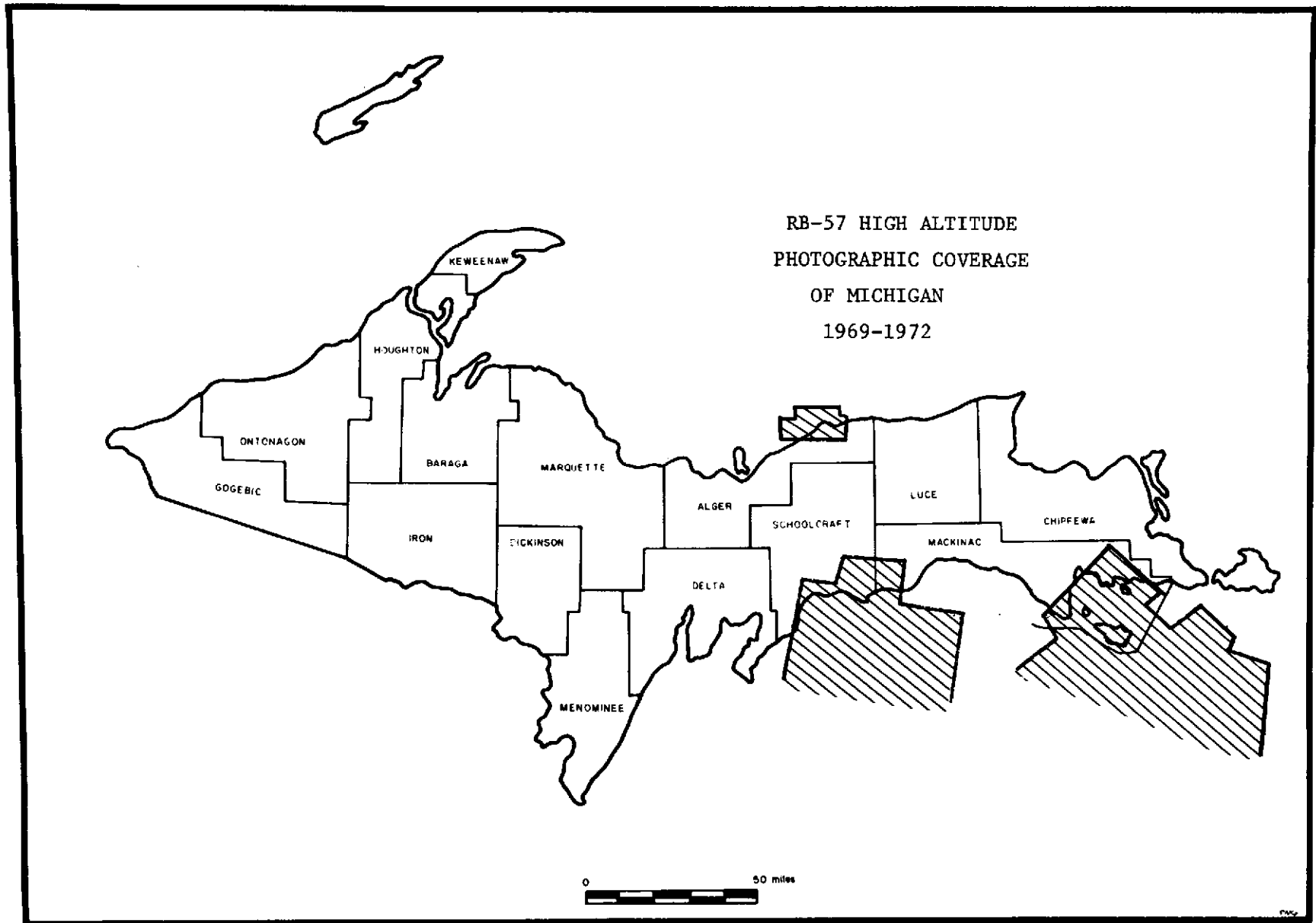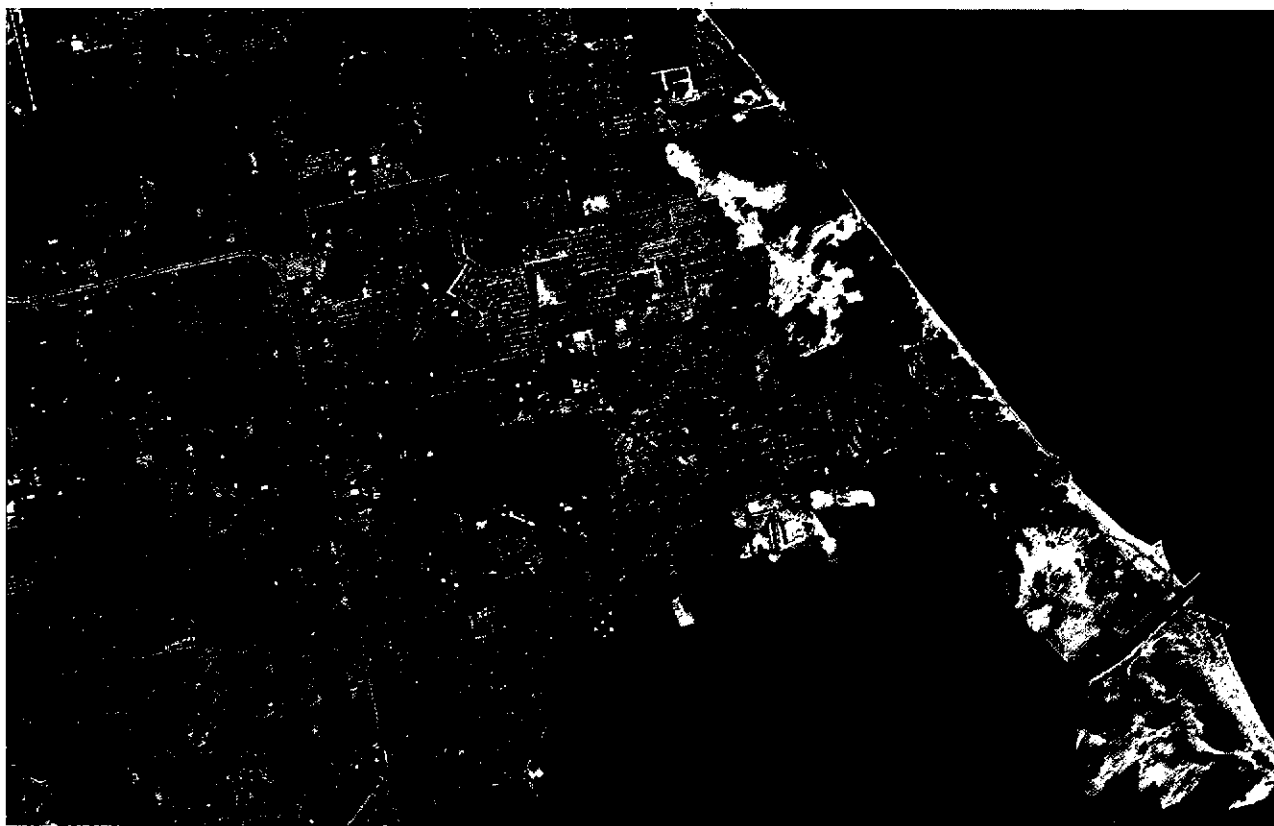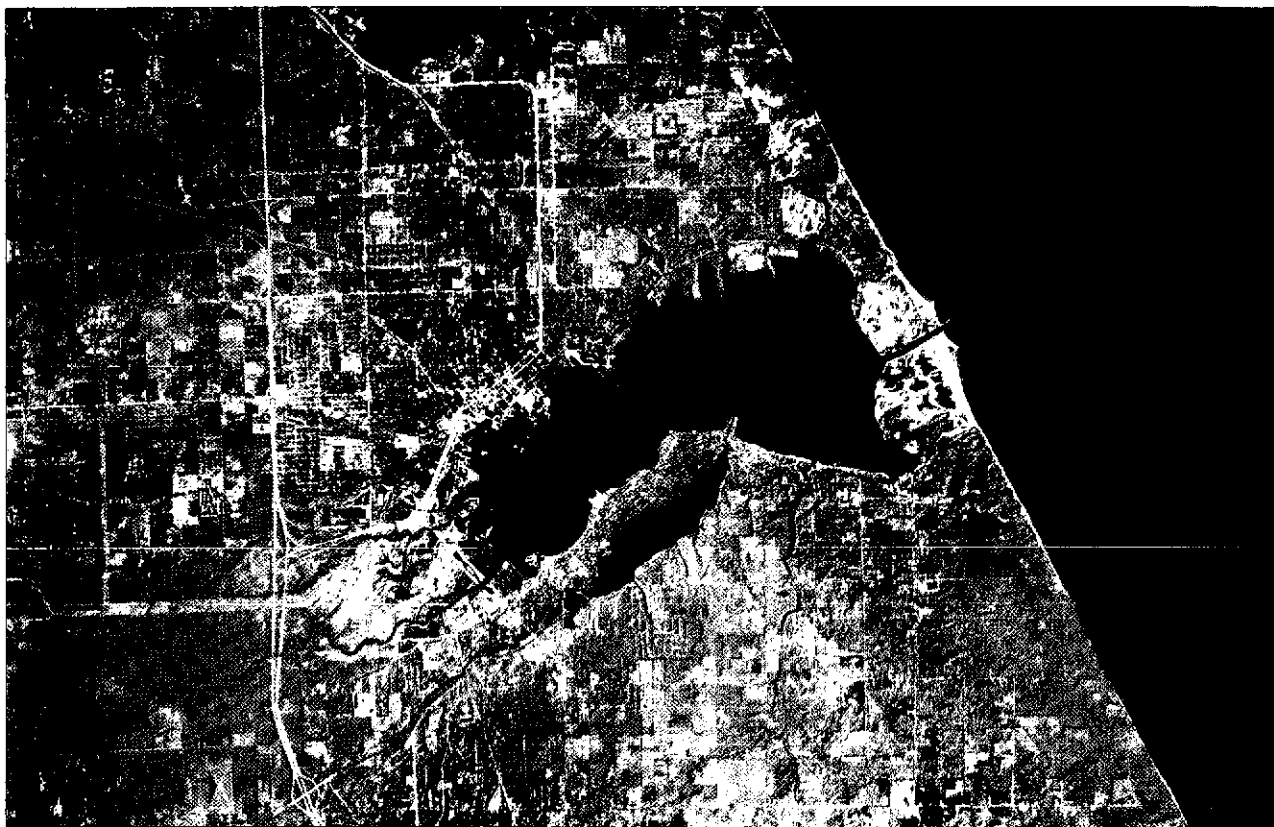
FIGURE 4

