

LANDSAT APPLICATIONS TO LANDSCAPE ARCHITECTURE

by

WILLIAM CURTIS LEEK

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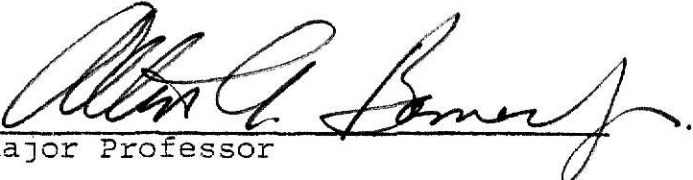
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**THIS BOOK
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THAT WERE
BOUND WITHOUT
PAGE NUMBERS.**

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RECEIVED FROM
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Introduction

Introduction: Remote Sensing

Let's start with the basics. Landscape architecture is the art of arranging or modifying the features of a landscape for aesthetic or practical reasons. A landscape architect works with the land. The Earth is the primary resource. In order to be a successful designer, one must understand that with which he works. A successful landscape architect must understand the Earth, in all of its phases, from every aspect, in all seasons. This understanding will consist of some knowledge which is physical, some which is emotional, some which is spiritual.

All physical knowledge concerns measurement of some kind: Latitude and longitude, acres and square feet, miles and kilometers, depth and thickness, populations and densities, elevations and altitudes. From man's very beginnings as an intelligent being, he has sought the best means for acquiring these measurements. The evolving history of collecting and recording these measurements cannot be given proper consideration in this short thesis. Rather, attention will be focused on one modern extension of data collection, the LANDSAT satellite remote sensing system, and its possible application to the practice of landscape architecture.

This basic question must now be asked: What is remote sensing? A basic answer: A process that allows man to

gather information on a subject from a distance through the use of mechanical or electronic instrumentation. A biologist studying bacteria colonies with a microscope is using remote sensing. A camera mounted in an airplane taking pictures of the Earth's surface is a remote sensing system. The giant telescopes at Mount Palomare are remote sensing devices for the study of outer space.

In his work as a professional designer, a landscape architect often has need for utilizing various methods of remote sensing to collect data, monitor activities and calculate measurements. Because of the unique features incorporated in LANDSAT--e.g., its multispectral scanner and its 18-day repetitive, sun-synchronous orbit pattern--its level of usefulness for collecting, monitoring and measuring physical resource and land use data may prove extremely useful for the discipline of landscape architecture.

This thesis will outline and illustrate the functions, limitations and applications of LANDSAT in land use/land cover studies and in site selection studies. Brief discussions of applications in other Earth disciplines will be presented. Examples of LANDSAT imagery and high-altitude photography will be presented to illustrate some of the practical functions of each and the differences between the two methods of remote sensing data collection.

The use of remote sensing techniques by landscape

architects and other physical designers will certainly increase in the future. The major objective of this thesis is to provide a basic understanding of how the LANDSAT system functions and of its application to physical design.

Chapter 1

Chapter 1: The LANDSAT System

The Purpose of the LANDSAT System--

It has become evident in recent years that many problems we face, such as pollution, drought and climatic changes, are of a global nature. "Satellites and other space vehicles are naturally suited to study such problems." (Short, et al, 1976). The Earth Resources Program, established by NASA in 1965, applies space technology to the study of these and other data collection problems. By acquiring information on a repetitive basis, Earth scientists and technologists can gain a better understanding of the causes of, and perhaps some of the solutions to, these problems. "The LANDSAT spacecraft represent the first step in merging space and remote sensing technologies into a system for inventorying and managing the Earth's resources." (McKelvey, 1976)

The purpose of LANDSAT is "to demonstrate the feasibility of systematic remote sensing from Earth orbit for resource and environmental monitoring." (Short, et al, 1976) To assist potential users in understanding and utilizing the LANDSAT products, NASA operates the Regional Applications Program, which is known as a technology-transfer operation. Its purpose is to conduct remote-sensing application projects for and in conjunction with government and private users. For Kansas, the RAP

center is located in Bay St. Louis, Mississippi.

"LANDSAT was designed so that its data would serve a large number of users within the United States and throughout the world. . . . [Imagery of the entire Earth's surface] is at everyone's fingertips; . . . the changing face of our planet, whether [induced] by natural forces or by man's often disruptive forces, is available for analysis on an 18-day cycle." (Williams and Carter, 1976) It will become increasingly necessary to continuously monitor the changes which occur on the landscape in order to wisely plan for the future allocation of natural resources and determination of land use areas. The availability of both natural resources and land area is constantly decreasing.

The LANDSAT system itself is a part of a larger system of Earth monitoring operations envisioned by NASA in the Earth Resources Survey Program. LANDSAT imagery provided a large overview at a small scale of the Earth's surface. Much basic information can be gleaned from the rather general data depicted in the imagery, leading to further detailed study of larger scale imagery collected by other remote sensing methods. Complementing the remote sensor data sources are such supplemental information as may be found on maps and through ground surveys.

It is with this in mind that NASA also provides a program of experimentation with and application of high-

altitude aerial photography to Earth resource studies. This imagery, at a larger, more detailed scale, is the next step in the remote sensing system for Earth studies. Further steps include low-altitude photography and ground surveys. LANDSAT is the first step in the system, and should be used accordingly.

The LANDSAT System--

To date, three satellites have been used in the LANDSAT program. LANDSAT 1 (originally named Earth Resources Technology Satellite--ERTS) was launched in July, 1972, and operated for almost six years before completely shutting down in January, 1978. LANDSAT 2 was launched in January, 1975, while LANDSAT 3 began its space career in March, 1978.

Each satellite orbits the Earth in such a manner that the entire surface of the Earth is covered once every 18 days, except for the polar areas which receive no coverage. With two satellites operating, total Earth coverage is achieved every nine days. The orbits are near polar (i.e.--near north/south) and are sun-synchronous (i.e.--designed to cross the equator at the same time of day, 9:30 a.m. on each southbound pass). This allows all imagery to be acquired between 9:30 and 10:00 a.m., facilitating comparison between orbits and seasons and taking advantage of the "intermediate to low sun elevation

[to] cause highlights and shadows that enhance subtle linear features, many of which represent faults and fracture zones." (Sabin, 1978) (See Figure 1.) LANDSAT 3 is equipped with a thermal sensor which allows night imagery to be acquired during the northbound orbit over the dark side of the Earth.

The remote sensing devices on LANDSAT "measure and record electromagnetic energy either reflected from or emitted by objects at or near the Earth's surface. The electromagnetic energy spectrum (EMS) includes gamma rays, x-rays, visible light, infrared, microwaves and others." (KARS, 1976) This sensing process is based on three concepts of physics (see Figure 3): 1) there is a source of radiation, the sun; 2) that radiation interacts with Earth surface features; and 3) that interaction can be detected. (Williams, 1978) Figure 4 shows the EMS, indicating which regions of the spectrum are detected by LANDSAT. Each satellite contains three methods of data acquisition: a multispectral scanner (MSS), a return beam vidiocon (RBV), and a data collection system (DCS).

The multispectral scanner (MSS) is an instrument which scans the surface of the Earth in a line perpendicular to the orbit path of the satellite, recording information in 79 by 79 meter (approximately 259 by 259 feet) ground resolution cells, also known as picture elements or "pixels". The scanline of pixels measures 185 kilometers (approximately

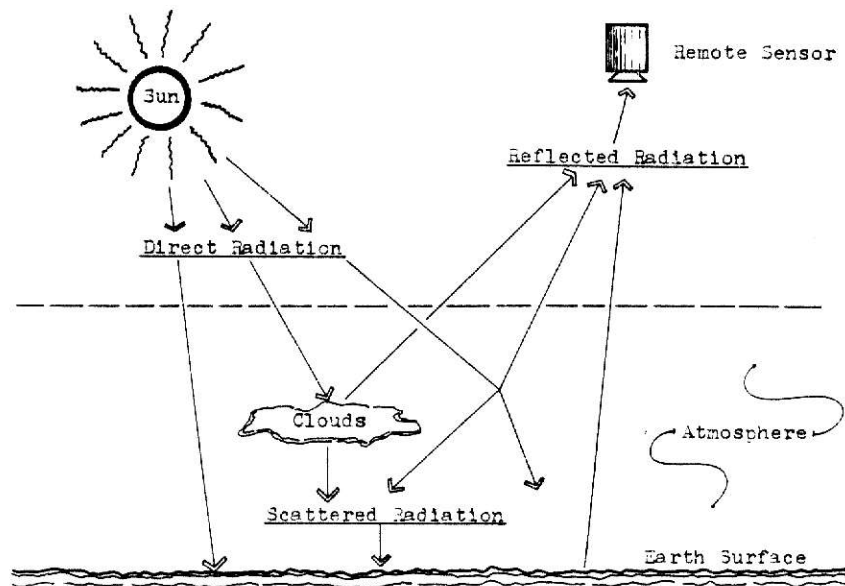


FIGURE 3: THE THREE CONCEPTS OF PHYSICS UPON WHICH THE REMOTE SENSING PROCESS IS BASED: 1) A SOURCE OF RADIATION - THE SUN, 2) INTERACTION OF RADIATION WITH EARTH FEATURES, AND 3) DETECTION OF THAT INTERACTION.

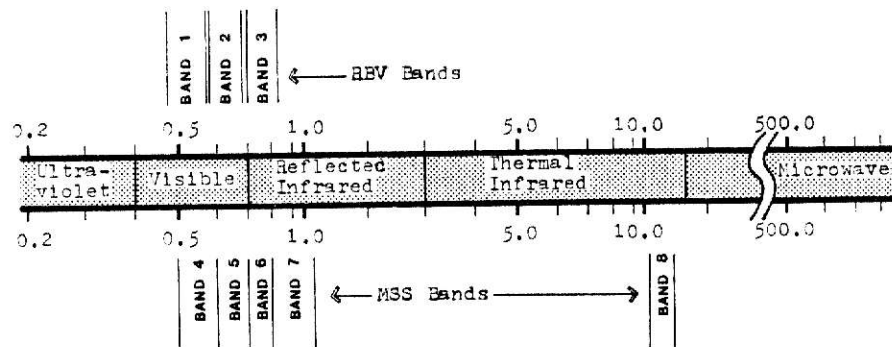


FIGURE 4: THE ELECTROMAGNETIC SPECTRUM (EMS). ILLUSTRATED IN THIS FIGURE ARE THE RANGES OF EACH LANDSAT BAND, INDICATING WHICH REGIONS OF THE EMS ARE DETECTED BY LANDSAT.

115 miles). "Data are acquired continuously along the orbit path and are transmitted to a ground receiving station for recording on magnetic tape. These tapes are processed to produce images . . . that cover a 185 by 185 kilometer area on the ground." (Sabin, 1978)

Within each pixel, the spectral reflectance values of each surface cover are averaged together to give one value for the entire pixel. Illustrated in sketch form in Figure 5a is a sample pixel centered over a portion of an interstate highway. The concrete pavement has a different reflectance value than the surrounding grass and trees. Figure 5b illustrates how the reflectance values may be averaged together by an MSS band. Because the multispectral scanner has four separate detecting and recording bands, it will produce four separate averages. Each band detects and records a separate narrow range of reflectance values, and records a separate narrow range of reflectance values, and the average reflectance value for each of the bands will be different. For example, in Bands 4 and 5, the reflectance value for pavement is more dominant than that for vegetation. Therefore, features such as major highways and major airport runways are more apparent in these two bands than they are in Bands 6 and 7, where pavement reflectance values are more similar to those for vegetation.

The reflectance value averaging which occurs in each

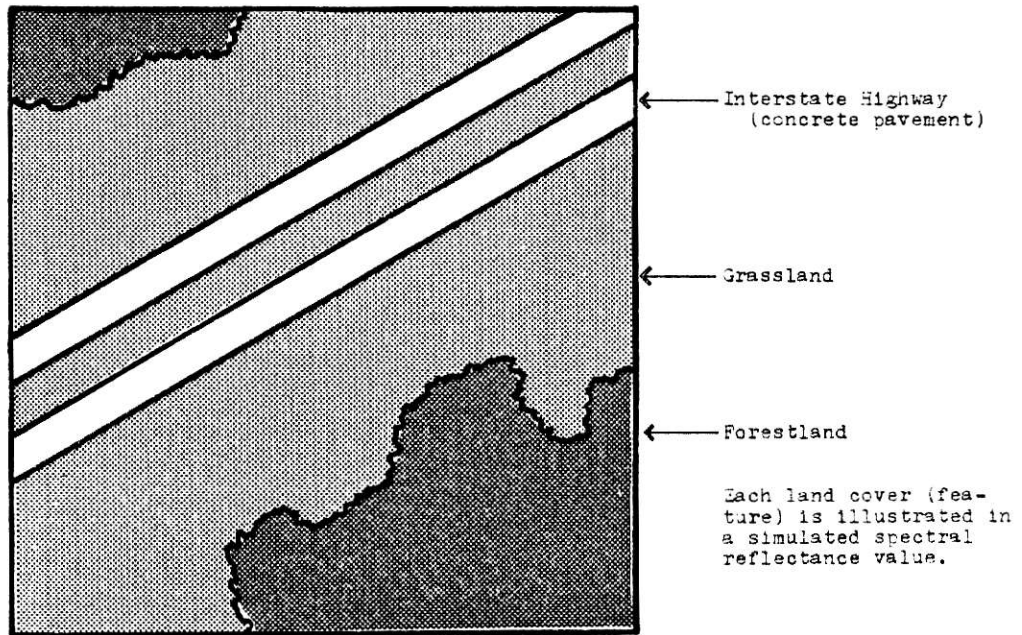


FIGURE 5A: A HYPOTHETICAL 79 METER BY 79 METER SQUARE OF THE EARTH'S SURFACE. EACH OF THE THREE SURFACE COVERS ILLUSTRATED HAS A UNIQUE REFLECTANCE VALUE.

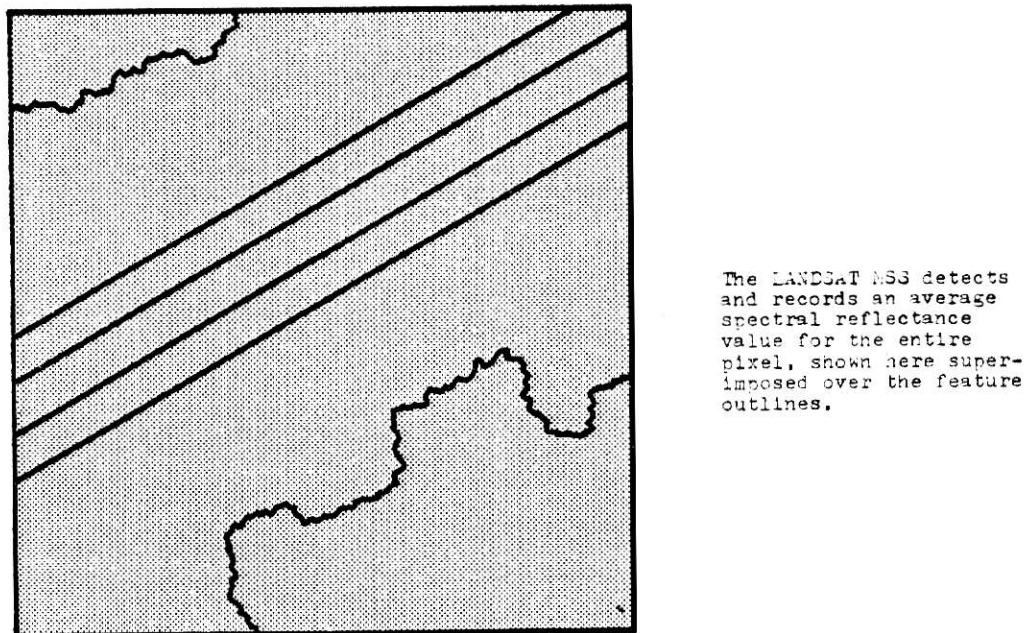
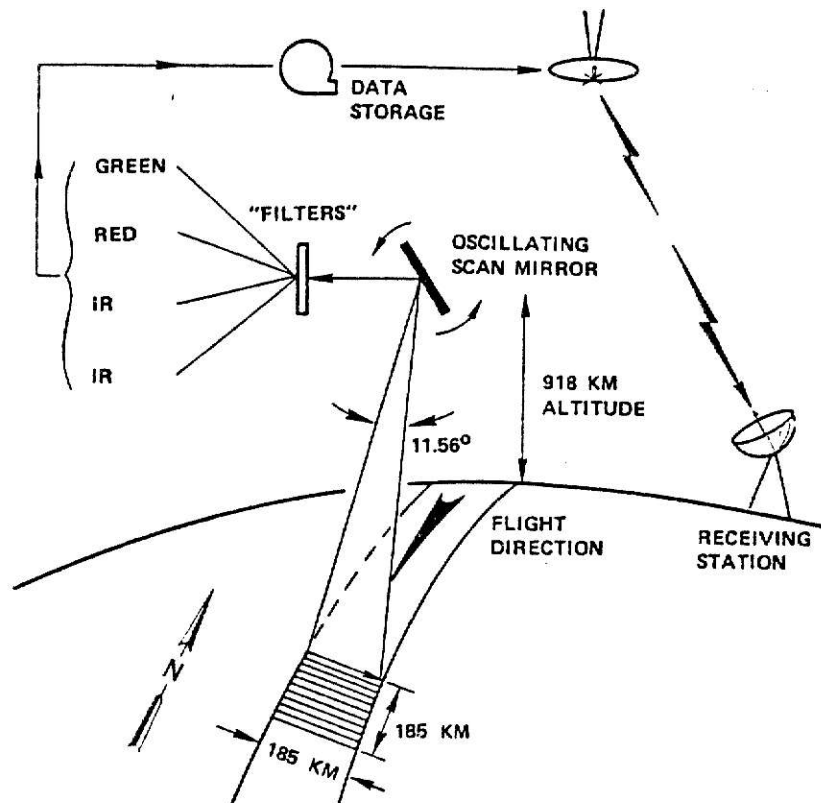


FIGURE 5B: THE SAME 79 METER BY 79 METER SQUARE AS IT HAS BEEN TRANSLATED BY LANDSAT INTO A SINGLE AVERAGE REFLECTANCE VALUE.

band is an important aspect of the LANDSAT system. It allows each band to emphasize certain land cover classes in the imagery over the surrounding landscape. Figure 7 is a graph representation of the reflectance values through a portion of the EMS for vegetation and soil. Notice that vegetation has a high level of reflectance above 0.8 μm , which is the band 7 range, while dipping down below the soil reflectance line between 0.6 and 0.7 μm , the band 5 range. This illustrates how band 7 and band 5 can be used to study vegetation and soil respectively. Of course, in all bands all of the surface features would appear. However, the narrow range of each band combined with the value averaging does allow some selectivity in resource study.

