REMOTE SENSING IN URBAN AND REGIONAL PLANNING

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To

my wife

MARY ANN WOODROFFE

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CHAPTER 1

INTRODUCTION

In the past few years, urban, regional and environmental planners have been confronted by many new problems. These problems require an assortment of information pertaining to man and his environment. Accordingly, the purpose of this thesis is to demonstrate how remote sensing can be implemented as a planning tool to help in analyzing and solving planning problems.

Remote sensing is a fairly new term, symbolizing the techniques of data collection using sensing equipment to detect wavelengths in the electromagnetic spectrum.[1] The actual field of remote sensing covers many other fields, such as; photo interpretation, photogrammetry and multispectral sensing.

In the field of urban planning, remote sensing techniques have in the past, and still do, offer an excellent means to analyse the changing physical forms of a city. By delineation of growth or blight areas over a period of time a planner can see the fluctuation of the problem areas much more readily than conventional methods. Thus remote sensing

[1]The visible spectrum is a small segment of the electromagnetic spectrum, (see Figure 2).

techniques establish a means of continuous monitoring of urban areas providing a basis for continuous development planning, which has only recently been introduced to planning agencies.

Regional planning, on the other hand, finds remote sensing's greatest assets in land-use identification and classification. Using remote sensing imagery, physical features, man made or natural, can easily be depicted by a trained interpreter or planner, resulting in a uniform identification and classification process for small or large areas.

For environmental planning, remote sensing techniques offer a data collection and storage system that can be used for urban and natural environments. This system helps provide planners with a better understanding of urban and regional phenomena related to the natural environment.

It is not surprising to find that all planners who have a good understanding of remote sensing techniques can assess, evaluate and monitor urban and regional phenomena much more quickly and accurately than by any other method. Remote sensing offers an economical, time saving, practical method to acquire information about the different environments, giving a visual perspective that becomes a permanent record.

CHAPTER 2

TECHNIQUES OF REMOTE SENSING

1. History of Remote Sensing

Remote sensing as seen today has only developed in the last 200 years, although it was the early Greeks who found that objects could be measured by bending or deflecting rays of light. Later, Leonardo da Vinci, Albrecht Dürer, and others described the principles of perspective geometry. It was not until Daguerre in 1839 used a fixing agent to retain a photographic image that these theories became practical. The first major application related to remote sensing was in the production of maps for towns and villages. By applying terrestrial photographs and simple geometry, map production time was considerably reduced.

In 1858 the photographer Gaspard Felix Tournachon ascended in a balloon to photograph an area near Paris for topographic map making. In the United States the first successful photographs to be taken from a balloon was over Boston by Samuel A. King and J. W. Black, in 1860.[2] From then on photography was used solely by the military and aided both sides in the American Revolution. During the first World War aerial

[2]Manual of Photographic Interpretation, pg. 3.

photography became a major tool of war. As aircraft were developed and modified so were aerial cameras and photographic techniques.

Between World War I and World War II many companies were created in Canada and the United States, as aerial photography suppliers and map makers.

During the Second World War the military once again made more improvements on aerial cameras, films and processing. They also trained many civilians in the art of air photo interpretation.

During the late 1930's and early 1940's Canada and the United States witnessed the emergence of planning agencies at various administrative levels: state or provincial, county, regional, metropolitan and city. The Chicago Planning Commission was one of the first to use aerial photography and photo interpretation in the making of their Master Plan of Residential Land Use.

Today most planning agencies use aerial photography, or have done so, in one way or another (see Figure 1).

2. Photo Interpretation

Recognizing features on aerial photographs is a highly skilled art, requiring years of familiarization with objects, based upon their pictorial elements, that is, shape, shadows, colour, dimension, tone, texture, pattern, location, and association with other objects.

The information is portrayed in a photograph taken on the earth's surface, in the air, or from space. Considerable information can be detected from a single photograph based upon two-dimensional study. However, much more information may be obtained from a three-dimensional stereoscopic image.

