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 Imagery as a Base for Thematic
 Mapping
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THE UNIVERSITY OF ALBERTA,
EDMONTON, ALBERTA
LARGOAT EST. THAGBY AS A CASE FOR
THEMATIC MAPPING.

by

ERIC J. DEW



A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF ARTS.

DEPARTMENT OF Geography

EDMONTON, ALBERTA

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FACULTY OF GRADUATE STUDIES AND RESEARCH

800

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in partial fulfillment of the requirements for the degree of
Master of Arts

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- 1) Map of Canada according to The National Geographic Society (Revised 1960)
- 2) Toronto-United Region, Viewed from the Earth Resources Technology Satellite.

ABSTRACT

The development of orthophotography and the subsequent production of orthophotomaps has laid the groundwork for the amalgamation of photo image and map symbol image. Due to the inherent characteristics of aerial photography, orthophotomapping has necessarily been undertaken at large scale. The considerable cost of producing an orthophoto image of a certain area at small to medium scales has inhibited their production as well as their orthophotomap counterparts. The establishment of satellite born remote sensors aimed at the earth's surface has provided these small to medium scale earth images. Data received from the LANDSAT system and reproduced in photographic form offer the cartographer and map user a new dimension in photo mapping. It is now possible to use low cost satellite imagery in the production of small to medium scale photo maps. One use of such photo maps incorporates the satellite image as a base for thematic mapping.

This study is an appraisal of the LANDSAT system and an evaluation of products produced by the system in light of conventional orthophoto materials. Thematic LANDSAT maps produced by two governmental agencies are reviewed and evaluated. Additional thematic LANDSAT maps incorporating the other standard cartographic techniques are constructed and evaluated. The construction of these maps takes place on two levels and at two scales: 1) a commercially produced LANDSAT map using a polychrome image printed at a scale of 1:250,000; and 2) the remainder of LANDSAT maps produced in manuscript form using a

monochrome image and photographically reduced to approximately
11,000 lines. The output scale of 1:25,000. These maps are then
evaluated and guidelines for the production of future thematic Landsat
maps are developed. A direction for future study of thematic Landsat
mapping is also indicated by this appraisal.

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TABLE OF CONTENTS

CHAPTER	PAGE
1 OBJECTIVES, AND METHODOLOGY FOR THE STUDY OF LANDSAT IMAGERY AS A THEMATIC MAPPING BASE	1
Introduction	1
Objectives and Methodology	2
2 THE LANDSAT SYSTEM	5
Introduction	5
Data Products	9
Geometric Fidelity	15
Resolution	16
Cartographic Aspects of LANDSAT Imagery	20
3 PHOTO MAPPING	24
Conventional Orthophoto Mapping	24
LANDSAT Orthophoto Mapping	30
The Economics of LANDSAT Photo Mapping	31
Nation's Capital Area ERTS (LANDSAT) Map	32
The National Capital Region - Experimental Photo Map	38
4 THE TORONTO CENTRED REGION MAP	42
Introduction	42
Mapping Constraints	43
Compilation and Design	45
Map Production	48
The Toronto Centre Region ERTS (LANDSAT) Map - Critique and Comparison	52

5	THEMATIC LANDSAT MAPS	64
	Introduction	64
	Conceptual Aspects of the Landsat Thematic Map	65
	Design and Production of Selected Thematic Landsat Maps	67
	Chorochromatic Landsat Map	69
	Landsat Image Dot Map	71
	Landsat Flow Map	73
	Choropleth Landsat Map	75
	Cartodiagram Landsat Maps	77
	Isarithmic Landsat Map	81
	Economic Aspects of Thematic Landsat Maps	83
6	CONCLUSIONS AND RECOMMENDATIONS FOR THEMATIC LANDSAT MAPS	85
	Best Use of the Thematic Landsat Map	85
	Conclusions and Design Guidelines for Thematic Landsat Maps	86
	Recommendations for Future Study	89

	BIBLIOGRAPHY	90
	APPENDIX I GLOSSARY	102

LIST OF FIGURES

Figure	Page
1. Typical LANDSAT Daily Ground Trace (Daylight Passes Only)	6
2. Coverage of LANDSAT Overpass on Successive Days	8
3. MSS Scanning Arrangement	10
4. LANDSAT Image of Toronto 21 August 1972 1029 15345	11
5. City of Baltimore Image 1062-15190	12
6. Minimum Cloud Cover on Canadian LANDSAT Images	14
7. An Analysis of LANDSAT Geometric Fidelity	17
8. Relative Position on an LANDSAT Image	18
9. Three Methods of Precision Processing Compared to Bulk Imagery	19
10. A Section of a LANDSAT Image Enlarged to 1:500,000	21
11. Map Symbolization and Photographic Detail	25
12. A Comparison of a Conventional Line Map and Orthophoto Map of the Gatineau Park Area	26
13. Density Distribution on an Aerial Photo Negative	28
14. Photo Mosaics of Montreal Undodged and Autododged Prints	29
15. A LANDSAT Print of the Montreal Area 1062 - 15170	33
16. A Section of the Washington D.C. ERTS (LANDSAT) Map	35
17. A Section of the ERTS Image Distributed with the Washington D.C. ERTS (LANDSAT) Map	36
18. A Section of the Ottawa LANDSAT Map and the Corresponding N.T.S. Topographic Map	39

19.	A Field of 10^4 1000' A. View of the Toronto Centre Region	46
20.	The Black Plate and a Large Colour Composite	47
21.	A Colour Balance Section of a Section of the Toronto ERS (LANDSAT) Map	53
22.	The Black Plate and Blue Plate Progressive Proofs of the Toronto ERS (LANDSAT) Map	54
23.	The Magenta and Magenta Plus Yellow Progressive Proofs of the Toronto ERS (LANDSAT) Map	55
24.	The Cyan and Cyan Plus Magenta Progressive Proofs of the Toronto ERS (LANDSAT) Map	56
25.	The Yellow and Yellow Plus Cyan Progressive Proofs of the Toronto ERS (LANDSAT) Map	57
26.	A Photoprint of a Section of the Toronto ERS (LANDSAT) Map	59
27.	An Experimental Chorochromatic LANDSAT Map	70
28.	An Experimental LANDSAT Dot Map	72
29.	An Experimental LANDSAT Flow Map	74
30.	An Experimental Choropleth LANDSAT Map	76
31.	An Experimental Cartodiagram LANDSAT Map UTILIZING Bar Graphs	77
32.	An Experimental Cartodiagram LANDSAT Map UTILIZING Circle Sectors	79
33.	An Experimental Cartodiagram LANDSAT Map UTILIZING Graduated Circles	80
34.	An Experimental Isarithmic LANDSAT Map UTILIZING Isopleth Lines	82

CHAPTER I

OBJECTIVES AND METHODOLOGY FOR THE STUDY OF LANDSAT IMAGERY AS A THEMATIC MAPPING BASE

1.1 Introduction

The launch of the Earth's first man-made satellite over twenty years ago was just the beginning in the development of satellites and satellite sensor systems. Advancements proceeded and more sophisticated, orbiting space platforms equipped with sensors aimed at the Earth, began collecting new data for all earth-related disciplines. The more recently launched LANDSAT satellite system (now two satellites) is one such development. Although the intended use of LANDSAT data is focused on extraction and interpretation of earth data, the natural extension of this earth information extraction lies in the direct and immediate function of LANDSAT data to Cartography. Just as the development of orthophotographs in 1954 laid the framework for the orthophotomap, the development of LANDSAT imagery lays the framework for the direct utilization of satellite imagery as a mapping base. LANDSAT photo mapping has adopted the design and form of the (previously accepted, annotated orthophotomap, primarily a topographic or a "balanced" type of maps.

The use of LANDSAT imagery as a thematic mapping base is relatively untried. The National Aeronautics and Space Administration (NASA) in the United States and the Canada Centre for Remote Sensing (CCRS) in Canada have each produced a 1:250,000 LANDSAT map with a minimum of

1.1 Introduction
The use of LANDSAT imagery for mapping has been discussed in several
publications (e.g., [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13]). However, little
theoretical or practical work has been done in the area of thematic interpretation of
the polar regions (except for north and south at 90°) is also being
produced by the same agency in cooperation with the American
Geographical Society and the National Science Foundation (MacDonald, 1974).
Some of the results of a study of interpretation and use, upon
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Geographical Society and the National Science Foundation (MacDonald, 1974).
Some of the results of a study of interpretation and use, upon
the USSR of Landsat imagery, are presented in this report.

1.2 Objectives and Methodology

The primary objective of these LANDSAT photo-mapping experiments is
to investigate the function of LANDSAT imagery as a base-map for more

complex, socio-economic themes. Since few image maps of this type have been published it will be necessary to (1) evaluate existing thematic LANDSAT maps that are representative of cartographic techniques previously employed, (2) construct and evaluate thematic LANDSAT maps using cartographic techniques that have not been previously employed, (3) determine if such maps are feasible and develop guidelines for the construction of future thematic LANDSAT maps, (4) and to define the best direction for the future development of thematic LANDSAT maps.

Evaluation of thematic LANDSAT image maps will follow traditional methods with a comparison of conventional orthophotography and orthophotomaps to LANDSAT imagery and LANDSAT image maps. The LANDSAT image maps, in turn, will be considered with respect to conventional orthophoto mapping problems and limitations. Consideration must be given to photo name content and map symbology content as well as the design of these two elements. Scale and generalization in relationship to map symbology and image depiction must also be taken into account.

To determine the feasibility of thematic LANDSAT mapping and develop guidelines for construction of future LANDSAT maps, experimental thematic LANDSAT maps will be constructed at two different image formats. One in which the LANDSAT image is produced in a polychrome utilizing the printing of different MSS bands in different colours and secondly the use of a monochrome LANDSAT image as a thematic mapping base. Additionally two scales of image-maps will be constructed and evaluated: the 1:250,000 scale which can also be compared to other LANDSAT Maps produced by NASA and CGRS, and the 1:750,000 which could conceivably

be a good idea to do for other experiments in the future. The results of the experiments should be concentrated on the effect of the experimental design on the results, especially in the case of the rate of the economic theory. There include both quantitative and qualitative representations. Guidelines for the development and construction of future LAMPAL maps should arise from production and evaluation of the dynamic LAMPAL maps fabricated in these experiments. As well the investigation of the LAMPAL system and its concrete applications should develop a possible direction for future study.

CHAPTER 2

THE LANDSAT SYSTEM

2.1 Introduction

The first of two earth resources technology satellites (LANDSAT 1)¹ was launched on July 23, 1972. The satellite now circles the earth in a near polar, sun synchronous orbit at an altitude of approximately 900 miles (1,448 kilometers). The orbit allows for an angle of illumination which varies only with the season of the year. Since the launch, LANDSAT 1 has completed over fourteen thousand orbits. Each orbit takes an average of 103 minutes to complete at a total of 14 orbits per day (Fig. 1) with 18 days to complete full earth coverage and start again on a new cycle. The new cycle has a ground trace overlapping the previous cycle. The amount of overlap is dependent on latitude and satellite pass with increasing overlap as the satellite approaches the poles. Areas within nine degrees of each pole are not imaged. LANDSAT 1 is still functioning beyond expectations and the second earth resources technology satellite, LANDSAT 11 has been launched on 22 January 1975. LANDSAT 11 is intended to replace LANDSAT 1, but it is not yet fully operational. However, MSS imagery is being received from both satellites. A third LANDSAT satellite is being planned for the more distant future (CCRS, 1974, 1975).

¹ The Earth Resources Technology Satellite (ERTS) system was officially designated "LANDSAT" in May of 1975.

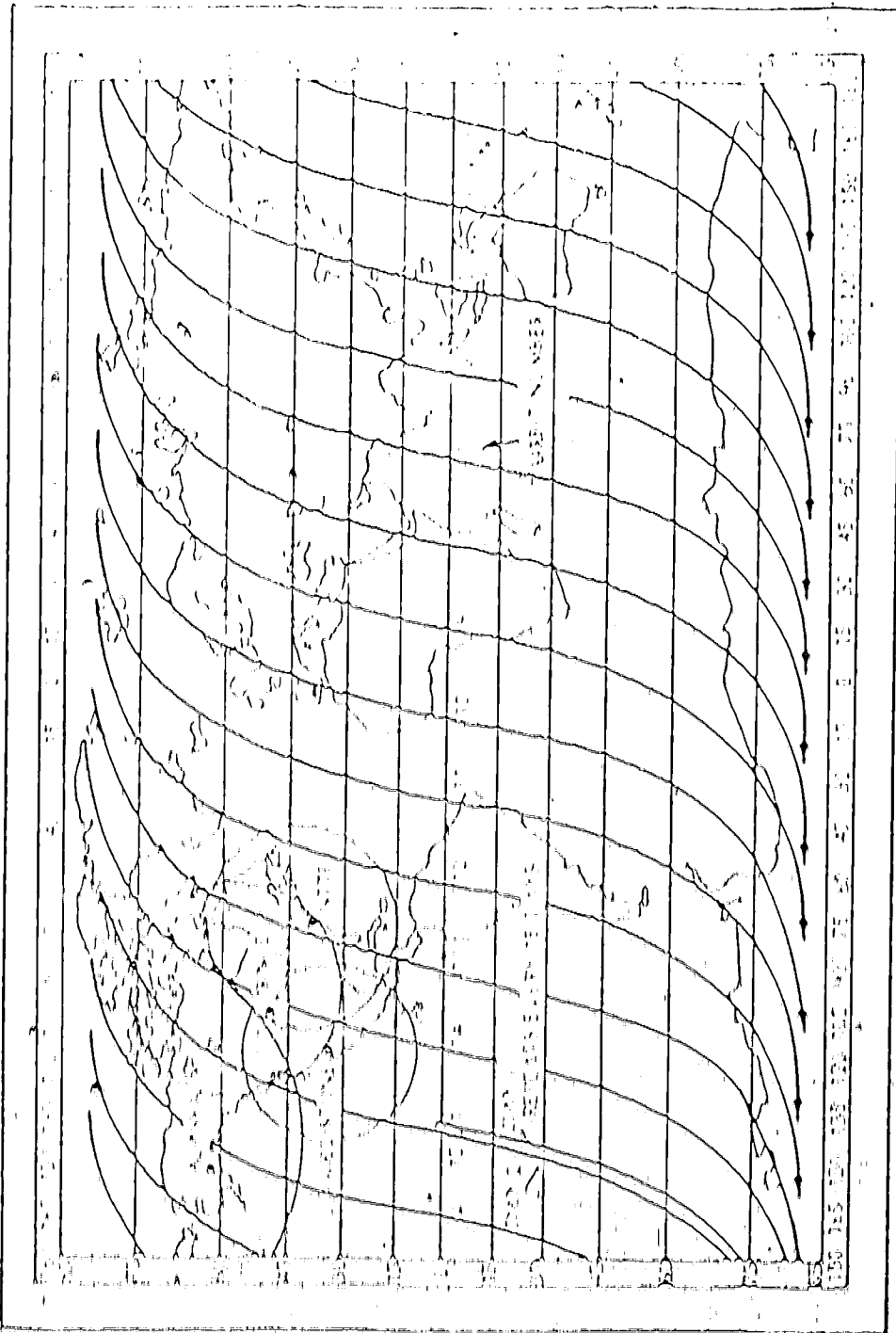


FIGURE 1

TYPICAL LANDSAT DAILY GROUND TRACE (Daylight Passes Only)

Due to the satellite's orbital inclination, the areas within 90° of the poles are not imaged.

The observation system of the spacecraft is divided into three sub-systems:

- 1) Data Collection
- 2) Return Beam Vidicon Camera and
- 3) Multispectral Scanner

Other systems exist on the spacecraft for attitude control, telemetry and maintenance of the satellite, however, these are the three systems with which records of earth data are made. Presently the Multispectral Scanner (MSS) is of prime importance to the cartographer. The Data Collection System (DCS) does not produce image products and the Return Beam Vidicon Camera System (RBV) was switched off early in the mission by NASA control and not reintroduced in LANDSAT II. Consequently, no imagery is being received from the RBV system at the present time.

The Multispectral Scanner (MSS) is the only operational imaging system remaining. It is a line scanning apparatus collecting earth data in four spectral bands with wavelengths as follows:

Sensor	Spectral Band No.	Wavelength in Nanometres (10^{-9} metres)
RBV	1	475-575
	2	580-680
	3	all bands solar reflected wavelengths
MSS	4	500-600 visible green to orange
	5	600-700 visible orange to red
	6	700-800 deep red to near infrared
	7	800-1000 near infrared

*Return Beam Vidicon Camera bands included for reference.

The size and weight of hardware have inhibited the inclusion of a full infrared channel.

As the satellite progresses along its orbital path the MSS system scans continuously in all four bands. The across track scan is

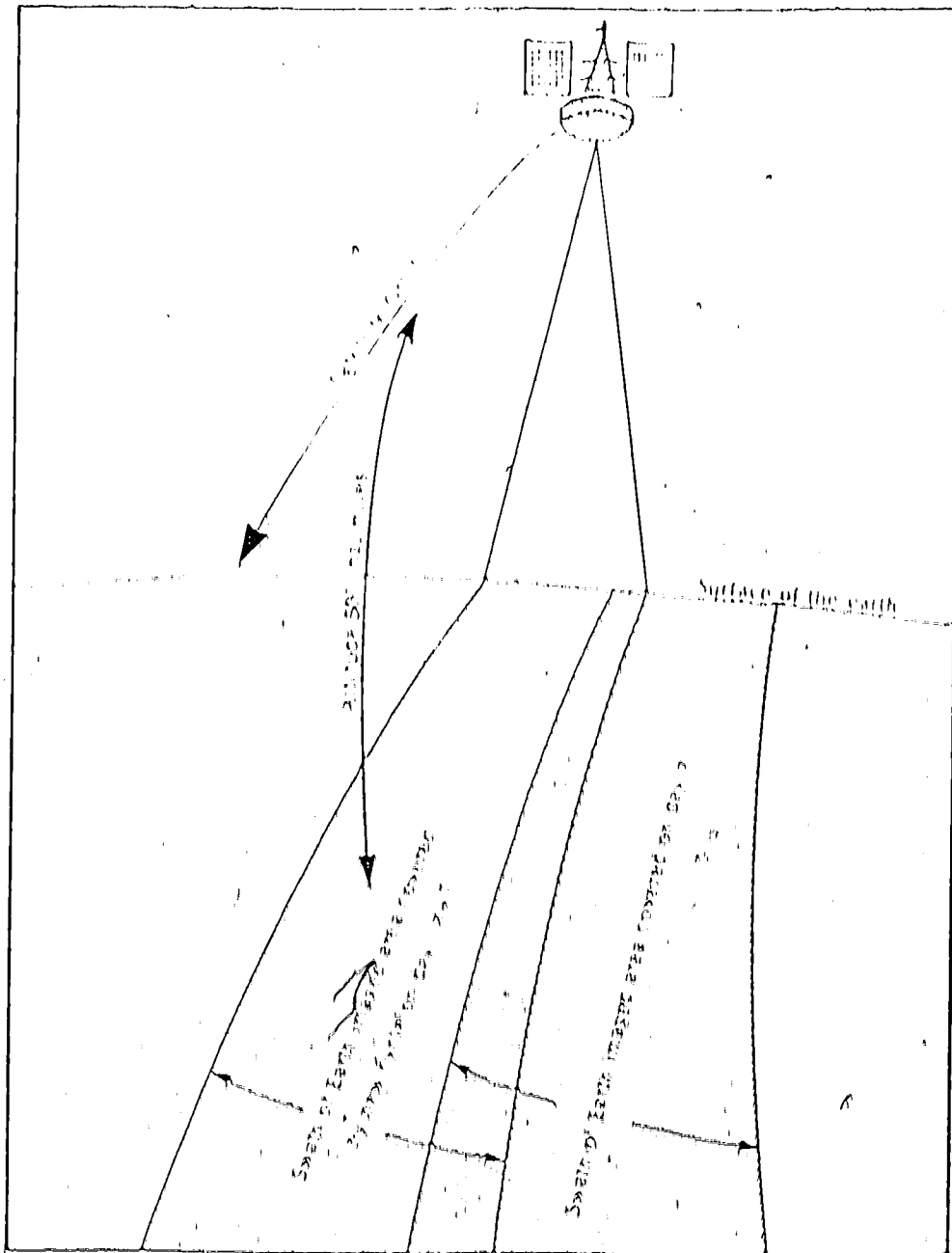


FIGURE 2

COVERAGE OF LANDSAT OVERPASS ON SUCCESSIVE DAYS

accomplished by a flat mirror oscillating at ± 2.89 degrees from nominal with a rate of 13.62 Hz. (NASA, 1972). The along track scan is produced by the forward motion of the spacecraft. The result is data collected in a continuous swath along the ground track at a width of 185 kilometres (Fig. 3). The instantaneous field of each detector covers a square earth area 79 metres on a side (theoretical ultimate resolution?). This area, termed a pixel, actually overlaps adjacent pixels in the same scan line (Malid, Nalepka; 1974). After the data is digitized on board the satellite, it is telemetered back to an earth satellite receiving station. Four stations now exist in North America (Fig. 1) and several have been constructed or are being constructed in localities throughout the world. CCRS is also planning a new receiving station in Eastern Canada.