RB-57 COLOR INFRARED IMAGERY
MUSKEGON, MICHIGAN

TOP PHOTO-1:120,000

BOTTOM PHOTO-1:60,000

FIGURE 5

is due to the way man-made features stand out on the landscape and to the increase in apparent color variations in agricultural areas, indicating crop types and conditions. Because of the lessened atmosphere attenuation, the film seems to have very high resolution quality.

MEDIUM-ALTITUDE PHOTOGRAPHY

The Agricultural Stabilization and Conservation Service (ASCS) of the United States Department of Agriculture has available medium-altitude black and white imagery at a scale of approximately 1:15,840 for Michigan. Most of the photography is black and white panchromatic, but some is black and white infrared photography. Black and white panchromatic film gives good-quality images of the ground factor, is highly suitable to land use interpretation, and is probably familiar to most planners. Black and white infrared photography is similar to color infrared, except that it is presented in black and grays. On this film there is no water penetration, which contrasts with the three feet in CIR photography. It is useful for shoreline delineation and some vegetation studies.

INTERPRETATION PROCEDURES

The interpretation procedures suggested here are designed for individuals primarily interested in land use information rather than for those experienced and technically familiar with remote sensing. Accordingly, before interpretation was begun by the MSU team, a survey of several non-technically oriented users and user groups was conducted. The purpose of the survey was to determine the equipment, methodology, and level of skill normally employed in photo interpretation. The results of the survey indicated that, in general, no special equipment was available, and that the existence of technical expertise and assistance was generally not known to the potential users.

Interpretation procedures suggested by this study are, therefore, designed to rely on (1) a limited amount of commonly available equipment, and (2) basic photo interpretation skills and experiences common among non-technical users.[3]

IMAGERY SELECTION

In a multi-level land use information system varying degrees of detail are needed for different classification levels. The most general level of information can be extracted from the satellite imagery, and the next, more detailed level is available from high-

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[3] The equipment used was: 10X tripod magnifier ($1.95), pocket stereoscope ($3.95), and at times a B&L zoom macroscope 10-3QX ($165.00). Light was provided by a portable light table ($24.00).

altitude aerial photography (1:120,000).[4]   Table 1 indicates the imagery useful for each of four levels of land use information in Michigan.

TABLE 1

IMAGERY SUITABLE FOR A FOUR-LEVEL LAND USE CLASSIFICATION SYSTEM

Level	Scale	Type of Imagery	Sensor-Platform
I	1:1,000,000	Analog MSS Imagery	Satellite
II	1:120,000	CIR Photography	High-Altitude Aircraft
III	1:60,000	CIR Photography	High-Altitude Aircraft
IV	1:15,840	B&W Photography	Medium-Altitude Aircraft

Quite obviously, black and white photography at a scale of 1:15,840 can provide all of the information needed for Levels I through IV. It would be quite costly to use this imagery for an inventory of the entire state, however. The satellite imagery can be obtained every 18 days, allowing an economic State-wide Level I inventory several times a year. Color infrared photography at scales of 1:60,000 and 1:120,000 can be economically flown over large areas of the state every few years. These scales require fewer photos if highly detailed information is not required to cover an area, hence fewer man hours to interpret them.

In large scale photography (1:15,840) large patterns can be missed due to the detailed information available on the photo. Various state and private agencies could use these photos for other programs, such as environmental impact assessment, thereby helping to further spread the cost burden of State-wide coverage. Also, small-scale imagery can show macro-patterns not visible on larger scale photography. Each type and scale of imagery can provide different information; the time and expense of processing and interpreting each type of imagery vary as well.

INTERPRETATION METHODS AND SITE SELECTION

Once the general types of sensor/scale systems to be utilized were selected, a wide variety of cultural and natural feature test sites were selected within Michigan. These sites were selected to have as many different types of features and land uses as possible, as well as having coverage by several different imagery types. It was then possible to illustrate and compare the images of specific features at the different

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[4] The first two levels used here draw heavily on the system suggested in Anderson, et al., A Land-Use Classification.

scales. Thus, the interpretability of different types of imagery could be evaluated on similar features, and the best sensor and scale systems could be recommended for use at different levels of land use information.