Generally, photo interpreters study photographs by first looking at the most familiar features and relating these to the least familiar. Some of the most familiar features are:

- transportation systems
- drainage patterns
- topography
- natural vegetation
- agricultural land use
- rural non-agricultural land uses
- urban land uses
- heavy industrial areas

These can easily be recognized on photographs or imagery by their pictorial elements. Some of the less familiar features are: houses, barns, traffic lights, etc.

When recognizing features on photographs one must keep in mind at all times the quality of photography or imagery to allow for distortions. This quality is controlled to a large extent by specifications and environmental conditions when the photography is obtained, thus resulting in obscuring some normally available information while emphasizing others.

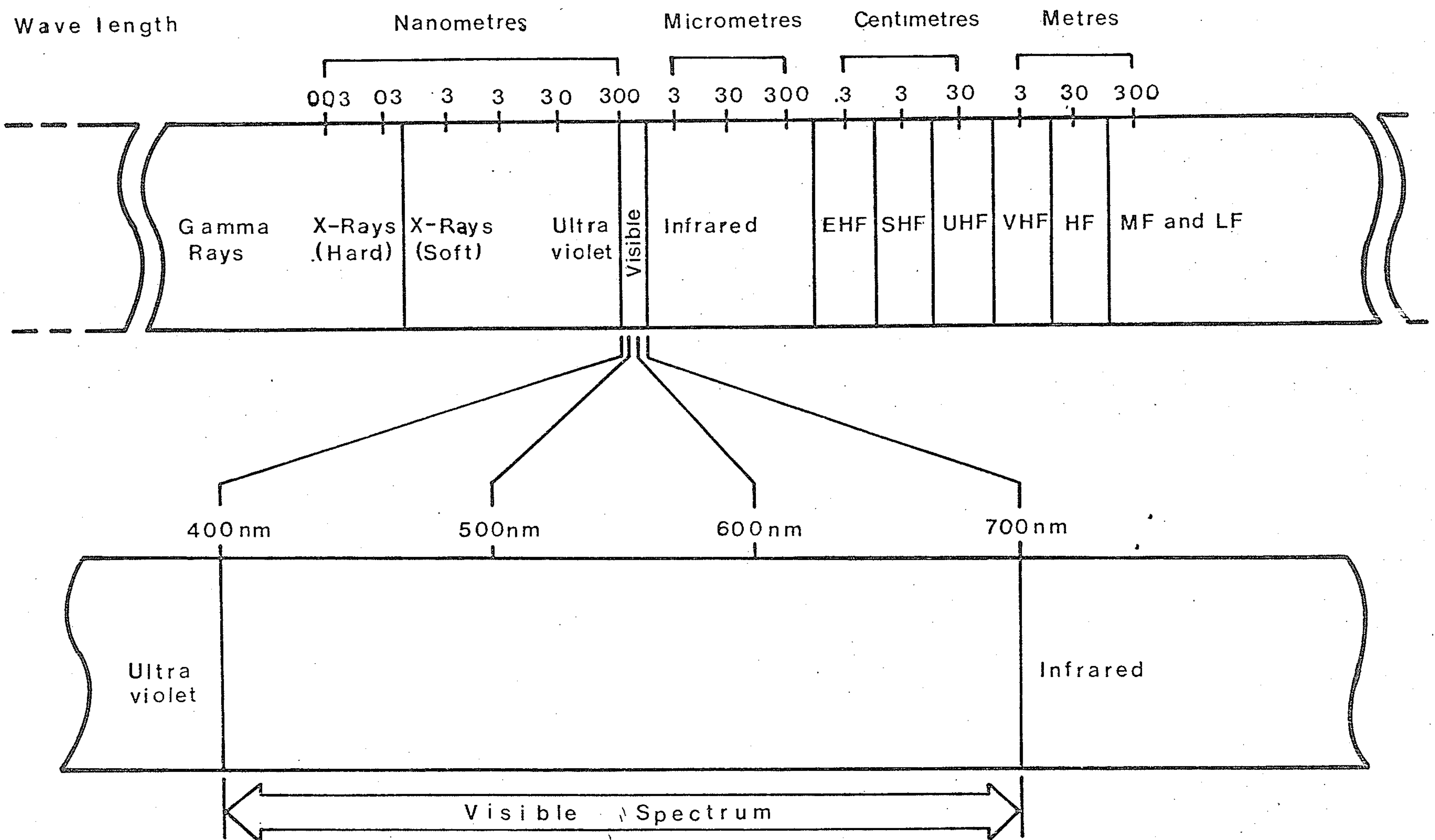
Becoming one of the most important pictorial elements in photo interpretation is colour. The human eye is found to be sensitive to radiation ranging in length from 0.40 (the violet threshold) to 0.70 microns (the red threshold).[3] It is substantially more sensitive to the middle range of this visible spectrum, the highest sensitivity being in the green range at about 0.54 microns (see Figure 2).