The multispectral scanner has been the primary sensor system of the program. Band 4 senses the green light energy in the 0.5 to 0.6 micrometer (μm) wavelength range. It "emphasizes sediment-laden water and delineates areas of shallow water such as shoals, reefs, etc., and is very sensitive to atmospheric haze." (Christenson, et al #75-5) Band 5, the red band, senses wavelengths in the 0.6 to 0.7 μm range, and emphasizes cultural features such as roads, airports, cities and town, military establishments, etc.

Band 6 is the first of two infrared bands, sensing wavelengths in the 0.7 to 0.8 μm range, while band 7, the second infrared band, senses wavelengths in the 0.8 to



page 9a

FIGURE 6: LANDSAT multispectral scanner. For each terrain scene, four images are transmitted to a receiving station. (From NASA, 1976, Figure 2-4.)

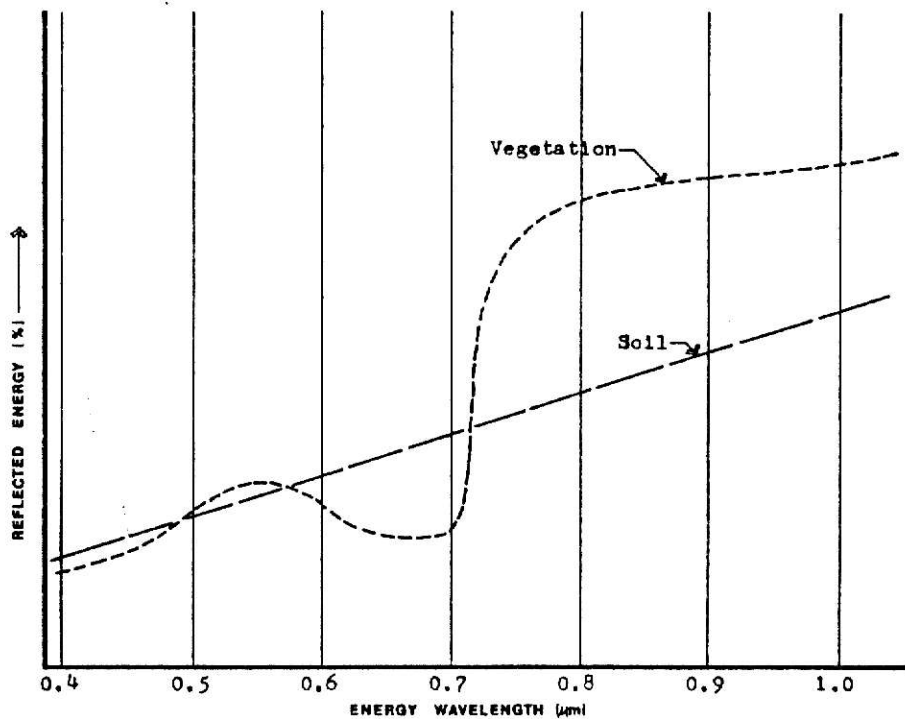


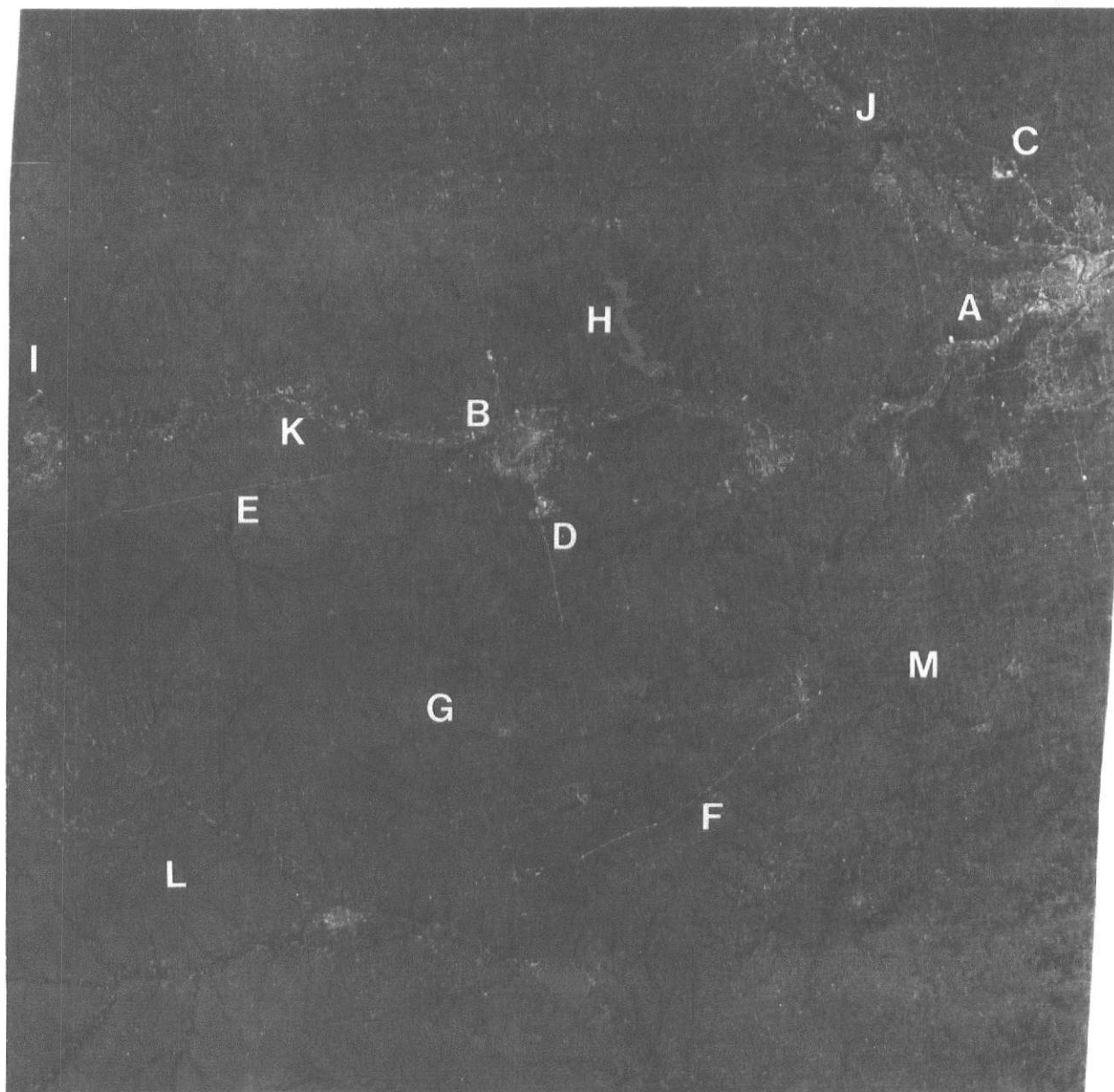
FIGURE 7: Graph representation of the reflectance values through a portion of the EMS for vegetation and soil.

1.1 μm range. (Refer to Figure 4 for a depiction of the band ranges.) Both bands 6 and 7 emphasize vegetation, the boundaries between land and water, and landforms, but band 7 penetrates atmospheric haze better than band 6, and is, therefore, more useful. (Christenson, et al, #75-5)

The data from the multispectral scanner can be presented in photographic form. When presented separately, each band appears in black-and-white. These are particularly useful in emphasizing scale and detail of individual land cover classes, as discussed above. However, two or more bands can be combined to form a color-composite image. Normally, bands 4, 5 and 7 simulate color-infrared photography. This presents a unique, "false-color" representation of the Earth's surface in which vegetation appears in shades of red and pink, pavement and urban areas in blue-gray to gray-white, water in light blue to black, and soil in white to tan to green-gray. These color-composites are well suited for viewing the over-all arrangement of cover features on the landscape.

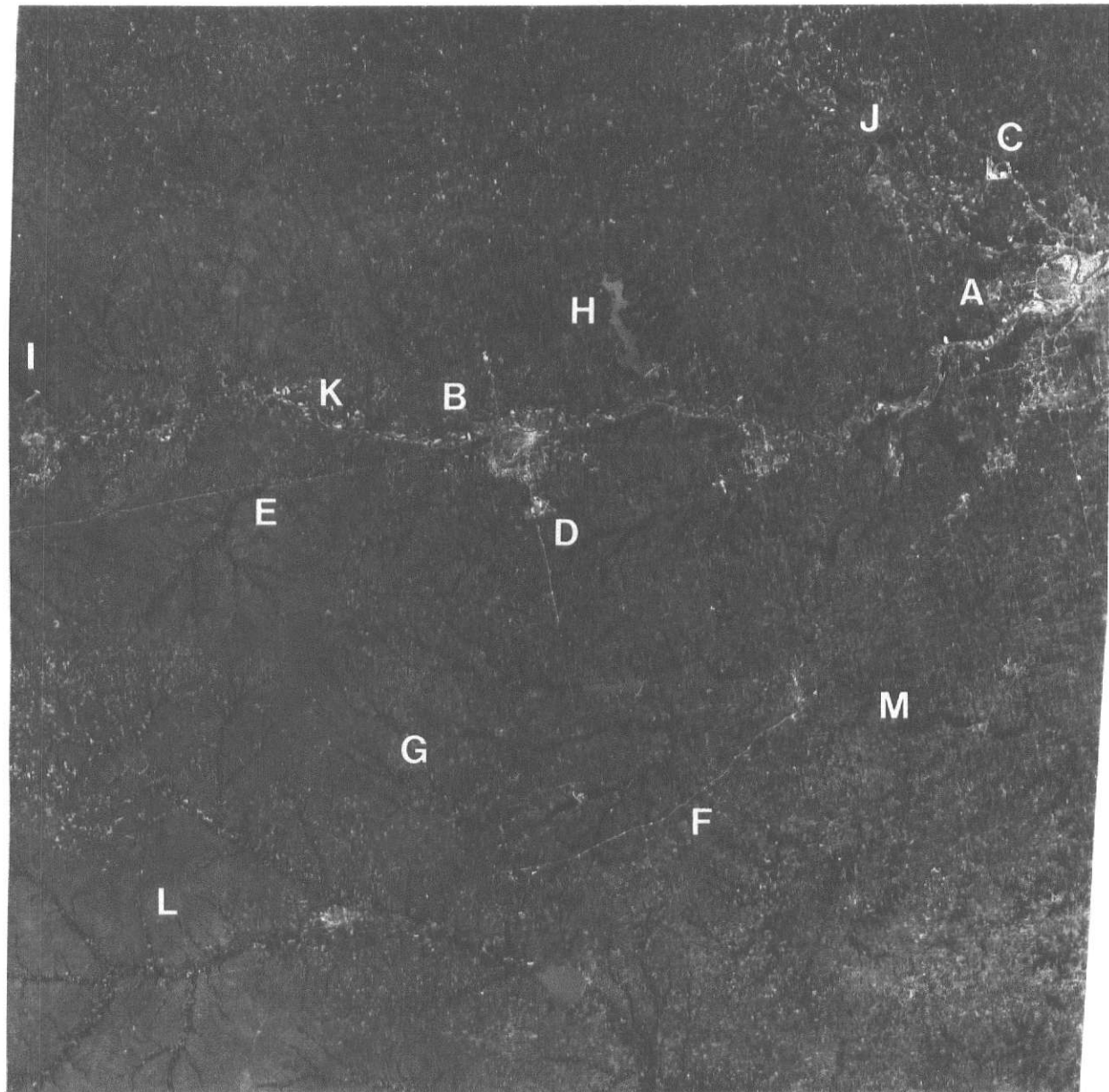
Plates 1 through 4 are reproductions of LANDSAT scene number 1399-16332, dated August 26, 1973, in bands 4, 5, 6 and 7 respectively. The scene is of Eastern Kansas, and the plates illustrate how different features appear in each band.

In both bands 4 and 5, urban land uses are quite



W096-301 26AUG73 C N38-53/W095-43 N N38-51/W095-33 MSS 4 W096-001 D SUN EL52 AZ131 N038-001 W095-30 190-5563-N-1-N-D-2L NASA ERTS E-1399-16332-4 01 W095-001
W096-301 W096-001 W095-301

PLATE 1
Eastcentral Kansas - Band 4
(1:1,000,000)
See discussion in text for explanation of labels.



26AUG73 C N38-53/W095-43 N N38-51/W095-33 MSS 5 D SUN EL52 AZ131 190-5563-N-1-N-D-2L NASA ERTS E-1399-16332-5 0

W096-301 W096-001 N038-001 W095-30 W095-001

W096-301 W096-001 W095-301

PLATE 2
Eastcentral Kansas - Band 5
(1:1,000,000)
See discussion in text for explanation of labels.

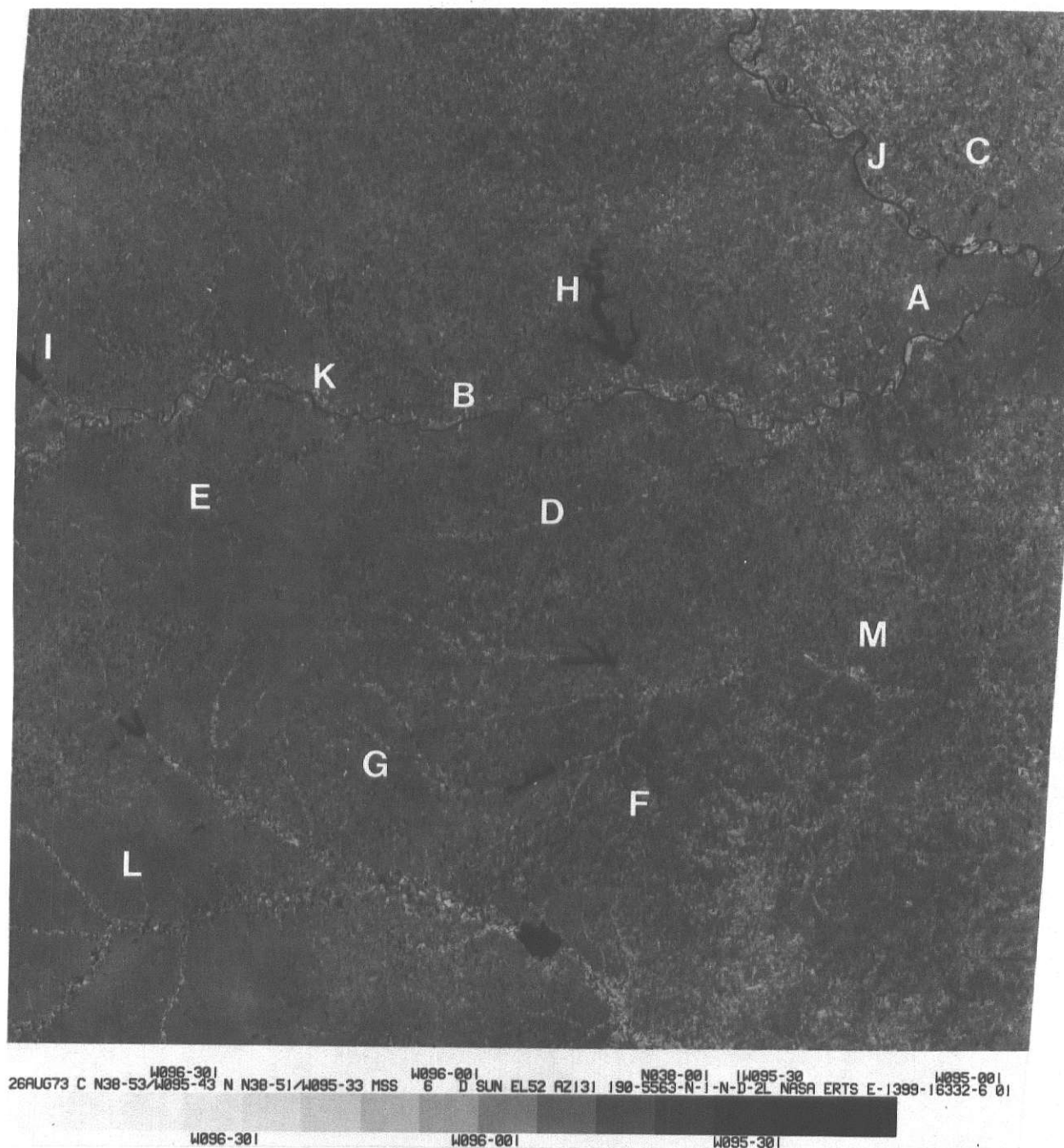
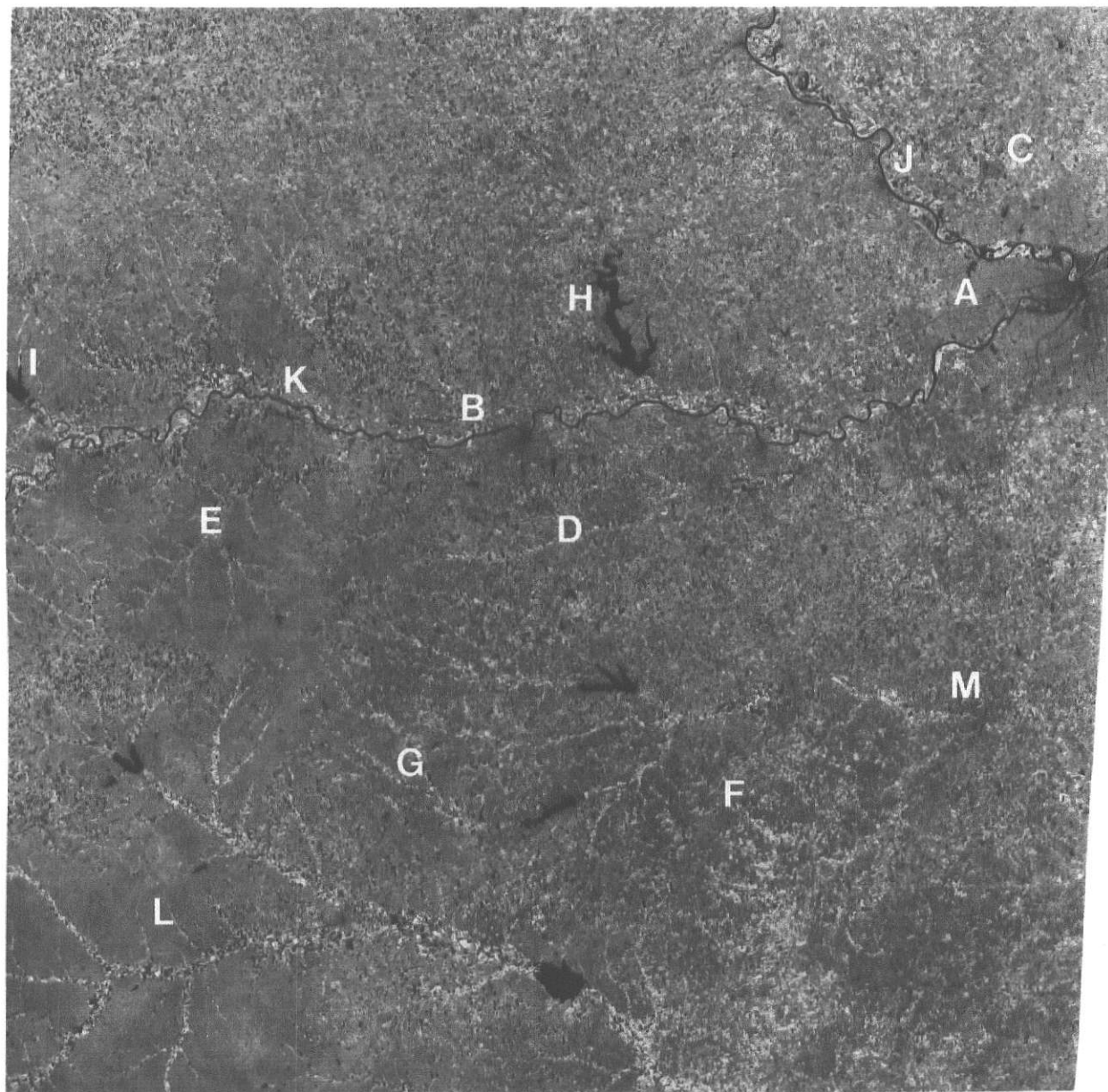


PLATE 3

Eastcentral Kansas - Band 6

(1:1,000,000)

See discussion in text for explanation of labels.