The specific interpretation process began with a detailed study of the smallest scale, most generalized image, of the ERTS satellite image. Each ERTS image is available in black and white transparencies of paper prints. Both prints and transparencies were used in the study, but the prints were found inferior in resolution to the transparencies. Transparencies were used for the rest of this study.[5]

The transparencies were placed over a light table and illuminated from beneath. Minute distinctions in tone, texture, and pattern density which normally facilitate interpretation were examined for each photograph. After preliminary identification on the basis of tone, pattern, and density, individual areas of specific land use were delineated on transparent overlays or directly on the photographs.

Following a full interpretation and annotation of the most general level (Level I), the same procedure was followed with Levels II, III, and IV. The types of land use features visible on each level of imagery that were not visible on the preceeding more generalized level were noted and recorded.

The procedure was carried out on relatively elementary equipment. Only in very limited instances was larger magnification used as an aid in interpretation and then only at a fairly low power (20x) and for corroboration. Thus, the supporting facilities consisted only of the film transparencies, portable light table, and 10X hand lens.

Interpretations were verified by field visits. Ground or field checking is important in photo interpretation and should not be over-looked. Some mistakes were made in interpretation, indicating that the techniques used, even by experienced interpreters, are not fool-proof, and errors will occur. However, it is much faster and cheaper to field check areas in questions, than to map the entire area on the ground.

INTERPRETATION RESULTS

Regardless of the imagery used, the interpretation method is generally the same -- differentiating areas of varying tone and textures, and then directly interpreting the features. Generally,

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[5] One exception was with the ASCS B&W photographs, as they were available only in paper prints.

the accuracy of identification determined by the experience and background of the interpreter, and the difficulty of the feature being identified.

In this section, interpretations are given of various photographs[6] of Michigan, and the means used to identify the features is described. Hopefully, this approach (instead of simply stating the results) will benefit the user in his attempts at interpretation. Using Figure 5, the user can check these features on non-annotated photos.

ERTS-1 SATELLITE IMAGERY

Urban features, even from ERTS-1 satellite imagery, at an altitude of around 600 miles, are among the easiest to identify. This is due, in part, to their contrast with the surrounding landscape. On ERTS imagery, fairly large urban areas stand out clearly; smaller urban areas appear somewhat less distinct (Figure 6). These large urban areas can be delineated and their major sub-regions can be fairly easily identified.

In this particular area (Figures 6 and 7), seven different land use types are identified. Among these the urban areas of Lansing and Grand Rapids, (Map Symbol "1") stand out clearly since they are lighter than the surrounding less densely built-up areas. The area designated as residential-commercial is also light, and their linear nature indicates the strip development and shopping plazas located along major roads.

The darkest of the three urban sub-categories (but lighter than the surrounding area) is the residential-suburban area. This is probably a lower density residential area, including large lawns and trees and thereby having a darker tone. Within the entire urban area, the light colored lines are major highways, which can be seen extending to various other urban areas (such as the interstate road network connecting Lansing and Grand Rapids.

Forest areas (Map Symbol "2"), are the second feature identified and appear in very dark areas. The shape of these areas is generally smooth with no particular form. The river vegetation (Map Symbol "3"), is also very dark, but can be distinguished from the forest by the

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[6] During interpretation, only second generation photographic images were used. All imagery was of high quality, with the RB-57 photography being color transparencies. For the printing of this report, however, black and white prints were necessary. A negative was made from the transparency and then reproduced as a paper print (fourth generation). The color infrared transparencies lost much of their quality when reduced to these black and white prints. Finally, the report printing process reduced the quality an estimated 15%. For this reason, the reader may question the ability to interpret the features mentioned. However, keep in mind that with the original imagery, these features stand out quite well, and interpretation is much less confusing.

FIGURE 6   ERTS IMAGE OF LANSING - GRAND RAPIDS AREA
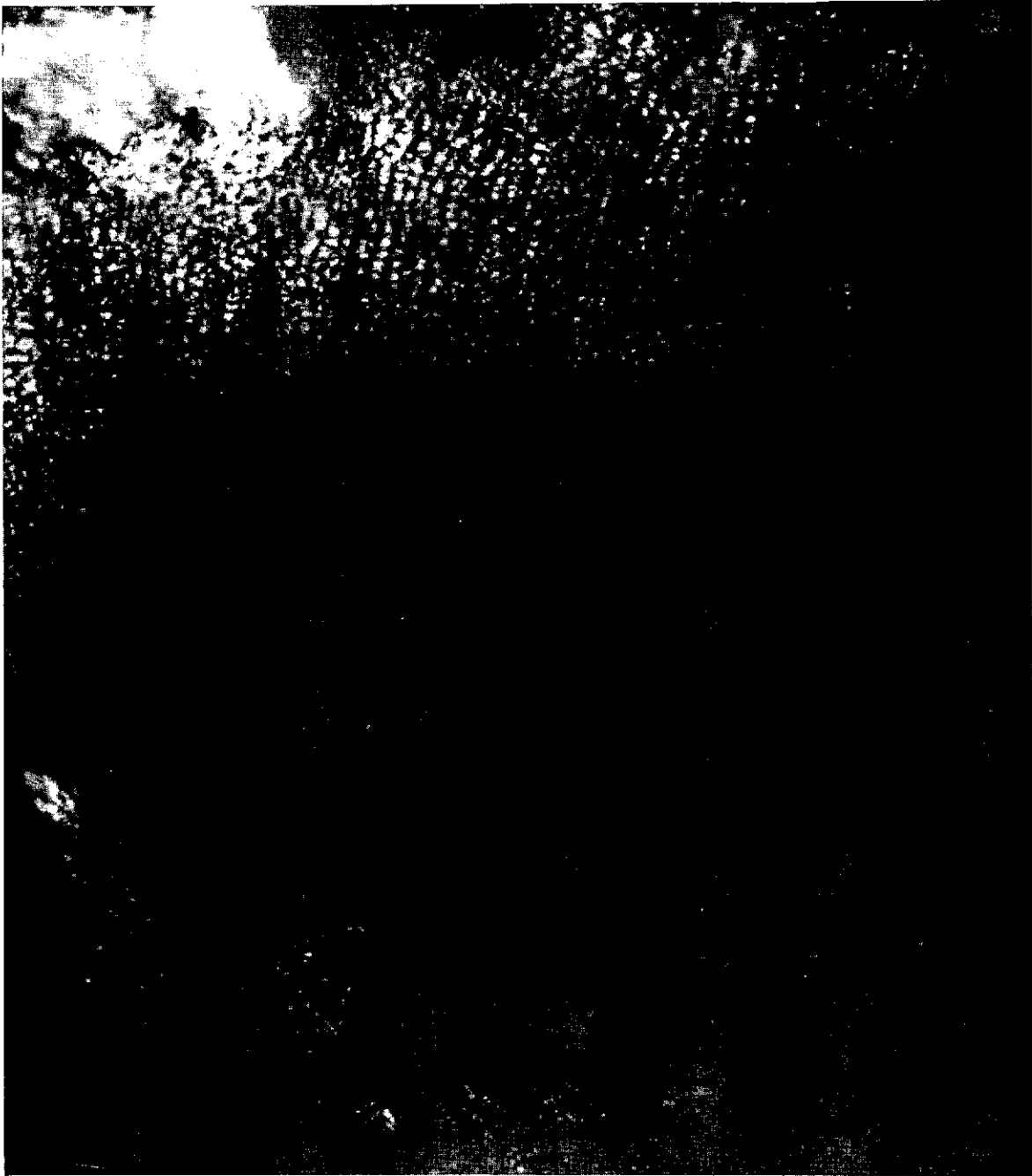
ANNOTATED MAP FROM ERTS IMAGE OF THE LANSING-GRAND RAPIDS AREA