Thus the eye can distinguish the many colour combinations in the environment.

[3] A micron, one millionth of a meter, or about one twenty five thousandth of an inch, is the unit by which infrared wavelengths are measured.

FIGURE 2

Electromagnetic Spectrum



3. Photogrammetry

Photogrammetry is the technique of making reliable measurements from photographs. Vertical and horizontal measurements are made on many different kinds of photographs, including aerial and terrestrial. A wide variety of investigators, engineers, planners, foresters, agriculturists, biologists, and medical doctors, have done many types of studies, ranging from power dam site selection to analyzing human bone structure, using photogrammetric techniques.

By far the largest application of photogrammetry has concentrated on aerial photography, although the principles apply to terrestrial and satellite photography as well (see Table 1).

Aerial photography is usually taken vertically from an aircraft giving a bird's eye view of the terrain below. The size and scale of the photography are determined by the flying height of the aircraft and the camera system used (see Figures 3 and 4).

With proper overlap of photographs - that is, say, 60% of both photos revealing the same terrain area from two vertical positions - one can with stereoscopic viewing equipment distinguish and measure the relief of features. With these two photographs and some basic measurements one can determine the height, size and distance of features such as trees, houses, telephone poles and lakes.

TABLE I

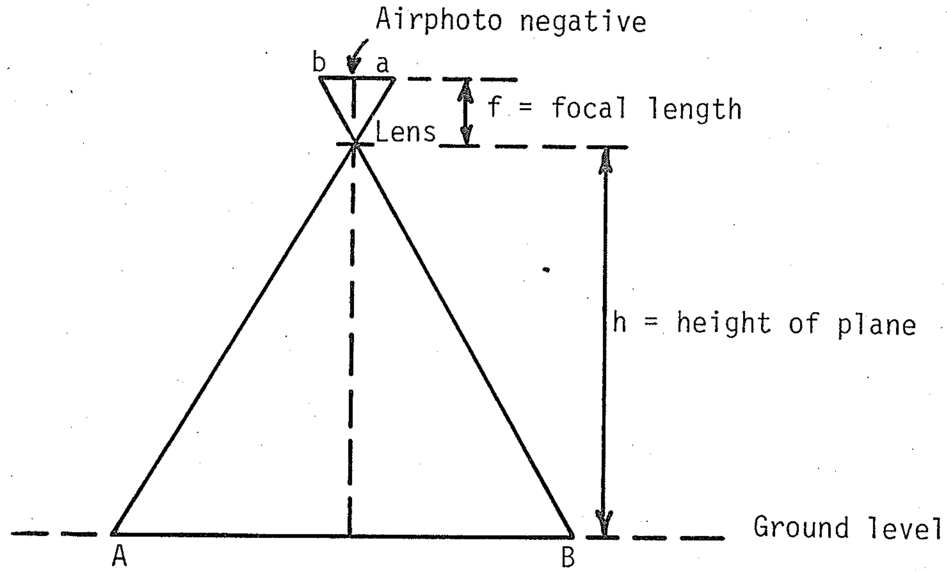
GUIDELINES FOR AERIAL SURVEYS

Description of Task	Film Type*	Season	Scale
Forest mapping; conifers	Pan	Fall, winter	1:12,000-1:20,000
Forest mapping; mixed stands	IR	Late spring, fall	1:10,000-1:12,000
Timber volume estimates	Pan or IR	Spring, fall	1:5,000 -1:20,000
Locating property boundaries	Pan	Late fall, winter	1:10,000-1:25,000
Measuring areas	Pan	Late fall, winter	All scales