W096-301 W096-001 N038-001 W095-301 W095-001
26AUG73 C N38-53/W095-43 N N38-51/W095-33 MSS 7 D SUN EL52 AZ131 190-5563-N-1-N-D-1L NASA ERTS E-1399-16332-7 01
W096-301 W096-001 W095-301

PLATE 4

Eastcentral Kansas - Band 7

(1:1,000,000)

See discussion in text for explanation of labels.

distinctive as light areas on the dark background of surrounding vegetation. Particularly noticeable are Kansas City (A) and Topeka (B). But, in bands 6 and 7, these and other urban land areas are not nearly as distinct. Similarly, the large airports and major highways are easily visible in bands 4 and 5, but not in bands 6 and 7. Noted here are Kansas City International Airport (C), Forbes Field (D), Interstate 70 (E) and Interstate 35 (F). The Kansas Turnpike (G) does not show up as well as either I-70 or I-35 because it has a different pavement material--asphalt rather than concrete.

Conversely, water bodies are more readily apparent in bands 6 and 7 than in bands 4 and 5. Notice Perry Lake (H), Tuttle Creek Reservoir (I), the Missouri River (J) and the Kansas River (K). But some features can easily be seen in all bands; for instance, the Flint Hills prairie lands (L). And notice the different appearance of trees along rivers between bands 4 and 5, where they appear dark, and bands 6 and 7 where they appear light. Also notice that the section line grid pattern (M) is visible in bands 4 and 5 while not in bands 6 and 7.

Now compare these plates of bands 4 through 7 with Plate 5 in chapter 5. Plate 5 is a color-composite of the same scene formed by combining the special data from bands 4, 5 and 7. Not all features are as distinctive in the color-composite as they are in some of the

individual bands. However, the land cover pattern of the entire scene is more easy to distinguish.

In addition to these four bands, LANDSAT 3 has a thermal band (band 8) which senses wavelengths in the 10.4 to 12.6 μm range. A major difference in the operation of this band is that it senses energy which has been emitted by rather than reflected off the Earth's surface. Band 8 will be especially useful in crop stress studies and soil moisture studies. (Lintz and Simonett, 1976) Also, as mentioned earlier, this band will allow the acquisition of night imagery, proving particularly useful for studies of heat sources, such as power plants, cities, and industrial installations. The night imagery of band 8 will have applications in geology "because the thermal effects of differential solar heating and shadowing are greatly reduced" allowing the detail of bare soil and rock formations to become visible. (Sabin, 1978)

The return beam vidiocon (RBV) is similar to a television system. In both LANDSATs 1 and 2, it contains three bands: band 1 senses energy in the 0.475 to 0.575 μm range (blue-green); band 2 in the 0.580 to 0.680 μm range (green-yellow); and band 3 in the 0.698 to 0.830 μm range (red-infrared). Each band has spectral emphasis similar to the corresponding MSS band ranges. (Refer to Figure 4 for a depiction of band ranges in the EMS). In LANDSAT 1, the RBV generated some excellent quality

imagery, but was found to be using too much of the satellite's solar generated electricity, so it was shut down early in the operation of the satellite. The RBV of LANDSAT 2 worked quite well, but was still found to be inferior to the MSS in image quality and has not been utilized to the extent planned.

In LANDSAT 3, the RBV "consists of two identical cameras operating in the 0.5 to 0.75 μ m range with a ground resolution cell of 40 meters. The two cameras are aligned to view adjacent 98 kilometer square ground scenes with 14 kilometers of sidelap. This produces a scene pair which measures 98 kilometers in the orbit track direction by 182 kilometers in the across track direction. Two successive scene pairs will cover the area of each MSS scene." (Sabin, 1978)

The purpose of the RBV is to provide finer resolution imagery than the MSS--40 meter pixels versus 79 meter pixels. The RBV allows only panchromatic (black-and-white) images, though; no color is available. However, the expense of its operation and of the ground equipment necessary to receive its signal limits use of the RBV.

With the multispectral scanner, the imagery is acquired in a continuous strip as the satellite completes its orbit. The return beam videocon has a ten percent forward overlap. The side lap for both systems of one orbit to the orbits immediately east and west ranges

from "14 percent at the Equator to 85 percent at the 80° parallel of latitude." (Christenson, et al, #75-5) (See Figure 2.)

The data collection system (DCS) simply relays data collected by ground-based sensors through the satellite back to NASA receiving stations, which are located in Alaska, California and Maryland. Such environmental data may include water surface and sub-surface temperature, soil moisture content and stress, volcanic temperature, geologic stress, wind speed and other climatic data. Many countries, such as Italy, Brazil and Japan, are installing ground-based sensors and transmitting stations to relay this data through LANDSAT to the United States. In this way, both government agencies and private firms will have access to environmental information from these countries and will be able to help them develop and protect their resources.

LANDSAT Products--

The spectral data detected by the satellites is transmitted to Earth and stored in digital form on magnetic computer tapes. The data is then available for study in either of two forms: as a reproduction of the magnetic tape, called a computer-compatible tape (CCT), or as a photographic image, as illustrated and discussed earlier. In addition to the difference in form, there is also a

difference in method of use between the two forms.

The photographic images allow the interpreter to use gray tone value, texture, feature shape, location and (sometimes) color in the interpretation process. However, interpretation of the data on the CCTs by computer is based solely on the gray tone values detected by the sensor. Feature shape, texture, location and color are not considered by the computer in the interpretation process. Furthermore, the equipment and technique necessary to perform computer analysis of the data is both specialized and expensive. For the average user, the photographic imagery is much easier to use.

The CCTs contain digitized data for each value of gray for each pixel in each band. The MSS recognizes 256 separate values of gray in each of the four bands. With 5,484,964 pixels in each image, this represents over 5.6 billion bits of information available for each MSS scene. For each image, the gray values can be grouped by the computer into value levels determined by the programmer/scientist. The number of levels used varies depending upon the imagery involved. For example, level one may contain gray values 0 through 100, while level two may contain only values 101 through 150.

The levels will be displayed in one of four methods: 1) by line printer; 2) by cathode-ray tube terminal, similar to a television screen; 3) by line plotter, which

outlines each area of homogeneous gray value; or 4) by film plotter, which will produce a photographic image. (Eyton, 1979) Each method can be programmed to output products at various scales. For example, the line printer produces maps at 1:24,000 scale when printing eight lines per inch, with each symbol representing one pixel.

From the computer output display, a number of training fields will be selected from each gray value to cover all areas of the map. These training fields will be ground-checked to determine what type of land use/land cover is associated with each gray value level. Once consistent land uses/land covers are determined, test fields will be selected from the output display and assigned a land use/land cover classification according to their representative gray value. These test sites will then be re-checked in the field for accuracy of interpretation. If the level of accuracy is high, the remainder of the map can be assigned land use/land cover classifications.

One easy, inexpensive method of analysis of computer data can be accomplished with the line printer display. A sheet of glazed acetate can be placed over the output display and the gray values outlined and labeled. If the output display is at a scale of 1:24,000, this acetate can then be overlaid onto the corresponding USGS 1:24,000 7½ minute quadrangle map for comparison of the land use/

land cover areas with the topographic, physical and cultural features delineated on the map. (Westerlund, 1979; Odenyo and Pettry, 1977)

It must be noted that, when outlining areas on the acetate overlay of the output display, total accuracy is not achieved. Each pixel is assigned to one land use/land cover class even though it may contain several, as discussed earlier. Furthermore, the pixels are square, creating a grid form of map, while actual land use/land cover areas are usually irregularly shaped. Still, one might argue that these discrepancies are acceptable considering the ground area of each pixel is only 1.1 acres.

The photographic images from LANDSAT are produced by computer processing of the digitized data through a film plotter. These images can be either film negatives, film positives or paper prints, and are available in scales ranging from 1:3,369,000 to 1:250,000. Table 1 lists the available photographic products.

The EROS Data Center (Sioux Falls, South Dakota 57198) provides, as a free service, computer searches of a user specified area of all imagery available for that area to anyone ordering LANDSAT products. This will provide the user with a list indicating image scene ID numbers, dates of acquisition, percent of cloud cover, image center-point and corner-point coordinates and quality ratings. The user can select images which provide

the best information available for study. (KARS, 1976)

Several comments are pertinent concerning these listings. First, the cloud cover rating are subject to a $\pm 20\%$ range of accuracy. Also, they do not specify the nature of the cloud cover; whether it be many small, scattered clouds or one large cloud bank. Second, the quality ratings pertain not to the imagery itself, but to how well the individual MSS bands were operating at the time of acquisition. (KARS, 1976)

All LANDSAT products are available to the international public.

TABLE 1: LANDSAT Photographic Images*

<u>Image Size</u>	<u>Scale</u>	<u>Format</u>
Black-and-White		
2.2" (5.6 cm)	1:3,369,000	Film Positive
2.2" (5.6 cm)	1:3,369,000	Film Negative
7.3" (18.5 cm)	1:1,000,000	Film Positive
7.3" (18.5 cm)	1:1,000,000	Film Negative
7.3" (18.5 cm)	1:1,000,000	Paper Print
14.6" (37.0 cm)	1:500,000	Paper Print
29.2" (75.0 cm)	1:250,000	Paper Print
Color Composites		
7.3" (18.5 cm)	1:1,000,000	Film Positive
7.3" (18.5 cm)	1:1,000,000	Paper Print
14.6" (37.0 cm)	1:500,000	Paper Print
29.2" (75.0 cm)	1:250,000	Paper Print

*Adapted from: Sabin, 1976.

Chapter 2

Chapter 2: Land Use/Land Cover Mapping From LANDSAT Data

Land Use Mapping--

Land use planning is defined as planning for the allocation of activities upon land areas for the mutual benefit of the land and the population. This entails:

- 1) forecasting requirements or demands for goods and services;
- 2) estimating the supply of land available to produce these goods and services in terms of area, location, quality, suitability and capability; and
- 3) evaluating, implementing and monitoring alternative management and control strategies. (Crowley, 1975)

In the past, the problem of acquiring relevant data has been a major limiting factor in land use planning. Land use planning has been severely hampered by the lack of up-to-date maps delineating natural and man-made land patterns, and by the continual changes taking place in these patterns. (Short, et al, 1976) Remote sensing techniques can contribute to more effective data collection and mapping in land use planning, but only if the results of the information gathering techniques give complete coverage and reliable, timely data at an appropriate scale. (Driscoll, et al, 1978)

The LANDSAT system adequately fulfills the needs of planners for an accurate, cost-effective, repetitive and properly scaled data source capable of illustrating

at least the basic categories of land use/land cover. From LANDSAT imagery, "Man's use of the land can be deduced or inferred indirectly from the identity and distribution patterns of vegetation, surface materials and cultural features as interpreted from images or computer-processed displays." (Short, et al, 1976) And, since satellite remote sensing can cover a large area in a short time and can easily be repeated on a regular basis, changes in use and cover can be detected without costly resurvey procedures. (Short, et al, 1976; Anderson, 1976)

The United States Geological Survey recognized the need for a uniform land use/land cover classification system usable across the country. In 1976, they developed a system which can be used as a basis for land use/land cover mapping utilizing remote sensing data sources.

A Land Use and Land Cover Classification System for Use With Remote Sensor Data (Anderson, et al, 1976) defines four levels of classification based on different sensors:

- Level I --Satellite imagery with little supplemental information;
- Level II --High-altitude aircraft imagery combined with topographic maps;
- Level III--Medium-altitude aircraft imagery combined with topographic maps and substantial amounts of supplemental information;
- Level IV --Low-altitude aircraft imagery with most of the information derived from supplemental sources. (Anderson, et al, 1976)

(NOTE: Supplemental sources refers to existing USGS maps, soil survey maps, hydrology maps, on-site investigations, etc.)

Only Levels I and II were categorized in the system presented. These are sufficient for state-wide or regional land use mapping programs. The USGS decided to leave Levels III and IV (and any successive levels) open for manipulation by local planning authorities to fit their particular situations. (Anderson, et al, 1976) Table 2 lists the Level I and Level II classifications of the USGS scheme.

"The approach to land use classification being proposed by the USGS is resource oriented. In using remote sensor data as the main data base, a 'cover' approach to land use classification must be used rather than an 'activity' approach. Farming, grazing and forestry are activities; cropland, rangeland and forestland are cover categories." (Anderson, 1976) The remote sensor does not detect the actual activity occurring on the land; only its cover. "Activity" or "use" implies an objective or a reason why the land is being used as it is. "Cover" refers only to the lands physical characteristic. For example, an area of forest cover in a satellite image or aerial photograph does not indicate that a forestry operation is actually taking place. The land may be in forest cover simply because the soils are too poor for agricultural use or because the area is in a flood plain

**THIS BOOK
CONTAINS
NUMEROUS PAGES
THAT HAVE INK
SPLOTCHES IN THE
MIDDLE OF THE
TEXT. THIS IS AS
RECEIVED FROM
CUSTOMER.**

**THESE ARE THE
BEST IMAGES
AVAILABLE.**

TABLE 1: Land Use and Land Cover Classification System
For Use With Remote Sensor Data*

1. Urban or Built-up Land	11	Residential
	12	Commercial and Services
	13	Industrial
	14	Transportation, Communi- cations and Utilities
	15	Industrial and Commercial Complexes
	16	Mixed Urban or Built-up Land
	17	Other Urban or Built-up Land
2. Agricultural Land	21	Cropland and Pasture
	22	Orchards, Groves, Vineyards, Nurseries and Ornamental Horticultural Areas
	23	Confined Feeding Operations
	24	Other Agricultural Land
3. Rangeland	31	Herbaceous Rangeland
	32	Shrub and Brush Rangeland
	33	Mixed Rangeland
4. Forest Land	41	Deciduous Forest Land
	42	Evergreen Forest Land
	43	Mixed Forest Land
5. Water	51	Streams and Canals
	52	Lakes
	53	Reservoirs
	54	Bays and Estuaries
6. Wetland	61	Forested Wetland
	62	Non-forested Wetland
7. Barren Land	71	Dry Salt Flats
	72	Beaches
	73	Sandy Areas other than Beaches
	74	Bare Exposed Rock
	75	Transitional Areas
	76	Mixed Barren Land
8. Tundra	81	Shrub and Brush Tundra
	82	Herbaceous Tundra
	83	Bare Ground Tundra
	84	Wet Tundra
	85	Mixed Tundra
9. Perennial Snow or Ice	91	Perennial Snowfields
	92	Glaciers

*From USGS Professional Paper 964.

prohibiting urban development. The interpreter must realize that LANDSAT can only detect "land cover", not "land use".

Furthermore, "a distinction must be made between land classification and mapping. Defined classification units may not always coincide with mapping scales. In many cases, the pattern of land class units is too intricate to be shown accurately and clearly at a scale selected for mapping. Consequently, class units must be combined into a mapping complex and identified on a map, with its legend, as a mapping unit occurring as a complex. This mapping unit is then described in relation to the characteristics and proportion each unit of the complex contributes." (Driscoll, et al, 1978) An example is the manner in which cities are delineated on land use maps. Cities consist of varying areas and densities of residential use, commercial use, industrial use, transportation links, recreational use and other such categories. These individual land uses will not be distinct in most small scale imagery, and, hence, will be grouped together and mapped as one classification called "Urban".

Prior to beginning the interpretation of any imagery, a reconnaissance of the study area should be completed. There are three advantages to such reconnaissance: 1) it provides interpretation clues for possible problem areas; e.g., two land uses which may look similar in the imagery

but which are different; 2) it provides familiarization with types of land uses in the areas; and 3) it provides a base for field checking after interpretation.

Case Study Examples--

In 1972 and 1973, Vegas conducted an experiment with two goals: 1) "to determine the physical land use data that could be extracted from a single frame of [LANDSAT] imagery by using various scales and bands;" and 2) "to extract a maximum of data from the imagery by using sequential seasonal frames." (Vegas, 1974) His basic aim was to develop a procedure which would be within the talent, equipment and resource limitations of a local or regional planning office. (Vegas, 1974)

In the experiment, centered in Harrison County, Mississippi, bands 4, 5 and 7 were investigated at scales of 1:250,000; 1:120,000; 1:62,500; and 1:24,000. The 1:250,000 scale was investigated because it is a standard USGS scale generally used for regional analysis. The 1:120,000 scale was studied for comparison of the LANDSAT imagery with some high-altitude aerial photography previously acquired for the study area. The 1:62,500 and 1:24,000 scales were studied because both are standard USGS scales available for most of the United States. (Vegas, 1974)

Positive Chronaflex enlargements (transparencies)

were processed and viewed on a light table for interpretation of land use and land cover. The following results were noted:

1. At 1:250,000 scale, for the entire county--
 - a) Ten categories were discernible: urban, agriculture, forest, water, wetland, major transportation and utilities rights-of-way, specific agriculture, lakes, barren land and borrow pits.
 - b) The small scale makes the delineation and coding process difficult.
2. At 1:120,000 scale, for a single township--
 - a) Twelve categories were discernible: residential, commercial, industrial, major transportation and utilities rights-of-way, forestland, streams and waterways, bays and estuaries, open water, non-forested wetland, sand fill, sand beaches, and cleared or stripped areas.
 - b) The scale makes the delineation and coding process difficult.
 - c) The image was slightly blurry.
 - d) Detail in the LANDSAT imagery is not as good as in the high-altitude aircraft photography.
3. At 1:62,500 scale, for a single township--
 - a) The image was blurry.
 - b) Delineation was difficult because patterns of land uses were not recognizable due to the large scale and small area of the display.
4. At 1:24,000 scale--unuseable due to very blurry image.