LAKE

MICHIGAN
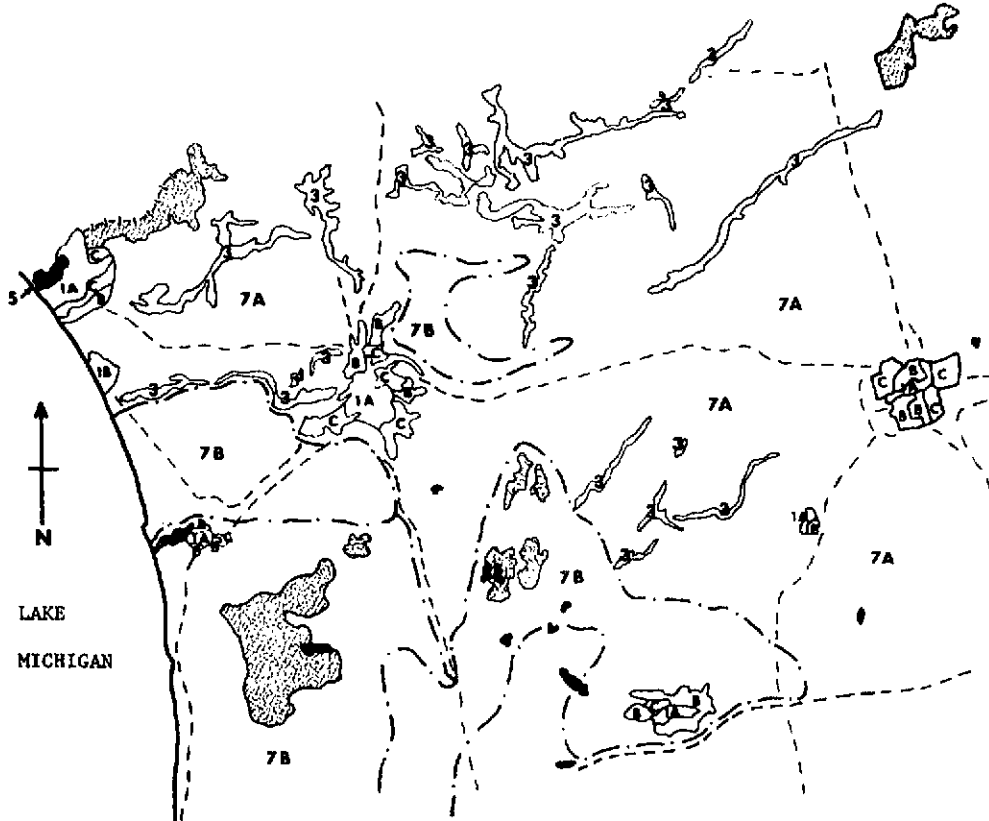
1. URBAN AREA

    A. CENTRAL CITY

    B. COMMERCIAL-RESIDENTIAL

    C. RESIDENTIAL

2. FOREST

3. RIVER VEGETATION

4. WATER

5. BARREN AREAS

6. HIGHWAYS - - - - -

7. AGRICULTURE — · — · —

    A. FIELD CROPS - INTENSIVE

    B. MIXED AGRICULTURE - IDLE

elongated winding lines which parallel rivers. At times, discriminating between these two may be different, as both are similar types of vegetation. For this reason, only the form of the forest and river vegetation provide a means of distinction.

Water bodies (Map Symbol "4") are very difficult to identify on Figure 6. This figure is a reproduction of ERTS band 5, a portion of the spectrum which poorly records water images. In examining Figure 2, bands 6 and 7, despite their scale differences, the water bodies are more easily seen.

Barren areas (Map Symbol "5") are even more easily identified (by virtue of tone contrast) than urban areas. The sand dunes located near Muskegon are more obvious than the city itself. In addition to sand dunes, other types of barren land, large extractive areas, new construction, and beaches (of sufficient size), are all shown as almost white areas on band 5.

The final major type of land use identifiable on the ERTS images are agricultural areas (Map Symbol "6"). These regions are identified by the field patterns (clearly visible in Figure 6). Some fields appear light and others dark, but the principal aid in identifying these features is their rectangular shape and the checkerboard pattern of field boundaries.

The agricultural areas in Figure 7 were divided into two types based on intensity of agricultural activity and the related concentration of cropped land. The first sub-area is intensive field agriculture (Map Symbol "7a"). This land consists of large plots where the preponderance of land reflects field patterns. These areas include land surrounding the city of Lansing, and northwest of the city of Grand Rapids. The second delineation is where the field patterns are not the majority of land use features. Here, either large areas of forest pasture or orchards are intermixed with field patterns of the area is obscured and there is no prominent pattern (such as southwest of Grand Rapids).

RB-57 HIGH-ALTITUDE PHOTOGRAPHY 1:120,000

There is a tremendous increase in detail when going from ERTS-1 imagery (1:1,000,000) to RB-57 photography (1:120,000). This is partly due to the scale increase, partly from a change from MSS analog imagery to photography, and partly to the change from a black and white image to a false color photography. Of the features identified from the ERTS-1 imagery, two are particularly complex and difficult to interpret, and thus, deserve more attention. These are urban and agricultural areas.

Figure 8 shows an RB-57 photograph of Muskegon, Michigan, at a scale of 1:120,000. This is about two miles to the inch. From the ERTS image only the lake and the sand dunes on the western shore were clearly visible. Muskegon was a light area showing little evidence of being an urban area. Figure 8, however, shows numerous

urban features. The most obvious is the road network, with the criss-cross
of white lines, indicating the city road pattern. The obviously divided
lines and clover leafs of the interstate highway are even more obvious.
Other easily identified urban features are the pattern of the wide runways
and the taxi strips of the airport. One is located at the bottom of
Figure 8.

Other urban features, shown on Figure 8 are:

A. Power Plant This is difficult to identify at this scale, but
    key features are a large coal pile, smoke stacks, and a pond
    for cooling the hot water.

B. Golf Course This is more easily seen on Figure 5, because of
    the color. It can be identified by a cleared grass area (light
    tone) with a darker tone for the fairways. Usually, they are
    located near urban areas.

C. Pulp Mill This is a very difficult industry to detect. At
    this scale one can only identify it as an industry, with
    large-scale pollution in the water.

D. Tank Farm This is simply a grouping of liquid or gas storage
    tanks. At location "D" the small white circles are cylindrical
    tanks (shadow on north side identified cylinder height). Thus,
    they store some liquid.

E. Barren Areas They are sand dunes; the extractive nature of the
    area cannot be easily identified at this scale, but careful
    viewing can identify conveyor belts for transporting sand.

F. Central Business District Most easily identified by the light
    tone and general built-up nature as compared to the rest of the
    city (excluding industrial and shopping centers).

G. Port Facilities They are identified by their location on the
    water, and the straight line structures (docks) into the water.
    If the docks and piers are very small, and small white dots are
    seen, the area is probably a marina.

H. Town Houses They are identified by the large connected
    buildings of different sizes. A large complex of these
    separated by wide roads but with no large open areas for
    parking indicates that only a few families live in each con-
    nected building.