Topographic mapping; highway surveys	Pan	Late fall, winter	1:5,000-1:10,000
Urban planning	Pan	Late fall, winter	1:4,800-1:9,600
Automobile traffic studies	Pan	All seasons	1:2,400-1:6,000
Surveys of wetlands or tidal regions	IR	All seasons-low tide	1:5,000-1:30,000
Archeological explorations	IR	Fall, winter	1:2,400-1:20,000
Identifying tree species	Colour	Spring, summer	1:600 -1:4,800
Assessing insect damages	Colour IR	Spring, summer	1:600 -1:5,000
Assessing plant diseases	Colour IR	Spring, summer	1:1,200-1:7,200
Water resources and pollution	Multispectral	All seasons	1:4,800-1:8,000
Agricultural soil surveys	Colour	Spring or fall, after plowing	1:4,800-1:8,000
Mapping range vegetation	Colour	Summer	1:600 -1:2,400
Real estate assessment	Colour negative	Late fall, winter	1:4,800-1:12,000
Industrial stockpile inventories	Colour negative	All seasons	1:1,200-1:4,800
Recreational surveys	Colour negative	Late fall, winter	1:5,000-1:12,000

*NOTE:
Color aerial photography can also be used-often to greater advantage than black and white photography.

Source: "Photointerpretation for Land Managers" Kodak Publication M-76, pg. 19.

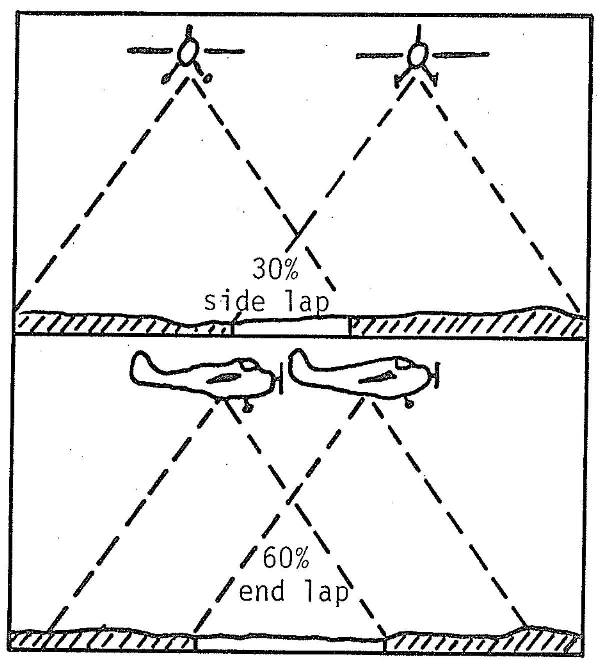
FIGURE 3



$$RF = \frac{ab}{AB} = \frac{f}{h}$$

Scale of airphotos.

FIGURE 4



Overlap of airphotos.

The ease with which these measurements are made is greatly influenced by the quality of the photographs. Affecting this quality is the amount of cloud in the photo, shadow caused by relief, glare from the sun, identification of ground control, and horizontality of the aircraft to the earth's surface.

Another type of air photo is the oblique aerial view. Oblique views are photographs taken toward the horizon, sometimes including the horizon, called a high-oblique. These photographs are taken in aerial photography missions for orientation of vertical photographs, or for different perspectives of the terrain. This is the view most commonly seen and understood by the public in advertisements, or personal slide shows.