Vegas determined the following considerations from his study:

1. For delineating land use of a single country or smaller area, aircraft photography is better

than LANDSAT imagery due to "clear definition of the subtlest variation between categories." (But Williams notes that all remote sensing systems can be used to map land use/land cover at all scales and for all areas, regardless of the size of the area. The difference between systems would be the level of data collected.) (Williams, 1979)

2. Viewing the same or different bands from two different dates of LANDSAT data in a stereoscopic viewer improved the interpretation for two reasons:
 - a) A false stereo effect was produced allowing some topographic relief to be seen. (The standard stereo effect is achieved by using two separate sensors spaced apart from each other and operating in unison. LANDSAT imagery can be used to achieve a "false" stereo effect due to different shapes and orientations of shadows in the imagery. This is also called a "solar" stereo effect.) (Miller, 1979)
 - b) "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 those areas to be noted and examined more closely."
3. Differences in accuracy of interpretability varied with the type of land use, ranging from 100% for both water and barren land to only 42.6% for urban/built-up land. (Vegas, 1974)

In a study of the Virginia Beach, Virginia, area, Odenyo and Pettry (1977) used digital analysis of LANDSAT computer-compatible tapes (CCTs) to create a land use/land cover map. The major objective of the study was (to determine the feasibility of producing an operational land use map by using the [computer] analysis approach." (Odenyo and Pettry, 1977)

The computer line printer output map was "overlayed with glazed acetate and the land use classes were delineated on the acetate." In large scale mapping, there is a problem with clearly delineating and coding many small, different areas of land use/land cover. In order to increase the legibility and clarity of the map in this study, no homogeneous land use/land cover areas of less than three contiguous pixels were outlined. The final map resulting from this process was quite accurate. Six of the nine Level I classes of the USGS classification system (see Table 2) are found in the Virginia Beach area. All six were definable in the imagery. Also, all six could be further classified into various finer levels. Table 3 lists the various levels and classifications defined in this study. (Odenyo and Pettry, 1977)

Computer Mapping--

In computer interpretation, "the classification is based solely upon similarity in spectral reflectance." (Odenyo and Pettry, 1977) It has been determined that similar land uses/land covers have similar spectral reflectances, which are different from the reflectances of other land uses/land covers. For example, concrete pavement has a different spectral reflectance than either healthy vegetation or water. These differences do vary between bands. The computer uses these spectral

TABLE 3: Legend of the Land Use/Land Cover Map Produced by
Machine Processing of LANDSAT-1 MSS Data*

<u>Map Symbols</u>	<u>Explanation</u>
Urban Areas	
Urm	Medium Density Single Family Residential with 15-22 Units per Hectare, (7-10 u/ac)
Uc	Extensively Paved Commercial Centers; includes Drive-in Theaters and large Warehouses
Url	Low Density Single-Family Residential with 4-14 Units per Hectare, (2-6 u/ac)
Agricultural Areas	
Aw	Areas in Transition From Wheat to Late No-till Soybeans
Ac	Corn Fields
As	Dense, Green and Leafy Early No-till Soybeans.
Ap	Pasture and Other Grass Land Areas; includes Golf Courses, Playing Fields and Some Lawns
Wooded Areas	
Fy	Young Forests, Mostly in recently abandoned Agricultural Lands, with Moderate to Sparse Undergrowth
Ft	Transitional Areas from Agricultural to Urban with Short Bushes and Tall Grasses
Fr	Old Residential Subdivisions in which Ornamental and Climax Vegetation almost Completely Cover the Houses and Streets
Water Areas	
Ws	Shallow Water Along Coastline, Submerged Shoal and Sandbars and Areas of Cloud Cover
Wr	River and Canal Water
Wb	Bay Water in Chesapeake Bay; including Lynnhaven Bay, Broad Bay and Little Creek
Ww	Waters of Back Bay with a Thick Growth of Weeds
Wc	Clear Non-ocean Water of Lakes, Inland Ponds and Some Parts of Back Bay
Wo	Atlantic Ocean Open Water
Wetland Areas	
Mp	Highly Branched, Moderately Tall Wetland Forest with Thick Undergrowth
Mf	Tall, Stemmy, Mature Hard Wood-pine Mixture with Thin Understory
Ms	Sea Shore State Park Vegetation Mixture

Table 3 (continued)

<u>Map Symbols</u>	<u>Explanation</u>
Mb	Short, Thick, Discontinuous Patches of Salt-Tolerant Bushes
Mn	Non-forested Wetland Areas Dominated by Various Salt Marsh Grasses
Bare Land Areas	
Bs	Highly Reflective Beaches and Other Excavated Areas Devoid of Vegetation
Bl	Partially Vegetated Lee-Wards of Beaches and Similar Inland Areas
Bm	Wet Mudflats and Tidal Flats Very Sparse in Vegetation
Other Areas	
Thr	Isolated Areas of Unique Land Uses Whose Characteristics are Dissimilar to All Others

*Odenyo and Pettry, 1977.

or tonal, variations to map land use/land cover.

When interpreting areal information from a photographic image, the human interpreter uses various clues to recognize the features in the image. These clues include the size of the feature, its shape, its location in the image, textures in the image, and gray tones or, when available, color. From this information he can identify the features in the landscape. (Eyton, 1979)

Because the computer recognizes only gray tone variations, it cannot make qualifying statements identifying the various tones with land uses/land covers. However, the computer is more accurate in recognizing the tonal variations. A human interpreter often allows the spectral reflectance of adjacent areas to influence

his classification of the immediate area of study.

The high speed of interpretation and the repetitive nature of LANDSAT coverage make temporal comparisons more efficient and faster with the computer. (Odenyo and Pettry, 1977)

Furthermore, areal measurement of existing or changing land uses are more feasible by computer line printer mapping. Each symbol represents one pixel, which equal 1.1 acres. All symbols (pixels) of similar tonal value can simply be counted and multiplied by 1.1 to determine the acreage of each land use/land cover. (Odenyo and Pettry, 1977)

Chapter 3

Chapter 3: Use of LANDSAT Data in the Site Selection and Analysis Process

The Site Process--

The selection and analysis of a specific site for a specific use is a phase of the design process with which a landscape architect is fully concerned. His training may not provide in depth expertise in all of the individual natural systems which make up the Earth's environment, but a landscape architect must be able to recognize and classify by priority of impact these systems as they influence site selection in relation to any proposed land use or development.

De Chiarra and Koppelman (1978) have outlined general factors (systems) a designer must study during the site selection process. These are:

- 1) soils;
- 2) vegetation;
- 3) hydrology;
- 4) climate;
- 5) topography;
- 6) aesthetics;
- 7) historical significance;
- 8) existing land use; and
- 9) physiographic obstructions.

Others have enumerated similar lists. (Simonds, 1961; Marsh, 1978; Lynch, 1962) "Each of these structural components [systems] represents areas of major environmental influence for most [land use/resource use] functions. The influence of each component naturally depends upon the type and intensity of the proposed function."

(De Chiarra and Koppelman, 1978) The soils and climate factors, for example, would probably exert more influence over agricultural land uses than they would over the siting of a residence, which may be more concerned with specific vegetative cover, aesthetics and nearby existing land use.

"It should also be emphasized that the type of information needed about each of the components depends upon the particular function being considered." (De Chiarra and Koppelman, 1978) For instance, the percolation capabilities of a soil type is of major concern in the location of a septic field, while for road construction, the compaction capabilities of the soil may be of major concern.

Lindgren (1979) notes that there are "three principle goals common to selecting the sites of most large facilities." These are:

- 1) to minimize the cost of developing the site;
- 2) to minimize disruption of natural and social environments; and
- 3) to minimize potential hazards or risks associated with the new facility.

By analyzing the presence and interrelationships of the various environmental components found on a particular site and allocating land use accordingly, these goals may be realized in the final design. "A seed of use wisely applied to a receptive site, should be allowed

to develop naturally, organically, in harmonious adaptation to juxtaposed functions and to its total environment." (Simonds, 1961)

Lindgren (1979) refers to Wobber and Martin in noting three stages of study in the site selection process:

- 1) regional examination to identify candidate areas;
- 2) identification of potential sites within candidate areas; and
- 3) selection of a single site.

In phase one, general land use patterns are delineated in order to determine their compatibility with the proposed operation or facility. Areas with resources necessary to the particular function may be noted for further study, while areas of conflicting land or resource use can be immediately excluded. An example of this phase would be locating forest areas for a timbering operation. Large area, small scale imagery such as LANDSAT data may well be used here. (Lindgren, 1979; Wobber and Martin, 1977)

Phase two concentrates on those areas previously noted for further study. More detailed information will be required on such factors as soils, slopes and geology, and the potential hazards of each. Information will also be required concerning the presence or absence of specific cultural features. This would include locating potential sites for specific operations such as a ski

resort or an industrial complex. Each instance has definite requirements. Here, larger scale photography, such as from high-altitude aircraft, will be necessary. (Lindgren, 1979; Wobber and Martin, 1977)

Phase three requires very detailed information which can usually be best acquired through ground surveys. This would include such data as from soil compaction and percolation tests, results of water quality tests, depth to bedrock, presence of endangered wildlife species, etc. The purpose of phase three is the selection of a specific site for a specific activity. (Lindgren, 1979; Wobber and Martin, 1977)

"Planners require different types of information during each stage and thus the utility of remote sensing varies according to the stage." (Lindgren, 1979) LANDSAT data is most useful in the initial phase of study to give a broad overview of the subject region. This illustrates the concept of a "remote sensing system", of which LANDSAT is but a part.

Case Study Example--

Peters (1976) discusses a project conducted by the Basin Electric Power Cooperative of Bismarck, North Dakota. The project involved locating a 345,000 volt transmission line route between Beulah, North Dakota, and Huron, South Dakota, a straight line distance of 275

miles. A two phase methodology was employed: Phase One identified alternative corridors and Phase Two identified line routes within the preferred corridor. The problem entailed selection of corridors that were the "least objectionable to the most people," and to select specific routes within the preferred corridor which proved to be the most environmentally acceptable. (Peters, 1976)

LANDSAT data was used in phase one of the study, identifying transmission line corridors. Because of the distance involved and the linear nature of the problem, large areas of land would be affected by the line, either directly, such as by clearing of vegetation, or indirectly, through aesthetics or electrical interference. Therefore, "vast amounts of data on land use and natural systems must be acquired and assimilated before potential corridors can be identified." (Peters, 1976)

There were two related objectives in the location of the corridors. The first was to be able to defend the choices of potential corridors by considering the total environmental system. "Without defensibility, later efforts to locate a route within the preferred corridor become essentially meaningless." (Peters, 1976) The second objective was to choose corridors compatible with existing land use patterns and values.

If the corridors chosen for detailed study do not comply with the limitations imposed by the various

environmental factors, then neither will the specific routes within these corridors. Furthermore, not only must the environmental limitations be met, the perceptions and values of the local population within the study area must also be considered. If the local economy, for instance, is agriculturally based, then agricultural land must be preserved above other land. Likewise, if the economy is forest resource based, then forest land must be preserved. (Peters, 1976)

Agriculture is the predominant land use in the Dakotas, which can readily be seen in the LANDSAT imagery. Therefore, corridors were located to "minimize impact on agricultural activities." (Peters, 1976) Efforts were made to separate agricultural land from non-agricultural land, and to locate the corridors on non-agricultural land whenever possible.

In this process of interpreting and separating land uses, five different spectral/temporal band combinations were studied for each LANDSAT imagery reference point used in the project. These combinations were:

- 1) early summer, band five;
- 2) early summer, band seven;
- 3) late summer, band five;
- 4) late summer, band seven; and
- 5) a color composite.

The images were enlarged from their original scale of 1:1,000,000 to a scale of 1:125,000 to match the county highway maps. (Peters, 1976)

For each LANDSAT image, the individual spectral/temporal combination which gave the sharpest separation of land uses was used as the main data source. This was usually the color composite. The other spectral/temporal combinations were subsequently studied to verify the primary image and to provide supplemental information where land uses may not have been apparent on the first imagery. (Peters, 1976)

Comparison between sensors and bands helped depict the various land uses. Peters reports that a 90% level of accuracy in the delineation process was achieved.

Comments--

Evans (1980) notes that LANDSAT imagery is not well suited to the site selection process because the type and amount of detailed information needed in such a study quickly surpasses that which LANDSAT is able to offer. Both Peters (1976) and Lindgren (1979) note that LANDSAT can be used in the very early stages, that of locating candidate areas. However, if the candidate area(s) is (are) already decided upon, such as locating a power plant to serve Topeka, then LANDSAT's usefulness has already been surpassed. In this respect, it appears to be too much to expect to be able to use LANDSAT imagery in a specific site selection study.

Chapter 4

Chapter 4: Other Applications of LANDSAT Data of Interest to Landscape Architects

The landscape architect must have a basic understanding of how the individual natural systems complement and accommodate each other in the total environment. (Simonds, 1961) This understanding is important in order to create a good, environmentally sound design solution to whatever problem with which the landscape architect is involved. "The landscape architect [should be] especially versed in the scientific fields of botany, geology, ecology and physiography as they apply to the total environment and life patterns." (ASLA, 1977)

The purpose of LANDSAT is to provide means to inventory and manage the Earth's resources. (McKelvey, 1976) This chapter will briefly review several applications of LANDSAT data to Earth studies. The results of these specialized applications may be of interest and use to landscape architects.

Agriculture, Forestry and Range Resources--

In these three disciplines, LANDSAT data have been used to monitor and inventory vegetation cover types and soils. Results of these applications have included: "crop species identifications with accuracies as high as 90%, highly accurate timber inventories, new and vastly improved soil and range classification maps and

detection of crop and timber diseases and infestations and changes in agricultural land uses." (Mercanti, 1977)

De Steiguer (1978) noted that, in forestry applications, "experiments have indicated that the greatest utility of MSS data is for the separation of forest from non-forest land on a regional basis." He further reported the attempts to distinguish species groups and areas of disease and other damage with visual interpretation of photographic imagery have not had positive results. However, "computer-aided analysis sometimes provides better results than conventional photo-interpretation of LANDSAT images. Scientists are able to classify MSS pixels into categories which may indicate tree species groupings and areas of disease or disturbance." (de Steiguer, 1978)

Williams and Haver (1976) report on a cooperative project of forest inventorying involving the NASA Information Transfer Laboratory (Intralab) and the Weyerhaeuser Company. The two major objectives of the project were:

- 1) to determine if LANDSAT data could "differentiate between pine stands, hardwood stands, pine-hardwood mixtures and clear-cut areas accurately enough to obtain reliable acreage estimates," and 2) to determine if LANDSAT data could further differentiate these general categories "into various sub-categories related to age, vigor, stand density or other stand characteristics based upon differing spectral reflectance." (Williams and

Haver, 1976)

Using computer processed data from August, 1973, and February, 1974, they found:

1. separation of hardwood and pine can be achieved with winter data and separation of the general pine category into sub-categories based on canopy closure could be accomplished with summer data; and
2. detection of cover change from forest to clear-cut or fire-burned could easily be accomplished with temporal studies; i.e., comparing a winter scene with the previous summer scene. (Williams and Haver, 1976)

In a study using visual interpretation of band 5 and band 7 MSS imagery, Morain and Williams (1975) found that areas planted in wheat in ten counties across Southwest Kansas could be accurately estimated. The LANDSAT-derived estimates were within 5% of the official United States Department of Agriculture's Statistical Reporting Service (USDA/SRS) harvested area figures, which were published in February, 1974, for the 1973 wheat crop. They were within 0.4% of the USDA/SRS August, 1973, area estimates. What makes this so significant is that the LANDSAT data used was acquired in March, 1973, five months prior to the USDA/SRS August figures. This five month difference is especially useful for short-term planning of agricultural production and marketing strategies. (Morain and Williams, 1975; Bauer, et al, 1978)

Morain and Williams do note, however, that this type of study is most accurate in "areas characterized by large fields and relatively simple cropping patterns. Regions

having a large number of crops grown in small, irregularly shaped fields will certainly not be as easy to evaluate." (Morain and Williams, 1975)

Westin (1973) describes a project by the Remote Sensing Institute of South Dakota State University to map soil association boundaries in South Dakota from LANDSAT imagery. Because soil profiles cannot be interpreted from satellite imagery and because they are often associated with vegetation types, vegetation patterns appearing in the imagery were the main interpretation key in the soil mapping project. Also included as interpretation keys were size of field, percentage of cover in pasture or rangeland, and local climate, especially temperature and precipitation. It was found that general soil association boundaries could be delineated from these factors. (Westin, 1973)

Baumgardner, Henderson, et al, (1973) found similar results when using computer analysis of LANDSAT for areas of Kansas and Texas. Soil association boundaries could be mapped and the results were comparable to conventional soil survey maps. (Baumgardner, Henderson, et al, 1973)

Geology--

Imagery from LANDSAT has been used extensively in the discipline of geology. Applications include: geologic structure mapping; mineral exploration; fossil and nuclear

fuel exploration; geochemical mapping; environmental monitoring of mineral related industries; and mapping of landforms and hazards. (Mercanti, 1977)

Using multi-seasonal LANDSAT imagery, Rabchevsky, et al, (1979) were able to map geomorphic provinces in the region of central and western Maryland, northern Virginia, parts of West Virginia and southcentral Pennsylvania. The seasonal change in the direction of sunlight on the Earth's surface provides variances in the spectral reflectance from surface covers, emphasizing major features in the imagery. Longer shadows in the winter enhance topographic features, while summer illumination makes both lithological and soil boundaries more apparent. (Rabchevsky, et al, 1979)

As part of their project, Rabchevsky, et al, produced transparent overlays from existing maps containing geomorphology, drainage systems, cultural features, vegetation, etc., to overlay the LANDSAT generated map. The comparison of these overlays with the LANDSAT imagery facilitated interpretation of the imagery and allowed for quick and easy revision of the existing maps from which the overlays were generated. (Rabchevsky, et al, 1979)

"LANDSAT imagery is definitely useful for regional geologic reconnaissance, provided the user is familiar with the subject matter, the LANDSAT system, and the imagery specifications. Field verification of interpreted results is definitely an integral part of the imagery

interpretation task." (Rabchevsky, et al, 1979)

Pertaining to the exploration for mineral resources, Smith (1977) notes "many ores are associated with fractures of fault systems, anomalies in topography, or coloration of surface rock, and that such guides are often distinguishable by [LANDSAT]." Because of LANDSAT's broad, regional coverage, surface indications of possible mineralization are often easier to define. Such indicators include: topography, igneous and other volcanic features, lineaments and geologic structure, mineralogical-lithological associations and stratigraphic sequence. (Smith, 1977)

Water Resources--

The need for water resource information has changed greatly since the early part of the twentieth century. Previously, knowing the availability and location of water sources was sufficient. With the extensive increases in the demand for water supplies in recent decades, allocation of the precious resource is rapidly reaching critical proportions. Hydrologists are continually analyzing water availability for proposed reservoirs, metropolitan water supply systems, agricultural irrigation systems and other needs. Predictions of flood occurrence, flood peak levels, quality of water, levels of sedimentation and siltation, etc., are also of major concern to the hydrologist. (Skibitzke, 1976)

LANDSAT has become a valuable aid in the information-gathering process for the study of the natural hydrological system. "The perspective gained by satellite remote sensing adds a real dimension to conventional hydrologic data collected at point stations. The two data sources combine to provide synoptic information on drainage basin characteristics, hydrologic controls, vegetative indicators of hydrologic conditions, hydrodynamics, lake processes and distribution of snow and ice." (Mercanti, 1977)

In 1974, the Wisconsin Department of Natural Resources undertook a project to "investigate the feasibility of using satellite imagery to monitor the water quality of inland lakes." (Scarpace, et al, 1979) Using the digital data from the LANDSAT computer-compatible tapes, they studied lakes above eight hectares (19.768 acres) in size, analyzing depth of the lakes, turbidity and trophic status. Their study led to three major conclusions:

- 1) the LANDSAT MSS is capable of monitoring lake trophic conditions;
- 2) multitemporal satellite data is necessary; and
- 3) corrections must be made for atmospheric effects on the data.