2.3 Data Products

Data from LANDSAT 1 and 1 $\frac{1}{2}$ are available from two government sources in North America:

The EROS Data Center
United States Department of Interior
Geological Survey
Sioux Falls
South Dakota, 57198
U.S.A.

The National Air Photo Library
Department of Energy, Mines and
Resources
615 Booth St.
Ottawa
Canada

Two private agencies, General Electric Corp. in the United States and Donald Fischer Associates in Canada, also provide imagery to the public. The government agencies provide LANDSAT data in two basic formats, 7 and 9 track computer compatible tapes (CCT) or photographic paper and film products. All of the MSS data received from the satellite is digital and can be used to produce images using a line printer directly or with the aid of an Electron Beam Image Recorder (EBIR) or a Laser Beam Image Recorder (LBIR) can be

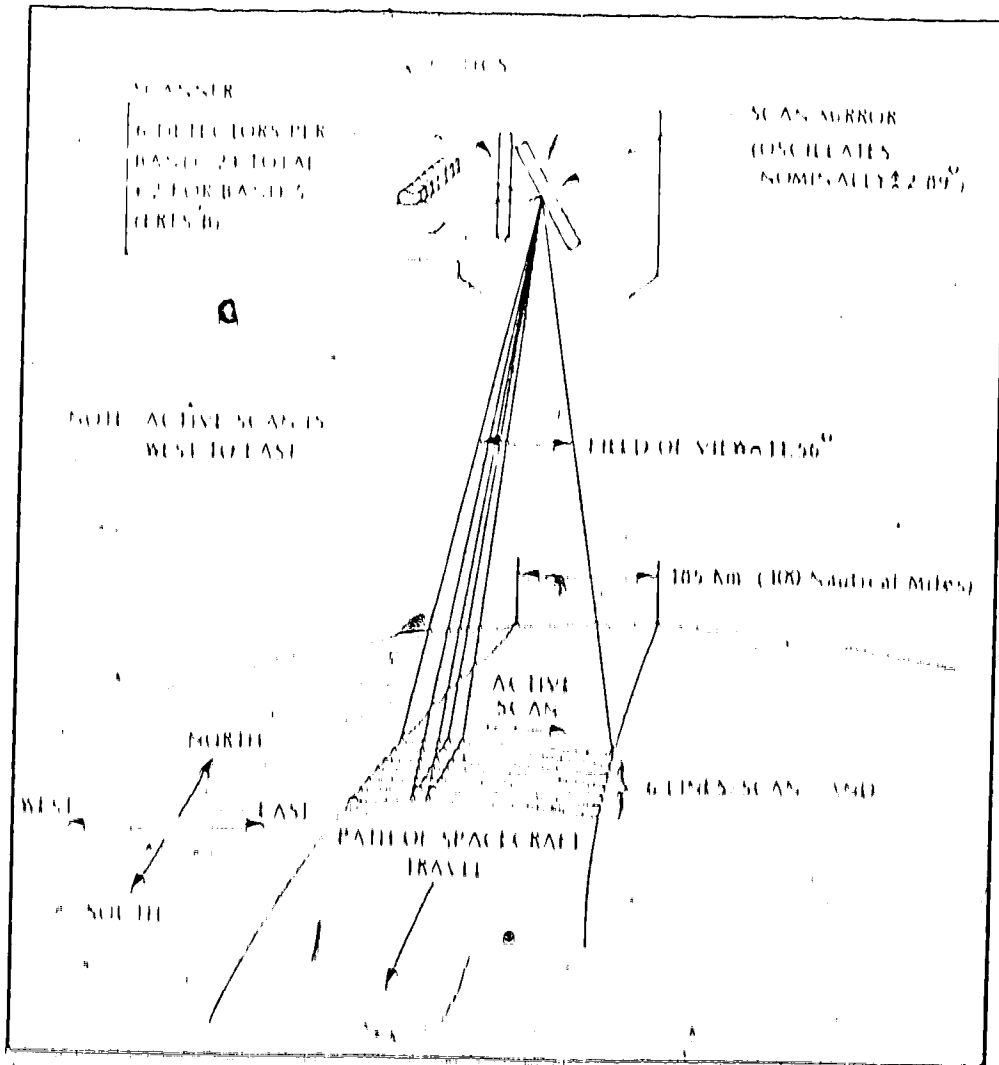
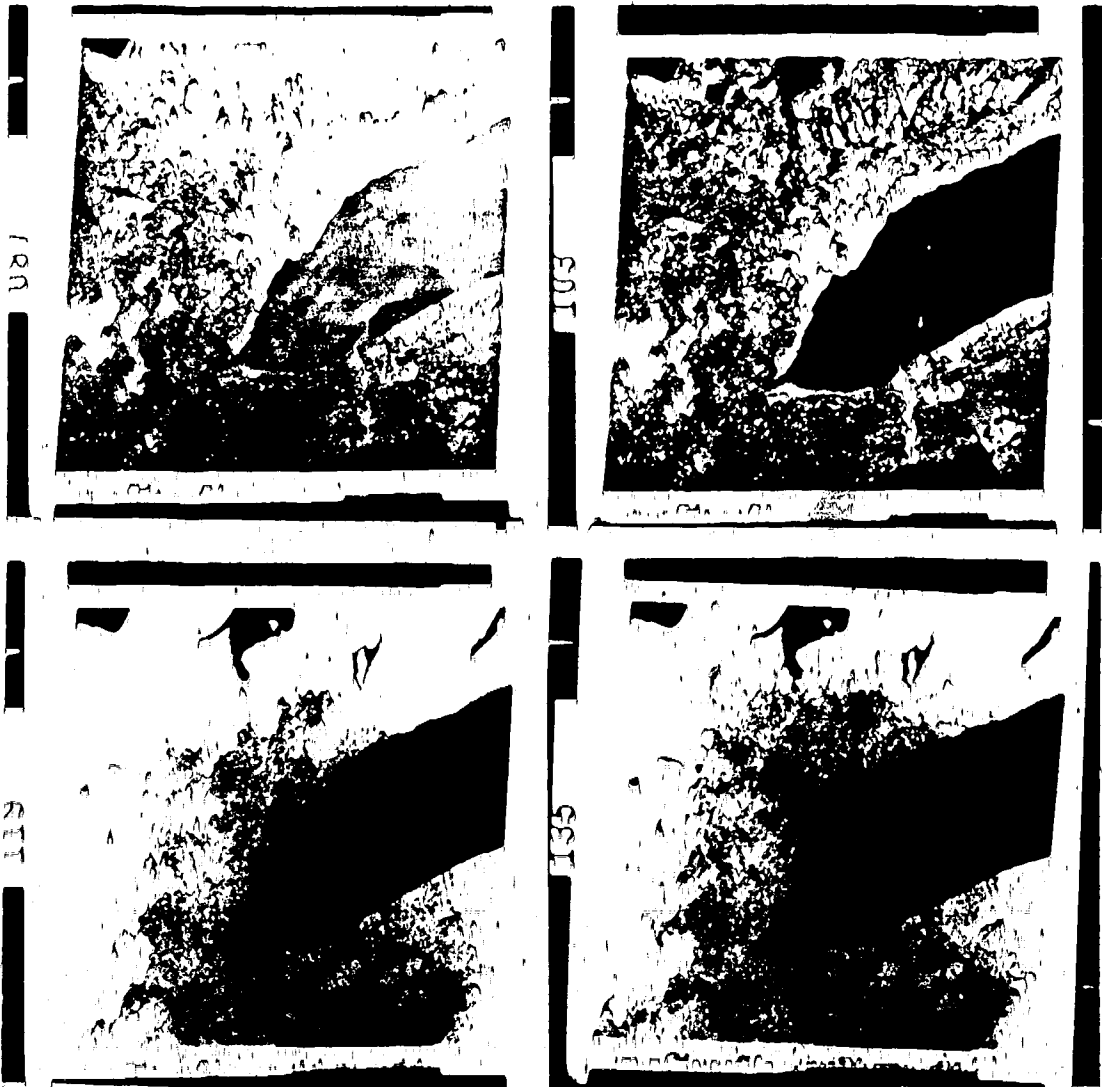


FIGURE 3
MSS SCANNING ARRANGEMENT
(after NASA, 1972)

FIGURE 4

LANDSAT IMAGE OF TORONTO 21 AUGUST 1972

1029 - 15345



Reproduced by EBIR
Clockwise from top left, MSS Bands 4, 5, 7, and 6.

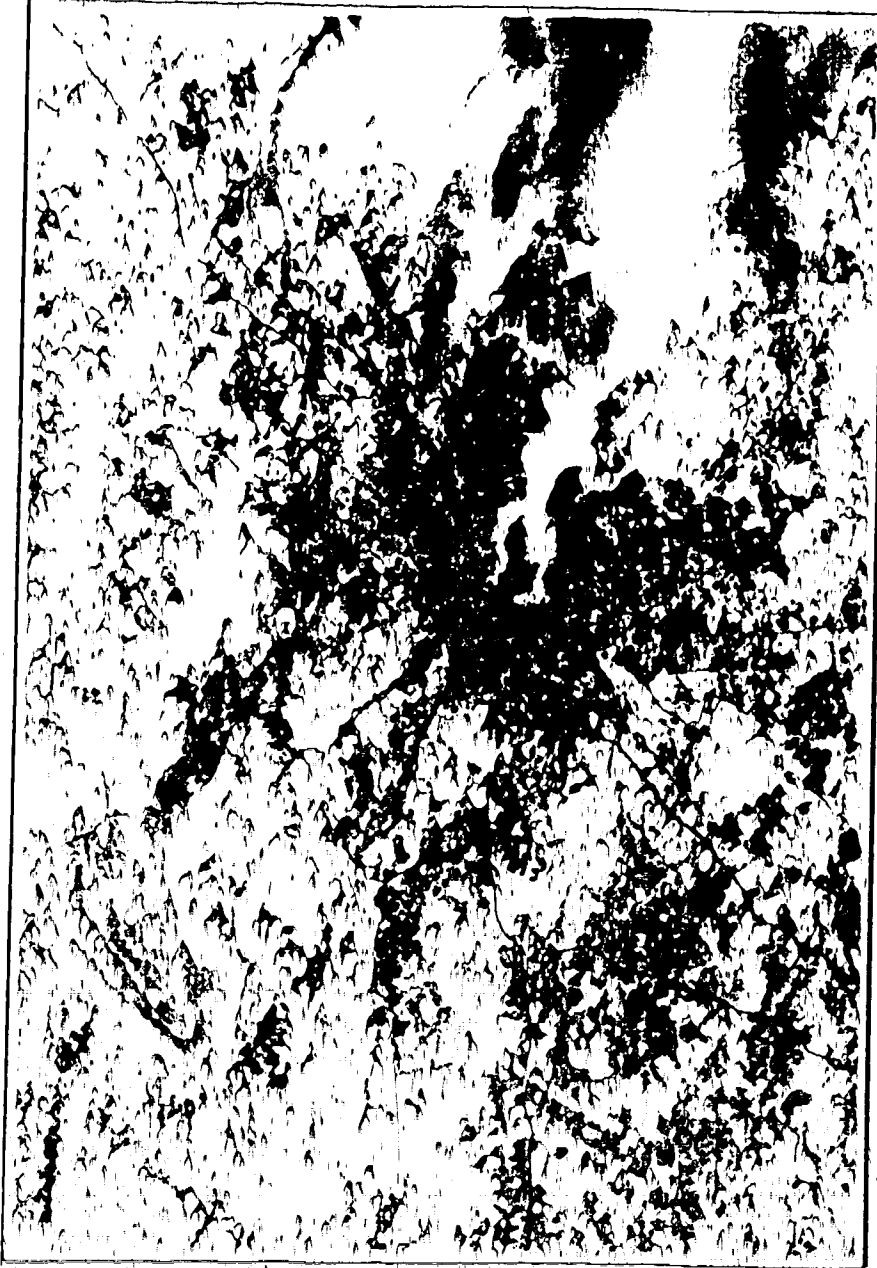


FIGURE 3

CITY OF BALTIMORE IMAGE 1682-15190
(After Rifman, 1973)

Reproduced by Line Printer, MSS Band 2

converted to photographic images. Both line printer and film writer ultimately offer a resolution down to one pixel. The United States and Canadian systems produce photographic imagery at two basic scales, 1:3,369,000 on 70 mm film and 1:1,000,000 printed on 9.5 inch film or paper. More recently CCRS has undertaken the production of larger film and paper prints up to 40 inches square. These photographic products have system corrections programmed into the imagery data where the computer tapes may or may not be corrected. Any of the four MSS bands can be purchased in computer tape or black and white photographic form. Colour composites of bands 4, 5 and 6 and 4, 5, and 7 are also available in colour photographic form. Examples of imagery from both formats are seen in figure 4 and figure 5 respectively.

The first year of operation produced more than sixty thousand scenes collected by LANDSAT 1. All of the United States and Canada and more than 3/4 of all continents have been imaged at least once. As of December 1974 there were over 11,500 scenes in black and white and over 3,250 in colour available for Canada. An index map of LANDSAT 1 data for Canada locates LANDSAT frames by picture centre number (see map insert - back flap). A cloud cover map (Fig. 6) is also available from CCRS. These two index maps in conjunction with an LANDSAT imagery catalogue greatly facilitate the ordering and collection of usable Canadian imagery. The United States also has a catalogue and index map scheme as well as an open browse file of images on microfilm. More recently CCRS has developed a similar browse file in Ottawa.

Scene corrected or precision processed imagery corrected for the Earth's rotation and adjusted to fit a U.T.M. grid is available only for a few select scenes. For the Canadian system "production of precision corrected imagery has been discontinued pending a major upgrading in the stability of the image recorder" (CCRS, 1974). NASA does maintain a facility for precision processing but at considerably greater cost than the standard product. Several private companies also produce precision imagery by specific request (Ritman, 1973) and at considerable cost.

2.4 Geometric Fidelity

Spacecraft attitude and the systematic error of the sensor combine to produce the majority of the planimetric deficiencies within the imagery. Other error sources arise from the configuration of satellite orbit and earth rotation. Algorithms for this later error can be applied to the imagery data on computer compatible tape to produce precision imagery. However, the Canadian and United States systems are only producing imagery on a regular basis which is corrected for the former internal systematic errors. Since the MSS does not have a reseau and preflight calibration data are unavailable, the production of precision processed imagery can be costly and time consuming. Certainly the most desirable image for cartographic purposes would be one with a minimum of planimetric distortion. Keeping in mind economy and the availability of system corrected imagery the question arises; what cartographic uses will the standard format imagery allow?

Bachofer (1973) in his analysis of several LANDSAT scenes produced by the United States system places image centre control to

within one standard deviation of the mean, then the error due to the deformation of the ground control points displacement has an effect from north to the south and west (Figure 7). This error varies for test sites at different latitudes. On recent Canadian imagery, this position error has been placed at ten kilometres. He continues his investigations with absolute location, band to band registration and temporal registration. These accounts for the MSS operation are summarized in Figure 7. Bachofer estimates the relative map accuracy, "... the measure of how well points in an image can be located with respect to other points in that image, that is, it is a measure of how well the internal distortions within the image are corrected" at 170 metres RMS. This value was determined by comparing RBV and MSS images of the same area where it was not possible to separate error contributed by each system. The composite error was 140 metres RMS.

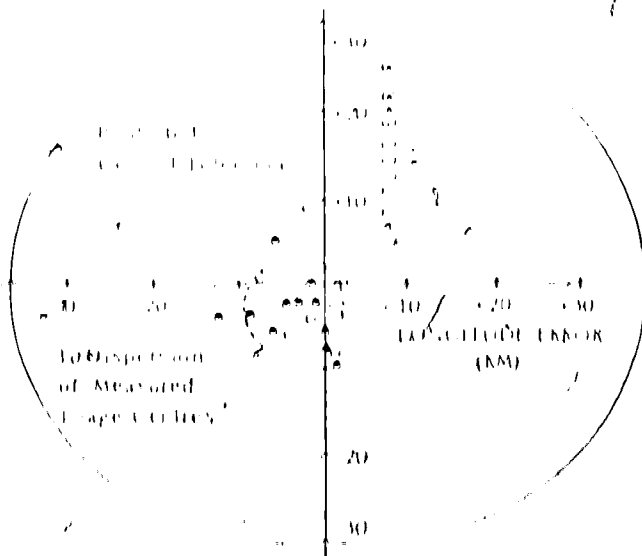
Other investigators (Colyoco et al., McIwen, 1973) plotted MSS images to ground control points and recorded distortions as large as 1000 metres with the best RMS position error of 233 metres. This appears to correlate with the variation of error recorded by Bachofer. Perhaps the best way to envisage the distortion in MSS system corrected imagery is to plot errors in a portion of an LANDSAT image against a U.T.M. map of the same area as in Figure 8.

2.5 Resolution

Theoretically, the smallest resolution element detectable by the MSS is 79 metres square, the area covered by the instantaneous field of view of each detector. Pragmatically, with contrast values being generally low the smallest resolved object has been approximately

ANALYSIS OF THE LOCALIZATION OF THE ELECTRIC FIELD*
(GEOGRAPHIC YEAR, 1973)

DISPERSION OF LOCALIZATION FROM NOMINAL CENTER



○ REAL TIME DATA
● RECORDED DATA

LOCALIZATION ACCURACY
(SYSTEM CORRECTED DATA)

2000	2000 METERS	LAUNCH THROUGH MID OCTOBER
1000	1000 METERS	MID OCTOBER THROUGH DECEMBER
500	500 METERS	1973
200	200 METERS	PREDICTED

PSD TO BASED SPECTRAL REGISTRATION METERS RMS

	MEASURED	PREDICTED
RMS	60	159

TEMPORAL REGISTRATION METERS RMS

	MEASURED	PREDICTED
RMS	105	275

VECTOR DISTANCE FROM ORIGINAL IMAGE

U.S. MAP & U.S. MAP ATED 0.1
EASE SIMCOE 1964

CANDIDATE IMAGE 100-1111-10112
OCTOBER 9 1963 0-1100 am



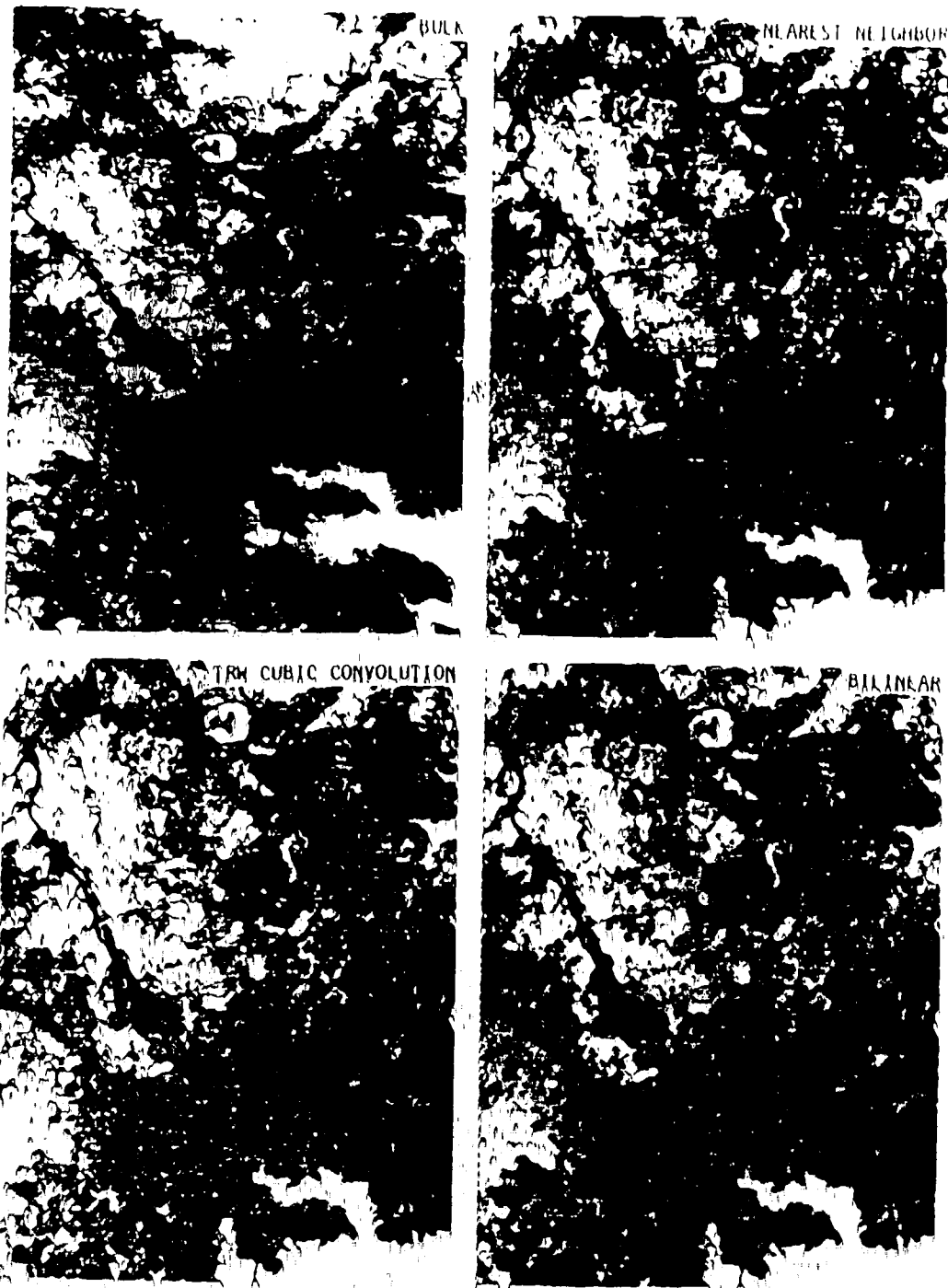


FIGURE 9
THREE METHODS OF PRECISION PROCESSING COMPARED TO
BULK IMAGERY
(after Rifman, 1973)

100 metres square with imagery programmed for maximum contrast (photographic products at 1:1,000,000). Without custom programming the resolution values come closer to 200-250 metres (Welch, 1973). Resolution is not necessarily the most adequate concept to use when interpreting regional information. Rosenberg (1971) in discussing detectability and recognizability states that signal (image) can be detected even though it is smaller than the resolution of the system. Anomalies such as this exist with the MSS scanner when it is capable of producing a "signal" for highways which are not as wide as 79 metres. This is evident even in conventional processing as in figure 10 with some of the minor county roads. The LANDSAT system is not a conventional photographic operation; with data in a digital form and the discrimination of four frequency bands conventional interpretive techniques may not be enough. For some cartographic purposes the degree of self-generalization provided by LANDSAT imagery can be most useful at this regional scale.