I. Marina The small boats are seen as dots.

J. Drive-In-Theaters This is easily identified by a triangle like
    shape with curved dark lines within, curved away from a dark
    point (screen). An area in the center without the lines is
    the projection house and snack bar.

Figure 8 points out a few of the identifiable features seen on RB-57 photographs of urban areas. In an agricultural area, interpretation of different types of features is necessary.

From ERTS imagery, only the 20-80 acre fields were visible. At 1:120,000, however, information on the crop in the fields can be extracted. Figure 9A is a print of CIR transparency of an area north of Lansing. From the original, different stages and conditions of the crops can be seen in the different shades of red. The following can be identified from this photo:

AA. Newly Plowed Fields These are black. The soil has recently been turned, and it is wet and fairly compacted. Compare this to --

BB. Bare Fields These are newly planted, but very little vegetation is present. They have been plowed, smoothed, and planted, and the moisture has had a chance to sink under the surface. The lightest are higher, drier sites.

CC. Idle Fields These are identified by dark spots (brush) located in a vegetated field. One or two spots may be trees, but a large number are brush. Also note the unkept or rough nature of the field.

DD. Woodlots These are dark, rough areas, almost appearing three-dimensional.

EE. Row Crops A well-kept field that shows row patterns and is somewhat rough in texture is probably a row crop.

FF. Field Crop This is smooth, uniform in texture, with no patterns within it.

Many other features are identifiable with 1:120,000 scale imagery, and Table II gives a partial list of these features. This scale imagery is particularly useful for regional planning, as only six photos are needed to cover an average size county. For more detailed planning, however, larger scale imagery is necessary. Here, the RB-57 1:60,000 CIR photography is particularly valuable.

RB-57 HIGH-ALTITUDE PHOTOGRAPHY, 1:60,000

Where the change from ERTS imagery to RB-57 1:120,000 scale photography was a major change, the change from 1:120,000 to 1:60,000 is not. Generally, this scale eases identification of features seen at 1:120,000 and allows for interpretation of some new features.

Figure 10 is a photograph of Muskegon on a scale of 1:60,000. This is the same area as Figures 5 and 8. The clues for interpreting Figure 10 are the same for Figure 8, with a few additions.
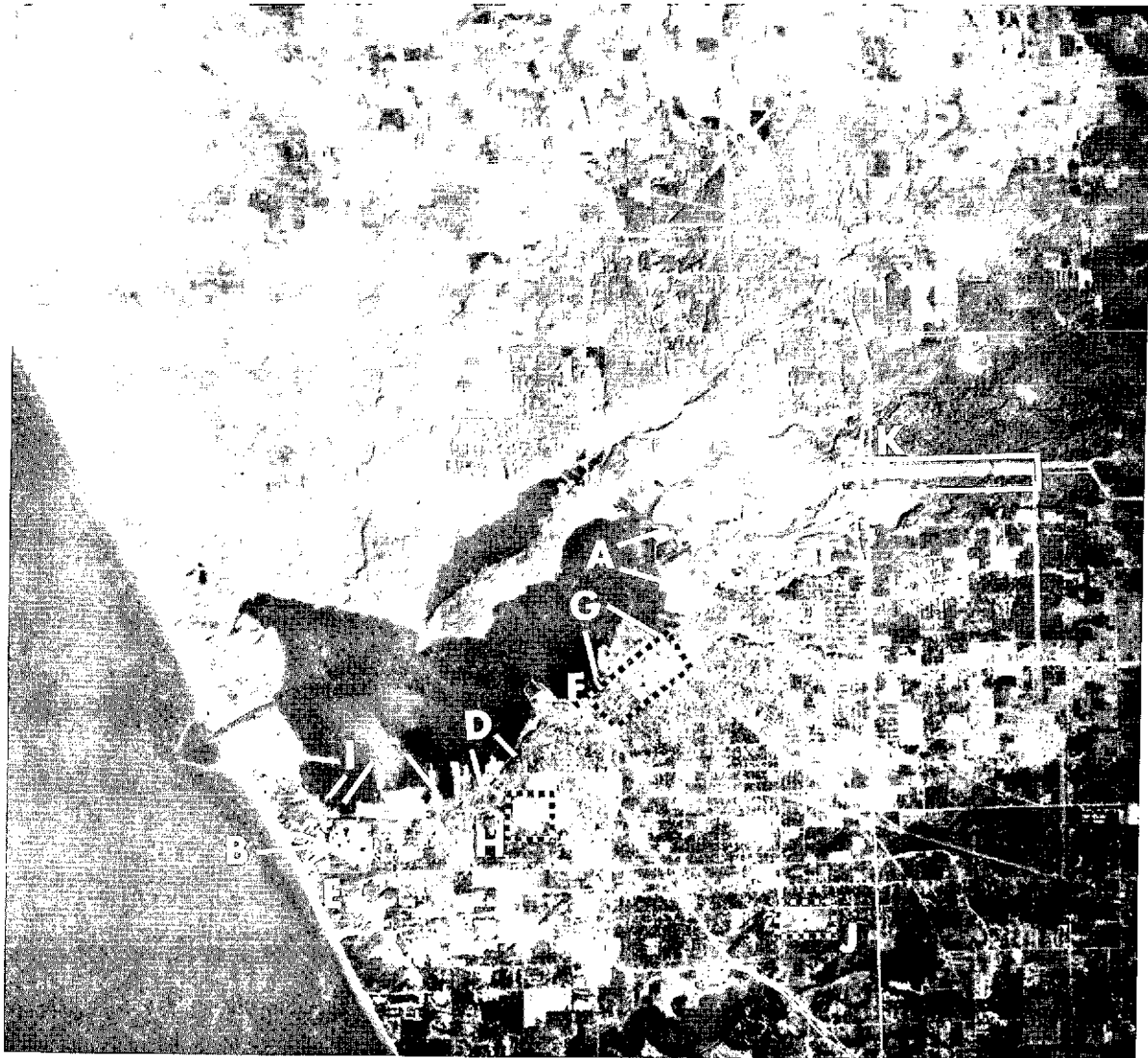
FIGURE 8

A	POWER PLANT	G	PORT FACILITIES
B	GOLF COURSE	I	MARINA
C	PULP MILL	J	DRIVE-IN- THEATER
D	TANK FARM	K	POWER LINE RIGHT-OF-WAY
E	BARREN AREAS (EXTRACTIVE)	R	RESIDENTIAL TOWN HOUSES
F	CBD AREA		

L. <u>Fabricating industry</u> This is usually a large group of connected structures with an associated parking lot. It can be separated with heavy industry by the lack of big smokestacks for heat (iron furnaces) or power. Usually it is located on a rail line.

M. <u>Residential area</u> These are easily identified by a small structure with a single driveway (two for a duplex). In older areas, trees tend to obscure the houses, making interpretation difficult. The density of houses can be determined by counting the structures under a grid.

N. <u>Liquid Gas Storage</u> This is a tank farm like D. The difference, however, is the roundish top of the gas versus the flat circular top of the liquid storage of D. Also the shadow of N is more pointed, indicating a spherical container.

O. <u>Shopping Centers</u> They are identified by a single or group of low, flattopped buildings occupying a considerable space. Also, associated with it is a very large parking lot, larger than the buildings.

P. <u>Schools</u> They are easily identified because of the track-football field and baseball diamond located near the flat-topped buildings. Old urban schools are more difficult to separate from surrounding buildings.