A composite picture, assembled by taking non-overlapping vertical aerial photographs, placing them together like a jigsaw puzzle and gluing or photographing them to make a map or large picture is called a mosaic (see Figure 5).

If the mosaic is constructed at a certain scale, using ground survey points, it is referred to as a "controlled mosaic". Otherwise it is referred to as an "uncontrolled mosaic". When assembled, both types of mosaics are excellent for planning purposes. With the use of transparent overlays one can show features such as property boundaries, trails, soil types, vegetation classes, land uses, parks, concentration of wildlife, different building types, and many more features.

Vertical photography is also used to make photomaps and orthophotomaps.[4] Both can be made from a single photo, a composite, or a mosaic and show clearly most of the information on the ground.

Types of film have a great effect on the quality of photographs and the distinguishing characteristics of the features. In the past, black and white film was used mostly for aerial surveys because of its low cost and high resolution. Today more aerial photography users prefer colour photography as it provides more information. There are approximately 80 shades of black to white, while colour has unlimited combinations and variations.

Colour quality is affected by haze, smog, and increased flying height. Hence when taking colour photography the most natural colour balance is achieved on a clear morning without a haze filter and a flying height approximately 2,000 feet or less. At higher altitudes haze filters are usually required; in fact, without the correct exposure and proper filter, colour aerial photographs are likely to be of poor quality.

To-date colour photography has not been used extensively in making regional terrain studies. It has not been demonstrated conclusively that interpretation of colour prints is easier, and more efficient, than interpretation of terrain from conventional black and white photographs with the exception being special limited studies, particularly where vegetation is concerned.

[4]Orthophotomaps are photomaps in which the image is distortion-free.

The cost of colour photography has been reduced in recent years, but is still substantially higher than that of conventional black and white aerial photography. The higher costs result not only from higher prices for materials, but more expensive processing and precision flying.

Conventional black and white film and normal colour film are sensitive only to wavelengths in the visible portion of the spectrum. Colour infrared film is sensitive to the visible and near infrared portions of the electromagnetic spectrum. Thus colour infrared film is not sensitive to thermal emissions (heat) which have wavelengths in the middle and far ranges of the infrared portion of the spectrum. But because it is like the visible portion, it contains wavelengths which are predominately the result of reflected rather than emitted radiation from the sun.

Colour infrared film uses the same dyes found in normal colour film, but each dye is made sensitive to a different portion of the spectrum. A "colour shift" thus results on colour infrared film whereby greens appear blue, reds appear yellow, and near infrared wavelengths appear red on the photographs [5] (see Figures 6 and 7). The red on the photographs is of considerable importance in that it is the healthy vegetation which has a strong reflectance in the near infrared portion of the spectrum. Different types of vegetation appear as different shades of red. As a result, infrared film has been an invaluable aid in the detection of

[5] "Aerial Photography As A Planning Tool", Proceedings of the Kodak Seminar: Kodak Publication M-128, pg. 17.

certain kinds of diseased plants and trees, or types and stages of growth, in agricultural and forestry research and management.

In the urban environment it has been found that the type and amount of vegetation and the degree of landscaping is an indicator of socio-economic status of residential neighbourhoods. Thus variation of the intensity of reds on an infrared photograph provides a dramatic and readily apparent initial indicator of the quality of the environment of most areas of a city.

The quality of infrared films to penetrate haze and smog makes it excellent for urban remote sensing, supplying a much sharper image than normal colour or black and white film.

4. Multispectral Sensing Systems

Over the last few years several new scientific developments in the field of aerial imagery have taken place, basically due to aerospace research. By using two or more sensors to receive electrical signals that modulate a light source, imagery of the earth's surface in different parts of the electromagnetic spectrum is produced. The operating system is usually referred to as multiband, spectral-zone, or multispectral sensing.

The multispectral sensing systems are usually installed in aircraft, but other platforms have been used such as balloons, helicopters, spacecraft and satellites.

As mentioned earlier visible light covers that part of the spectrum having a wavelength between 0.40 microns in the violet band and 0.70 microns in the red band. This is a very small portion of the known spectrum of electromagnetic waves emitted by the sun (see Figure 2).