2.6 Cartographic Aspects of LANDSAT Imagery

Some of the advantages and limitations of LANDSAT imagery should now become apparent. Map accuracy standards for United States topographic and related maps dictate that 90 per cent of well defined detail be plotted to within 0.5 mm of its correct position. Converting this to ground distances, planimetric detail must be located within 500 metres (300 metres RMS) at a scale of 1:1,000,000, 250 metres at 1:500,000 and 125 metres at 1:250,000 (150 m RMS and 75 m RMS respectively). Keeping in mind the mapping accuracy of LANDSAT imagery, topographic and similar maps could only be undertaken at scale of less

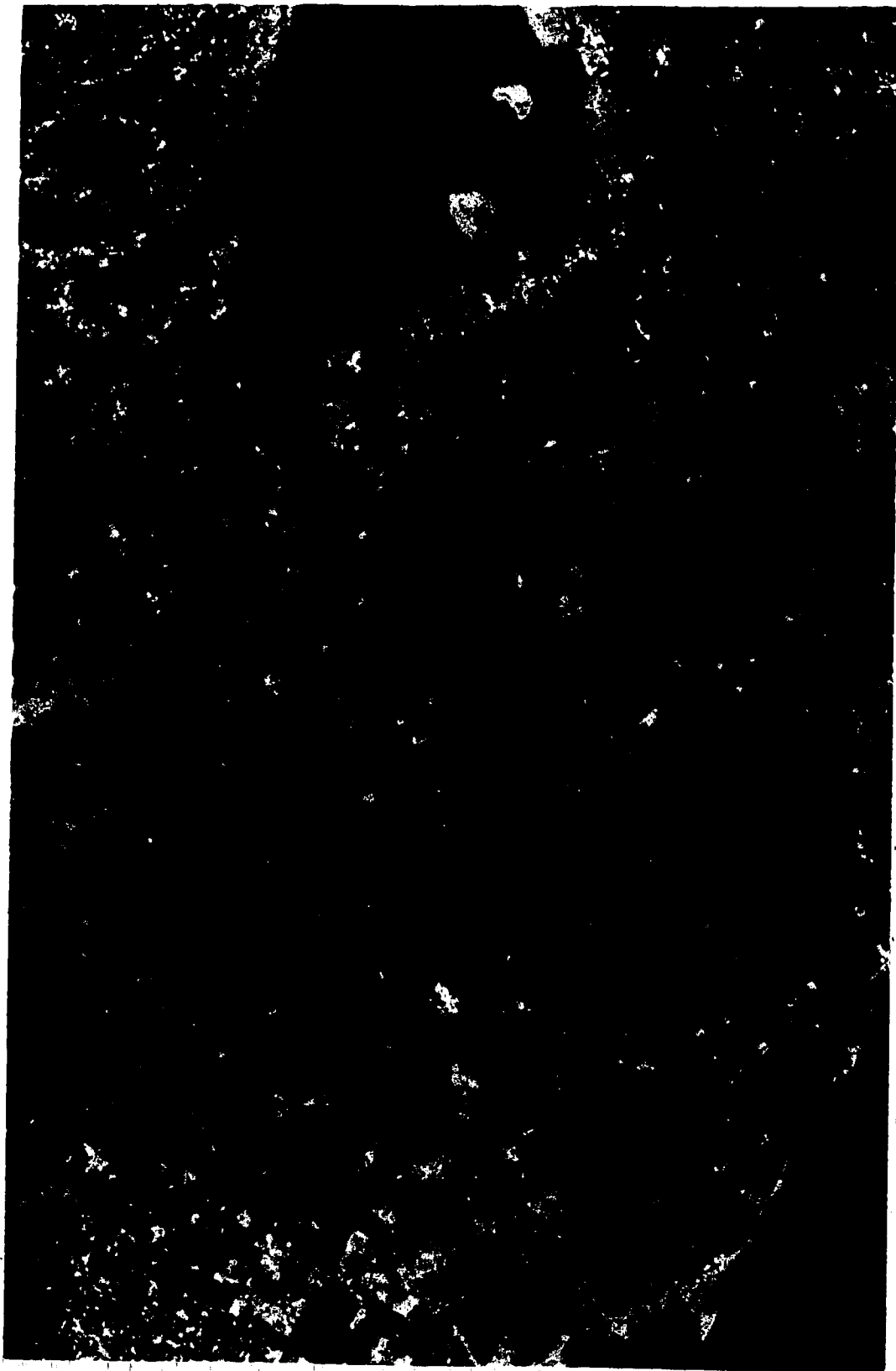


FIGURE 10

A SECTION OF A LANDSAT IMAGE ENLARGED TO 1:500,000.

Note the smaller county roads

than 1:500,000. Topographic mapping with LANDSAT is further complicated by the fact that ground resolution values of the 250 metre format (Colvocoresses, 1972, Welch, 1972) limit the mapping capabilities even further and would be compatible only at scales less than 1:500,000. It can, however, be applied to maps other than standard topographic products.²

If LANDSAT imagery does not comply with topographic mapping standards, could it be used for mapping thematic topics? Thematic mapping at scales of 1:500,000 and 1:1,000,000 is quite common. Although the data plotted on a photographic base are most uncommon, the photographic data have not existed at these scales before. For the first time cartographers have the capability of viewing large regional areas on a single photographic plate. LANDSAT data are regional scale data provided in a time series and allow dynamic as well as static topics to be viewed and recorded (Falconer, 1973). Colvocoresses (1973) in discussing the "Unique Characteristics of ERTS" mentions the near orthogonality of an ERTS (LANDSAT) image:

"... The field of view of the ERTS MSS extends only 5.67° from the nominal vertical. The near orthogonality of ERTS imagery precludes compilation of topographic (contour) maps but simplifies small-scale planimetric mapping and revision".

These three characteristics (1) the near orthogonality of the imagery, (2) the large areal extent of single images with a relatively homogeneous density gradient, and (3) the availability in a time series should provide an excellent base for correlating abstract

² It should be remembered that these are the regular LANDSAT products, with custom processing to projections such as U.T.M. the locational maximum error of planimetric detail is reduced to 100 m. The resolution goes down to the theoretical maximum of 79 metres (Rifman, 1975).

thematic map data to actual radiometric earth data, producing a thematic LANDSAT map (Adams, Falconer, 1973).

CHAPTER 3
PHOTO MAPPING

3.1 Conventional Orthophoto Mapping

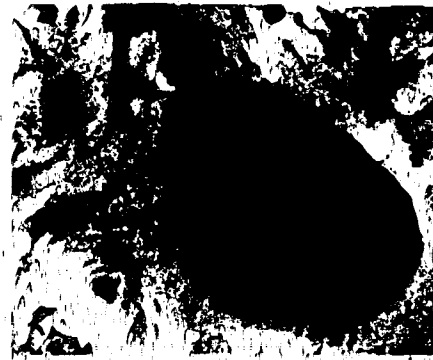
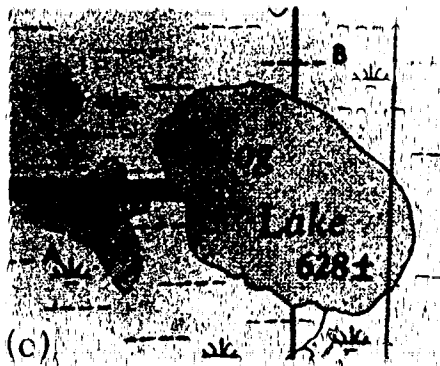
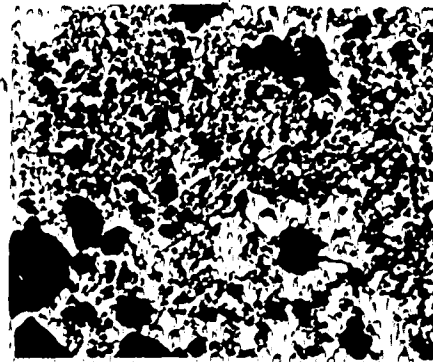
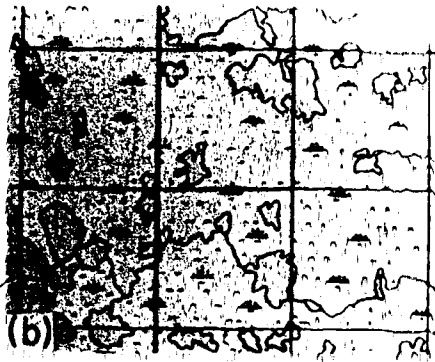
In 1954 the first orthophotographs were developed and cartographers began to evaluate and refine these into new map products. The invention of planimetrically correct aerial photographs made orthophoto mapping a practical proposition. Although photo maps of this type are most useful they have not yet replaced conventional maps but rather have become supplemental maps. The ultimate best use of these "supplemental" maps is still in dispute. Whatever the outcome of such a dispute, orthophoto images offer the cartographer some appealing characteristics as well as disquieting ones.

The major dispute is about the value of image content, more precisely photo image content and its counterpart, map image content. The abstract symbology traditionally found on maps is simply inadequate in some instances (Fig. 11). In other mapping situations the photographic detail sets up a "noise"³ which severely inhibits the interpretation of pertinent map symbology (Fig. 12). Beck (1966 and 1967) summarizes photo map content into three picture categories: (1) planimetry, (2) lettering and conventional symbols and (3) the illustrative picture. The question of how much geographic

³ noise ... any signal, manifested in any form of energy, that occurs irregularly with respect to the signal of interest, and tends to obscure that signal (Cornsweet, 1971).

FIGURE 11

MAP SYMBOLIZATION AND PHOTOGRAPHIC DETAIL
(after Fleming, 1971)



- (a) Marsh and swamp (wooded) areas as portrayed by both a line map and a photo detail at 1:50,000. Only the lakes at "A" have not been recorded on the map.
- (b) The same marsh symbol as in (a) Now means a multitude of small lakes. The photographic image is able to convey far more information about the terrain.
- (c) Two quite different symbols, the string bog symbol at "A" and the marsh symbol at "B" on this 1:250,000 map distinguish between two terrain types that do not differ from each other by as much as those illustrated in (a) and (b).



FIGURE 17,
A COMPARISON OF A CONVENTIONAL LINE MAP AND ORTHOPHOTIC MAP
OF THE GATTINEAU PARK AREA

annotation should be added to photo maps becomes difficult when the cartographer realizes that whatever cartographic enhancement is added, the same area of photo image content has been lost or covered up. There is essentially, "no free space available (contrary to a map), so that each supplementation diminishes the content of the picture" (Forstner, 1968). What is an adequate but just representation of photo map symbology? Such a question can only be answered with respect to the intended use and the economic factors surrounding the map production.

Since orthophotomaps depend on conventional and wide angle, aerial photography another difficulty with orthophoto mapping arises: the density gradient of the image. The variation in density is attributed to the altitude/azimuth of the sun and the fall off in illumination through the camera lens (Fig. 13). Serious problems develop when combining different images to form a photo mosaic or in this case an orthophoto plan. Tonal mismatches on adjacent flightlines and prints can be reduced but not always eliminated (Heming, 1971). This becomes of particular interest when photo mapping is undertaken at scales smaller than those achievable through single aerial photographs. In fact, Beck (1966 and 1967) feels that the problem of orthophoto mapping at scales of 1:1,000,000 and less cannot be solved satisfactorily and that, "The orthophoto of medium and smaller scales (without transformation of its picture) in general has no chance to act directly as a modified map depiction", "... Although aerial photographs taken from artificial earth satellites are already used for several important purposes" (Forstner, 1968):

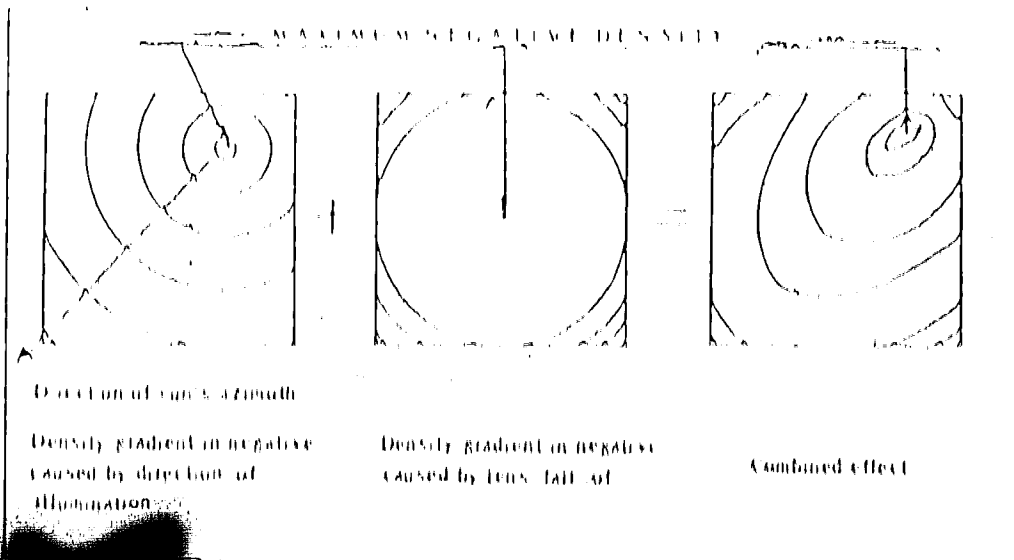


FIGURE 13

DENSITY DISTRIBUTION ON AN AERIAL PHOTO NEGATIVE

(after Fleming, 1970)

1-20
1970

FIGURE 14

PHOTO MOSAICS OF MONTREAL UNDOGGED AND AUTODOGGED PRINTS,
(after Fleming, 1970)



In any respect if orthophoto maps are to become functional at all scales more interpretation of the photo image will be needed by the map user. This may put greater stress upon an educational system that teaches photo interpretation techniques as well as map interpretation techniques (Bardy, Rolland, Laramie, 1973), but the long term benefits should be rewarding. When the user becomes able to decipher the wealth of detail in the photo and correlate that information to the more symbolic map information a positive step towards more objective mapping will be made. Maybe this is easier than it sounds.

"Fortunately, interpretation of the photographic image does not present serious difficulties, and it is our experience that persons, such as farmers, not accustomed to using maps, have less difficulty in reading the photographic image of the earth." (Blachut, 1968).

3.2 LANDSAT Orthophoto Mapping

With the initiation of the LANDSAT program some of the limitations of conventional orthophoto mapping should now be reviewed. LANDSAT imagery, although not universally suited to mapping at scales greater than 1:250,000, provides an adequate base image for mapping the "smaller" scales (i.e. 1:1,000,000) mentioned by Beck. The imagery system of LANDSAT being a scanning apparatus is more able to produce a relatively uniform density gradient. Radiometric infidelities exist but at comparatively lower levels than those experienced by conventional aerial photography. The necessity of combining several photographic images of different tonal values, is reduced if not eliminated in some cases. Falconer (1973), when discussing LANDSAT imagery, has stated that "the tone of the print is such that for many inter-

this respect "This, on the basis of obtaining cloud free coverage of a specific area, ERS is no quicker than aerial survey ..." (Stewart, Fleming, 1975). This problem should be further reduced with the introduction of LANDSAT II imagery. As with any mapping project the ultimate decision about imagery will be based on factors such as scale, specific purpose, timing, etc. However, considerable advantage is gained by having to dodge only 5 prints, if any, and since coverage now exists for most of Canada the production of photo maps at small to medium scales should cost very little, in both time and money. An LANDSAT print as in figure 15, at a scale of 1:1,000,000 for a single band costs only 2 dollars.

3.4 Nation's Capital Area ERS (LANDSAT) Map

The Geological Survey of the United States Department of Interior with assistance from the National Aeronautics and Space Administration published the first map using a LANDSAT image as a mapping base early in 1973. The map covers the Baltimore, Washington D.C. areas and includes portions of the Potomac River and Chesapeake Bay. This LANDSAT map was produced at a scale of 1:250,000 with an image size of 29 inches by 28 inches. The map was printed on 100 pound enamel coated stock with overall trimmed dimensions of 33 inches by 31 3/4 inches. The satellite image is reproduced to simulate colour infrared photography corresponding to standard colour composite processing by NASA. The map was printed at the 1:250,000 scale with 150 lines per inch screens using process colour. Positive images of MSS bands 4, 5, and 7, were utilized when band 4 was printed in yellow, band 5 in magenta, band 7 in cyan with black reserved for cartographic

05SEP72 0343-28 087-4-22 X 0428-21 07-0-24 025- 2 3 304 1.43 4150 104 000000 1-0-0-1-1 1:PS E-1062-13170
UTM PROJECTION ZONE 18
POSITION ERROR 3-100
SCALE 1:1,000,000 ECHES 10
05 08 28 40
IMAGED 25SEP72 131171 3 GM
PRECISION PROCESSED 73 JAN 17



FIGURE 15

A LANDSAT PRINT OF THE MONTREAL AREA

1062 - 15170

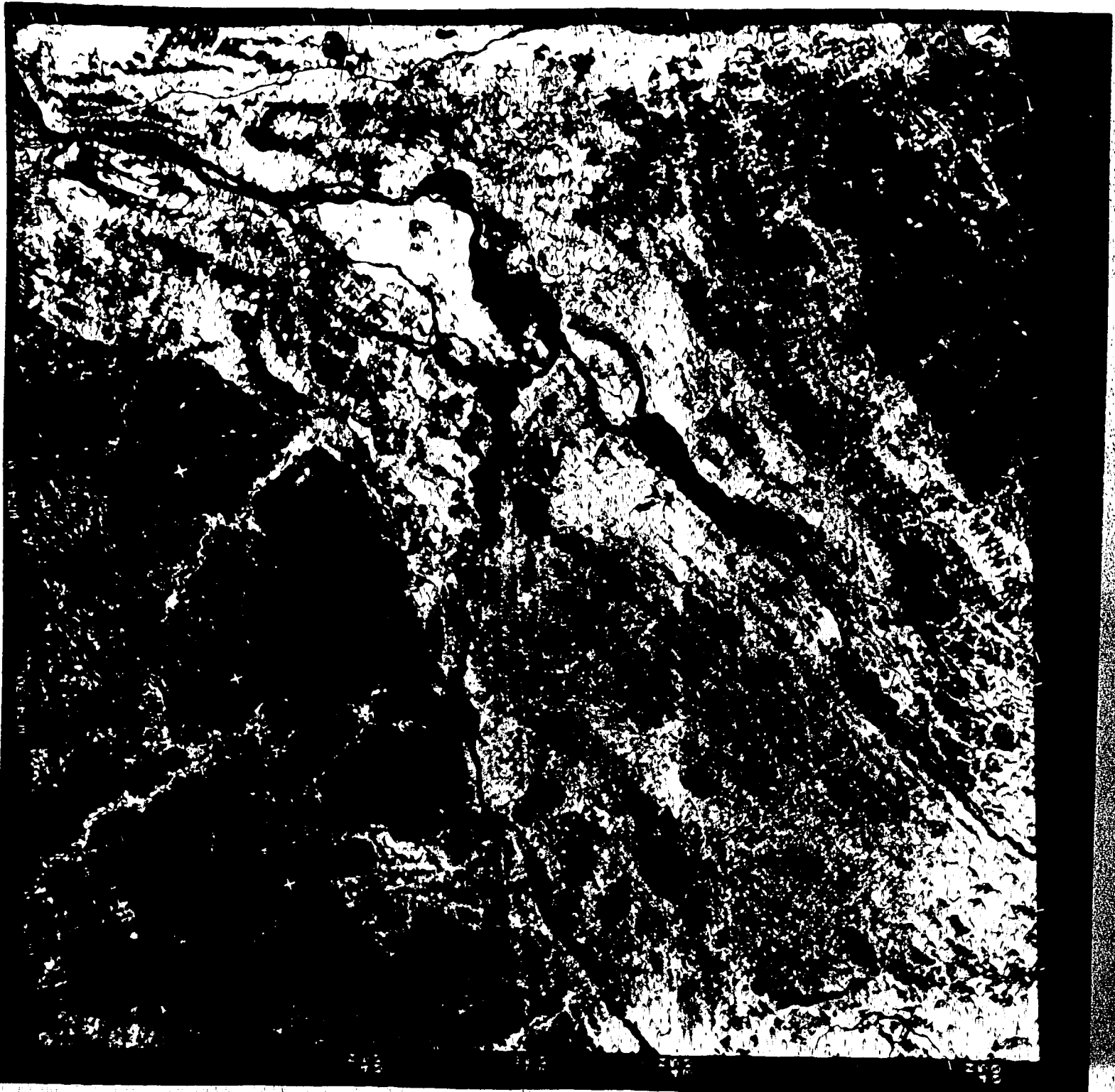
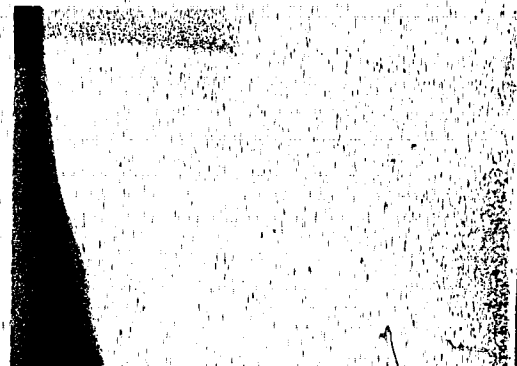


FIGURE 15

A LANDSAT PRINT OF THE MONTREAL AREA

1062 - 15170



symbolology and type. The map and print of the LANDSAT image without enhancement at the same scale was distributed at the Second Symposium on Significant Results Obtained from the Earth Resource Technology Satellite-1, March 5-9, 1973. Sections of the map and the accompanying LANDSAT image print are illustrated in figures 16 and 17 respectively.