They also found the study to be very cost-effective.

Estimated costs were \$13,000 to \$14,000, including the CCT costs, the computer time costs and the computer operator salaries. Not included in this estimate were the WDNR personnel salaries for approximately twelve months.

(Scarpace, et al, 1979)

White (1978) noted that "a critical need exists for adequate mapping of [reservoirs] on a regular basis in order to determine their location and quality as sources of potable water." The goal of White's study was to develop a technique to accurately measure the surface area of reservoirs which would correlate surface area measurements with reservoir volume and match within $\pm 10\%$ the volume estimates published by the U.S. Army Corps of Engineers and the U.S. Geologic Survey. (White, 1978)

White found that using an electronic digital planimeter in combination with LANDSAT imagery of 1:500,000 and 1:250,000 scales provided results within the stated accuracy range of $\pm 10\%$. When the planimeter was used with 1:1,000,000 scale imagery, the results were close to this range. He also tested a dot grid measurement method, with 64 dots per square inch, finding it to be within the stated $\pm 10\%$ range at 1:250,000 scale and close to the range at 1:500,000 scale. Results are noted below:

Planimeter	at	1:1,000,000	+12%	of	USACE/USGS
"	"	1:500,000	+7.3%	"	"
"	"	1:250,000	+9.6%	"	"
Dot Grid	"	1:500,000	-13%	"	"
"	"	1:250,000	+8.2%	"	"

(White, 1978)

Barnes, Bowley and Simmes (1973) conducted a study to map snow cover in Arizona and in California using LANDSAT data. They found that both MSS-4 and MSS-5 bands show

great contrast between snow covered and snow free areas, but that MSS-5 is more useful because it penetrates atmospheric haze better. Snow cover can be differentiated from clouds with little difficulty because: the configurations are very different, the snow boundaries are sharper, snow texture is more uniform and terrestrial features define both snow covered and snow free areas. (Barnes, et al, 1973)

They concluded that, in mapping snow cover, LANDSAT is more accurate than an observer mapping from an aircraft, but not as accurate as high-altitude aerial photography. Because of its fairly accurate nature, the method of mapping snow cover from LANDSAT appears to be cost-effective and worthwhile. They did indicate that a more frequent cycle of coverage may be helpful, due to the effects of excessive snow melt or snow accumulation within the eighteen day LANDSAT cycle and the possibility of cloud cover on the day of LANDSAT coverage. (Barnes, et al, 1973)

Environmental Studies--

Increased public concern over environmental issues has led to the establishment of governmental regulations requiring the inventorying and monitoring of environmental conditions. Because of the repetitive nature of coverage and the multispectral qualities of the imagery, LANDSAT can be a great aid in inventorying and monitoring environmental conditions and disruptions. (Mealor, 1979) Types

of studies in which LANDSAT imagery have aided investigations include water and air pollution detection and monitoring, water and vegetation classification, wildlife habitat and stripmine monitoring and climatic studies.

The Maryland State Geological Survey conducted an experimental project to develop a rapid and inexpensive manner to provide "accurate information on the location, size and condition of areas affected by surface mining."

(Anderson, et al, 1977) Results of the experiment indicated:

- 1) locations of mines were easy to distinguish and map;
- 2) area measurements were determined to be 92% accurate for small mines (less than 100 acres) when compared with low-level aerial photography and 97% accurate for large mines (greater than 100 acres); and
- 3) conditions of the mines could generally be determined whether they were active, partially revegetated or mostly revegetated.

The repetitive nature of the LANDSAT coverage is very helpful "for effective enforcement of state [and federal] mining and environmental regulations," especially "when used in conjunction with aircraft photography and field verification inspections." (Anderson, et al, 1977)

Williamson and Gilbertson (1973) conducted a study to "determine whether [LANDSAT] imagery could be used to identify natural features threatened by [the construction of a freeway through Knysna area of South Africa], and to provide a quantitative estimate of the likely extent of damage to the indigenous montane forest."

They found that:

- 1) the freeway would cross four estaurine ecosystems, possibly causing siltation damage;
- 2) the freeway would pass through two areas of indigenous forest, destroying part of the forest; and
- 3) the freeway would traverse areas of vegetated coastal dunes, possibly causing subsidence and wind and water erosion.

These findings, including the estimated areal extents, were compared with official estimates of areas and extents of damage to the environment and were found to be very accurate. The official estimates were said to have taken four years to produce, while the estimates based on LANDSAT imagery required only a few weeks. (Williamson and Gilbertson, 1973)

Summary--

These detailed areas of study and sample projects have been briefly described as they may prove useful to landscape architects in applying LANDSAT imagery to the site analysis/design process. While most landscape architects may not be directly involved in such specialized projects, they should at least have an appreciation and basic knowledge of various Earth resource disciplines. In order to plan for the most efficient use of a particular site or resource, one must have a basic understanding of the total environmental system. LANDSAT, with its broad coverage and repetitive cycle, can help one gain such understanding.

Chapter 5

Chapter 5: Case Studies

In this chapter, three land use/land cover maps will be presented. One is of eastcentral Kansas, from Manhattan to Kansas City, interpreted from 1:1,000,000 scale LANDSAT imagery. The second is of Topeka and part of Shawnee County, interpreted from the same LANDSAT image enlarged to 1:125,000 scale. The third is also of Topeka and part of Shawnee County, interpreted from high-altitude aircraft photography at a scale of 1:125,000. The interpretation and mapping processes of each will be discussed and a comparison of the final products and processes will be made.

Following this, a hypothetical site selection study will be conducted in the southwest Shawnee County area, locating sites for a proposed large-scale residential development. The 1:125,000 scale enlargement of the LANDSAT image will be used as the main data source.

Eastcentral Kansas--

From the color-composite of LANDSAT image 1399-16332, dated August 26, 1973, six of the nine USGS Level I categories could be distinguished. (See Plate 5.) These were: urban and built-up land, agricultural land, rangeland, forestland, water and barren land. The imagery and resulting map are both at the scale of 1:1,000,000. Some

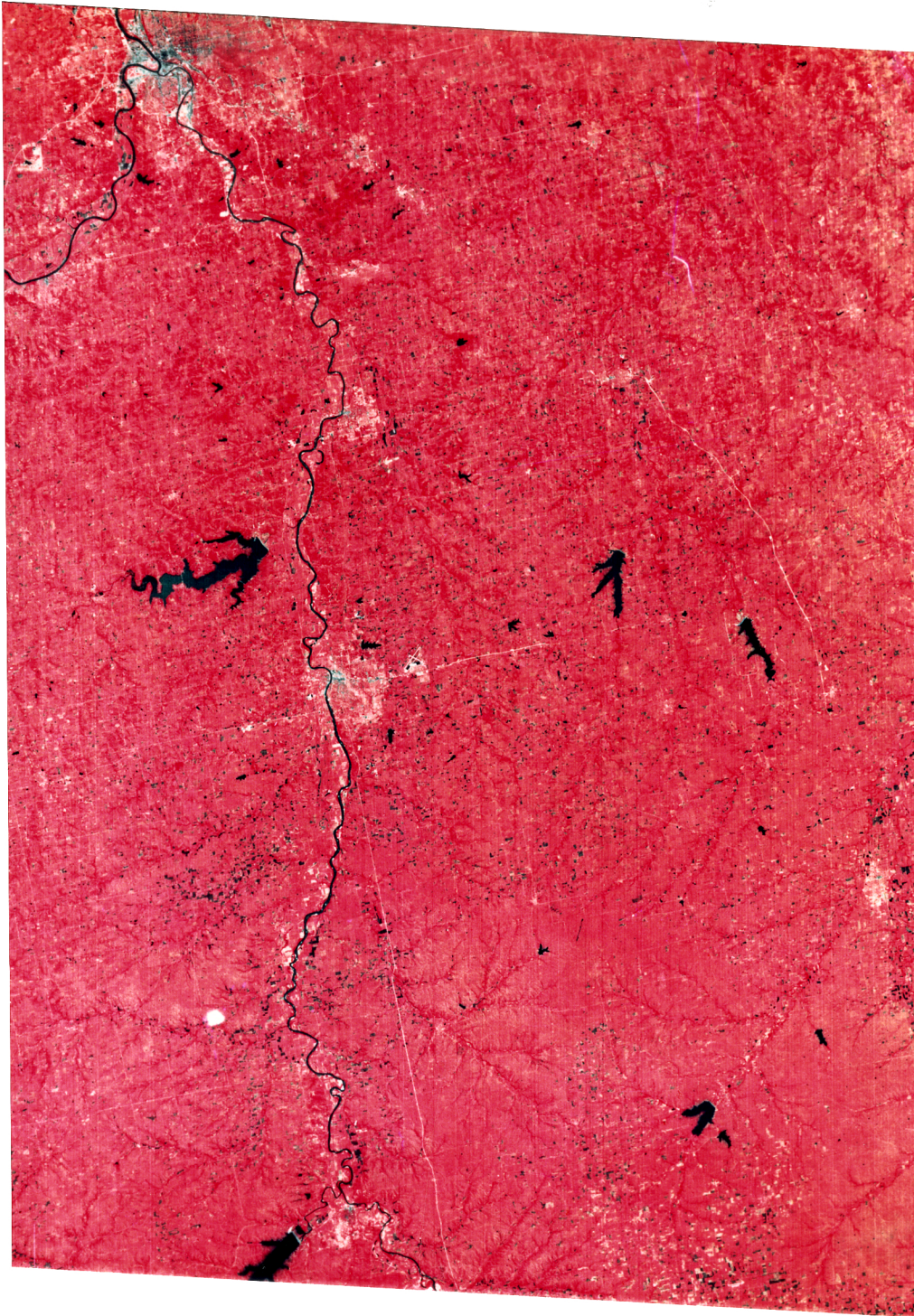
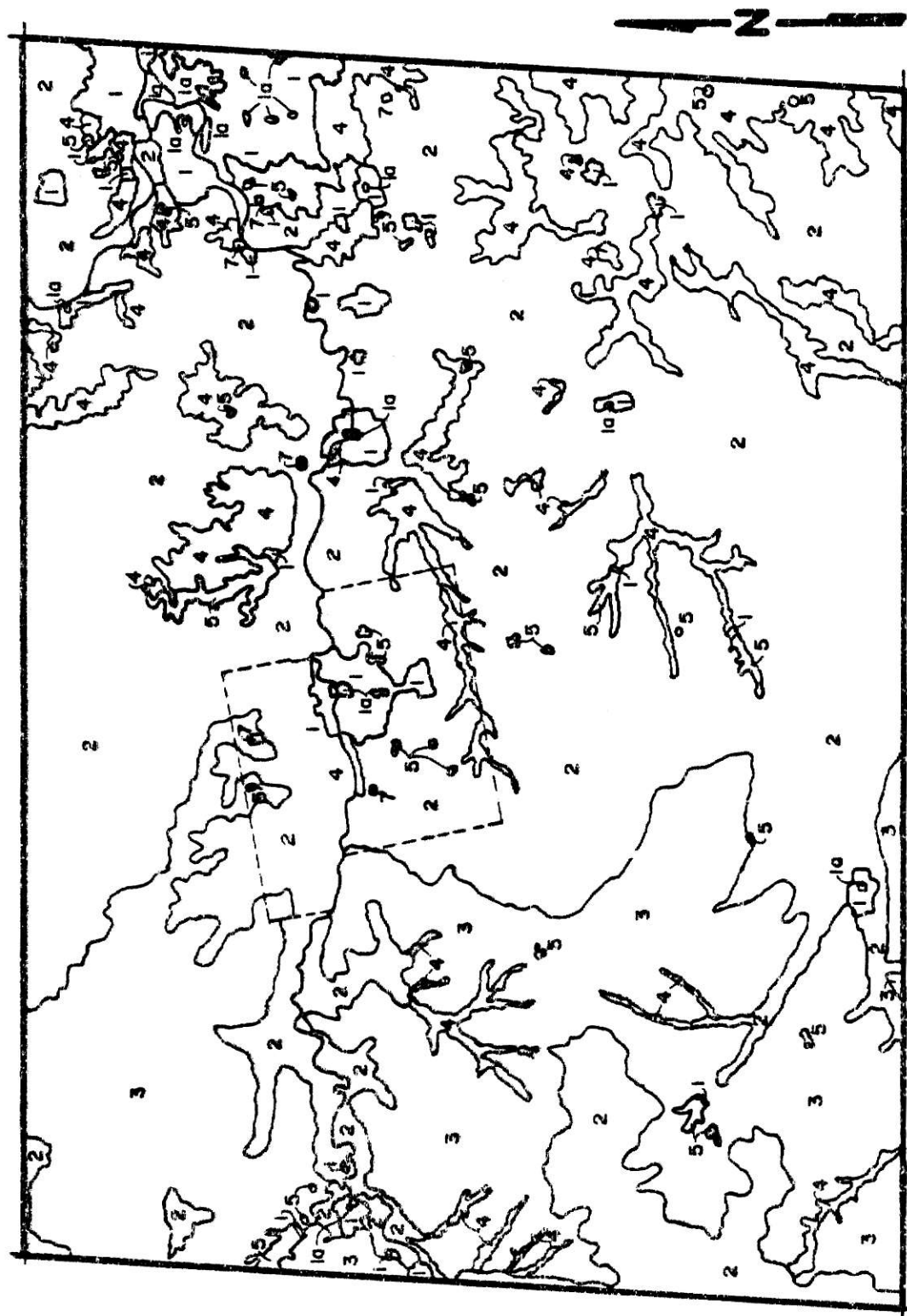


PLATE 5
LANDSAT Image of Eastcentral Kansas--1:1,000,000



Map 1. LANDSAT (1:1,000,000)

LEGEND: Map 1--LANDSAT (1:1,000,000)

<u>Number</u>	<u>Description</u>
1	Urban or Built-up
1a	Heavy Urban or Built-up
2	Agriculture
3	Rangeland
4	Forestland
5	Water
7	Barren Land

of the Level II categories were distinguishable. However, mapping these second level categories was hindered by the small scale. (See Map 1.)

For instance, in most of the urban areas, the concentrations of industrial and commercial activities appear as blue-green-gray coloration. For both Kansas City and Topeka, mapping these business districts was possible because they cover extensive areas. For the smaller urban places, the commercial-industrial complexes occupy less area, making them less easy to distinguish and to outline on the map. Therefore, the accuracy of these mapped areas is limited.

Generally, the urban and built-up areas were delineated by noting the blue-green-gray areas and including the white or pinkish-tan surrounding areas in the outline. Several exceptions to this do appear. Kansas City International Airport, Forbes Field, the Sunflower Army Ammunition Plant and the large reservoir dams are included in this category. Most of the small cities and large towns, e.g., Holton, Alma, Osage City, etc., were distinguishable only upon comparison of the imagery with a Kansas road map.

Forestland was delineated by outlining the area of dark red coloration. In infrared photography, the dark red color is associated with healthy, growing vegetation, which, in August in Kansas, applies to woodlands in full

foliage. Where the dark red color was mottled with lighter reds and pinks, an attempt was made to separate forest-land from other categories by outlining those areas composed of mostly dark red.

Rangeland in Kansas is generally associated with grass and scrubland. In the imagery, these areas appear as light red to pink to pinkish tan coloration characterized by a lack of a section-line road grid. Within these areas, the drainage pattern can be recognized.

Water stands out quite boldly as the dark blue-black color. The large reservoirs and lakes can readily be outlined on the map. Small lakes and large ponds are visible in the imagery. However, outlining them was very difficult due to the small scale. In addition, not all of the small, dark spots in the imagery are bodies of water. Rather, many are fields of bare ground, which show up in a dark gray-green to black coloration. Therefore, no attempt was made to map all of the small water bodies. Shape of the water bodies can also be an interpretation clue. Because the lake and reservoir shore lines follow contour lines and generally point up the river valleys, the resulting shapes lend an identity to the lakes and reservoirs. The Missouri, Kansas and Big Blue Rivers are shown linearly on the map.

Only a few small areas of barren land were mapped. In the imagery, they appear in white. Not all of these

have been confirmed as barren. Some are known to be quarries or landfills. Others have been included in this category without being positively identified.

All other areas not identified in any of the above categories were included in the agricultural land classification. The outstanding characteristic of this land is the section-line road grid pattern apparent in the imagery.

The Southwest Topeka Metropolitan Area (LANDSAT)--

A land use/land cover map of the Topeka area was produced using the same LANDSAT image number 1399-16332, now enlarged to a scale of approximately 1:125,000.