In agriculture, few differences appear between the two scales of RB-57 photography. Figure 9B shows an agricultural area near Muskegon. Actually no new agricultural features were identified on the 1:60,000 scale imagery.[7] Referring again to Table II, the new features that were identified on 1:60,000 imagery are listed.

MEDIUM-ALTITUDE PHOTOGRAPHY

The fourth level of imagery is the medium-altitude black and white panchromatic photography. This level of imagery does not give much new information, but does greatly aid in identifying items which were identified at 1:60,000, positive identification occurs at 1:15,840. Figures 12, 13, and 14 show these figures, more detail can be seen, but the basic feature is still unchanged. For example, on Figure 8, the power plant (A) was identified at a scale of 1:120,000, but at the fourth level of imagery the overhead crane, used to carry coal to the plant, can be seen.

In agricultural interpretation (Figures 15, 8, 16) again very little new information is found. Only the scale of this information varies. This scale change is quite important, as delineating areas

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[7] Letters AA were not located on 9, but they could be identified at 1:120,000.

FIGURE 9   1:120,000 RB-57 PHOTOGRAPH OF AREA NORTH OF LANSING

AA   NEWLY PLOWED FIELDS

BB   BARE FIELDS

CC   IDLE FIELDS

DD   WOODLOTS

EE   ROW CROPS

FF   SMALL GRAIN (FIELD CROP)

for maps or measuring areas becomes more accurate. Here a 32nd of an inch error is not as critical as the same error at a scale of 1:120,000.

In interpreting natural features (Figure 16), the true value of black and white panchromatic film is seen. In this photo the white ridge areas in the water show the submarine lake features. This may be important to coastline planning, as may the beach ridges. These are seen as breaks in the vegetation available at smaller scales, and may be important to the planner.

If more detail is needed, higher levels of imagery may be necessary (1:10,000-1:5,000). These, however, are necessary only for small selected areas, and should be considered on an individual problem basis. The previous Levels (I-IV) are valuable enough to be provided on a state or region basis.

FIGURE 10   RB-57 PHOTOGRAPH OF MUSKEGON MICHIGAN, 1:60,000

A	POWER PLANT	G	PORT FACILITIES	N LIQUID GAS STORAGE
B	GOLF COURSE	H	TOWN HOUSES	O SHOOPING CENTER
C	PULP MILL	I	MARINA	P HIGH SCHOOL
D	TANK FARM	J	DRIVE-IN-THEATER	S BASEBALL DIAMOND
E	BARREN AREA	L	FABRICATING INDUSTRY	X MOBILE HOME PARK
F	CBD OF MUSKEGON	M	HIGH DENSITY SINGLE FAMILY	

FIGURE 11   1:60,000 RB-57 PHOTOGRAPH OF AGRICULTURAL AREA NEAR MUSKEGON

BB   BARE FIELDS

CC   IDLE FIELDS

DD   WOODLOTS

EE   ROW CROPS

FF   SMALL GRAIN CROPS

GG   PINE PLANTATION

HH   TILED FIELD

FIGURE 12   ASCS PHOTOGRAPH OF MUSKEGON MICHIGAN, 1:15,840

B	GOLF COURSE	M_1	HIGH DENSITY RESIDENTIAL
C	PAPER MILL	M_2	MEDIUM DENSITY RESIDENTIAL
E	BARREN AREA (EXTRACTIVE)	M_3	LOW DENSITY RESIDENTIAL
I	MARINA	Q	CEMETERY

FIGURE 13   ASCS PHOTOGRAPH OF MUSKEGON MICHIGAN, 1:15,840

FIGURE 13   ASCS PHOTOGRAPH OF MUSKEGON MICHIGAN, 1:15,840
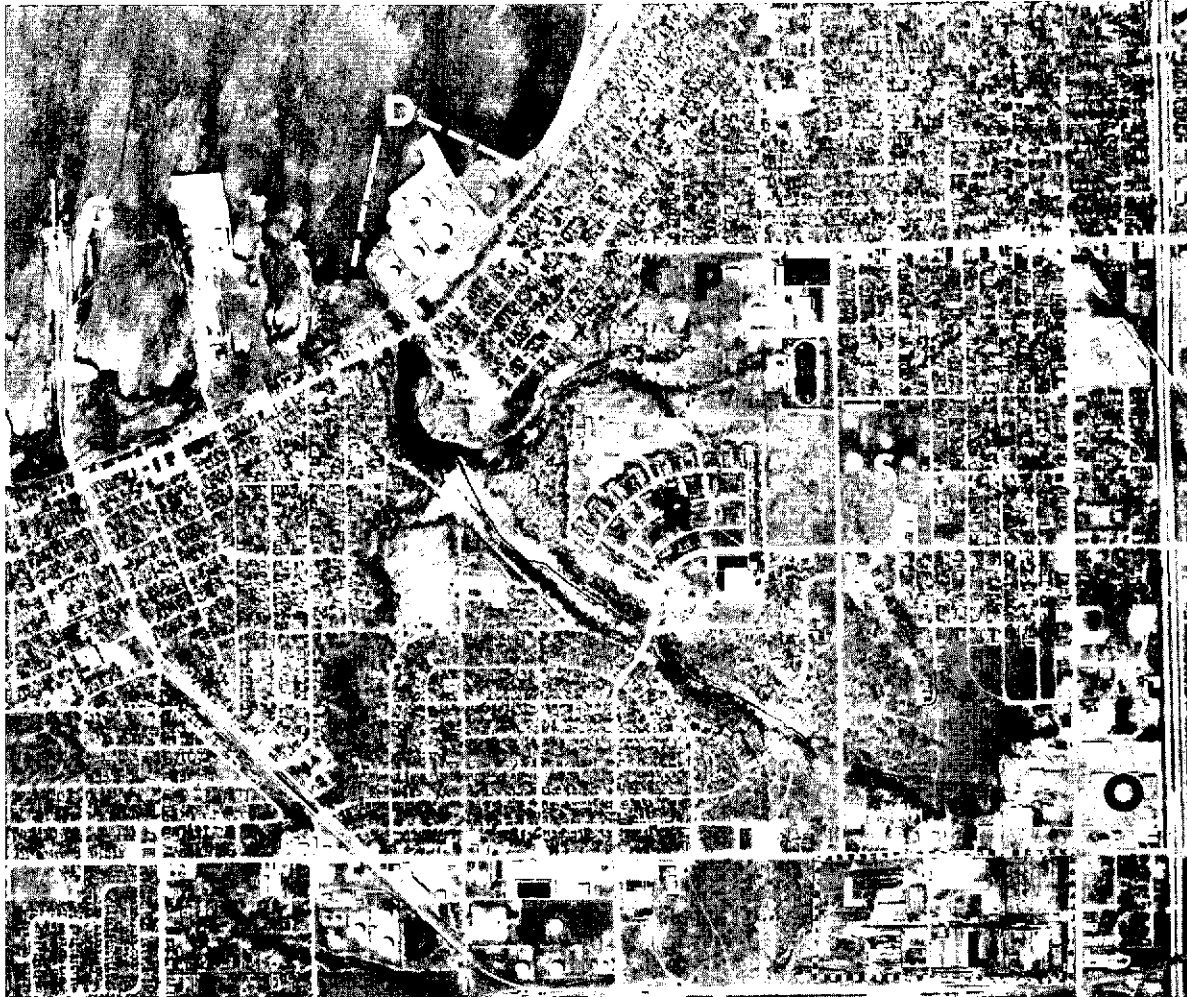
D	TANK FARM	P	SCHOOL
G	PORT FACILITIES (SHIP DOCK)	R	TOWN HOUSES
L	FABRICATING INDUSTRY	S	RECREATION (FOOTBALL, BASEBALL)
O	SHOPPING CENTER		