The cartographic annotation uses open symbols for both point and line representation whenever possible. In other cases they are held to minimum size. Apart from the symbol used for mud and sand, no areal symbolology exists other than delineation by a surrounding border line and what can be interpreted from the imagery - forested areas, built up urban areas, etc. The only relief representation offered by the annotation is the use of spot elevations on land and generalized 30 foot contours for hydrographic relief. The boundary of land and water delineated only by the image but the names of major mountains are included as additional locators. Point symbols are used to indicate power plants, storage tanks, churches, schools, mines, towers, beacon lights, small communities, small airports, and seaplane bases; in essence they are the standard symbols used on conventional 1:250,000 topographic maps. The line symbolology maintains the same topographic set of symbols showing highways, multiple to single lane with highway numbers on open shields; railway lines, multiple or single track; state, district, city, and reserve boundaries; power transmission lines are also indicated with a line symbol. In some cases these line symbols are incomplete such as along river channels and in spots that would be delineated by additional printed colours on standard topographic maps of this scale. Such inconsistencies indicate that the black symbolology for the U.S.G.S. 1:250,000 topographic map series was overprinted on an LANDSAT image base. Perhaps this use of

C

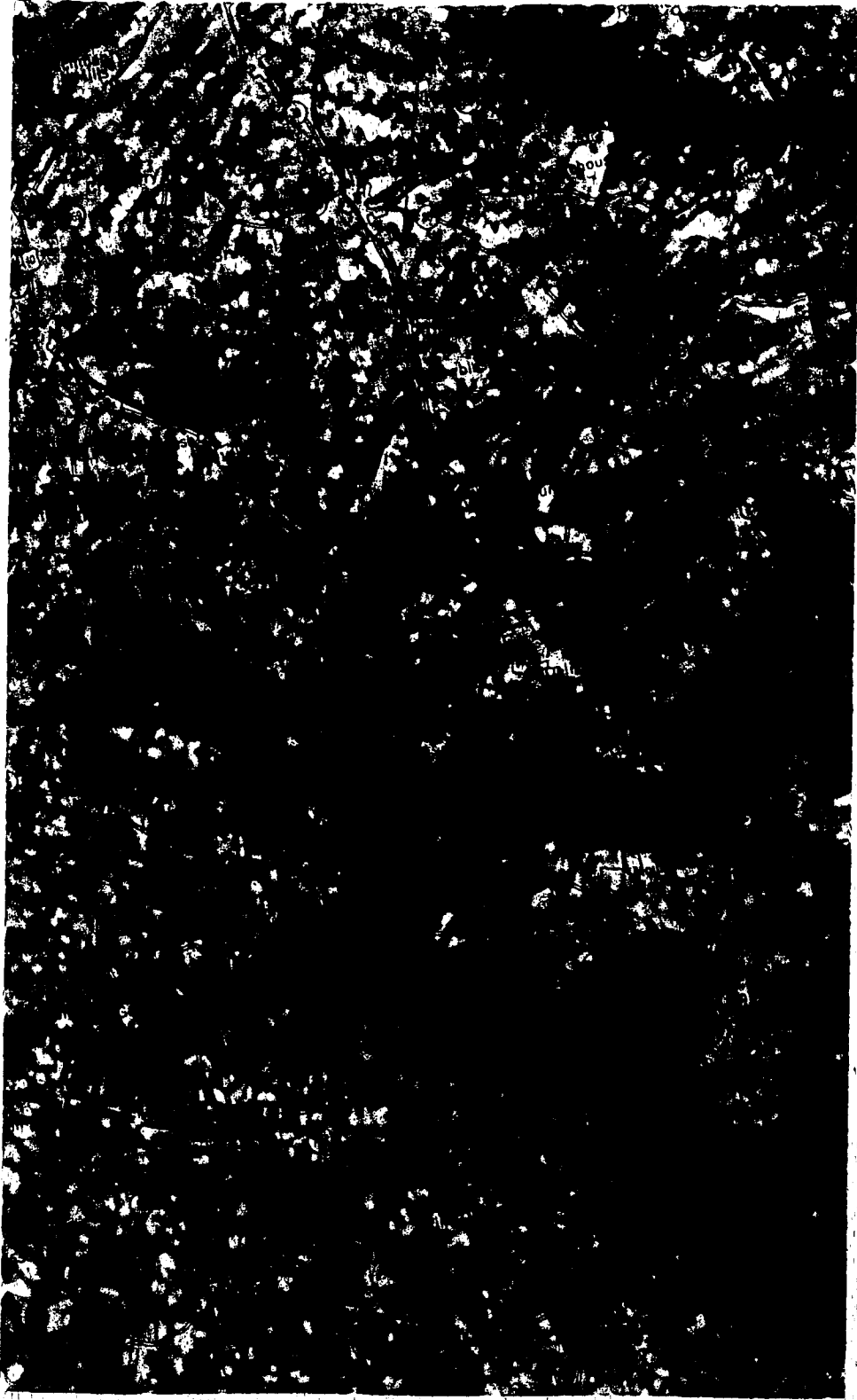


FIGURE 16

A SECTION OF THE WASHINGTON D.C. ERTS (LANDSAT) MAP



FIGURE 17

A SECTION OF THE ERTS IMAGE DISTRIBUTED WITH THE WASHINGTON D.C.
ERTS (LANDSAT) MAP

standard topographic symbols is enough justification for the conspicuous lack of legend and explanatory information. A representative fraction with miles and kilometres bar scales are included, however. External grid reference indicators differ from those used on the topographic map series while the internal tick marks remain the same. The only external grid markings are two longitudes and one latitude similar to those found on the LANDSAT image. A north arrow does exist in the lower right corner. Type for the map is also the same as that used on the black printing plate of topographic series: principally variations of Roman and Gothic styles with serif and sanserif, upright and italic, using both upper and lower cases.

The map is basically a general reference map relying heavily on type written information and the fundamental symbol map⁴ representation. The compilation time was held to a minimum by combining the LANDSAT image with a standard topographic overprint. The cartographic information is clear and easily read and the image information offers the map user an abundance of data not available in conventional maps of this type. A prime example of such user interpreted information is the easily seen areal extent of concentrated sediment load in the Potomac River. The only real drawback to the image is a certain fuzziness indicative of image processing at the time of publication. Since that time films have been developed which will reproduce 45 lines per mm (Falconer, 1974) and should help to reduce this problem in the future. In any case, 1:250,000 does seem to be the maximum enlargement

⁴ Although all maps have symbols, the "symbol map" referred to here is a qualitative representation where "data are presented in the form of a specific symbol which can be of a pictorial, geometrical, evocative or alphanumerical design." (Klawe, 1973; Ratajski, 1963).

permitted by the standard LANDSAT image product. Although this deficiency exists, the combination of user interpreted LANDSAT image and conventional map symbology has produced a distinctive and effective map product.

3.5 The National Capital Region - Experimental Photo Map

Another LANDSAT map has been produced by the Canada Centre for Remote Sensing. This map is centred on the Ottawa-Hull region and includes 10,000 square kilometres of surrounding area. It is printed at a scale of 1:250,000 and covers portions of the NTS series maps 311 and 316. The map is printed on 100 lb. enamel coated stock with trimmed dimensions of 31 inches by 23 inches and a printed map image size of 16 3/4 by 17 1/2 inches. A short explanation of the satellite sensors including the colours in which the spectral bands are printed and a rudimentary interpretation guide are printed beside the map image in both English and French. The Ottawa LANDSAT map was distributed after the Second Canadian Symposium on Remote Sensing in mid 1974 and may be obtained through CCRS, Ottawa.

The Ottawa LANDSAT map like the Washington D.C. map was printed to simulate a colour infra-red aerial photograph. Simulated colour infra-red processing is also a standard medium for CCRS colour composite imagery. The LANDSAT image is printed with 150 line screens and again uses process colour printing. Unlike the Washington map each of the spectral bands used, is printed in two colours: band 4 represented by blue on the map is printed in magenta and cyan, band 5 uses cyan and yellow to produce green, and band 7 is printed in yellow and magenta to produce a red colour on the map image. The effect attained is a strikingly sharp and clear image.

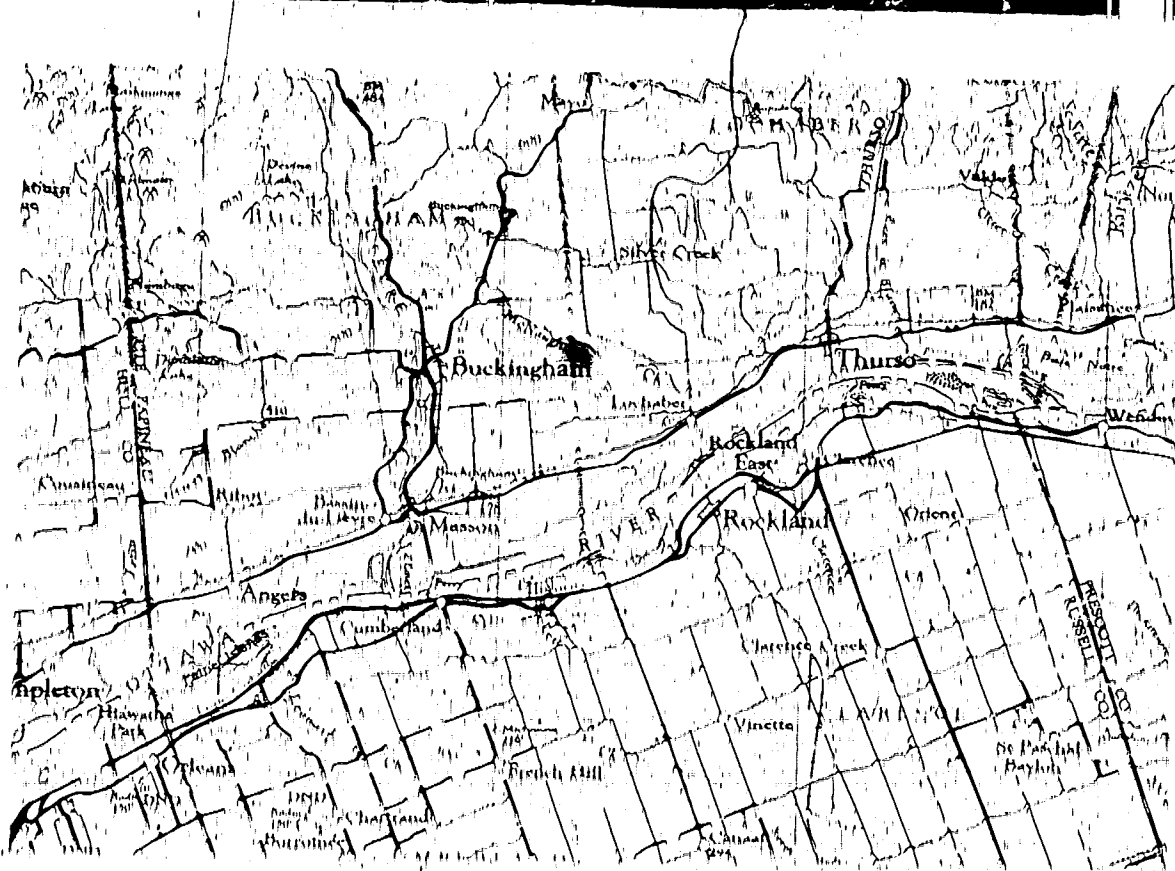
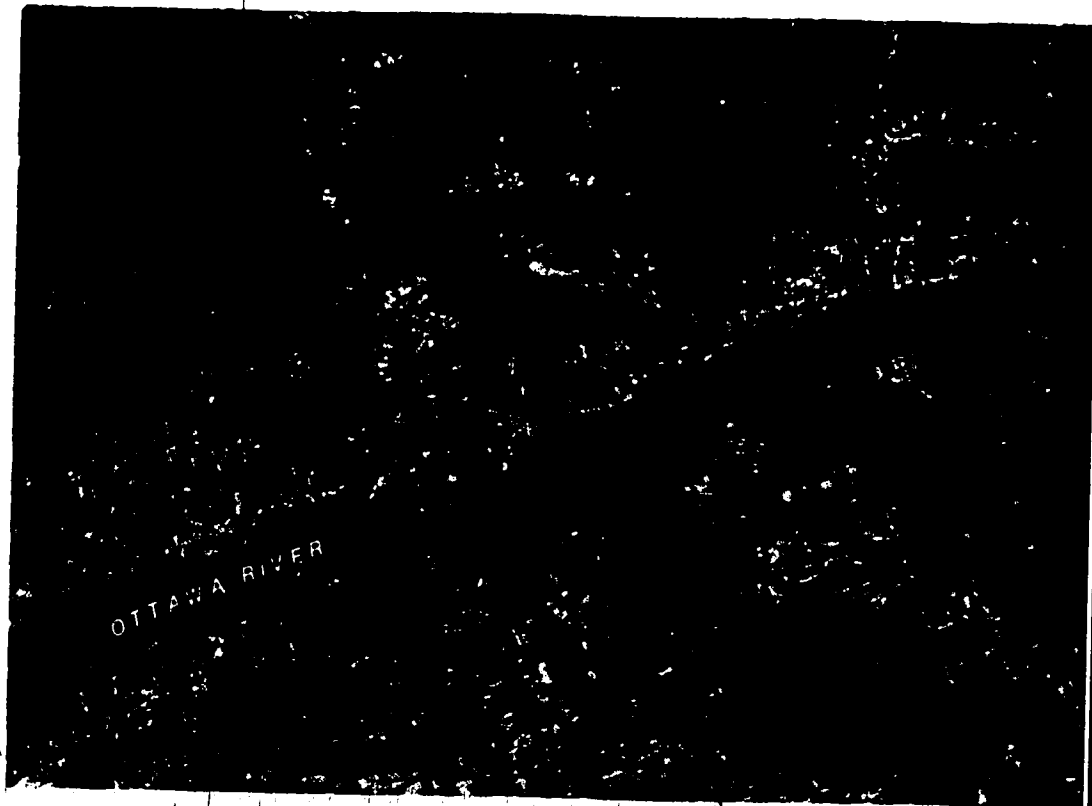


FIGURE 18

A SECTION OF THE OTTAWA LANDSAT MAP AND THE CORRESPONDING
N.T.S. TOPOGRAPHIC MAP

and which could be easily interpreted by the map user.

The symbols for the map are held to an absolute minimum. Only four point symbols, in conjunction with type are used to represent all features on the map. They designate towns, highways, airports and quarries. All symbols are open symbols and allow the under image to be seen. Type appears in both black and a cancel or white form, the latter being used on some hydrographic features such as the Ottawa River. All type is sans serif and in a style similar to Univers. Upper and lower case as well as an Italic are used. Type is used in many cases to delineate linear and areal features such as power lines, railway lines and city areas like Ottawa. Scale is illustrated by a representative fraction and by mile and kilometre graphic scales. Only a section of the original LANDSAT image has been utilized, however, it has been trimmed and oriented with North at the top. This allows the standard N.T.S. borders and grid systems to be employed. They include a ten thousand metre Universal Transverse Mercator grid and a longitude/latitude grid with fifteen minute markings. Legend, titles, and scales are also written in English and French. No indication of relief is represented. Examples of sections of the Ottawa LANDSAT map and the corresponding N.T.S. map are given in figure 18.

Perhaps the greatest difference between the Ottawa and Washington D.C. LANDSAT maps is in the conceptual design. The Ottawa map relies almost entirely on interpretation of the LANDSAT image to convey information. Map symbology is very sparse, consequently it produces the impression of an annotated photograph rather than a map or photo map. Any additional information needs to be derived from the corresponding N.T.S. 1:250,000 map sheets, 31E and 31G, however, these sheet

numbers are well noted on the map. The map was distributed alone, so one wonders if it is to stand alone. The Washington D.C. map, on the other hand uses map symbology liberally, compared to the Ottawa map but it was distributed with an LANDSAT image print completely lacking in symbology. The image quality of the Ottawa LANDSAT map is exceedingly better than the "fuzzy" Washington image but the lack of map information gives it an unfinished look. The problem arises once again, how much map information should be added to a photo map? Perhaps the question, "What information should be added to a photo map?" should be seriously considered. Both agencies, CCRS and NASA, seem reluctant to have a LANDSAT map stand on its own for this type of "symbol" representation.

CHAPTER 4

THE TORONTO CENTRED REGION MAP

4.1 Introduction

The ERTS (LANDSAT) map of the Toronto Centred Region was conceived, initiated, and designed as an experimental project by the map authors.⁵

The nature of the experimental map was intended to capitalize on the compromises made during production to evaluate the primary objectives and publish the results at the Second Canadian Symposium on Remote Sensing, in Guelph, on May 1, 1974. The primary objectives were:

- 1) to produce a LANDSAT map, basically general reference, but developing a more thematic content (i.e. an "areal extent" component) emphasizing a suitable combination of map symbology and image symbology;
- 2) to manipulate the hues and saturations of the MSS spectral signatures in reproduction to help develop a more natural appearing landscape with elements approximating hypsometric tints;
- 3) to evaluate the use of a LANDSAT image as a thematic cartographic base;
- 4) and to stimulate potential and future investigations of LANDSAT mapping in which the LANDSAT image is used directly as a mapping base.

The authors also felt an additional responsibility to construct the LANDSAT map at its maximum allowable scale, 1:250,000 and examine this scale of imagery for mapping. This not only facilitated a greater

⁵ The design and production of this map was coordinated by Dr. Allan Falconer and Fred Adams in association with the Department of Geography, University of Guelph.

main area to be mapped, but also provided a means for evaluation of the use of the elements of the larger scale comparison between this map sheet and the Washington D.C. and Ottawa LANDSAT maps would be facilitated if all were produced at the same scale. Although mapping at this larger scale was initially considered an asset, disadvantages came to light when further constraints were placed on the imagery.

4.2 Mapping Constraints

Imagery and map specifications needed to be established before any preliminary mapping endeavors could begin. Map requirements dictated the Toronto Centred Region as the area to be mapped. This was due primarily to the need of the map to be correlated with an existing on-going project in this Great Lakes area. Other factors lending additional weight to this decision were; the availability of extensive data for the region, the diversity of cultural and physical characteristics of the area, and the market potential within the region if the map was to ultimately become a commercial endeavor (dictated by funding sources). These mapping constraints directly controlled the specifications for a suitable image and were considered simultaneously with imagery requirements. The imagery needed to have been centred on Metropolitan Toronto and cloud free, or nearly so. Secondly the imagery should have been of highest definition permitting enlargement to final map scale. Thirdly the imagery should have been precision processed to maintain map accuracy requirements.

A review of available imagery, in concert with the map-making objectives of the project, required a decision to be made. The decision was to use the best available imagery from the 1960's. One was made because of the poor image quality available. More recent (CRS) imagery which was better in resolution quality existed, however, this Landsat pass was split into two images by standard CRS processing and equipment for reproaching was not available. Consequently, the decision to use the best resolution imagery, maintaining Metropolitan Toronto at or near the centre of the image was established. A further concern was the wide area of the image which was lost due to the complete lack of available imagery from the CRIS or Landsat system. Both of these problems can be overcome for future Landsat mapping but could not be controlled by the map authors, and since the primary objectives of the map were design oriented, compromises were made.