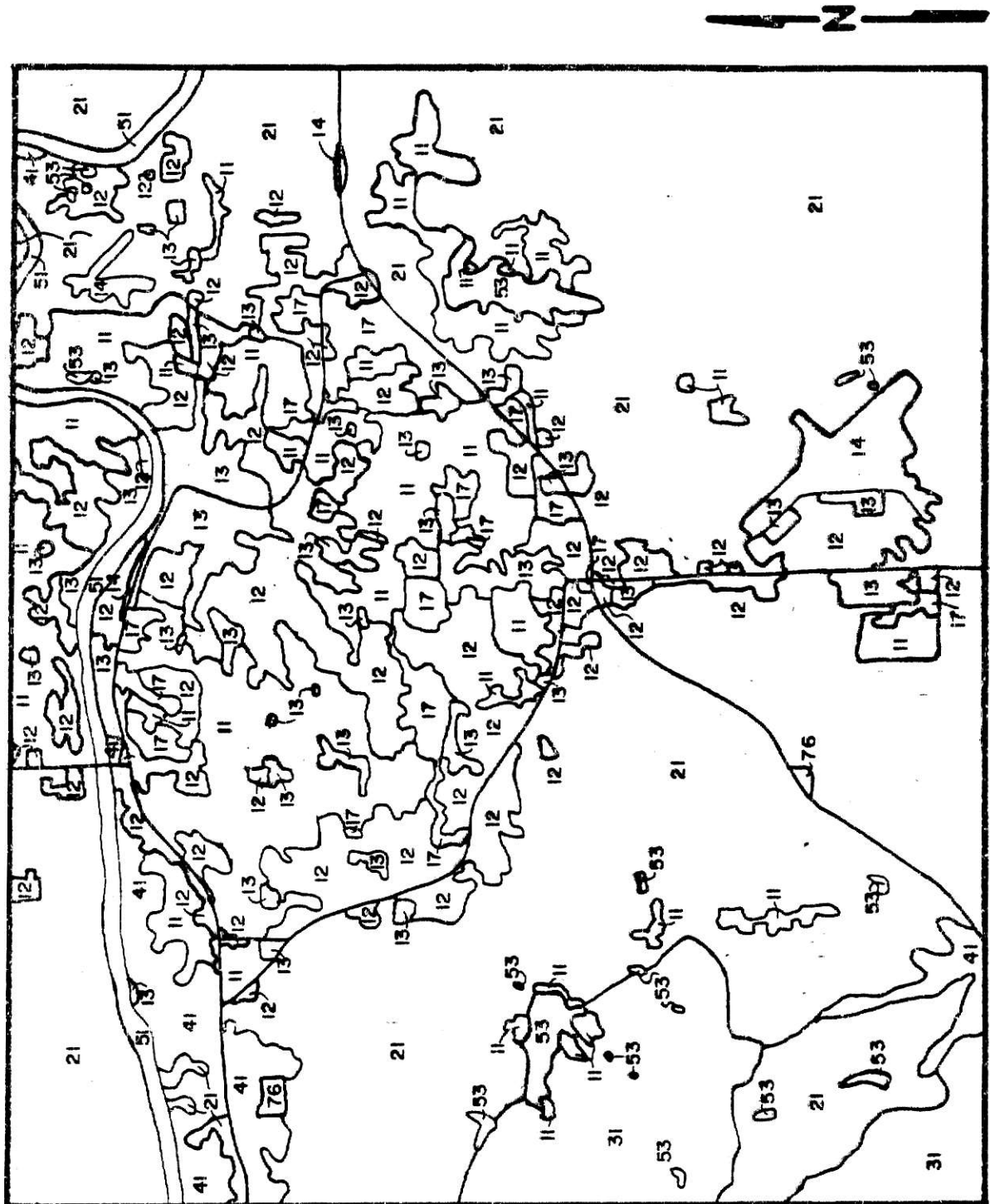
(See Plate 6 and Map 2.) From this enlargement, urban land patterns of the USGS Level II could be estimated.

Within the urban and built-up limits, those areas of bright blue were interpreted as solid pavement and/or buildings, indicating the heaviest concentrations of commercial and industrial activity. These correspond to the CBD, commercial development along major streets, industrial complexes, major shopping centers and railroad freight yards. The areas of mostly blue with speckled red and white indicate mixed commercial, industrial and residential land use. This occurs mainly in the immediate vicinity of the CBD, and indicates that the older residential sectors have been partially taken over



PLATE 6 LANDSAT Image of Topeka, Kansas--1:125,000

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Map 2: LANDSAT (1:125,000)

LEGEND: Map 2--LANDSAT (1:125,000)

<u>Number</u>	<u>Description</u>
11	Residential
12	Light Commercial/Service/Industrial
13	Heavy Commercial/Service/Industrial
14	Transportation
17	Other Urban or Built-up
21	Cropland and Pasture
31	Herbaceous Rangeland
41	Deciduous Forestland
51	River
53	Reservoir
76	Mixed Barren Land

by commercial and industrial activities.

The white and mostly white areas indicate commercial tracts (large areas of concrete pavement, such as a parking lot) or bare ground with buildings in various stages of construction (land in transition). In 1973, when this image was acquired, there was much building activity taking place in southwest Topeka along the I-470 bypass. This is clearly indicated in the image.

The red-pink or mostly red areas in the image correspond to residential sections, while those areas of deep red indicate parks or cemeteries with extensive tracts of healthy vegetation, mainly trees.

Outside the limits of the built-up areas, land uses become a little less distinguishable. The fields which have recently been plowed appear in a dark blue-gray coloration. Only the largest of these have been mapped. Most of the remaining rural land appears in red or red-pink coloration. This is mainly grassland, with some trees occurring along streams and watercourses. The grassland in fenced pastures is practically indistinguishable from that in open rangeland. However, the presence of section line roads can be described as a characteristic of surveyed and fenced fields, indicating agricultural land use. Therefore, the absence of section line roads is taken as an indication of open rangeland. In this image, most of the open rangeland occurs in the southwest

and west with some in the southeast.

The Kansas River appears as a jagged stripe of blue-gray across the top of the image, while lakes and ponds appear in dark blue-black. The runways of Forbes Field and Billard Field can be seen quite easily.

The Southwest Topeka Metropolitan Area--

Using a NASA-flown high-altitude color infrared aerial photograph acquired in June, 1974, as the main data source, a land use/land cover map for the southwest Topeka metropolitan area was produced. (See Plate 7 and Map 3.) As with the LANDSAT imagery, this photography was overlaid with a sheet of glazed acetate. On the acetate, the land use/land cover areas were outlined, producing a map at the same scale as the photography, 1:125,000. Many Level II categories were discernible, and a few Level III categories were further distinguishable.

Only two types of residential land use were easily distinguishable. The single family category was used to denote all urban areas characterized by a uniform pattern of streets and regularly and closely spaced small structures. Any concentrations of small structures occurring in rural areas were also mapped as single family. Duplexes and mobile homes were included in this category as they were not separately distinguishable. Multiple family housing denotes those large apartment complexes



PLATE 7
High-altitude Aerial Photograph of Topeka, Kansas--1:125,000

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LEGEND: Map 3--High-altitude Aircraft (1:125,000)

<u>Number</u>	<u>Description</u>
111	Single Family
112	Multi-family
121	Commercial/Services/Industry
122	State Capitol
141	Highway Interchange
142	Rail Yard
143	Airport
144	Utilities
171	School
172	Park
173	Golf Course
174	Fairground
175	Cemetary
176	Vacant Urban Land
177	Hospital
210	Cropland and Pasture
310	Herbaceous Rangeland
410	Deciduous Forestland
510	River
530	Reservoir
761	Landfill
762	Other Mixed Barren Land

apparent in the photograph. These usually had a uniform pattern of easily distinguishable structures surrounded by parking lots. Small apartment blocks and other group living structures were not discernible and, therefore, were not mapped separately.

The differences between commercial, industrial and service uses were not readily distinguishable, and no attempt was made to map them individually. They were grouped together into a single category which includes all those areas characterized by blue-gray coloration and rectilinear building patterns. The complex west of Forbes Field and two drive-in theaters were also included in this category. Particularly noticeable is the CBD in the upper right corner of the map and photograph.

Large railroad freight yards are visible and were mapped. These are linear areas of dark blue-gray coloration. Forbes Field, the only airport in the image, is readily visible and is mapped as a separate category. Also, large highway interchanges are mapped separately.

Several recreation areas are noticeable. Golf courses are characterized by the pattern of red or bright red fairways and greens. One exception is the public golf course west of Topeka which was under construction at the time this photograph was taken. Here the fairways and greens are light blue-gray to pink in color, indicating they have recently been planted and are not fully mature.

Other extensive areas of vegetation within the city limits are mapped as parks if supplemental information indicated they were such. However, some of these areas were not so noted in any available information, and were, therefore, classified as vacant land. Two cemeteries were also individually mapped, being characterized by a looped road system within what otherwise would be classified as vacant. The Mid-America Fairground was mapped separately. Its structures surrounded by open space and its large, oval race track help distinguish it.

The location of schools, both public and private, and at all levels from elementary through university, are noted on supplemental maps. These maps were compared with the photograph to outline the schools on the acetate. No attempt was made to map them separately, either by administration/ownership or by level. Small, privately owned professional or technical schools, such as secretarial schools, are not distinguishable in the photograph and are not mapped. Neither are any schools associated with local medical facilities mapped in an educational category.

Hospitals and large medical facilities are mapped separately, as they were generally noted in the supplemental maps and are discernible in the image. The State Capitol is mapped separately. The Governor's Mansion, although publically owned, has been included in the single

family category as its primary use is residential.

In the photograph, woodland (forestland) appears as bright to dark red coloration characterized by a coarse texture. In this part of Kansas, most woodland occurs along streams and rivers, as in this image along the Kansas River. Rangeland in this map has been delineated by outlining those areas of grassland in the photograph which lack two features: division into rectilinear fields and indications of cropping or plowing.

Lakes, reservoirs and ponds appear in a range of color from dark blue-black to bright white. Lake Sherwood shows the darkest color, comparable with the color of the large water bodies in the LANDSAT image. However, the small lakes and ponds in this photograph display their levels of siltation/sedimentation. The darker blue color of the water indicates a low level of siltation/sedimentation, while the lighter blues indicate higher levels. Those ponds in the lower right corner of the photograph appear as bright white due to sun reflectance. The Kansas River has some siltation/sedimentation, indicated by the blue-gray color. Color may also provide an indication of depth in clear water, the darker color corresponding to deeper water.

Several areas in the upper left corner of the photograph appear to be bare, dry soil. These may result from large grading operations preparatory to construction of

residential subdivisions. However, two appear to be sanitary landfill sites, and are mapped as such. The other bare sites are mapped as vacant land. All other areas have been included in the agricultural land category, the best indication of which is the rectilinear pattern of fields.

Comparison--

The differences between the three images are immediately apparent. While the enlargement of the LANDSAT image (Plate 6) allows delineation of land use/land cover patterns at a higher level than the original LANDSAT image (Plate 5), it does not allow the same accuracy as the high-altitude aircraft photograph (Plate 7). This is, in turn, reflected in the maps. (Maps 1 through 3).

Map 1, from the LANDSAT image at a scale of 1:1,000,000, includes the boundary of Shawnee County (shown in the dashed line.) Within the County, only a very general delineation of land use/land cover can be depicted, including an outline of the Topeka built-up area and the two heaviest concentrations of commercial-industrial activity. In Map 2, the patterns are more defined, with some separation of residential, commercial, industrial, recreational and other uses permitted. However, even here the pattern lines are not very accurate because the image enlargement is too blurred. In contrast to

this, the high-altitude aircraft photograph is very sharp and allows much more accurate outlining of the land use/land cover patterns. Notice in Map 3 that the use area lines can even follow the grid pattern of the city streets and rural section line roads. Also, mapping along streams can be more easily accomplished from the high-altitude photograph than from the LANDSAT enlargement.

One must remember, though, that the LANDSAT images are much easier to acquire than the high-altitude photographs, once the satellites have been launched and placed in operation, and are less expensive, too. This is especially important to consider when long-term, repetitive coverage is necessary for the project. The high-altitude photographs are more suited to focusing-in for a more detailed study of the project area.

Site Selection Study--

This study will simulate the role LANDSAT can play in the site selection process for a large scale development. The objective of this simulation is to determine whether or not LANDSAT adequately fills the role as an analysis tool for the land planner and developer. In order to define the performance level required from LANDSAT, it was decided to focus on residential planning.

The first stage of this project consisted of mapping those features which would have a direct bearing on

locating a large scale residential project. These features included: network of major roads and highways, commercial centers, airports, the landfill, the limits of the Topeka built-up area and such scenic features as rivers, lakes, woodlands and grasslands. For purposes of discussion in this simulated study, "large scale residential project" is being defined as providing building sites for a minimum of 100 single-family homes at a ratio of one dwelling unit per gross project acre.

At the completion of the mapping exercise, a land use development analysis was begun. Urban extent, topography, vegetative cover, scenic views, drainage patterns and other components which would influence site locations were evaluated.

Following the area analysis, five sites were chosen from the enlargement as potential development sites. Generally, the sites chosen were those which appeared from the image to satisfy three criteria: 1) have a high degree of scenic value determined by the natural features near and at the site; 2) have a convenient relationship to existing community facilities; and 3) contain a minimum of 100 acres. (It is not possible to locate 100 individual building sites within any given tract of land in this enlargement due to the small scale and the blurred quality of the image.) Descriptions of the five sites as they appear in the image are presented.

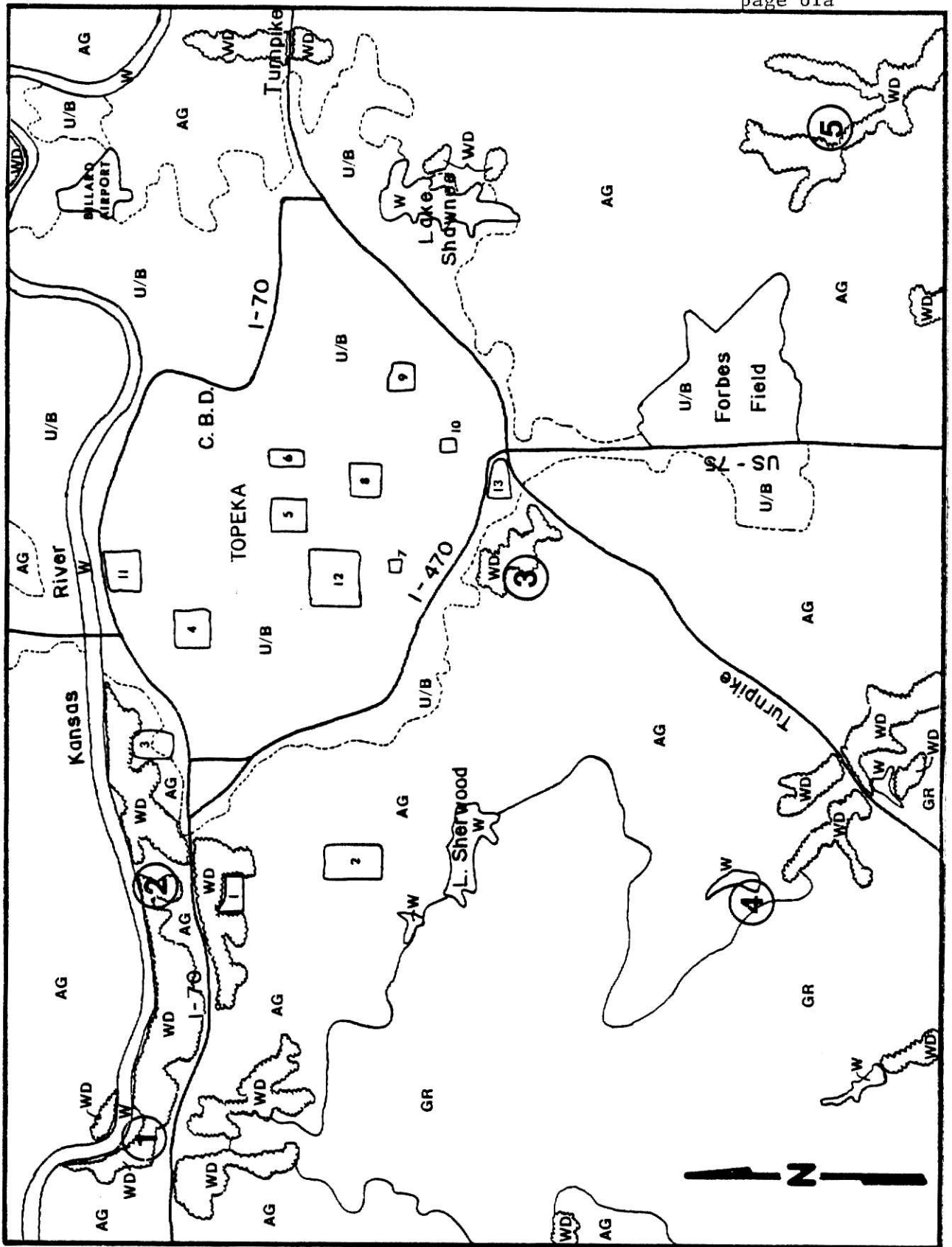
The Mapping--

The mapping was completed by placing a mylar overlay on the image and outlining those natural and man-made features which would bear on the successful development of a residential project. (See Map 4.) Land cover patterns, highway network and major point features such as shopping centers, airports, parks, lakes, hospitals, universities, industrial centers and the fairgrounds were outlined for special attention during the study.

The Analysis--

The most noticeable aspect about the coloration of the image is the distinct demarcation between the urban and built-up areas and the rural areas. (See Plate 5.) The various shades of red indicate different types of vegetative cover, extensive in this image because it portrays much of rural Shawnee County. The large conglomerate of whites, blues and grays, with some red and pink, represents the limits of the Topeka built-up area. On the south and west edges of Topeka, this boundary between urban and rural is quite sharp. From the point of view of limiting urban sprawl, it would be desirable to restrict any further growth in this direction to those areas immediately adjacent to the current limits of built-up Topeka, shown on the map.

The second most noticeable aspect of the image is



Map 4: Site Selection Study (1:125,000)

LEGEND: Map 4--Site Selection Study

U/B	Urban and Built-up Land
AG	Agriculture
WD	Woodland
GR	Grassland
W	Water
	Major Highways
	Limits of Woodland
	Limits of Topeka Urban and Built-up land

Existing Features:

- 1 Landfill
- 2 Topeka Public Golf Course
- 3 Menniger Foundation
- 4 Gage Park and Zoo
- 5 Washburn University
- 6 Fairgrounds
- 7 Brookwood Shopping Center
- 8 Topeka Country Club
- 9 Shawnee Country Club
- 10 White Lakes Shopping Center
- 11 Kansas State Hospital
- 12 Veterans Administration Hospital
- 13 Southgate Commercial and Industrial Subdivision

the network of major highways and roads. While there are five major highways leading into and through Topeka, not all of them are readily accessible to commuters. The Kansas Turnpike, visible here as a dark diagonal line in the lower left center of the image, is not accessible at all. Consideration is currently being given by State Highway authorities to building a turnpike interchange in the vicinity of Auburn, Kansas, which is just off this image to the south. However, as there are no firm plans for this interchange at this time, and as Auburn is farther south than the area under consideration for development, it would not be wise to count on an interchange as an asset to any development in the area.

Both of the two other highways which serve the area southwest of Topeka, US-75 and I-70, provide direct access to Topeka. Of course, I-70 is a limited access highway; therefore, any development near I-70 should be located in the vicinity of an existing interchange. Since there are several interchanges west of Topeka, this should not present any serious difficulties. US-75 is accessible along its entire route.

Most of southwest Shawnee County is serviced only by section-line roads, visible in the image as a faint grid running north-south and east-west. This does present a limiting factor to development in areas away from

the major highways, as there are no direct routes into Topeka via county roads.

Kansas has a reputation for being a state lacking in scenic interest. The impression others generally have is that Kansas is flat, with little scenic relief in the way of forests, mountains and attractive water features. However, this LANDSAT image does reveal some scenic elements worthy of note.

Kansas is dotted with numerous lakes and reservoirs, several of which are visible here as dark blue/black configurations. Because waterside property, or property near and accessible to water, is in demand, these lakes can become major focal points for development of a large-scale residential project. As viewed in this image, several lakes near Topeka already support residential developments. Lake Shawnee, immediately east of Topeka, and Lake Sherwood, to the west, are two such developments.

However, several small lakes southwest of Topeka appear in this image to be undeveloped. These might be good locations for future residential development, assuming that development near any lake can be accomplished in an environmentally safe manner.