FIGURE 14 ASCS PHOTOGRAPH MUSKEGON MICHIGAN, 1:15,840

A   POWER PLANT

F   CENTRAL BUSINESS DISTRICT

R   APARTMENT

S   PARK

T   PARKING LOT

U   HEAVY INDUSTRY

V   JUNK YARD

W   OUTDOOR STORAGE

X   MOBILE HOME PARK

FIGURE 15   ASCS PHOTOGRAPHS OF AGRICULTURAL AREAS NEAR MUSKEGON, 1:15,840
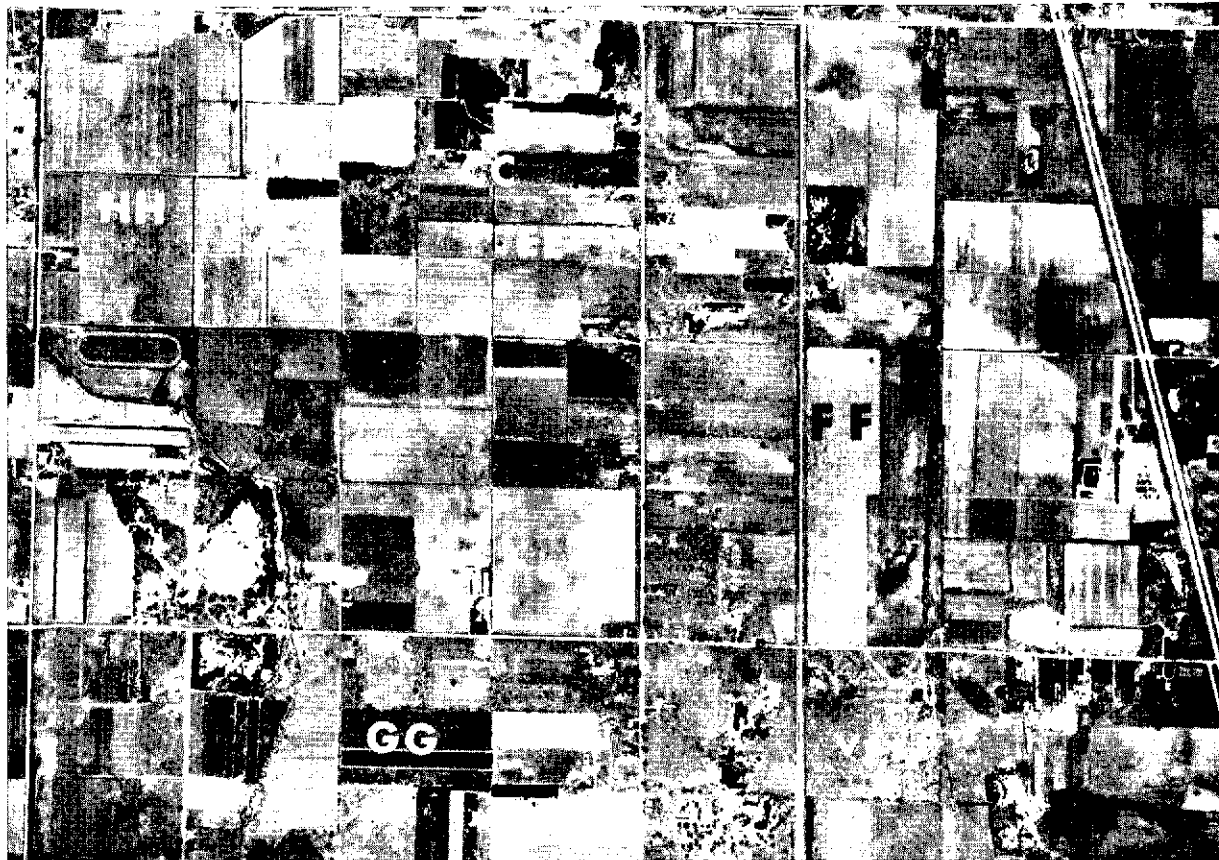
V   JUNK YARD

CC   IDLE AGRICULTURE

EE   ROW CROPS

FF   SMALL GRAINS

GG   PINE TREE PLANTATION

HH   TILLED FIELDS

AA   NEWLY PLOWED

DD   WOODLOT

II   ORCHARD

JJ   NEWLY PLANTED FIELDS

KK   HAY FIELD BEING CUT

LL   MOISTURE PATTERNS
     (MOTTLED APPEARANCE)

FIGURE 17 ASCS PHOTOGRAPH EMMET COUNTY, MICHIGAN, 1:15,840
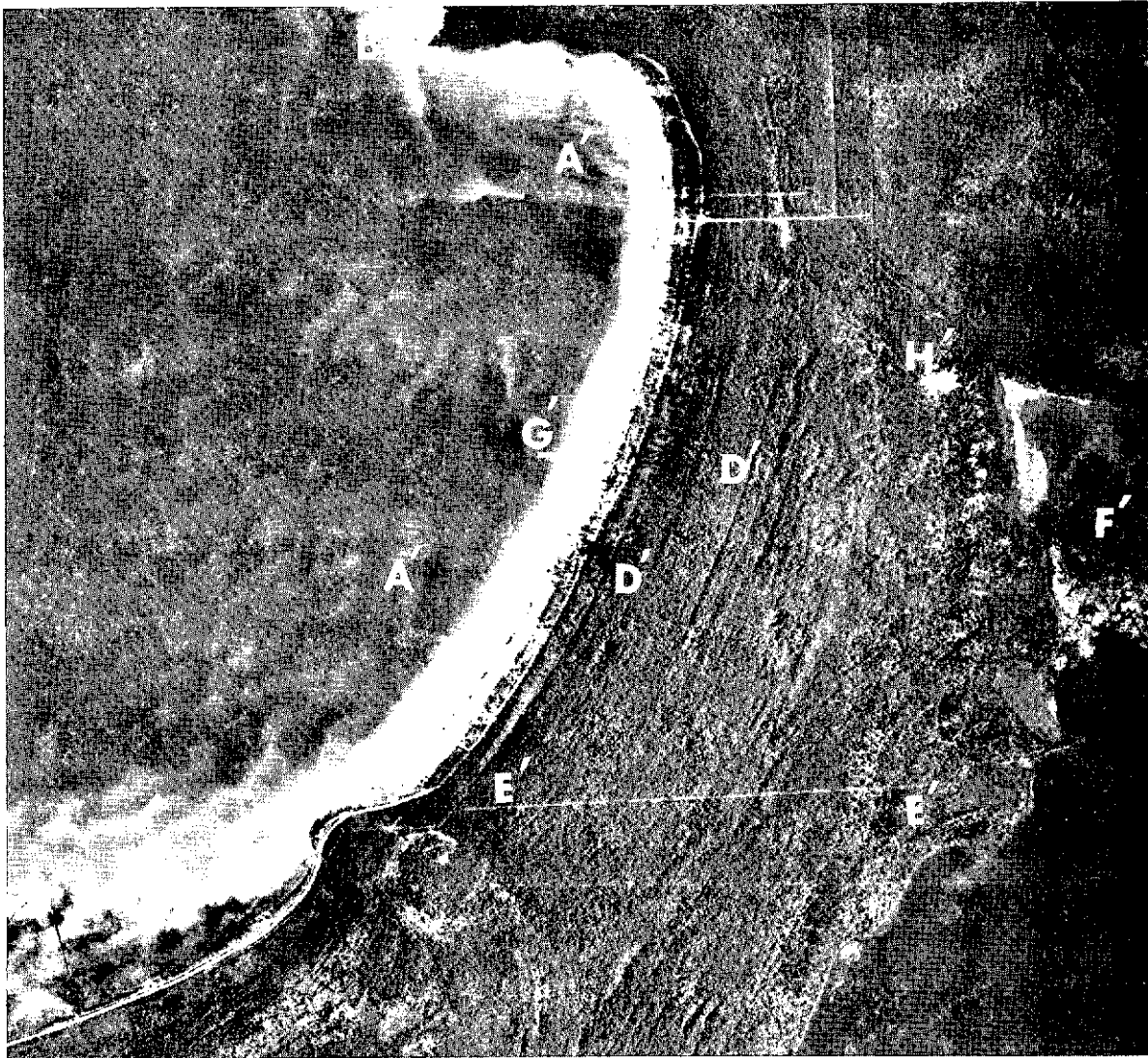
A'	SHALLOW WATER FEATURES	E'	POWER LINE RIGHT-OF-WAY
B'	SAND SPIT	F'	BOG
C'	DRAIN	G'	BEACH
D'	BEACH RIDGES	H'	SAND DUNE