Most of the theoretical difficulties that were so administrative in nature, directly associated with negotiations of equipment and co-operating agencies. The end result was a map physically produced at three organizations; the University of Guelph for compilation, Lockwood Survey Corporation for scribbling, and Graphic Litho Plate for all photography, registration and plate making. Time constraints were severe considering the administrative intricacies of the three organizations plus those of York Litho Company, the printers. The compilation started in mid-December of 1973 and the map was to be off the presses in mid-April, 1974 just before the 2nd Canadian Remote Sensing Symposium.

4.3 Compilation and Design

The production of the Toronto IRIS (LANDSAT) map actually began sometime before its compilation, with the construction of two sketch maps using photo prints of a LANDSAT colour composite as a base. Since so few LANDSAT maps existed at that time a greater insight of the LANDSAT map design was needed. These preliminary maps helped to achieve this. They were compiled at the standard LANDSAT format scale of 1:1,000,000 on a simulated infrared image using bands 5 and 7 of the 21 August 1977 NASA scene. One preliminary map had monochrome black symbology while the other utilized red, yellow, blue, and black. A print of the latter sketch map appears in Figure 19. The most striking initial impression was that the symbology covered too much of the image detail.

Concurrently, investigation proceeded on the image itself. Due to the inherent characteristics of the MSS, any image produced from the system is essentially a false colour image. This image could have simulated a more natural landscape as easily as it could have simulated an infrared photograph. At this time NASA and CCRS also started producing an alternative image to the simulated IR image which approached the desired colour combination for the map. However, the map authors believed that more experimentation was needed. Through the media of diazo colour composites the different LANDSAT bands were manipulated producing combinations that more closely simulated a natural landscape. Examples of a NASA simulation and a Diazo colour composite appear as prints in Figure 20. Experimentation with both positive and negative colour diazo reproductions of the four MSS bands constructed a combination similar to that which was ultimately used.

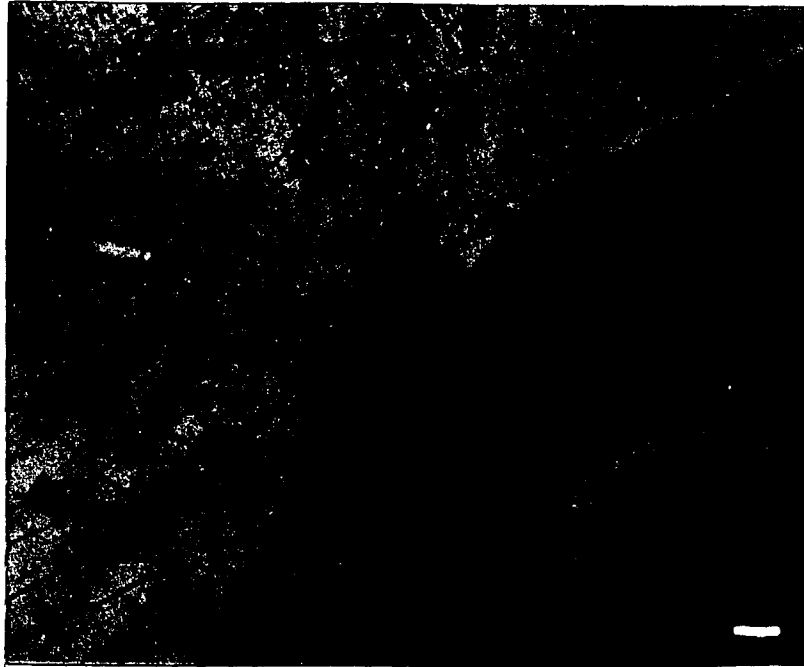


FIGURE 19

A PRELIMINARY LANDSAT MAP FOR THE TORONTO CENTRED REGION

Approximate Scale 1 to 2 Million

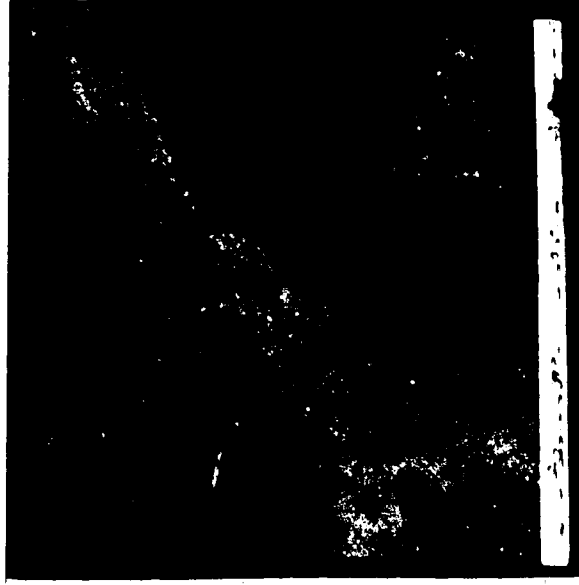
FIGURE 2C
A NASA SIMULATION AND A DIAZO COLOUR COMPOSITE



NASA SIMULATION

The red - brown colour for water area in the Diazo composite was masked out for the final reproduction.

Approximate scale : to 3.3 million.



DIAZO COLOUR COMPOSITE

Having completed the preliminary investigations of image and map, the coordination and final design could start. Beginning with the original concept, the LANDSAT image was intended to be equally important as the map symbology. To accomplish this the maximum LANDSAT image scale (1:250,000) was used as well as a level of symbol generalization greater than that found on traditional maps of this scale. This combination intended to grant as much map area as possible for the LANDSAT image representation. The level of symbolization was comparable to that found in maps of 1:500,000. A factor of image generalization exists in all frequency; so, in every respect the image itself was also generalized. A combination image of three bands 4, 5, and 7 reduced this generalization. Once the theoretical level of generalization was finalized, compilation began, relying on available topographic maps at a scale of 1:50,000 and 1:250,000; but relying more heavily on interpretation of the actual LANDSAT image and supplemental high altitude aerial photography. Whenever possible the image itself determined the amount of simplification (i.e. the coastal boundary or the extent of urbanization).

4.4 Map Production

The conversion of the map design to a final printed format developed through several stages. After the initial compilation at the final scale the compiled sheets went to Lockwood Survey Corporation where they were converted to scribe sheet separations. Since some type and symbols appear in different colours such as blue and green, the pertinent line work was scribed on white scribecoat which later served as a base for stick up lettering. These were then photographed

producing a negative of both type and line work. Type such as highway designations and graticule markings were produced directly on scribe sheets using a Leroy scribe. When the scribe sheets were completed, they returned to Guelph for paste up and the production of the urbanized area mask. These sheets then went to Graphic Litho Plate Ltd. where working negatives, masks, and master negatives were constructed. A summary of the scribe sheets, masks, and working negatives appear as follows:

1. Graticule and Degree Markings were scribed on amber scribe coat to be used directly as a working negative.
2. All type to be produced in black was stuck up on stable base cronaflex and converted to a working negative.
3. Type for the blue lake and river designations was stuck up on the white scribed sheet of hydrography and photographed for a working negative.
4. Highways were also scribed on white scribecoat, airport annotation added, and then photographed to produce a working negative.
5. County boundaries were done by the same method on white scribecoat with type stuck up directly on the scribed sheet and photographed to produce a working negative.
6. A closed window mask of urbanized area was produced by hand on stable base cronaflex.
7. A closed window water mask was also produced using a negative of MSS Band 7.
8. Working negatives of MSS Bands 4, 5, and 7 already existed at this time in a halftone form.

The decision to use process colour instead of flat colour printing followed from a need to economize. Light colours would need to be printed if a flat colour printing were to be used and that would require an extra run through a four colour press. Ultimately a five colour press would be used combining process colour with an extra blue colour printed. Consequently the final design was planned for printing black, blue, magenta, cyan, and yellow. The LANDSAT image bands were printed in magenta, cyan, and yellow using 150 line/inch screens of eighty-five percent. Map annotation used combinations of all colours. The working negatives, positives, and masks were brought together to produce the following printing design:

Black Printing Plate

combined elements: - graticule and grid annotation.....positive
 (for master negative - all type place names blackpositive exposure)

Produced master negative of: type and graticulenegative

Printing: - graticule and type in 100% black (see figure 22)

Blue Printing Plate

combined elements: - hydrography combined on
 (for master negative - hydrography place names scribecoat exposure)

Produced master negative of: hydrography and type negative

Printing: - hydrography and type in 100% blue (see figure 22)

Magenta Printing Plate

combined elements: - 150 l/in halftone of MSS Band
 (for master negative exposure) 4-85% screennegative
 - highways and highway place namespositive
 - county boundaries and county place namesnegative

Produced master negative of: - half tone of MSS Band 4positive
 - open window highways and place namesnegative
 - closed window mask for county boundariespositive

- Printing: - an 85% halftone image of MSS Band 4 in a negative form
- highways and highway place names in 100% magenta
 - county boundaries and place names in 0% magenta or white, later to be printed in cyan and yellow (see figure 23)

Cyan Printing Plate

- combined elements: (for master negative exposure)
- 150 1/in halftone of MSS Band 5-85% screennegative
 - highways and highway place namesnegative
 - county boundaries and county place namespositive
 - open window for urbanized areanegative

- Produced master negative of:
- halftone of MSS Band 5positive
 - closed window mask of highways and place namespositive
 - open window county boundaries and place namesnegative
 - closed window mask of urbanized areapositive

- Printing: - an 85% halftone image of MSS Band 5 in a negative form
- highways in 0% blue to be printed by magenta
 - county boundaries and place names in 100% cyan
 - urbanized area in 0% cyan to be printed by magenta and yellow (see figure 24)

Yellow Printing Plate

- combined elements: (for master negative exposure)
- 150 1/in halftone of MSS Band 7-85% screennegative
 - highways and highway place namesnegative
 - county boundaries and county place namespositive
 - open window for water areanegative

- Produced master negative of:
- halftone of MSS Band 7positive
 - closed window mask of highways and places namespositive
 - open window of county boundaries and place namesnegative
 - closed window mask for water areapositive

- Printings - an 85% halftone image of MSS Band 7 in a negative form
- highways in 0% yellow to be printed by cyan
- county boundaries and county place names in 100% yellow
- 0% yellow printed on water areas printed by cyan and magenta (see figure 25)

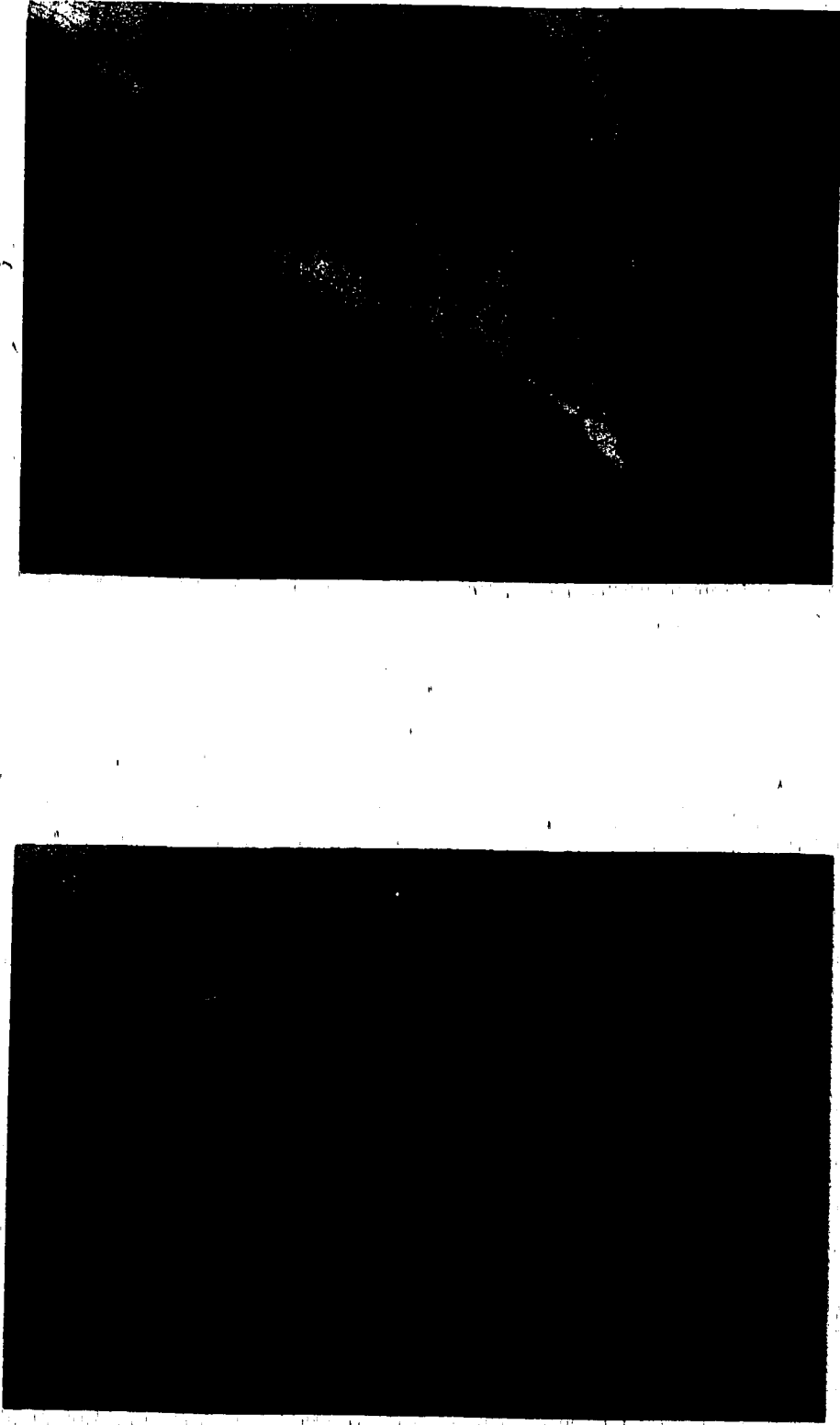
The final Toronto ERTS (LANDSAT) map design yielded a map not greatly dissimilar from a conventional thematic map of the same content and area. Yellow from Band 7 has been masked out of the water area leaving a more conventional blue with magenta highlighting sediment load. Negatives of the MSS images were used to maintain as much of the image information as possible but still mask out the oversaturated brown developed in the preliminary image colour balance (see figure 20). Cities usually shown in some combination of pink or red or yellow on conventional maps are here displayed with a combined printing of magenta and yellow, the cyan being masked in the urbanised areas. The colour balance achieved created a yellow-green colour for woodland and dense vegetation. A darker green would be more appropriate for designating wooded swamps and river valleys, however, low lying areas would with conventional hypsometric tints be delineated by a lighter, more yellow green. This latter convention was utilized here as it provides greater contrast with the blue line detail overlain for hydrography and hydrography place names.

4.5 The Toronto Centre Region ERTS (LANDSAT) Map - Critique and Comparison

The Toronto map like the Washington D.C. and Ottawa maps has been published at a scale of 1:250,000 resulting in an image size of 29 inches by 29 1/2 inches printed on 200 lb. enamel coated paper with trimmed dimensions of 42 inches by 38 inches. Explanatory information concerning the satellite system, printing, and map design is printed

FIGURE 21

A COLOUR BALANCE PROOFING OF A SECTION OF THE TORONTO ERTS (LANDSAT) MAP

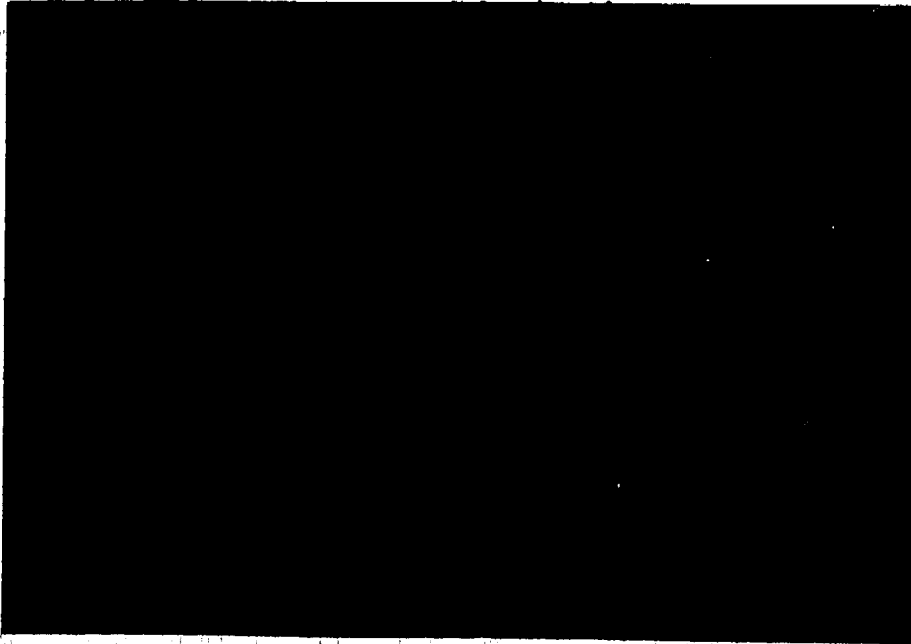


This proofing was produced from the working negatives and positives to test the colour balance before master negative construction. On the yellow-red version cyan has been masked from the land area.

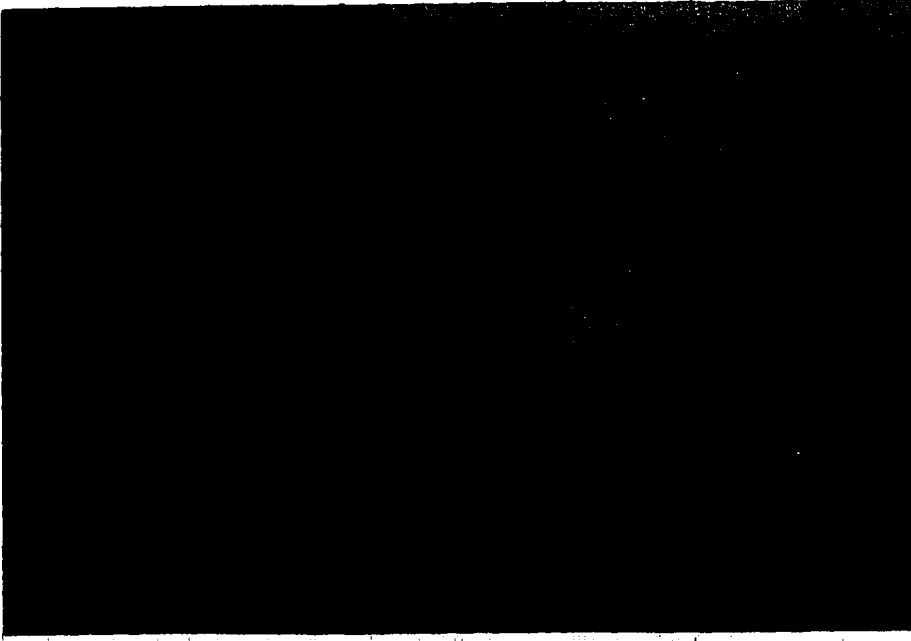


FIGURE 22

THE BLACK PLATE AND BLUE PLATE PROGRESSIVE PROOFS OF THE TORONTO ERTS (LANDSAT) MAP



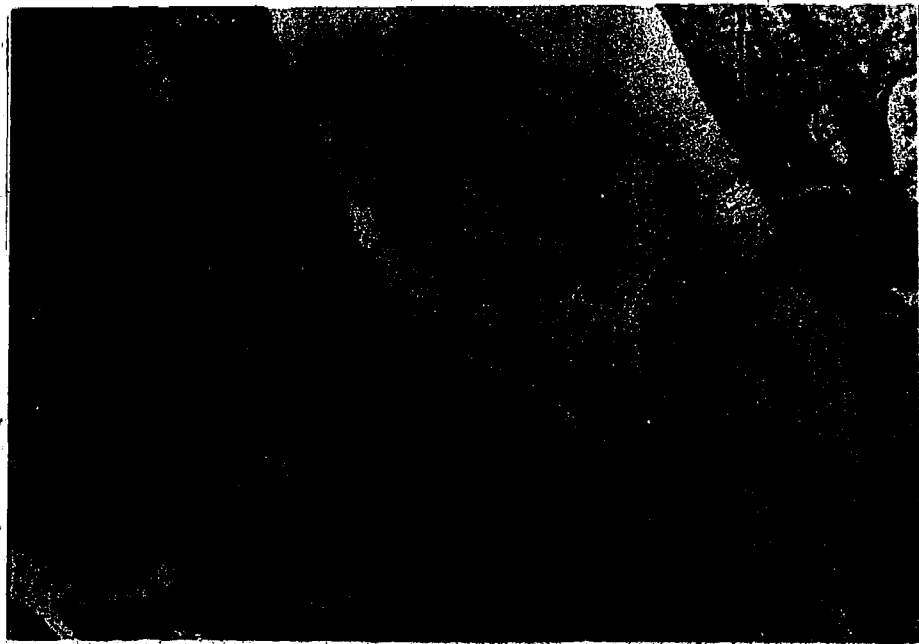
BLACK



BLUE

FIGURE 23

THE MAGENTA AND MAGENTA PLUS YELLOW PROGRESSIVE PROOFS OF THE TORONTO ERTS (LANDSAT)