The infrared portion of the spectrum is so broad that different sensors are required to record different portions. Investigators usually subdivide the infrared band into photographic infrared, near infrared, middle infrared, and far infrared. The boundaries between these divisions are not clearly defined and usually overlap.

Infrared photography depends on reflected or absorbed energy from the sun. Infrared imagery, operating between 0.90 microns and the far infrared section of the spectrum, depend on thermal energy; i.e., heat emitted from buildings, or heat re-emitted from terrain at night after having been absorbed in the day time. This thermal energy recorded in the middle infrared band can be monitored only during the night where black and white, colour, and near infrared photography cannot. Far infrared imagery on the other hand can be recorded either during the day or night without serious interference from the sun.

5. Radar Imagery

The band of the electromagnetic spectrum lying between 1 millimeter and 1 meter is referred to as the microwave region. This is the range in which radar operates - radar being an abbreviation of radio detection and ranging, where two antennae transmit a short pulse of energy of known characteristics to either side of an aircraft or ship. The energy then returns as reflected energy. The returning echos are converted into electron beams that flash across a cathode-ray tube, a line at a time. A camera records each line on a moving film to build up a photographic-like image of the terrain.

Side-looking airborne radar, commonly abbreviated SLAR, has radar imagery covering strips from 50 to 100 miles in width on both sides of the aircraft's flight line. The ground surface directly below the aircraft is not covered.

The techniques used in interpreting radar imagery are much the same as those used for conventional aerial photographs. And, like air photos, radar images should be oriented so that the shadows fall toward the observer to give the proper appreciation of depressions and high points.

6. <u>LANDSAT Imagery</u>

Remote sensing of various types carried in space vehicles provide us with extremely small-scale images of the earth's surface if the vehicle is operated at orbital altitudes. Pictures of our planet showing remarkable clarity and great coverage have been obtained in this manner. Mosaics and maps are being made from some of these pictures taken with very high resolution lens and given a scale of 1 inch equal to 80 miles on the earth's surface.

In particular, the repetitive data acquired on an 18 day cycle by NASA's Earth Resources Technology Satellite (ERTS-1) are available in four spectral bands. Such data, at scales of 1:250,000 and smaller, can assist all planners, particularly regional and resource planners (see

Figures 8 and 9).

The Canadian Program of Remote Sensing handles ERTS imagery, now LANDSAT, from a tracking and recording station at Prince Albert, Saskatchewan. In Ottawa a data handling facility and reproduction and distribution center, has been established in conjunction with the National Air Photo Library.

LANDSAT images can provide information for geological mapping at small scales, mineral exploration, analysis of contemporary terrain conditions, progress of freeze-up and break-up, construction sites, and transportation routes. In the absence of suitable topographic maps, LANDSAT imagery can serve as small scale base maps (less than 1:250,000).

LANDSAT data are currently acquired by a multispectral scanner (MSS) in 4 wavebands.[6]

MSS Band 4 visible green (yellow-green)	500-600 nanometers
MSS Band 5 visible red (orange-red)	600-700 nanometers
MSS Band 6 photographic infrared	700-800 nanometers
MSS Band 7 photographic infrared	800-1100 nanometers

Black and white images for each band and two types of colour composite are commonly available. C1, a colour composite which simulates colour aerial infrared photography, is a combination of the two visible bands MSS Bands 4 and 5 (see Figure 8), and one infrared band usually

[6]Alan F. Gregory: "Applications of Remote Sensing with Special Reference to the Geosciences", Seminar paper, Department of Geology, University of New Brunswick, March 7, 1975.

MSS Band 6. C2 is a combination of the visible red MSS Band 5 and the two infrared bands MSS Bands 6 and 7 (see Figure 9). Each type of image emphasizes different aspects of the scene and hence is more useful for some observations and measurements than others. A generalized listing of uses for each waveband is presented in Table 2.