SUMMARY AND CONCLUSION

The success and ease of interpreting specific features depends on the types and quality of imagery employed. The interpretation uses of ERTS-1 imagery depend on the band used, as each band produces a different image of the same area. Band four is generally the best for identifying submerged shallow water features such as bays, sediments suspended in water, and current patterns. Band five is better suited for identifying cultural features, such as roads, urban areas, and extractive industries. Agricultural field patterns are also easily picked up on band five, but band six seems better suited to interpreting these field patterns and provides supplementary information for interpreting urban areas. Forests, barren areas, and river or wetland vegetation are easily identified on either band five or six. Band seven is especially good for identifying water bodies and topographic relief; cultural features are difficult to identify in this band.

Because of its scale, ERTS-1 imagery seems best suited to identifying the macropatterns of urban areas, major highways, forests and agricultural areas. It also allows large areas of a state to be easily and quickly identified and mapped.

The interpretation of RB-57 color infrared film indicated that a considerably great volume of data seems available from it than from ERTS imagery. This increase in information is at least partially attributable to the increase in scale from 1:1,000,000 to 1:120,000. But, in addition, the RB-57 sensor is a camera rather than a multi-spectral scanner (MSS). A photograph is capable of much higher resolution than the MSS analog image and is usually free from electrical interference or static. The RB-57 image has the added advantage of color; this provides another dimension for image interpretation. The infrared film has the haze penetration capability of band six of the ERTS-1 satellite.

Increasing the scale of photography from 1:120,000 to 1:60,000 does not add as much new information as the increase from the ERTS-1 scale to the 1:120,000 scale RB-57 imagery. However, 1:60,000 scale imagery is well suited for fairly detailed land use studies, environmental impact studies, inventories or various types of vegetated land, and a number of county and regional planning uses.

Color infrared film is not useful for interpreting submerged water features.

Agricultural Stabilization and Conservation Service black and white photography at a scale of 1:15,840 provides limited additional information to that available from the CIR 1:60,000 photography. This is probably due to the fact that ASCS is available only in black and white. Color photography provides many more recognizable shades than does black and white photography. Also, false color film shows cultural features far better and due to its infrared nature, produces a clearer image than ASCS film.

Possibly, if this Level IV imagery were CIR film or were at a scale of 1:10,000 or larger, more information would be added; however, the cost of obtaining such imagery may be prohibitive.

The greatest single advantage of Level IV imagery appears to be that interpretation was quite definite in comparison to the interpretation of other scales where some error might exist. Also more detailed measurements could be made at 1:15,840, such as miles of shoreline or sizes of structures.

In summary, inexperienced users employing very simple inexpensive unsophisticated equipment can extract large amounts of information out of existing imagery. ERTS imagery yields general regional patterns (Level I). RB-57 imagery at 1:120,000 scale provides fairly detailed information on land use (Level II), and at 1:60,000 scale gives more detail (Level III). Finally, 1:15,840 scale imagery provides clarification of Level III and provides a larger format for measurements and mapping (Level IV). Each sensor/scale has its own best uses, advantages, and disadvantages, and the user must select the sensor/scale system which best meets his needs.

TABLE II

CATALOG OF ACTIVITIES IDENTIFIED AT THE FOUR LEVELS OF INTERPRETATION

LEVEL I ERTS-1 Satellite Imagery	LEVEL II High Altitude Photography RB-57, 1:120,000	LEVEL III High Altitude Photography RB-57, 1:60,000	LEVEL IV Medium Altitude Photography Black and White
Urban & Built Up Land			
Core Residential/ Commercial	Individual Structures Residential Areas	Single Family Residential Swimming Pools Apartment Complex Mobile Home Park	House Types High-Rise Structures Garden Apartments
	Shopping Plaza Commercial Cluster Strip Commercial	Mobile Home Sales Parking Lots with Cars	Pleasure Boat Sales Building Under Construction
	Administrative Buildings Schools University Complex		Institutional Buildings
	Cemetery		
	Golf Baseball Drive-In Theater Marinas	Boat Dock with Small Boats	Power Boat-Wake Park

	Heavy Industry
	Tank Farm
	Light Industry
		Junk Yard
		Extracting Industry
		Fabricating
		Processing
		Gas Storage
			Power Plant –
			  Coal Piles
			  Overhead Crane
			  Water Pipes
			  Open Storage Area

TABLE II
(cont'd.)

LEVEL I	LEVEL II	LEVEL III	LEVEL IV
Excavations	Excavating Industry		
Airports	Airport Terminal Building Aircraft Hangars		
Highways	Highway Interchanges Divided Highways Bridges Rest Areas		
Railroads	R.R. Switching Yards		R.R. Box Cars
Utilities	Power Line R.O.W. Secondary Roads Tertiary Roads Port Facilities – Ships		

Agriculture

Intensive Field	Pasture Small Grain Crop Row Crop Orchard Farmsteads Sod Farm Idle Land	Stacked Field Crops Long Barns Bush Crops	Field Access Routes High Bush Fruits Low Bush Fruits Inactive Orchards Christmas Tree Farms Pine Planting–Idle Land

TABLE II
(cont'd.)

LEVEL I	LEVEL II	LEVEL III	LEVEL IV

Forest

Forest	Conifers	Plantation (harvesting)	Reforestation
	Deciduous	Natural Forest (harvesting)	
	Brush		
	Mixed		

Water

Lakes	Meander Scars	Beach Features	Submerged River Channel
Rivers	Water Pollution	Lagoons	Beach Ridges
	Streams		Dredging Operations
	Small Bodies of Standing Water		Offshore Bars
	Shallow Water Features		Shallow Water Features
	Breakwaters		
	Eddies		
	Sand Bars		

Non-Forested Wetlands

River Vegetation	Flood Plain	Floating Vegetation	
	Wetland - seepage	Wet Areas	
	Non-seepage	Marsh	
		Bog	

Barren Land

Sand Dunes	Sand Roads	Small Unvegetated Areas	
	Sand Ridges		
	Beaches		
	Campsites		
	Boat Launching		
	Parking Lots		
	Breakwater		

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