In addition to numerous lakes and reservoirs, the Kansas River flows through Topeka, and is visible in the image. The blue/gray coloration of the river in this image indicates heavy siltation and sedimentation,

which would negate use of the Kansas River for swimming and boating purposes. However, the river, with its attendant wooded banks, can be a positive scenic element when viewed from nearby houses.

The various shades of red and pink in the image relate to variations of vegetative cover in the area. The patches of dark red correspond with the healthiest vegetation, which in Kansas in August is the tree cover. The scale of this image, 1:125,000 or one (1) inch equals two (2) miles, allows only the large tracts of woodland to be visible. These are generally stream or river bank thickets, as this section of Kansas does not contain extensive forest cover.

The large extent of off-pink coloration in the lower-left and left-center of the image corresponds with the beginning of the Konza Prairie and Flint Hills grasslands region. Here is an area of subtle, deceptive beauty. Some may consider it stark and almost desolate, but the prairie grassland, with its rolling terrain and limitless horizon, offers a peaceful scene to those who view it.

While the area may be interesting scenically, the soils of the grasslands may present some limitation to large scale development. Three general soil series make up the majority of soil types found in the grasslands of southwest Shawnee County--Ladysmith, Martin and Sogn. All three have severe limitations to septic

tank disposal systems and moderate to severe limitation to sewage lagoon disposal systems, generally due to slow permeability, steep slopes or hard rock close to the surface. Furthermore, both the Ladysmith and the Martin soil series provide poor suitability for foundation support of low buildings because of high shrink-swell potential and poor shear strength. Only the Sogn series is good for foundation support because it has hard rock near the surface. (Abmeyer and Campbell, 1970)

Some general aspects of rainwater runoff and surface drainage patterns can be viewed in this image. Because woodlands in Kansas are often associated with streams and rivers, the course of the waterways can be followed in the image by observing the linear patterns of bright red coloration.

This allows us to note several topographic features of this area. The land south and east of Forbes Field drains to the southeast, away from Topeka. Development southeast of Forbes would not contribute to flooding within the urbanized area. There also appears to be a highpoint southwest of Lake Sherwood, draining to the southeast by way of several visible stream courses, and to the north toward the Kansas River by way of another stream. Again we can note that development in this area would not contribute to flooding within the Topeka city limits.

Within the vicinity of the Kansas River we can see that the visible land use/land cover pattern north of the river shows large rectangular fields associated with flat, lowlying floodplains. The dark coloration of many of these fields, resulting from a close-to-the-surface ground water level, further attests to the area's floodplain character. These lands are unsuitable for development.

However, because the south bank is heavily wooded rather than cleared for agricultural purposes, we can conclude that it is somewhat steeply sloped or it has poor quality soils or both. Development along the south bank would be safe from flooding. On the other hand, the steep slopes and poor soils could be factors for limiting development.

The single most notable feature in the LANDSAT image is Forbes Field. Because the runways are so distinctive, the take-off and landing patterns of aircraft using the airport can easily be established. This will allow the developer to map aircraft noise as a factor to be considered in locating a site for residential development.

From the above information, five potential development sites were located in the image which seem to possess desirable qualities for residential use. The following is a discussion of these five sites and their

individual positive and negative characteristics as viewed in the LANDSAT image. While these may not be the best potential sites available near Topeka, they do represent a diversity of land use/land cover types in the area, illustrating that LANDSAT is capable of providing some analytical assistance in the site selection process.

The Sites--

Site #1, Riverview, has several positive assets, the most prominent of which is the excellent scenic view of the Kansas River rounding the bend. Because Kansas is not generally known by out-of-staters to have waterside property available, this might be a strong drawing card for potential buyers. Of course, the Kansas River is not very desirable from a recreational standpoint, it being too muddy and swift flowing for swimming and boating purposes.

In addition to the water, Riverview also benefits scenically from the woodland surrounding the site, visible as bright red coloration in the image. The cooling effects of the summer shade and the spectacular scene of autumn color would be welcome to Riverview home-owners. The woods are also a natural wildlife habitat, supporting a variety of flora and fauna, a further attraction to potential home buyers.

As noted in the Analysis, this area probably has

poor soils on a sloping terrain. Each of these features could hinder development of this site, especially if the terrain is steeply sloping. Construction procedures on sloping sites are more expensive than on moderate sites.

The site benefits from its proximity to Interstate 70, which provides quick and easy access to both downtown and suburban Topeka commercial districts. The white, horizontal stripe in the image depicts I-70. However, individual highway interchanges are not detectable in this enlargement. Reference was made to the aerial photograph to determine interchange locations. As it happens, an interchange does exist immediately south of the site. Were this not so, Riverview would lose some of its appeal to potential homeowners.

Otherwise, Riverview does not suffer any particular drawbacks. It is not near enough to Forbes Field to be bothered by air traffic noise. It is also far enough from both the sanitary landfill and Topeka industries to avoid problems with air pollution and unpleasant odor.

The second site, River Woods, shares many characteristics with Riverview. It also is situated in a wooded area on the south bank of the Kansas River. As such, it has similar scenic, topographic and soils aspects as Riverview. Likewise, the proximity of the site to I-70 offers quick and easy access to downtown and suburban shopping districts. Again, it was necessary to refer

to the aerial photograph to determine the location of the nearest interchange.

However, this site does suffer from one glaring drawback. It is only one mile due north of the sanitary landfill. This could be particularly unpleasant during the hot summer months when the south and southwest winds carry the odor from the landfill toward the site.

The only other potential drawback to the River Woods site which can be depicted from this enlargement is that it is on line with the main runway at Forbes Field. However, the distance from the site to the end of the runway is approximately ten miles, so there may not be any problems with aircraft take-off and landing noise.

Site #3, Topeka Village, is not so lucky. It sits directly on line with and is only two to three miles from the end of the main runway. This is a very objectionable feature as noise from take-off and landing activities could be quite loud, and could cause lagging interest in the development among potential homeowners.

Otherwise, Topeka Village does offer some attractive amenities. It is close to Topeka, making commuter travel quite easy, particularly to White Lakes Mall, Brookwood shopping center, and other points in south Topeka. Also, the image indicates from the bright red coloration that this site is wooded, offering both attractive scenery

and a pleasant environment, as well as wildlife habitation.

The presence of woodland in this area probably indicates that either the soil or the topography is not suitable for agricultural use. There appears to be a creek traversing the area, which could cause flooding problems in the development. Otherwise, Topeka Village is not situated on any significant bodies of water. It is close enough to Lake Sherwood to benefit from its attractions.

The fourth site, Prairie Lake Estates, differs from the other sites in that it does not contain extensive wooded land. As such, it lacks the one feature which makes any homesite attractive in Kansas--shade. On the other hand, Prairie Lake Estates offers a tremendous opportunity to develop a solar and wind energy based community. There are no obstacles which would hinder the harnessing of these two energy sources. With proper road layout, homesites can be tucked into the hillsides for optimum solar orientation.

This site is located on a small lake out on the Tall Grass/Flint Hills prairie, recognizable in the enlargement as the large expanse of pinkish/light red coloration in the lower left corner. Few of the section line roads generally associated with more agriculturally developed lands are visible in this area.

The Flint Hills offer some excellent scenery which some homeowners may appreciate. The same development

layout which allows optimum solar orientation could also present the homesites with long scenic vistas of the prairie grasslands and the lake. And the lake itself, seen in the image as the dark blue/black feature, will attract some homeowners.

The site has two major disadvantages. First, it is the farthest of the five sites from Topeka in both miles and time of travel. Since Prairie Lake Estates is not near a major accessible highway, all commuter and shopping trips would have to be by way of county roads. As these follow section lines, there is no direct route into the urbanized area.

In addition to this, the soils of the prairie grasslands are not well suited for development. As noted in the analysis, residential projects would have problems with both waste disposal and foundation stabilization.

Shawnee Forest is the fifth site under consideration in this study. Its primary asset is the extensive woodlands lining the streams which flow through the area. The trees provide both a cooling effect on the area and an enhanced scenic view. In addition, the combination of woodland and stream acts as a focal point in drawing deer, turkey, pheasant and other fauna to the area, and provides an environment conducive to a wide range of native flora. All of this will act as a drawing card to potential buyers.

The streams indicate the possibility of varied topographic relief in the area of Shawnee Forest. While this adds to the site scenically, it may hinder the arrangement of lots and building sites. This would be especially true if the area has rocky soil. Steep slopes and shallow bedrock add to the cost of construction.

The major disadvantage to this site is its location--only three miles from and almost directly in line with the end of the main runway at Forbes Field. Noise from take-off and landing activities could discourage people from buying in this development.

Access from Shawnee Forest to Topeka shopping and business districts is fairly good. It is only four miles east of US-75, the major access to Topeka from the south. Of the sites considered in this study, Shawnee Forest also has the easiest access to the Forbes Field business district.

Analysis of LANDSAT Usability--

The enlargement of the LANDSAT image worked quite well in this hypothetical preliminary study, especially in allowing the writer to complete an area analysis. From the image, individual selection criteria could be examined for each site. In particular, the image was especially useful for noting the scenic values and land uses near the sites. Data on these two criteria are

often not available.

Commuter accessibility was somewhat more difficult to analyze. While the major highways are readily visible in the image, the county road system is less distinct. This data is available from road maps, and would be better studied from them. The take-off and landing patterns for Forbes Field were not difficult to estimate as Forbes stands out quite distinctly in the image. Data on soil types, vegetative quality and surface drainage patterns were also available from the image, and decisions on site conditions could be made with some reference to these natural systems.

It cannot be emphasized enough that LANDSAT imagery is useful primarily in preliminary studies. As can be seen in this sample problem, even the enlargement provided only limited information on the various sites. The resolution is small, while the enlargement is blurry. Furthermore, all of the data gained from this study could have been found in other sources, principally road maps and aerial photographs. LANDSAT's primary assets are its widespread coverage and its cycle of repetition. No other land resource information system currently available to the public can match these two features.

However, it should also be emphasized that the amount and type of data one is able to glean from the LANDSAT imagery is directly related to the training and

education one has had in the area of land resources. A geologist will be able to make evaluations of geologic formations, a forester of woodlands, and a hydrologist of water qualities. They may not, however, be able to cross the boundaries into other fields of study. The site conditions described here are presented from the viewpoint of a Land Planner whose educational background is in landscape architecture. Other researchers would probably evaluate the area and the sites differently. Therefore, a site analysis and design team should include professionals from all or most of the land resource disciplines.

Chapter 6

Chapter 6: Future Satellite Remote Sensing

LANDSAT D and LANDSAT D-Prime--

A fourth satellite, LANDSAT D, will be launched in late 1981. The first LANDSATs were successful as experimental projects. They demonstrated that it is feasible to provide cost-effective, repetitive data from space, and that potential markets exist for the use of these data products. However, the selection of band and orbital parameters for the first three LANDSATs "involved a series of compromises, principally between agricultural, hydrologic and geologic uses." (Lintz and Simonett, 1976) LANDSAT D will be designed to produce products primarily for use in vegetation studies, with overlap into the land use mapping disciplines. (Tucker, 1978) Other satellites are planned for other disciplines; for example, GEOSAT for geologic studies, SEASAT for marine and oceanographic studies and MAGSAT for study of Earth's magnetic field.

LANDSAT D, which will be redesignated LANDSAT 4 after a successful launch, will carry a multispectral scanner and one additional sensor. Known as the thematic mapper (TM), a more advanced multispectral scanner, it will operate similarly to the MSS. It will scan the surface of the Earth in a line perpendicular to the orbit path of the satellite for a distance of 185 kilometers.

The images it produces will cover a 185 by 185 kilometer area, as in the MSS images. But the TM will have a finer ground resolution cell (pixel) of 30 meters, compared to 79 meters for the MSS. Each pixel will have a nominal ground area of 0.2 acres. LANDSAT D will not carry a return beam vidiocon. (Plain Brown Wrapper, 1979, Vol. 1, #4, p. 5; Williams, T. H. L., 1979.)

Furthermore, the TM will operate in seven band ranges, compared with the four or five bands for previous LANDSATs. These band spectral ranges will be as follows:

TM-1	0.45 to 0.52 μm ;
TM-2	0.52 to 0.60 μm ;
TM-3	0.63 to 0.69 μm ;
TM-4	0.76 to 0.90 μm ;
TM-5	1.55 to 1.75 μm ;
TM-6	2.08 to 2.35 μm ;
TM-7	10.40 to 12.50 μm .

(LANDSAT Data Users Notes, 1979, #7, p. 4.)

TM-1, TM-2 and TM-3 are designed to detect varying concentrations of chlorophyll in vegetation. TM-1 will also be sensitive to carotinoid concentrations, and TM-2 to green region rediances. TM-4 will sense vegetation density or biomass. Both TM-5 and TM-6 will detect levels of water in plant leaves. TM-7 will detect thermal properties, similarly to band 8 in the MSS. (Tucker, 1978)

LANDSAT D will also have different orbital parameters than the previous satellites. It will have a lower altitude of about 700 kilometers which, in part, contributes to the finer resolution of the TM over the MSS. The

earlier LANDSATs had an orbit of about 920 kilometers.

LANDSAT D will also have a shorter repetition cycle of 16 days, compared to 18 days for the earlier satellites.

(LANDSAT Data Users Notes, 1979, #7, p. 4) Finally, LANDSAT D will have a later sun-synchronous orbit. Where the earlier LANDSATs operated at approximately 9:30 a.m. local time, LANDSAT D will operate at 11:00 a.m. local time. This will be more optimal for vegetation studies, but less advantageous for geologic studies. (Lintz and Simonett, 1976)

In addition to LANDSAT D, a back-up satellite, LANDSAT D-Prime, will be ready for launch about six months after LANDSAT D's launch. It will be similarly equipped as LANDSAT D. Should LANDSAT D fail in service for some reason, LANDSAT D-Prime will be available to take its place. If LANDSAT D operates as planned, D-Prime will be re-designated LANDSAT E. Then, when LANDSAT E is launched, the two will operate together in an eight day cycle. Both LANDSATs D and D-Prime (E) are designed to be space shuttle compatible; that is, they will be retrievable by the space shuttle, refurbished on the ground and later relaunched. (Plain Brown Wrapper, 1979, Vol. #4, p. 5)

The new projects in the NASA space program will make LANDSAT data available faster. In April, 1979, the Domestic Communications Satellite System (DOMSAT) went into operation. It provides data transmission linkages

between the NASA ground receiving stations and the Goddard Space Flight Center (GSFC) data processing facilities in Greenbelt, Maryland, and between the GSFC and the EROS Data Center in Sioux Falls, South Dakota. Previously, LANDSAT data had been shipped between these locations via the postal service. (Plain Brown Wrapper, 1979, Vol. 1, #4, p. 1)

"DOMSAT is a generic name for a number of domestic satellites owned by RCA, Western Union and others, who sell time to users after paying NASA to launch their satellites." RCA will operate the DOMSAT performing the LANDSAT data linkages, providing a two-to-three day turnaround from the time LANDSAT detects the data until the time it is received at EROS Data Center. This is a great improvement over the four-to-six week turnaround time previously experienced. (Plain Brown Wrapper, 1979, Vol. 1, #4, p. 1)

Secondly, a new Tracking and Data Relay Satellite System (TDRSS) Terminal is under construction in White Sands, New Mexico. Scheduled to be operational for LANDSAT D, it will take the place of the three ground receiving stations now operated in Alaska, California and Maryland. The TDRSS high-speed data handling facilities coupled with RCA's DOMSAT linkages will allow the GSFC data processing facility to receive data within ten minutes of the time it is detected by LANDSAT. This

would further reduce turnaround time to only 24 hours.
(Plain Brown Wrapper, 1979, Vol. 1, #4, p. 5)

The Applicability of LANDSAT D Products--

The LANDSAT D TM images are similar to the images produced by the earlier LANDSAT MSS. The TM also measures and records electromagnetic energy reflected and emitted at the Earth's surface. This data is then used to produce simulated photographs at the EROS Data Center. The same detecting and recording properties of the MSS operate in the TM. That is, the TM detects all spectral values found within each pixel, but records only an average value for the entire pixel in each band.

However, due to the smaller spatial resolution, greater detail will be visible in LANDSAT D imagery, showing finer patterns and more subtle textures. This should increase the usability of LANDSAT D imagery in the design profession as well as in other Earth studies.

The aspects of the finer resolution of the TM will allow smaller areas of homogeneous land cover to be visible in the imagery. The smaller nominal ground area of 0.2 acres allows smaller land cover areas to be detected. Also, the small pixel size will work to "sharpen" the edges of homogeneous land cover areas. That is, instead of having the edges averaged into 79 meter pixels, the edges will be reduced to 30 meter pixels.

Figure 8a illustrates a portion of a hypothetical LANDSAT image superimposed with the 79 meter pixel grid. Notice the area taken-up in the image by the edge pixels (shaded) as opposed to the area of the homogeneous land cover pixels. Compare this with Figure 8b, which illustrates the same portion of the hypothetical LANDSAT image superimposed with the 30 meter pixel grid. In Figure 8b, less of the image is taken-up by the edge pixels (shaded), allowing more of the homogeneous land cover area to be detected, as well as sharpening the edges of those land cover areas.

The important aspect of this finer resolution is that it will provide increased information. Urban land cover patterns will be more distinct, with spectral reflectance values for parking lots, major structures, parks and recreation areas, and residential sections of varying densities readily defined. Major street and road patterns within urban areas will also become more apparent, as will railroad beds, especially those for multiple track. In rural areas, lesser highways will become visible, as are the major highways in the current MSS imagery. Smaller streams and ponds, along with smaller areas of vegetative cover will also be detectable by the TM.