7. Summary

Remote sensing, which includes photo interpretation, photogrammetry, and multispectral sensing, is a relatively new field in which space age technology and the computer have recently opened up new vistas.

Photo interpretation is a highly skilled art involving training and familiarization over time.

Photogrammetry is the science of making measurements on photographs and has concentrated on aerial photography, providing much valuable information for professional people and the public.

The actual method of using aerial photographs involves becoming trained in the orientation and use of stereoscopes and measuring equipment in order to recognize and identify the features. The interpreter studies the characteristics of these features separately, then in relation to each other and in relation to the whole pattern.

Black and white photographs are used extensively in planning large areas because of their low cost and high accuracy in measuring. The main use of colour photography is in low level flying of relatively small areas of terrain, displaying information not obtainable by conventional

TABLE 2

Generalized List of Uses for Each LANDSAT Waveband
(for well-illuminated, snow-free scenes)

	Feature	Band 4	Band 5	Band 6	Band 7	C1	C2
1.	well exposed soil and bedrock, beaches, salt flat, desert drainage	F*	E	F	P	G	F
2.	geological structure, surficial textures, lineaments	F	G	E	G	G	G
3.	landforms	F	E	G	F	E	G
4.	soil moisture	P	F	G	G	F	G
5.	rivers and streams	P	F	G	E	G	G
6.	boundaries of water bodies and wetlands, flooding	P	F	G	E	G	E
7.	water turbidity, submarine topography	G	E	F	P	G	F
8.	water penetration	E	F	P	P	F	P
9.	vegetation coverage and stress (including logging, forest fire scars, etc.)	F	G	G	G	E	G
10.	anthropogenic elements (urban development, transportation infrastructure)	G	E	P	P	E	G
11.	rural land use, agriculture	G	E	E	E	G	G
12.	atmospheric transmission (through smoke, haze and dust)	P	F	G	E	F	G

*Arbitrary ratings of Excellent, Good, Fair, Poor from experience.

Object resolution averages about 200-300 feet with higher resolution for objects of high contrast.

black and white photography. Colour aerial films are best suited to provide information on cultural features, gullies, erosional landforms, and in soil variations. Colour infrared film generally is better suited for mapping, drainage and vegetation.

The newest and most exciting advances in remote sensing techniques are in multiband sensing with the use of spacecraft. These operate in portions of the electromagnetic spectrum from the microwave to the ultraviolet region. Infrared, microwaves, and radar sensors operate under both day and night conditions, and radar sensors are not seriously hindered by clouds and bad weather. Thus, regardless of weather or light conditions, information about the terrain can be gathered.

Since the United States NASA program ERTS (now LANDSAT) started, Canada has been receiving photographs by satellite from 480 nautical miles up. The satellite covers Canada every 18 days, at a scale of 1:1,000,000. The images are received in Prince Albert, Saskatchewan and then sent to Ottawa for development into photographs. The Department of Energy, Mines and Resources in Ottawa interprets the results and rates the quality of the imagery as good, fair and poor then releases the photographs to interested persons.

From this overview it is apparent that new sensor systems are providing additional information on both natural and man-made features beyond the capability of films in cameras and beyond the limits of human vision.

CHAPTER 3

URBAN PLANNING APPLICATION

1. Introduction

At no time in history has man assembled in such large numbers, as evidenced today in our major cities. In less than 200 years places like New York have grown from relatively small towns, to cities with populations in the millions.

In recent years changes in the urban pattern have been very rapid, thus causing extensive spreading into the surrounding countryside. In cities like Winnipeg, the population has doubled in 35 years. Other cities in Canada such as Montreal, Toronto, and Vancouver have grown at much faster rates.

Commerce and industry has shifted from the centre to the outskirts of the city, mostly because of the increased use of the car which has changed the habits and movements of most of the population. As a result, the capacity of existing facilities such as roads, sewage disposal, water supply, and availability of land for all new essential services and utilities has frequently been overextended. A speedier and less costly means of evaluating these trends of urban development, is required so that one can keep pace with the pressure of extending or constructing new