MAGENTA



MAGENTA PLUS YELLOW

FIGURE 24

THE CYAN AND CYAN PLUS MAGENTA PROGRESSIVE PROOFS OF THE TORONTO ERTS (LANDSAT) MAP



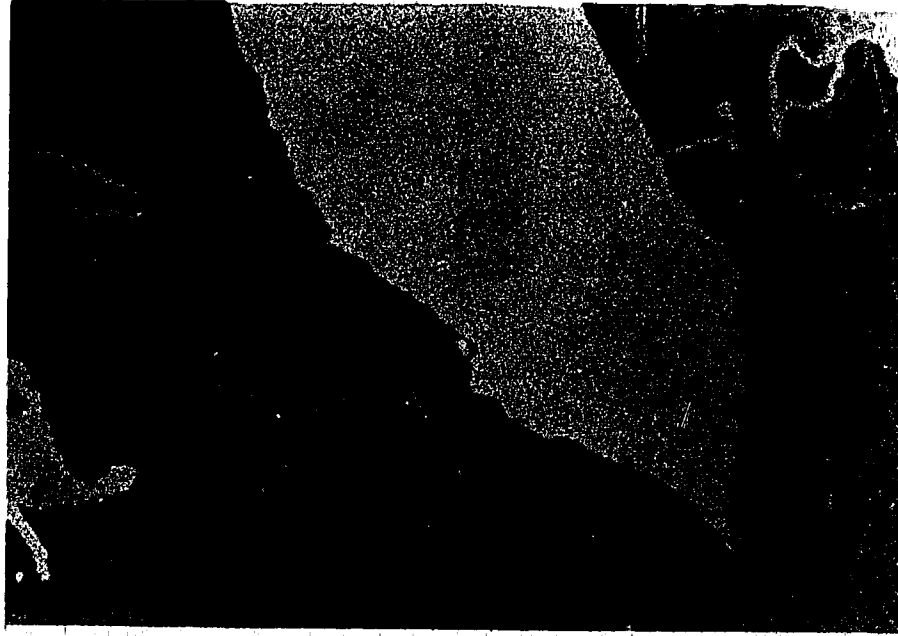
CYAN



CYAN PLUS MAGENTA

FIGURE 2E

THE YELLOW AND YELLOW PLUS CYAN PROGRESSIVE PROOFS OF THE TORONTO ERTS (LANDSAT) MAP



YELLOW
KOTTEX



YELLOW PLUS
KOTTEX

TORONTO-CENTRED REGION

FROM THE EARTH RESOURCES TECHNOLOGY SATELLIT

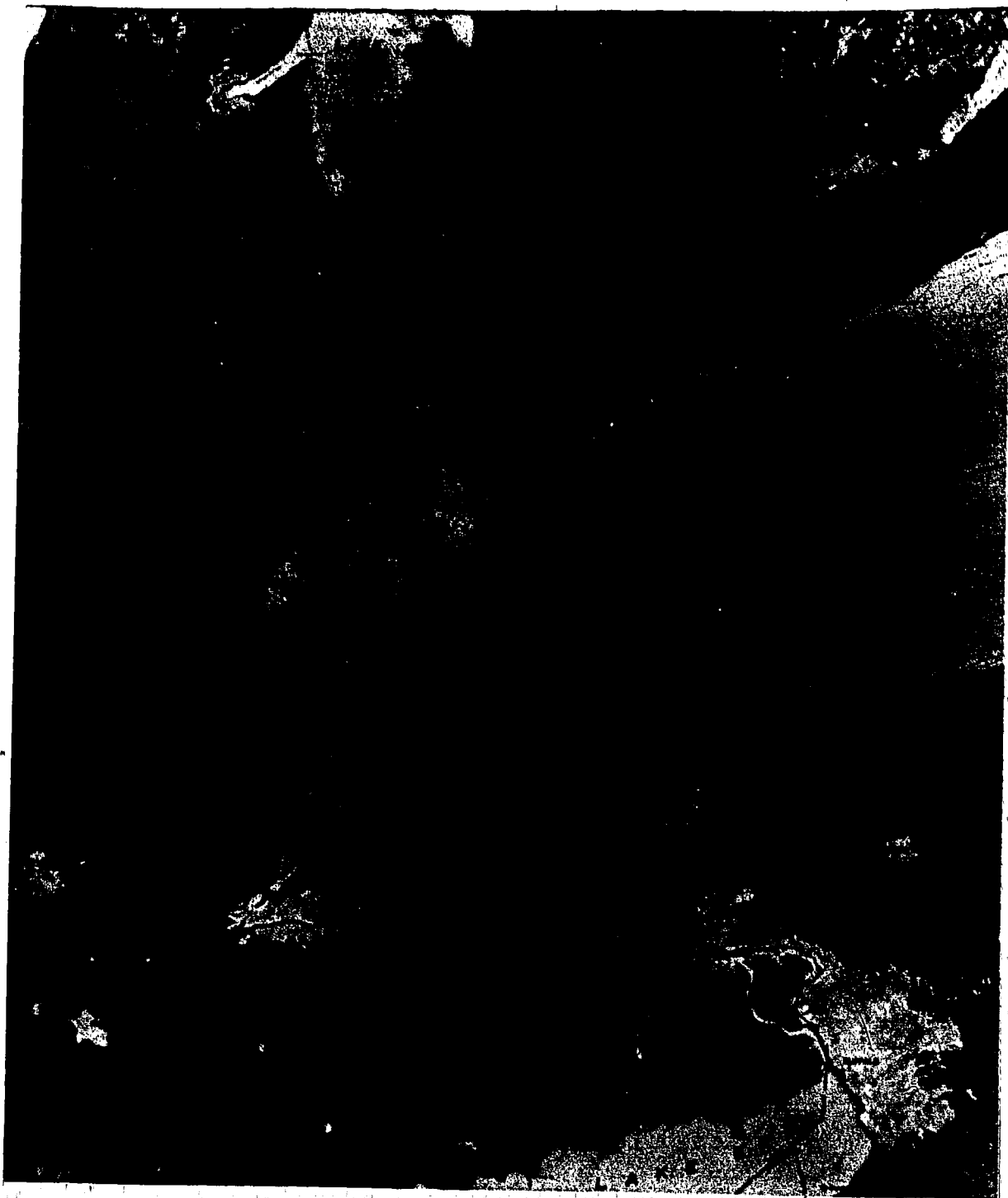


FIGURE 26

A PHOTOPRINT OF A SECTION OF THE TORONTO
ERT'S (LANDSAT) MAP

an additional section to the north indicates the position error of the centre, necessary due to a lack of a more precise reference system. The grid clearly printed in black is graduated in degrees and minutes at intervals of thirty minutes, for both longitude and latitude. An explanatory note beside the image map stresses that the grid should also be viewed with reference to the position error. Type faces used on the map are conventional and rely heavily on simple sans-serif styles of *Nimbus* and *Times* in both upper and lower case. The use of Italic type is restricted to hydrographic features, with Bodoni upper and lower case for six circles, miles and feet headings, Italic in upper case for major lakes. These latter type faces are the only two faces having serifs. Excluding title, type sizes on the map range from six point to twenty four point. The use of type size classifies features ordinarily as would a topographic map at this scale. Although all symbols are boxed in legend exists on the map.

The Toronto ERTS (LANDSAT) map, differs from the two previous LANDSAT maps by having a major aerial extent component devoted to portraying urbanized areas. Although effective when considering the contrast values of the orange urban area and surrounding "green" landscape a loss of detail in urban areas is apparent. This is brought about by the masking of MSS Band 5 (printed in cyan) from the urban areas. An exposure through an open window mask of the urban area detail from Band 5 could have been made with the result of printing both MSS Band 4 and MSS Band 5 in Magenta. This would have provided more detail allowing a greater image interpretation potential. Additionally the quality of the imagery itself is lacking. That fuzziness found in the Washington D.C. ERTS (LANDSAT) map is also

evident here. A certain amount of this is due to a band to band misregistration which could only have been solved by precision processing. However, the technique used in the Ottawa LANDSAT map of printing each spectral band in two colours might have improved the sharpness. Much image information is still usable despite this lack of resolution. The general appearance of the image-map is more natural than its simulated infrared counterparts and the contrast between light green wooded valleys and their corresponding rivers is adequate and provides a clear representation. The illusion of hypsometric tints, on the other hand, is deceiving since the spectral responses are based more on vegetation regimes than actual elevations.

Cartographic symbology may be overgeneralized but if the quality of the image could have been improved this level of generalization would be acceptable and in review of the map objectives even better. The symbology can easily be visually classified in order of dominance or importance with the areal extent of urbanized area ranking first, Niagara Escarpment second, major highways third, and country boundaries of least importance. This latter symbol blends with the image and is inconspicuous but is easily read with close inspection. The lack of a legend is disturbing even though the majority of features are clearly labelled. The symbols themselves are very simple and cover as little of the image as is necessary. The symbol misregistration can only be attributed to improper or incomplete proofing and editing.

The Toronto ERTS (LANDSAT) map is the most thematic of the three maps discussed. The Washington D.C. ERTS (LANDSAT) map relies heavily on a topographic symbol representation while the Toronto ERTS (LANDSAT) map relies on the areal extent technique. The Ottawa LANDSAT map employs

virtually no enhancement relying heavily upon the image itself to carry the message. This reliance is not complete since only a section of the LANDSAT image is mapped. This section is extracted from the image and aligned to North producing "neat" graticules parallel to the map boundaries unlike the other LANDSAT maps; which maintain the graticule at an angle but cover the entire LANDSAT image area. The Toronto IRTS (LANDSAT) map again differs from the other image-maps in the production of a false colour "natural" landscape and by printing the negative MSS Bands instead of positives.

Maintaining few similarities, three different approaches to LANDSAT mapping or rather the use of the LANDSAT image as a mapping base, have been developed. The ideal approach appears to be a combination of all three. Each map has developed techniques which should improve the overall status of LANDSAT maps. The LANDSAT map at this scale is capable of supporting a large amount of cartographic enhancement as evidenced by the Washington D.C. map, even though in some cases it appears congested. A level of generalization less than that of conventional maps is still needed, however, topographic map references of the comparative LANDSAT image area should be supplied on each LANDSAT map. The Toronto IRTS (LANDSAT) map has developed a useful approach to colour balance of the image. Although the Infrared simulation is informative to a trained image interpreter, a more natural appearing image would be of greater use to a larger map audience. Other colour combinations could be achieved for particular thematic purposes providing sufficient explanatory information regarding the MSS Bands is given on the LANDSAT map. Image enhancement and clarity can be considerably improved by printing one MSS band in more than one colour.

as with the Ottawa LANDSAT map. One drawback remains; if the LANDSAT map is to become successful, better processing techniques in image resolution and geometric fidelity need to become more accessible. Although image enhancement and precision processing techniques exist, the cost of such techniques still remain beyond the budgets of most potential users. This is not to say that the LANDSAT image in its present low cost, standard format could not be used as a mapping base at smaller scales with greater thematic content.

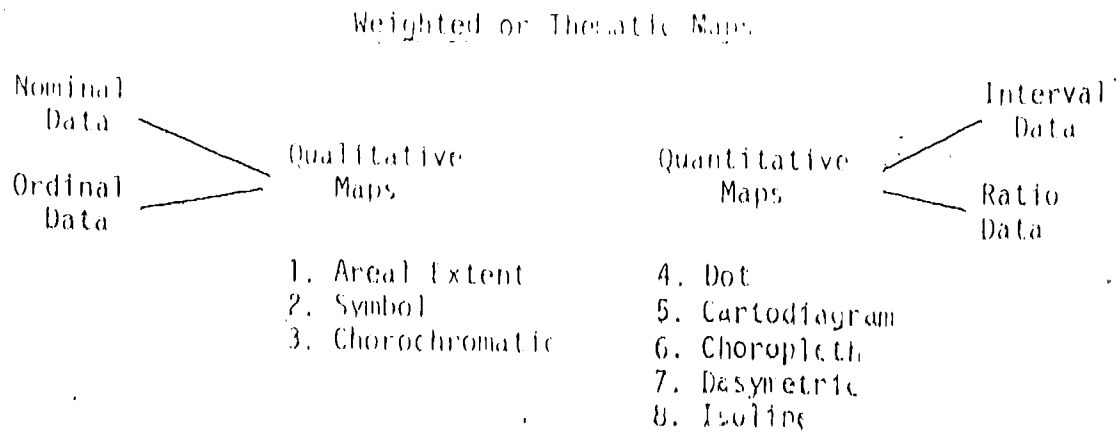
CHAPTER 5

THEMATIC LANDSAT MAPS

5.1 Introduction

As maps and map products have evolved with the development of new cartographic techniques and methodologies a need to establish a terminology to communicate those techniques arises. The first definitions must come with the maps themselves. Maps may be classified by many methods or approaches such as, map scale, or map data classification, or map purpose and audience. Although some systems are more generally accepted and some less, a useful and straight forward approach based primarily on map purpose and technique will be adopted here. Professor J.J. Klawe in 1973 developed an approach based on two general map categories, "balanced" and "weighted" maps. Balanced maps are maps in which all map elements are of equal importance. No map component, whether human or physical is stressed or emphasized to the detriment of the other map elements. Topographic maps are classified in this category. Weighted maps, on the other hand, do emphasize particular aspects or topics in maps. These maps are more commonly called thematic maps and depict selected socio-economic or physical themes (i.e. population density or mean annual stream flow). Klawe combines this classification scheme with a previously accepted definition of cartographic methods (Ratajski, 1963) and produces a working classification system for thematic or "weighted" maps. The eight cartographic techniques are summarized by qualitative and

quantitative methods as follows:



These nine basic mapping techniques or methods of representing data on maps are representative of all thematic mapping. As the discipline advances, new techniques may be discovered but for the present all two dimensional, printed thematic maps use one or combinations of the above methods. Special methods have been developed for relief representation some of which have not been included here; such as relief shading. These techniques are more commonly used on balanced maps. For this study mapping techniques will be confined to statistical data representation and since the previous chapter employed on LANDSAT mapping at the 1:250,000 scale, smaller scales will be discussed here.

5.2 Conceptual Aspects of the LANDSAT Thematic Map

The ever increasing demand for more cartographic products, of better quality, and in less time requires that the cartographer of today be continually searching for new data sources, techniques, technological advances, essentially anything which will allow him a better communication for less money. Many such advances have been

adopted useful to the ultimate benefit of both cartographer and map reader. The development of the LANDSAT system is one of the more recent advances now available to the cartographer.

The LANDSAT image for many purposes provides not only an excellent data base but also an excellent data base-map. Compilation of an adequate base map for thematic objectives consumes considerable time, energy and funds. That exercise entails the selection of a suitable projection and the location and generalization of topographic features to be included for reference on the map. The LANDSAT image can be programmed to fit several projections, the most common being the Universal Transverse Mercator. This projection is already being used extensively on topographic maps from which base maps for thematic topics are often compiled. With selection of the most recent quality imagery the locational features supplied by the LANDSAT image are the most up to date possible and are frequently more exacting in both location and content. Generalization of the LANDSAT mapping base occurs in a uniquely conceptual area apart from that of conventional map generalization. Instead of deciding the degree of line and symbol generalization such as the simplification of a coastal boundary (this is already achieved by the imagery) the LANDSAT image requires generalization along two lines: the selection of the suitable MSS spectral band or bands, and the control and manipulation of positive-negative and/or composite images of those bands. Compilation and generalization of the hidden information (county boundaries, place names, etc.) and the thematic topic proceeds as with conventional thematic maps.

Logically, the effectiveness of the LANDSAT image as a mapping base would be greatest when the relationship between the thematic content and the LANDSAT image can be easily deciphered by the map user. This would require a degree of interpretative skills on the part of the map user. The complexity of the graphic image in some ways would be increased and the map user would be required to turn that complexity into a useful communication. This does not imply that the map user could not derive useful information from the more complex LANDSAT map. So few LANDSAT maps exist that the opportunity for evaluation of the LANDSAT image by the map user is virtually nonexistent. A great deal of psychological and empirical testing is needed before an answer could surface. Such an investigation is beyond the scope of this study, however, preliminary research has been undertaken. Unlike conventional methods, no guidelines exist for the design and production of thematic LANDSAT maps. Through the production of thematic LANDSAT maps utilizing the basic cartographic methods the first steps towards development of those guidelines are undertaken.

5.3 Design and Production of Selected Thematic LANDSAT Maps

In chapters two and three considerable discussion was undertaken concerning the use of Areal Extent and Symbol or Alpha-numeric methods in conjunction with the LANDSAT images and will not be repeated here. The Dasymetric technique will also not be considered due to the extensive knowledge of the mapped area inherently required by the technique. In outward appearance the design of the dasymetric map is similar to those methods which classify the entire area of the map; chorochromatic, choropleth, and isarithmic. Economic reasons also

dictated a limit to the amount and the three types of cartographic
were described to be of greatest importance. Consequently additional
LANDSAT maps were made utilizing the following cartographic methods:
Chorochromatic, Dot, Cartograms using flows, bar graphs, circle
sector symbols, and graduated circles; Choropleth; and Isarithmic
(Figures 27-34).

Compilation for each of the thematic LANDSAT maps was undertaken
at a scale of 1:250,000. Standard 9 inch by 9 inch LANDSAT image
film positives were enlarged to this scale and converted to negatives.
Each of the images were then halftoned using a 110 lines per inch
screen. The orthochromatic film sheets of the halftone images were
used to produce Diazo Colour images. Many different image colour
combinations were combined with a thematic overlay and evaluated.
The image was, however, in a monochrome of one or several bands. A
monochrome instead of a false colour composite was used for three
reasons: 1) At this early state in the development of the LANDSAT map
it seemed best to anticipate possible design problems developing in
the contrast between LANDSAT image and thematic representation.
Consequently the LANDSAT image is held to a minimum level of map
content leaving the maximum flexibility to communicate the thematic
element which, of course, is the primary purpose of the map. The
maintenance of this minimum level is also aided by using the negative
image print on the maps.

2) Considering printing costs today, the most economical use of the
LANDSAT image in thematic mapping is similar to the approach used for
shaded relief plates; the use of a single colour, base image depicting
the natural landscape with a map annotation overprint. The LANDSAT

image would not need to be rotated to represent the natural landscape, it records the natural landscape. (2) Finally, costs for this study.

The LANDSAT image, produced by both CCP and NASA, when combined with the thematic overlays was used to simulate a printed map using a flat colour process. The thematic overlays were produced using a combination of tetratone shading film, coloured ink and stick up type produced by both impression and photographic type machines. The maps are essentially copies of mechanical maps to be used for evaluation before reproduction. A certain amount of image degradation is apparent in the photo prints of these manuscript maps, however, with a printed version this can be easily overcome (see Figures 27-34). The themes, themselves, were chosen to be representative of cartographic methods. Although compiled for the entire LANDSAT scene, the theme maps were squared to maintain a more conventional format.