Along with the finer spatial resolution, the TM has a finer spectral resolution. "The bands are more sharply defined in LANDSAT D than in LANDSATs 1, 2 and 3

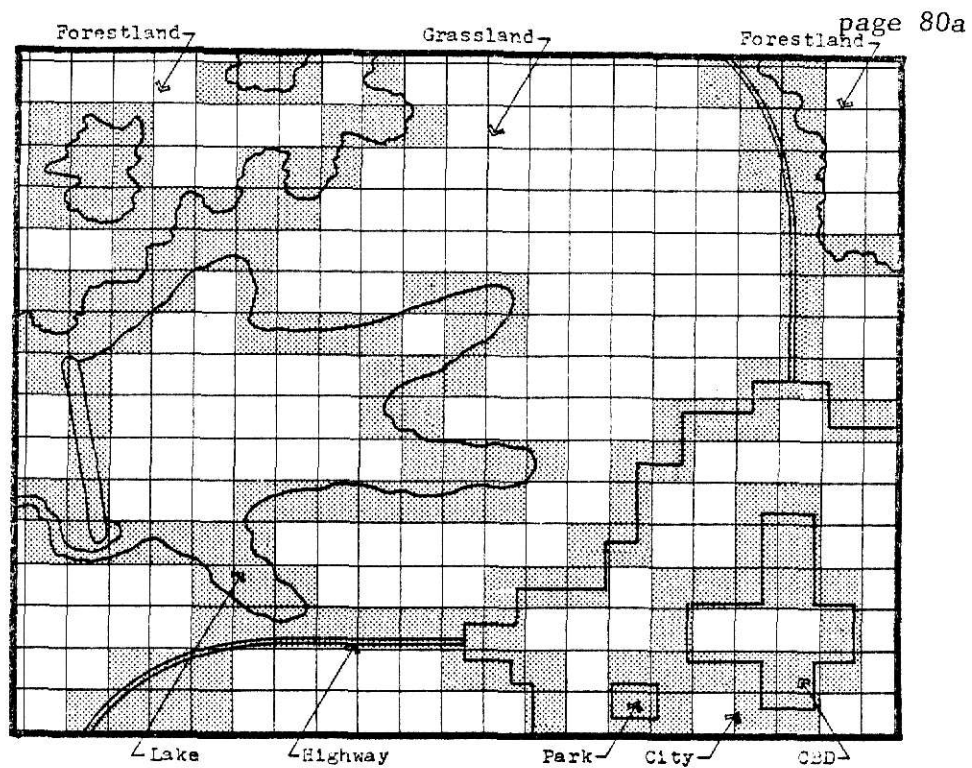


FIGURE 8A: A PORTION OF A HYPOTHETICAL LANDSAT IMAGE
SUPERIMPOSED WITH THE 79 METER PIXEL GRID.

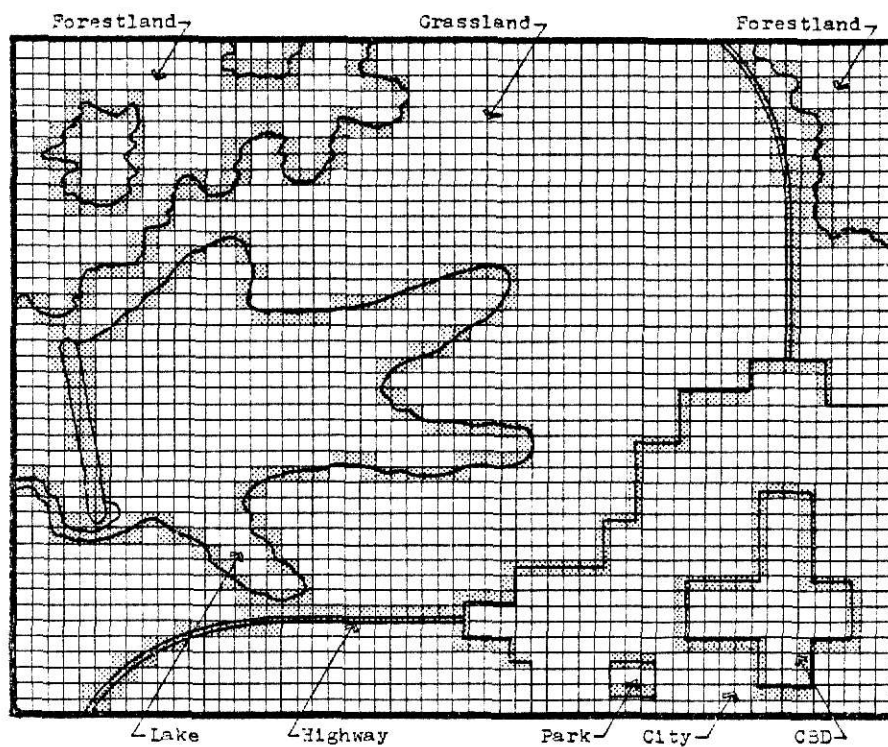


FIGURE 8B: THE SAME HYPOTHETICAL IMAGE SUPERIMPOSED
WITH THE 30 METER PIXEL GRID.

in order to emphasize more clearly fundamental energy-matter interactions." (Lintz and Simonett, 1976) In the MSS, the band ranges were defined to the nearest tenth of a micrometer (μm), which were generally referred to as the green, red, near infrared and far infrared ranges. The TM band ranges are defined to the nearest hundredth of a micrometer, based upon extensive research aimed at defining optimal spectral bands. For instance, TM-4 (0.76 to 0.90 μm) is designed to detect biomass, the volume or density of living vegetative matter within an area. In the MSS, this range is divided between two bands, 6 and 7, which also detect energy from other vegetation energy-matter interactions, thereby confusing the efforts of plant scientists studying biomass.

Comparison of LANDSAT D and High-altitude Photography--

With the finer resolution made available by the TM, the LANDSAT imagery will approach the visual qualities of high-altitude aircraft photography. However, even with enlargement of LANDSAT D imagery, a person still sees only a grid pattern of pixels, each shown in a single shade of gray representing the average spectral reflectance value of all land cover features found in that pixel. This is fine for detecting large masses of land cover or land use activities. But some studies may require the greater definition of cultural features available with

high-altitude aircraft photography. Where LANDSAT D will produce a simulated photographic image based on a 30 meter pixel grid, high-altitude photography is better able to define the actual individual ground features.

Of course, all forms of remote sensing have their "resolution limits". For the first three LANDSATs, this limit is defined by the 79 meter pixel, while for LANDSAT D it will be defined by the 30 meter pixel. But even aircraft photography has a limiting factor. This is the size of the silver halide crystals within the film. Each of these crystals, even though randomly scattered across the film as opposed to the orderly grid of the LANDSAT pixels, acts as an individual ground resolution cell. That is, it detects and records one, and only one, spectral value or color, just as the MSS and the TM record only one value for each pixel. It follows that a film type, when used in low-altitude aerial photography, will have a finer ground resolution than the same film type used in high-altitude aerial photography because each crystal will cover a more extensive area of Earth surface in the high-altitude application. (Williams, T. H. L., 1979)

LANDSAT operates on a continuous, repetitive cycle. This makes the LANDSAT imagery relatively inexpensive. One image covering an 185 by 185 kilometer area costs only \$12.00 for a color-composite paper print at a scale

of 1:1,000,000. Comparatively, high-altitude photographic missions are very expensive due to the high-altitude performance standards and the corresponding maintenance and operation standards. (NASA, Ames Research Center, 1978)

NASA, USGS and other government agencies have available for public purchase photography acquired on previously flown missions, covering most of the major metropolitan areas and many rural areas. These photographs are inexpensive and can be used for Earth studies. Furthermore, USGS recently initiated a program to fly the entire United States every three years at high-altitude with the intent to map land use/land cover. The first of these photographs and resulting maps should be available soon. (Williams, T. H. L., 1979)

Other Satellite Sensor Systems--

Among the sensors carried on the Skylab satellite launched in 1973 were two systems which could be used extensively by landscape architects and other Earth designers. The Multispectral Photographic Camera (MPC) "consisted of six cameras with matched lenses all designed to photograph the same area on the ground." (NASA Facts, 56/1-75, 1975) These six cameras took photographs in different wavelengths of radiation reflected from surface features, similar to the MSS of LANDSAT. But the MPC is a

real photographic system while the MSS produces only simulated photographs composed of pixels.

Skylab also carried an Earth Terrain Camera (ETC), a single camera producing a larger scale photograph of a smaller ground area than the MPC produces. Because of its larger scale, the ETC photographs show greater detail than the MPC. (NASA Facts, 56/1-75, 1975)

While Skylab is no longer in operation, having disintegrated upon re-entry into the Earth's atmosphere in 1979, instruments similar to the MPC and the ETC would be welcome additions to the current satellite remote sensor program. Although they could not be carried by LANDSAT, due to film handling logistics, they could be part of regularly operated manned space shuttle flights. The MPC could offer the same multispectral qualities of the LANDSAT MSS with the detail delineation of real photography. The ETC, with its larger scale, approaches the detail of high-altitude aircraft photography.

Either of these systems would be useful to landscape architects because of their real photographic qualities. The ETC would be an especially valuable aid in the site selection and analysis process. While high-altitude aircraft photography has the larger scale and better detail necessary for site work, ETC photography would be much less expensive to acquire if it were available from regularly scheduled space shuttle flights. This

would be valuable for seasonal comparisons of the site. This author would like to see some remote sensor system similar to the MPC and the ETC carried on future Earth resources satellites.



PLATE 8
LANDSAT Image of Topeka, Kansas--1:250,000



PLATE 9
LANDSAT Image of Topeka, Kansas--1:500,000

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Glossary

GLOSSARY

aerial--supplied, performed or carried by means of aircraft.

areal--pertaining to the quantitative measure of a surface.

ASCS--American Soil Conservation Society.

atmosphere--the gaseous envelope surrounding the Earth;
the air.

band--a set of adjacent wavelengths in the electromagnetic spectrum with a common characteristic, such as the visible band. (Ford, 1979)

biomass--that part of a given habitat consisting of living matter, as per unit area or per unit volume of the habitat.

carotinoid--any of a group of red and yellow pigments contained in animal fat and some plants.

CCT--computer-compatible tape; one of the two forms in which LANDSAT data may be purchased.

chlorophyll--the green coloring matter of leaves and plants essential to the production of carbohydrates by photosynthesis.

color-composite--a color image produced by projecting two or more black-and-white images of the same scene through different color filters onto a common base. (Ford, 1979)

color-infrared--a three layer color film sensitized to green, red and near-infrared. Conventional color film is sensitized to blue, green and red. (Ford, 1979)

DCS--data collection system; one of the three forms of resource data acquisition carried by early LANDSATs.

density slicing--equidensitometric processing; the principle of level slicing, whereby the continuous light intensity range in an image, represented inversely by film emulsion density, is divided into a number of discrete intervals or "levels". The image is reconstructed so that areas within each interval are depicted by a single gray-tone symbol, or color. The object is to group and accentuate features of interest by placing them in a different density level from their surroundings, i.e., to increase

desired contrast and suppress undesired contrast.
(Ford, 1979)

digital analysis--the computer analysis of digital data gathered by multispectral scanners in satellites.
(Ford, 1979)

DOMSAT--a generic term for any one of several domestic communication satellites operated by private firms.

ecology--the branch of biology dealing with the relations between organisms and their environment.

energy-matter interactions--the reflection or emission of electromagnetic energy from matter, especially that energy which can be detected by remote sensors.

electromagnetic radiation--energy emitted or reflected in the form of electromagnetic waves. (Ford, 1979)

EMS--electromagnetic energy spectrum; the range of electromagnetic energy as measured by wavelength.

ERTS--Earth Resources Technology Satellite. Designation of the first satellite in NASA's Earth Resources Survey Program. In 1974, the satellites were redesignated LANDSAT.

ETC--Earth Terrain Camera. A single camera carried by Skylab, variously equipped with black and white, natural color and color-infrared films. The image covered a ground area of approximately 68 x 68 miles at a scale of about 1:950,000.

fault--a break in the continuity of a body of rock.

filter--as in photography; a screen of dyed gelatin or glass for controlling the rendering of color or for diminishing the intensity of light.

fracture zone--an area characterized by faults and fractures.

gamma-rays--a high frequency, highly energetic, penetrating radiation emitted from the nucleus of a radioactive atom.

geography--the science dealing with the areal differentiation of the Earth's surface, as shown in the character, arrangement and interrelationships over the world of such elements as climate, elevation, soil, vegetation, population, land use, industries, national and political entities, and of the unit

areas formed by these individual elements.

geology--the science that deals with the physical history of the Earth, the rocks of which it is composed and the physical changes which the Earth has undergone or is undergoing.

geomorphology--the study of the characteristics, origin and development of land forms.

GEOSAT--a satellite designed for geologic studies.

gray-scale--the range of gray from the lightest (white) to the darkest (black).

ground resolution cell--that tract of land detected at an instant by a remote sensor as it scans the Earth's surface. Also known as a picture element (pixel).

ground scene--a single frame or image produced by a remote sensor.

ground survey--a survey of a tract of land to confirm that information interpreted from a remote sensor image. Also known as field checking.

hectare--a unit of land measure equal to 10,000 square meters; equivalent to 2.471 acres.

high-altitude--photography acquired by aircraft at altitudes above 40,000 feet.

homogeneous--having a common property throughout.

hydrodynamics--the science of the mechanics of fluids.

hydrology--the science that deals with the occurrence, circulation, distribution and properties of the water of the Earth and the Earth's atmosphere.

igneous--produced under intense heat, as rocks of volcanic origin.

imagery--a visual representation of energy recorded by remote sensing instruments. (Ford, 1979)

indigenous--originating in and characterizing a particular region or country; native.

infrared--that part of the invisible electromagnetic energy spectrum which is contiguous to the red end of the visible portion of the EMS and which comprises

electromagnetic radiations of wavelengths from 0.8 to 100 microns.

kilometer--a unit of linear measure equal to 1000 meters; equivalent to 3280.8 feet or 0.621 miles.

LANDSAT--a generic term designating any one of several satellites designed for Earth resource studies.

land cover--the physical cover of the land; e.g., trees, water, concrete, grass, etc.

landscape architecture--the art of arranging or modifying the features of a landscape, an urban area, etc., for aesthetic or practical reasons.

land use--the manner in which land is used; e.g., forestry, recreation, urban, grazing, etc.

lineaments--distinguishing linear features in the landscape, especially geologic features.

linear--having the form of or resembling a line.

lithology--the science dealing with the mineral composition and structure of rocks, especially with such characters of structure as can be studied without high magnification.

low-altitude---photography acquired by aircraft at altitudes less than 15,000 feet.

medium-altitude--photography acquired by aircraft at altitudes between 15,000 and 40,000 feet.

meteorology--the science dealing with the atmosphere and its phenomena, including weather and climate.

micrometer--a unit of length equal to one millionth of a meter. Also called a micron.

micron--see micrometer.

microwave--an electromagnetic wave of high frequency, usually having wavelengths from 1 millimeter to 50 centimeters.

mineralogy--the science of the study of minerals.

MPC--multispectral photographic camera. A remote sensor carried by Skylab composed of six cameras, each

imaging the same ground area simultaneously using different film/filter combinations.

MSS--multispectral scanner. A scanning device carried by LANDSAT composed of multiple sensors, each imaging the same ground area simultaneously detecting different portions of the E.M.S.

NASA--National Aeronautics and Space Administration.

near-infrared--that part of the infrared portion of the EMS which is closely contiguous to the red portion of the EMS, composed of wavelengths from 0.7 to 1.5 micrometers.

overlap--the amount by which one photograph includes the area covered by another photograph, usually expressed as a percentage.

photography--the process or art of producing images of objects on sensitized surfaces by the chemical action of light or of other forms of radiant energy such as x-rays or gamma-rays.

photosynthesis--the synthesis of complex organic materials, especially carbohydrates, from carbon dioxide, water and inorganic salts, using sunlight as the source of energy and with the aid of a catalyst, such as chlorophyll.

physiography--the science of physical geography; geomorphology.

pixel--picture element. See ground resolution cell.

radiation--the process in which energy is emitted as particles or waves.

RBV--return beam videocon; a remote sensing device similar to a television camera mounted in the early LANDSATs.

reflectance value--the amount of electromagnetic energy reflected by an object relative to the surrounding area.

remote sensing--the process by which an object is studied from a distance using instrumentation.

satellite--a man-made device launched from the Earth into orbit around a planet or the sun.

scale--a ratio between two sets of measurements.

scene pair--two adjacent RBV images which combine to cover half of the corresponding MSS image. Two consecutive scene pairs correspond to a full MSS image.

SEASAT--a satellite design to study the oceans.

sensor--any device used to detect electromagnetic energy.

Skylab--a manned spacecraft used to study the Earth's surface.

soil association--a landscape that has a distinctive proportional pattern of soils.

soil series--soils which have profiles almost alike.

solar orientation--position in relation to the solar azimuth and elevation at any particular time of the day.

spatial--of or pertaining to space.

spectral--of, pertaining to, or produced by a spectrum.

spectrum--a spatial representation of radiant energy in order of their wavelengths.

stratigraphy--a branch of geology dealing with the classification, correlation and interpretation of stratified rocks.

sun-synchronous--a satellite operated in such a manner that the orbit covers a portion of the Earth's surface at the same time locally each day.

synoptic--taking a general view of the principal parts of a subject.

temporal--of or pertaining to time.

terrestrial--pertaining to, consisting of or representing the Earth as distinct from other planets; of or pertaining to land as distinct from water.

TM--Thematic mapper; a remote sensor similar to the MSS.

tonal--pertaining to the system of tones or tints, or the color scheme, of an image.

topography--the relief features or surface configuration

of an area.

trophic status--the occurrence of nutritive processes,
as in a lake or pond.

turbidity--murkiness due to stirred-up sediment, as in a
lake or pond.

USACE--United States Army Corps of Engineers.

USDA/SRS--United States Department of Agriculture/
Statistical Reporting Service.

USGS--United States Geological Survey.

visible light--that portion of the EMS which is visible
to the unaided eye.

wavelength--the distance measured in the direction of
propagation of a wave, between two successive points
in the wave that are characterized by the same phase
of oscillation.

LANDSAT APPLICATIONS TO LANDSCAPE ARCHITECTURE

by

WILLIAM CURTIS LEEK

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Department of Landscape Architecture

KANSAS STATE UNIVERSITY
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As part of the Earth Resources Survey Program, established in 1965, the National Aeronautics and Space Administration has created and operated a series of remote sensor satellites. Given the generic term LANDSAT, these satellites scan the Earth's surface with their electronic instrumentation, detecting the presence and pattern of Earth resources. From this collected data, scientists may study the Earth's resources, collecting inventories and formulating policies for the use and preservation of these resources.

Landscape architects should be familiar with how the LANDSAT system operates and what products are available. This thesis describes LANDSAT and outlines methods for the use of LANDSAT products in the discipline of landscape architecture.

Land use/land cover mapping is one area of Earth study which often involves landscape architects. Two features of the LANDSAT system enhance its capability to collect data on land use/land cover: its extensive coverage and its cycle of repetition. These features allow small scale, large area mapping of land use/land cover patterns and detecting changes in these patterns.

Selecting potential sites for land development projects and transportation routes is a three-phase process. LANDSAT's extensive uniform coverage facilitates its use in the first phase of the process, examining regions

to identify candidate areas. These areas must then be examined in greater detail to locate potential sites, from which one site will finally be selected.

In addition to land use/land cover mapping and site selection, LANDSAT data have been applied to studies in agriculture, range resources, forestry, geology, hydrology and other environmental sciences.

In Chapter 5, several case studies are presented to demonstrate the usefulness of LANDSAT data. Three land use/land cover maps have been delineated: one from LANDSAT data at a scale of 1:1,000,000; one from LANDSAT data at a scale of 1:125,000; and one from high-altitude aerial photography at a scale of 1:125,000. The differences in scale and image resolution are compared, and the mapping procedures described. Then a site selection study focusing on Topeka, Kansas, was completed. In this study, the LANDSAT image at the scale of 1:125,000 was used to locate potential sites for a large scale residential development project.

In the final chapter, future planned LANDSAT missions are discussed. Recommendations are made concerning improvement of LANDSAT data collection methods.