CHROMOCHROMATIC LANDSAT MAP

Physiography Toronto Centred Region

- 12 Element Thematic Overlay
- Black Halftone Image, Single MSS Band

The large number of classifications on the Physiography LANDSAT map demands not only a monochrome form of LANDSAT image but a monochrome of a neutral shade or colour. A halftone black/gray LANDSAT image provides the base for this map. A careful selection of hues for the classifications is mandatory since their appearance will alter with the varying amount of black added by the image. Additionally if hues are too similar the possibility of category confusion arises (See Hill Plains - drumlinized and Shale Plains, Figure 27). Care must also be taken to preserve the illusion of transparency; if the

PHYSIOGRAPHY TORONTO-CENTRED REGION

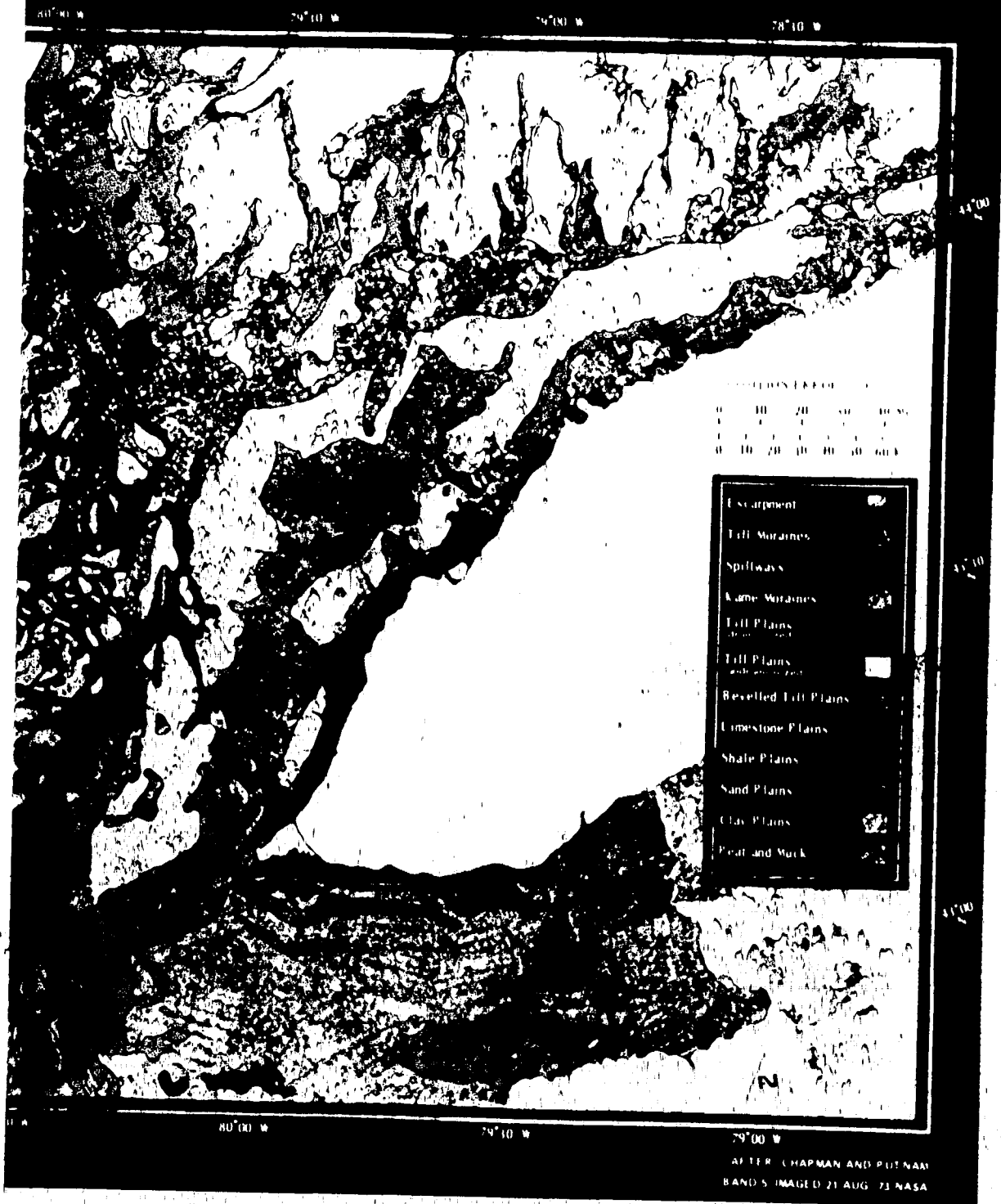


FIGURE 27

AN EXPERIMENTAL CHOROCHROMATIC LANDSAT MAP

LANDSAT image is to function at least to some extent. A balance between image and map elements must be achieved. If the colour overlay is too saturated the combination of that category colour and image detail could produce a dark unreadable area, as in the "Shale Plains"/"Till Plains" in figure 27, even though the areal extent of these categories is still communicated the information supplied by the LANDSAT image is lost. The individual categories in the legend are produced from a segment of image extracted from a duplicate image and reproduced here with the thematic colour overprint. The image segments are extracted from areas that are indicative of the actual map classification (i.e. the image for a section of "Sand Plains" was extracted from a Sand Plain area on the image). The categories in the legend should be as indicative of the actual area on the LANDSAT map as is physically possible, a point confirmed by other LANDSAT maps. The high number of categories make the design of this LANDSAT map difficult for complete communication. The complete classification of the image area functions well provided the image itself has sufficient contrast.

LANDSAT IMAGE DOT MAP

Population Distribution Winnipeg Area, 1971

- 2 Element Thematic Overlay
- Green Halftoned Image of Band 6

The LANDSAT Dot Map, as in Figure 28, has only two thematic elements to be communicated in conjunction with the LANDSAT image, a line element representing census division boundaries and the dot representation of population. The dot map, although relatively simple in design does take on some of the traits of the previous chorochromatic map; all of the map area is classified by the image. Gross, nominal

POPULATION DISTRIBUTION WINNIPEG AREA 1971

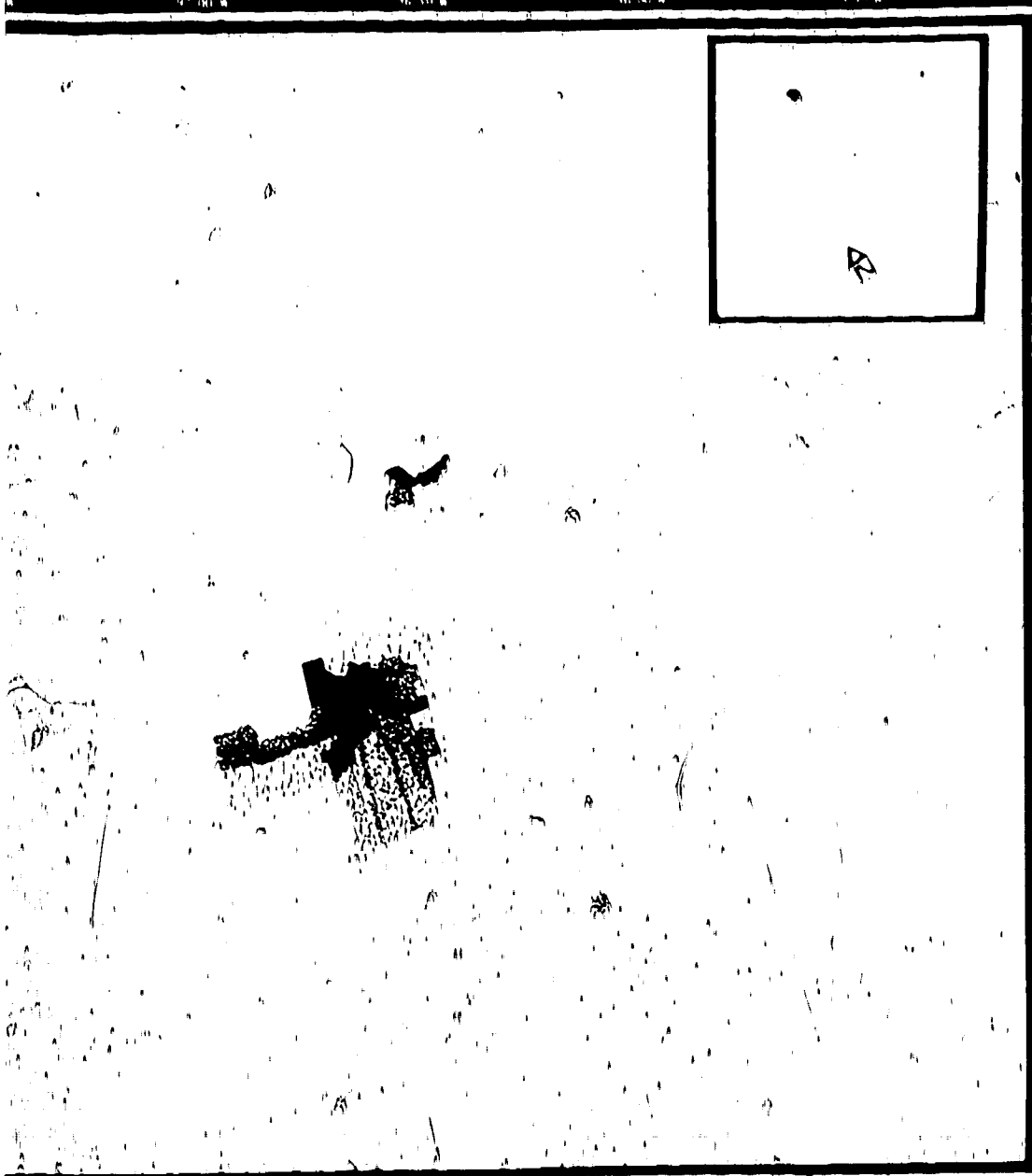


FIGURE 28

AN EXPERIMENTAL LANDSAT DOT MAP

categories of landscape such as shield area, farming areas, and urbanized areas are easily detected on the image. In the LANDSAT Dot Map the distinctive urbanized area patterns produced by the imagery are virtually obliterated by the coarse grid dots. This can hardly be avoided since the coarse grid is needed for the dot communication on any dot map not just the LANDSAT dot map. The two remaining areas do provide a visual correlation relating a very generalized land use to location of population. The alternative provided by conventional symbolization would have blank or white areas providing little information to the map user. Careful consideration must be given to contrast levels between image and dot. If the dot isn't prominent, it could be entirely lost within the LANDSAT image. Consequently, the selection of hue for both image and dot is most important.

LANDSAT HQW MAP

Mean Annual Stream Flow Toronto Centred Region

- 2 Thematic Elements
- Magenta Half-tone Image, Band 5

Unfortunately the LANDSAT image does not record some features at a suitable contrast level for mapping purposes. Some elements or themes such as hydrography, appearing as a black overprint on Figure 29, are for the most part interpretable on the LANDSAT image and can nearly always be detected by a pixel printout map, but conventional image processing doesn't develop a level of contrast suitable for thematic representation. Consequently the need arises for the cartographic enhancement of the major river and stream network. Considering the contrast level of the image, this enhancement needs to be continued for the lake shore boundaries as well. Another method of alleviating this problem would be to print an image combining two MSS Bands, Band 5 for

MEAN ANNUAL STREAM FLOW TORONTO-CENTRED REGION

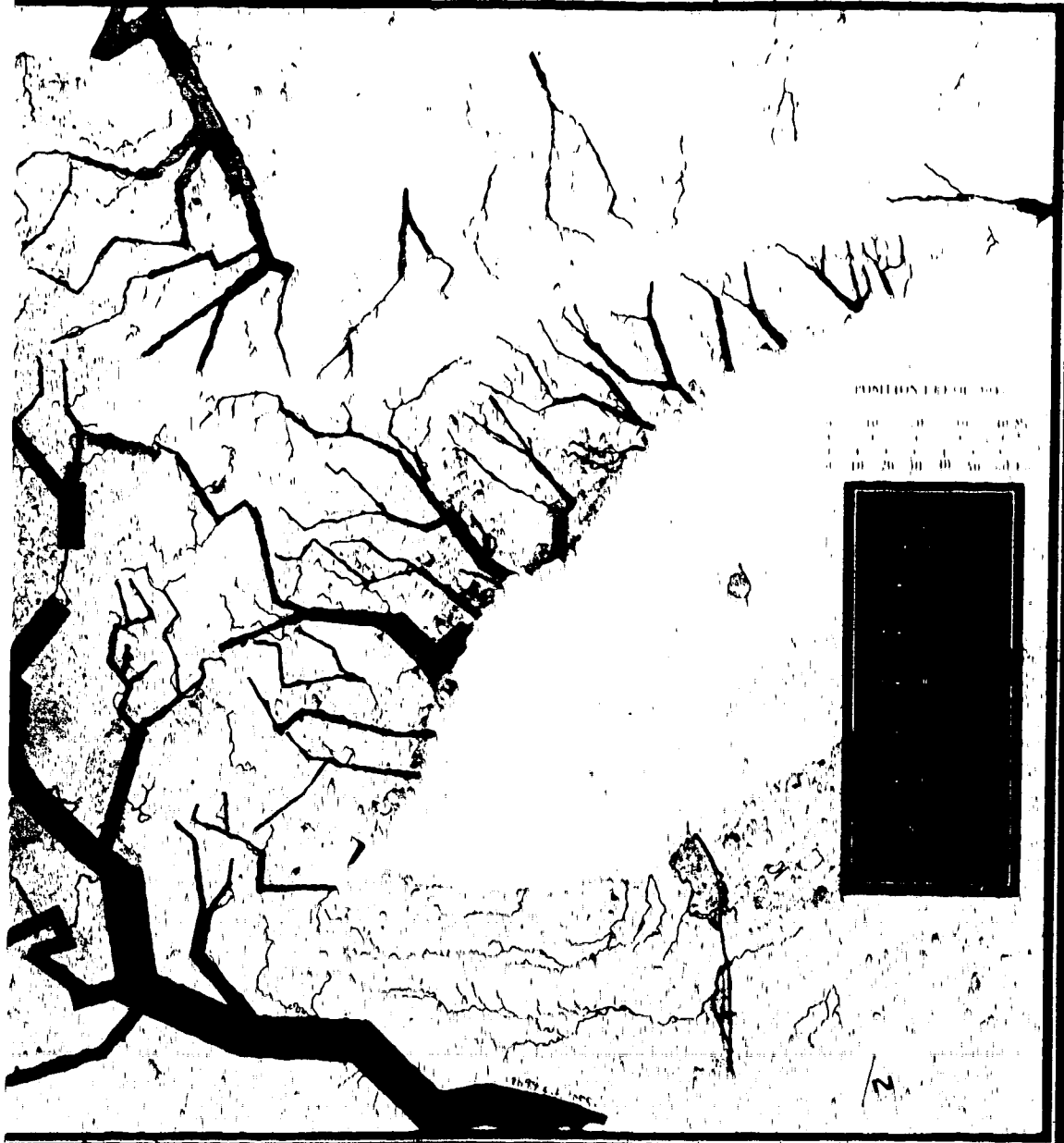


FIGURE 29

AN EXPERIMENTAL LANDSAT FLOW MAP

topographic and cultural features and Band 7 to delineate coastline boundaries.

The thematic component is once again occupying the dominant graphic role. The graduated stream flow representation is transparent, allowing the image to be viewed, but at the same time the contrast is great enough to be easily read. Due to the simplicity of the stream graduation symbol the legend is easily decoded even though the symbol in the legend does not utilize a LANDSAT image print extracted from the stream area on the image as in Figure 27.

CHOROPLETHIC LANDSAT MAP

Residential Intermittent Hydro Customers Lake Simcoe Region 1970

- 6 Thematic Elements

- Green Halftone Image, Combined Bands 4, 5, 6.

This LANDSAT map stresses the fact that the categories in the legend must appear with the appropriate area of the LANDSAT image as an underprint. The alteration of colour by the LANDSAT image is considerable and must be taken into account. The legend is completely unusable unless it can relate the legend classification to actual map area. The choroplethic classes are easily distinguishable within the six category series but there remains a considerable variation of brightness within the categories as the landscape recorded by the image changes. Although this variation in brightness cannot be eliminated, to facilitate map interpretation by the user, sections of the LANDSAT image must be included in the appropriate map legend categories. A portion of this change in brightness also develops as a function of the cartographic method and thematic topic. The original map uses a black/grey image, however, this hue has been

IDENTIAL INTERMITTENT HYDRO CUSTOMERS LAKE SIMCOE REGION 1970

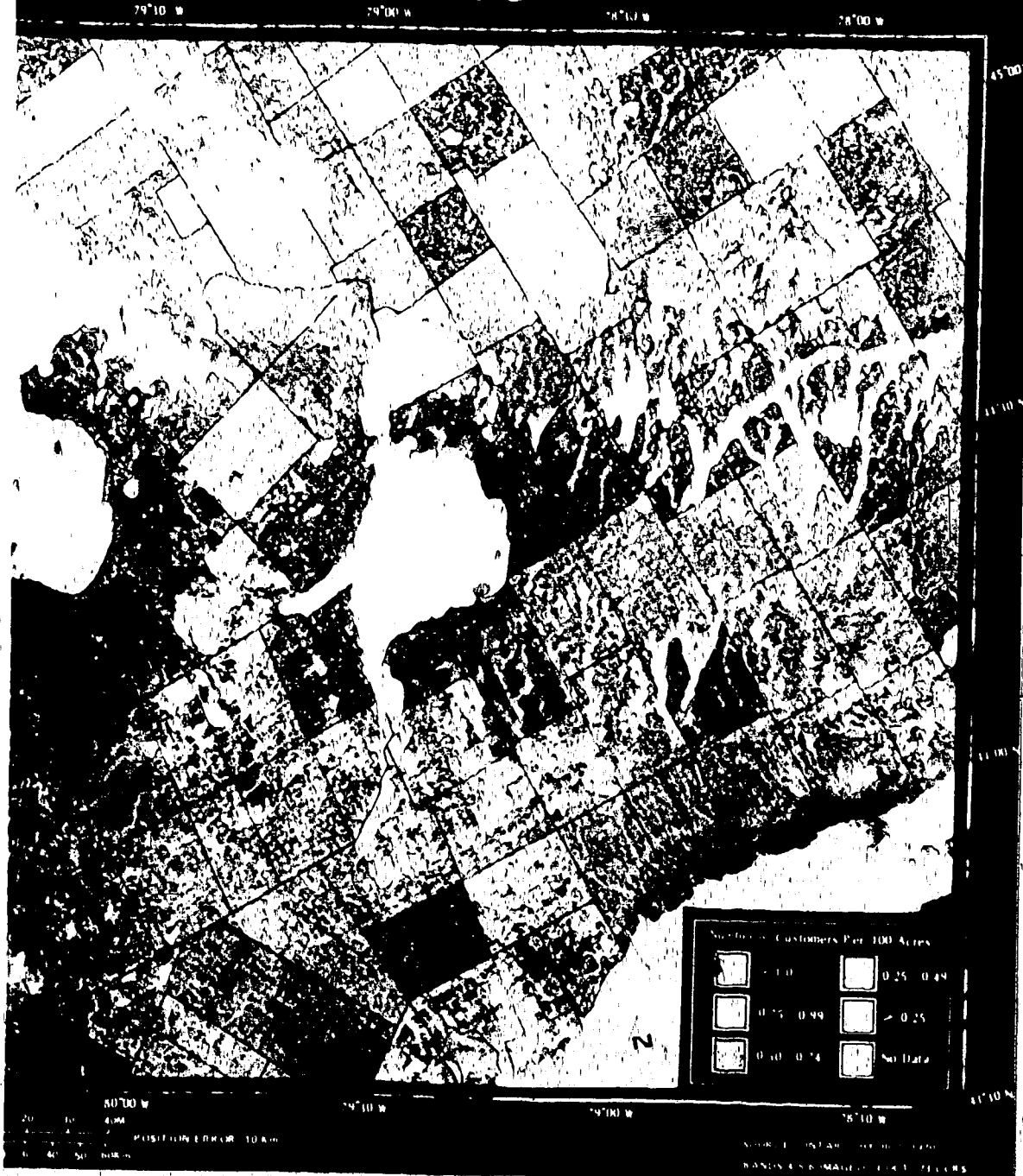


FIGURE 30
 AN EXPERIMENTAL CHOROPLETH LANDSAT MAP

altered by photographic reproduction. Unlike the chorochromatic map's use of boundaries delineated by physical features, the choropleth map uses census boundaries which quite often do not correspond to variations in the physical landscape. However, the shield area and accessibility to lake shore boundaries can be visually correlated to high density areas of intermittent hydro customers.

The resolution of this image exceeds that of the previous LANDSAT maps for two reasons. The image is a combination of MSS Bands and a image quality from CCRS processing is also superior for this particular scene. The image in this map appears of equal if not greater dominance than the thematic component.

CARTODIAGRAM LANDSAT MAPS

Building Permits Issued Lake Simcoe Region 1973

Steam and Hydro - Electric Power The Vancouver Region 1972

Population Distribution Toronto Centred Region 1971

- 2 Thematic Map Elements on each map

- Two maps use combinations of Bands 4, 5, 6; the third uses Band 5

The first map, Building Permits Issued - Lake Simcoe Region, applies a bar graph with six categories to aggregate data for each township census division. The image is the same one used for the CHOROPLETH LANDSAT MAP, however, it is illustrated by a less dominant, violet halftoned image. This image could be greatly increased in saturation without appreciable effect on the thematic representation (see figure 31).

The circle sector map for electric power in the Vancouver Region uses a minimal saturation, cyan LANDSAT image to depict the physical landscape. Again there is no problem reading the thematic sector

BUILDING PERMITS ISSUED LAKE SIMCOE REGION

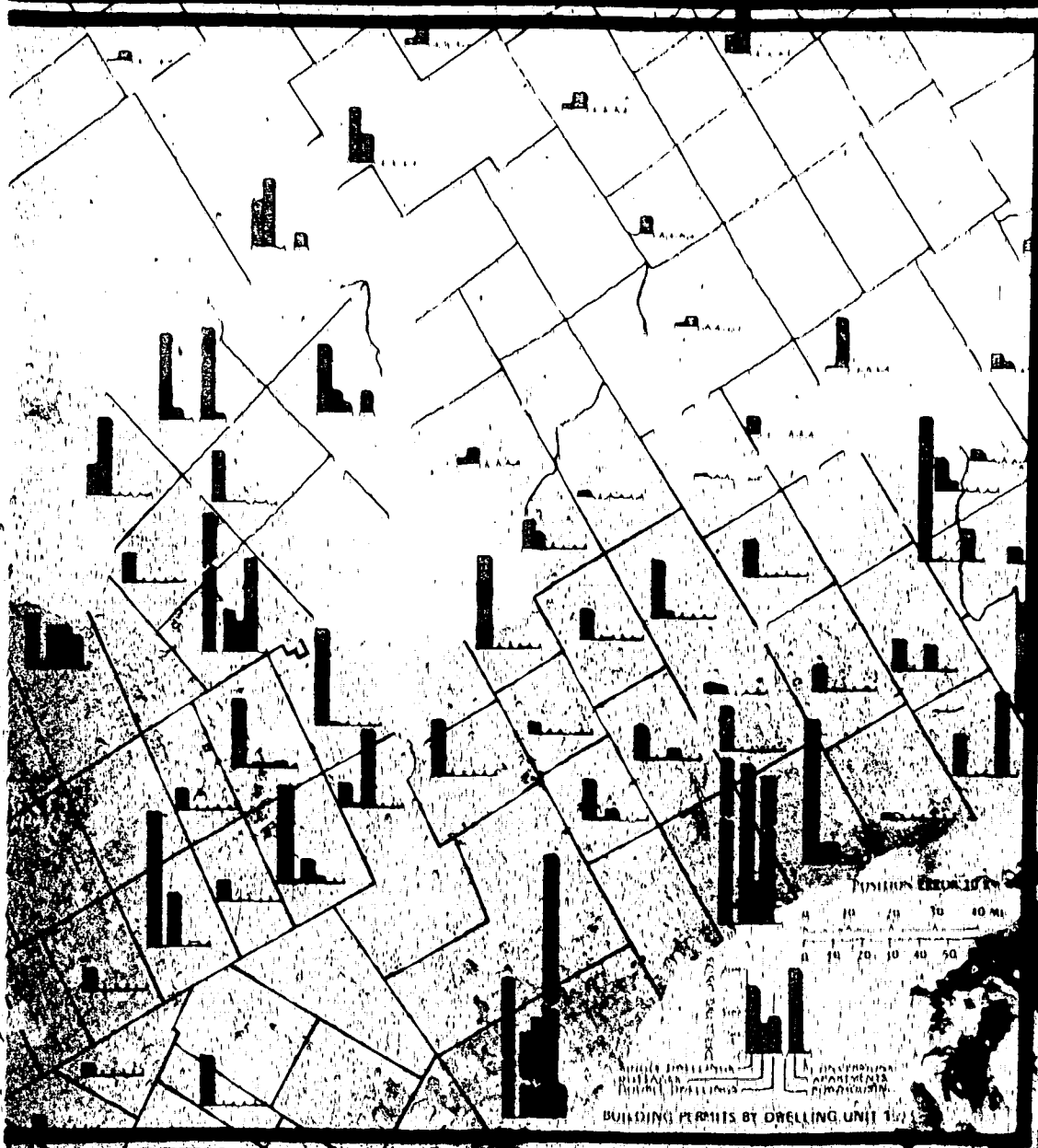


FIGURE 31

AN EXPERIMENTAL CARTODIAGRAM LANDSAT MAP
UTILIZING BAR GRAPHS

STEAM AND HYDRO - ELECTRIC POWER THE VANCOUVER REGION 1972

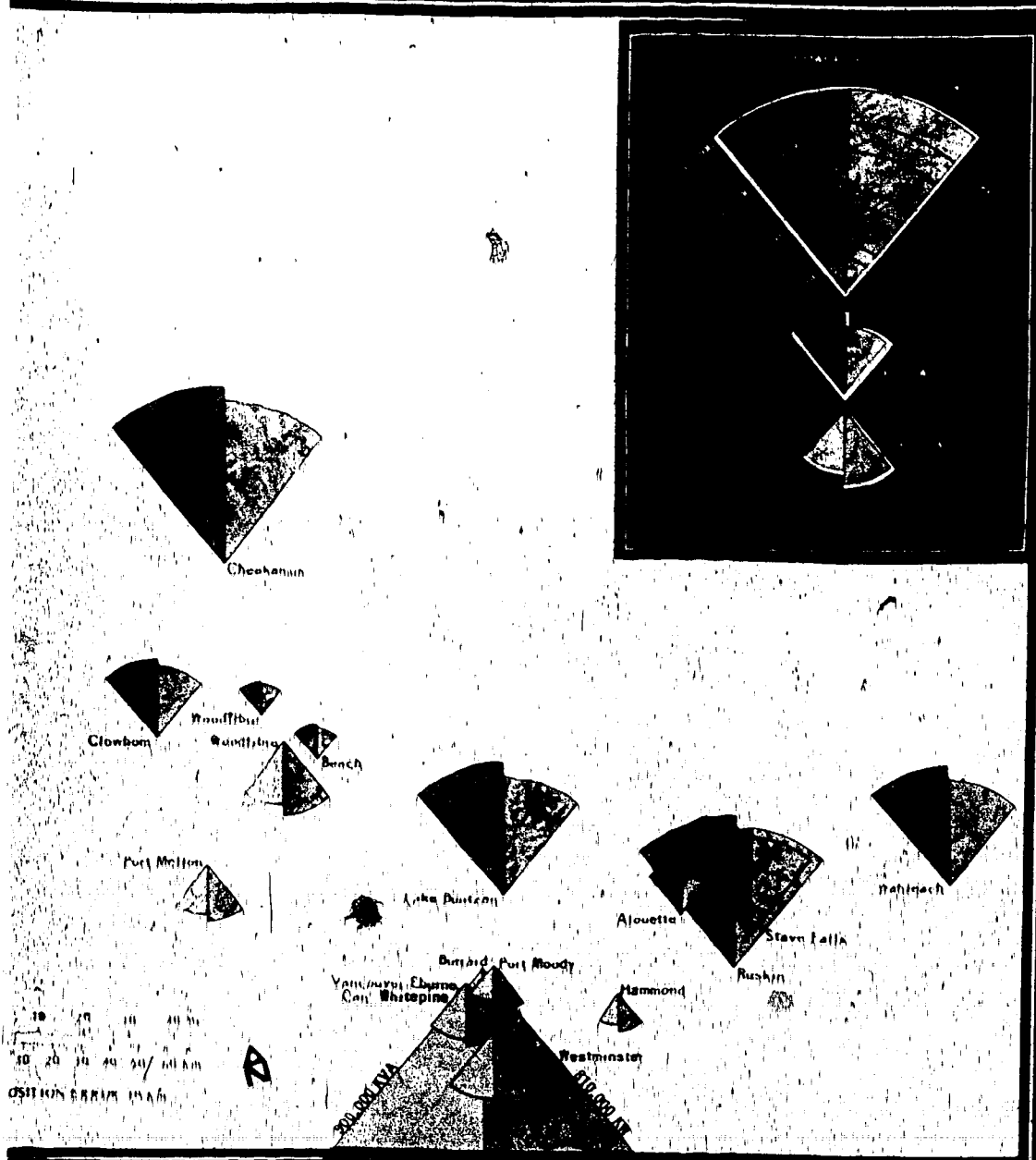


FIGURE 32

AN EXPERIMENTAL CARTODIAGRAM LANDSAT MAP
UTILIZING CIRCLE SECTORS

POPULATION DISTRIBUTION TORONTO CENTRED REGION 1971

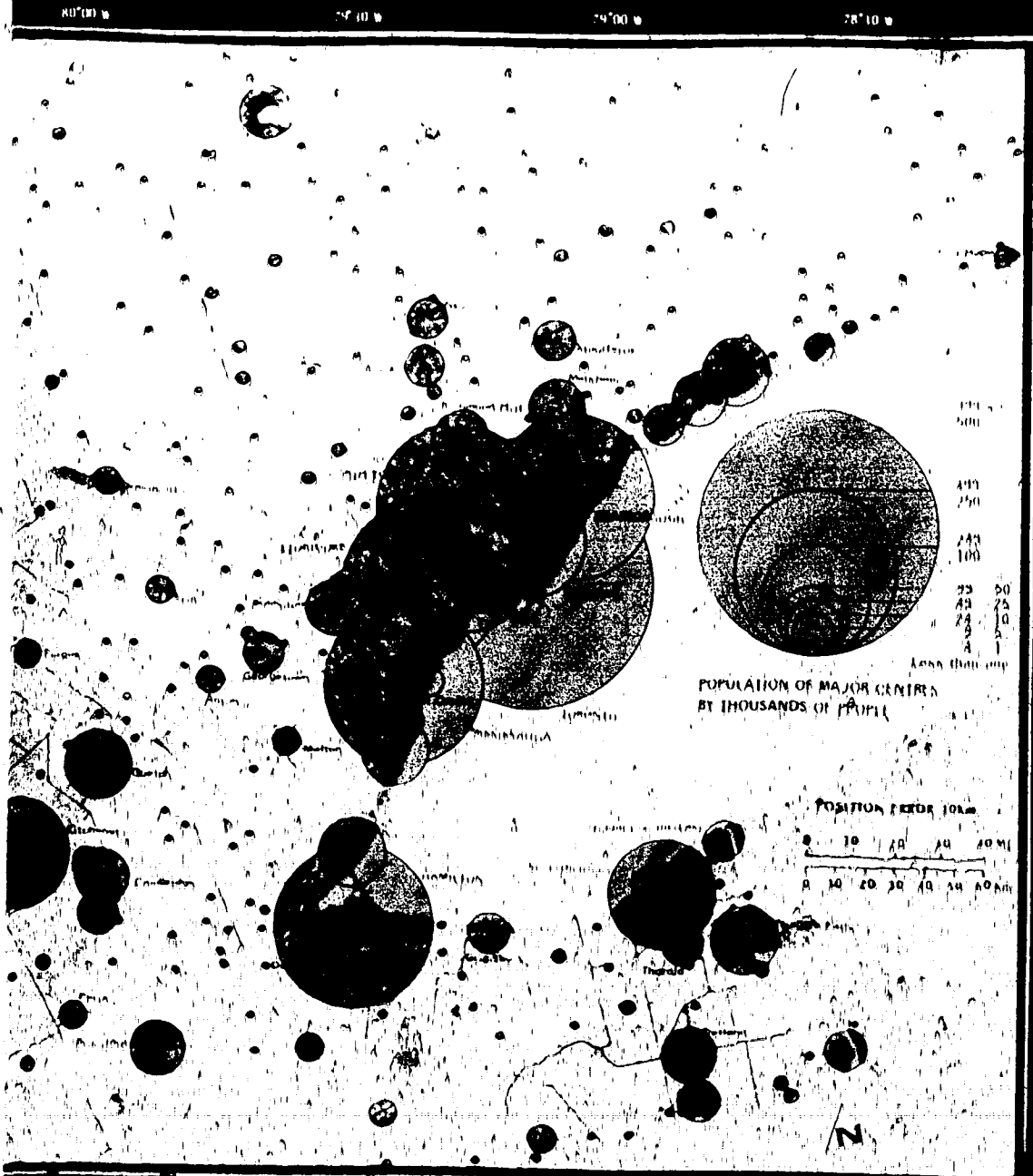


FIGURE 33

AN EXPERIMENTAL CARTODIAGRAM LANDSAT MAP
UTILIZING GRADUATED CIRCLES

symbols but the detail supplied by the LANDSAT image needs to be increased. For this map, particularly for the depiction of the glacier or snow covered areas (represented by the darker cyan in the image) a positive inset would have been more suited. The map audience does, however, receive an impression of the watershed areas upstream from the hydro electric plants and should also be capable of correlating the large steam generating output with the Greater Vancouver Area (see Figure 32).

The graduated circle LANDSAT map of population distribution in the Toronto Centred Region appears here, as the most effective cartodiagram LANDSAT map representation. It combines township boundaries graduated circles (in pink) and the LANDSAT image (in a blue halftone). The darker blue areas created by the spectral response of the urbanized areas in the image combined with the pink graduated circles tends to emphasize the urban area boundaries. The facility to evaluate and compare the actual size of urbanized area with the size of population is readily available (see Figure 33).

All of the cartodiagram techniques offer less difficulties in design and construction of LANDSAT image maps than those techniques requiring the classification of the entire LANDSAT image area. This is due to the well defined boundaries and shapes of the cartodiagrams and the greater design flexibility offered by mapping only two or three discrete thematic elements.

ISARITHMIC LANDSAT MAP

Population Density Toronto-Centred Region 1971

4 Thematic Elements

• Violet Halftone Image, Band 5.

Two types of isarithmic maps exist, isometric and isopleth. The

POPULATION DENSITY TORONTO-CENTRED REGION 1971

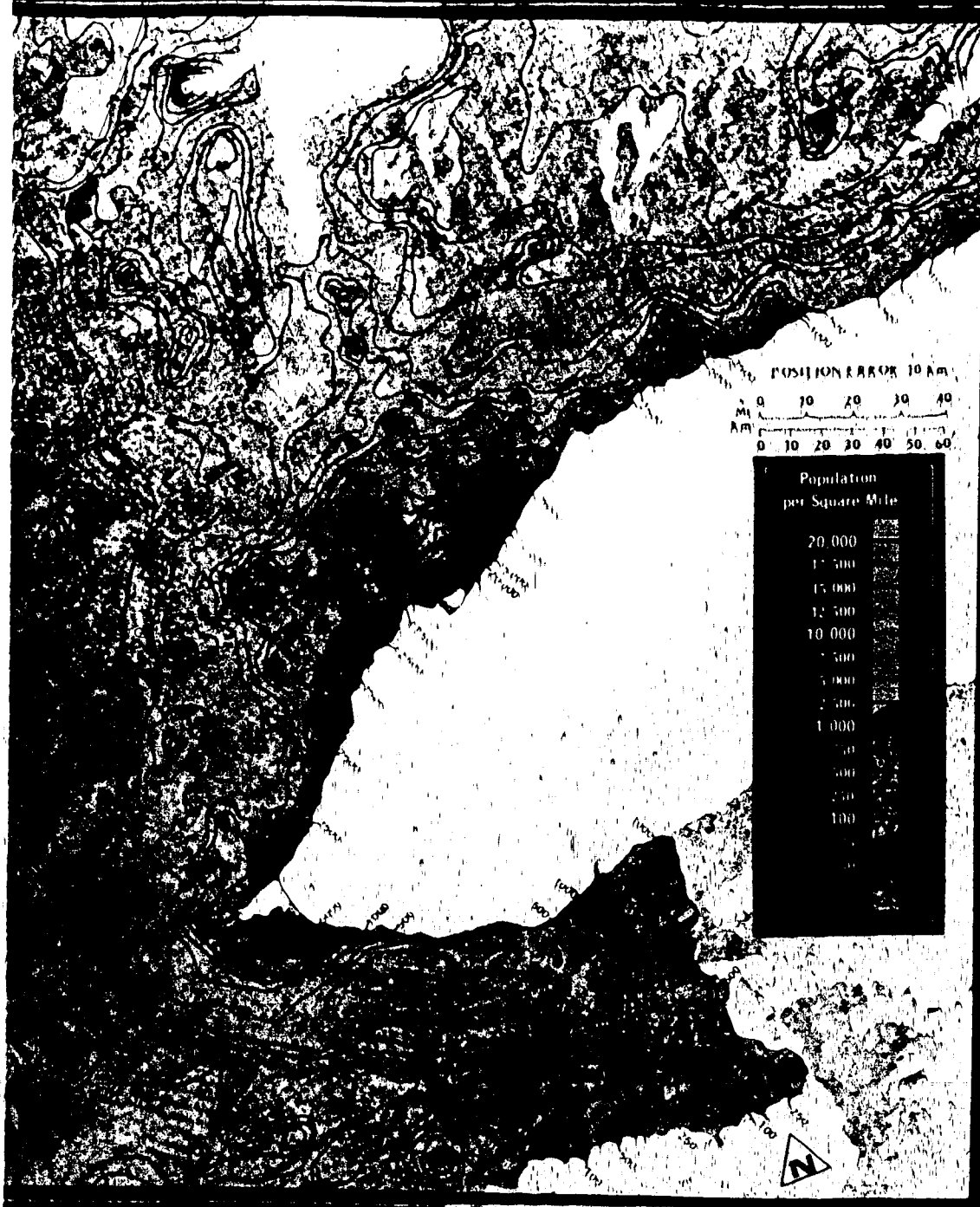


FIGURE 34

AN EXPERIMENTAL ISARITHMIC LANDSAT MAP
UTILIZING ISOPLETH LINES

difference originates in the manner of utilization of values, rather than in the graphic design or map appearance, both are an effective representation. The Toronto Central Business Population density map utilizes the isopleth method with data points derived from township and incorporated city population densities. Isopleth lines have also been added to the map. These four layer shadings have class boundaries of 100, 1000, 10,000 people per square mile (see Figure 34). Green is used for the lowest population category with yellow and orange for increasing density, concluding with magenta for the highest population. A violet halftone line provides the image base. This combination provides a suitable contrast configuration for the map. The added detail supplied by the LANDSAT image in the urban areas tends to promote this layer shading effect by providing the illusion of depth. The legend once again illustrates the need to use an actual image underprint for the correct classification. The category division at 1000 people/sq. mile is a critical one and its communication is severely impaired by the lack of image detail. Several colour combinations were attempted for the actual isoline but the reversion to black ultimately provided the best contrast. Just as with the other maps, classifying the total image area proper selection of image and thematic overlay colours is necessary.

5.4 Economic Aspects of Thematic LANDSAT Maps

Taking into consideration the cost of the LANDSAT image in photographic form and its inherent adaptability the cost of an LANDSAT map shouldn't amount to much more than the expense of an extra printed image. In many instances the cost of compile time in man hours can actually be reduced and the amount of compile time for the thematic

element is not going to be larger than that of a conventional map. The selection of suitable colour contrasts for map image and LANDSAT image could be time consuming but cost would diminish with more LANDSAT mapping experience. If the LANDSAT image were to be treated as conventional shaded relief plates are on maps today, the cost would be minimal. Pragmatically the LANDSAT image could function in just that way; as an additional clarifying element of the mapped topic.

The LANDSAT image also has considerable potential for automation of the thematic LANDSAT map. At the present time programs exist for the extraction of generalized landuse patterns from LANDSAT data (Ellefson, 1974; Joyce, 1974). Automatic thematic LANDSAT mapping could be carried further with the establishment of a library of computer produced map symbols (Peucker, 1972; Linders, 1973). This library in conjunction with a statistical data bank could automate the entire process. The computer could receive the LANDSAT Data directly from the satellite; process and record the image on a fitted grid (Chapman 1974; Hooper, 1974); sort the appropriate statistics from a data bank for the relevant census divisions included on the image; reproduced the established map symbology in conjunction with the LANDSAT image; all to be displayed by a cathode ray tube viewer. This is a projection of one possible approach to thematic LANDSAT mapping which would require considerable funding.

Another more realistic economic approach incorporates the direct use of the LANDSAT image/photograph, ordinarily available at minimal cost. The manuscript map of this chapter are intended to illustrate maps this type of use. This avenue to thematic LANDSAT mapping could conveniently be exploited by thematic cartographers with limited budgets.

6. CONCLUSIONS AND RECOMMENDATIONS FOR THEMATIC LANDSAT MAPS

6.1 Best Use of the Thematic LANDSAT Map

The development of thematic LANDSAT systems can occur along two channels: one having ultimate long term benefits and the other using available imagery, now. The longer range plan could incorporate completely automatic systems where LANDSAT data could be received, processed, combined with statistical data and displayed by the computer. With a television display, facility for adjustment of image to suit contrast, generalization, and symbolization could be left in the hands of individual map users. This capacity combined with pre-established formats and combinations of image maps stored in the computer could revolutionize our concept of the map. As computer technology develops, the automated LANDSAT maps will become more of a reality.

The more conventional use of thematic LANDSAT maps utilizing standard photographic image products shows great promise. These photo-maps can be produced quickly and cheaply but its success will depend upon the map users reaction to the photo element of the map. If he can successfully interpret image data and incorporate that information into his concept of the thematic topic then "reality" will be incorporated in the thematic map. In any case the LANDSAT map will not replace the conventional representation; but if used wisely in conjunction with conventional maps, should supply additional data to the map user.

6.2. Construction of the Landsat image } The first LANDSAT Map

Several LANDSAT computer experiments have been undertaken in an attempt to develop guidelines for the selection and construction of the first LANDSAT map. These experimental endeavors, far from being conclusive, were intended to provide further research and develop a concept of the problem area. The following guidelines will hopefully aid these ventures.

1) The comparison of the first LANDSAT mapping scales points the direction for future LANDSAT maps. The three 1:250,000 LANDSAT maps are all somewhat lacking in image detail. Many features interpretable on the LANDSAT image leave much to be desired when placed in a map situation. Indeed, an image of exceptional quality is needed before enlargement to this 1:250,000 scale should be attempted. Furthermore, the geometric fidelity of the image has a difficult time meeting map accuracy standards for this scale. Recent investigations (Wong, 1975) indicate that the LANDSAT image can now easily meet map accuracy standards for enlargements to 1:500,000. Considering the majority of thematic uses, the 1:500,000 to 1:1,000,000 mapping scale of the LANDSAT image is ideal for the production of the smaller scale thematic photo maps. This has not been feasible in the past due to prohibitive costs. Essentially a new area of cartography is opened for development.

2) The construction and evaluation of the different cartographic methods indicates some techniques used for thematic representation are more readily adapted to the LANDSAT image than others. Methods using areas to delineate spatial distributions proved extremely difficult for development of suitable designs. These techniques employing a classification of area on the LANDSAT image rely on an overprinted

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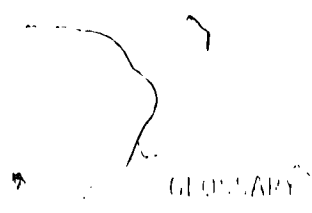
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Across-track - across the direction of spacecraft ground track; sometimes called horizontal when referring to output product coordinates.

Along-track - in the direction of the spacecraft ground track; sometimes called vertical when referring to output product coordinates.

Altitude - the distance from the nadir ground point to the spacecraft.

Brightness - that aspect of the perception of a patch of light as the intensity (quanta per second per unit of retinal area) varies.

Bulk Processing Subsystem - see Initial Image Generation Subsystem.

CCRS - Canada Centre for Remote Sensing.

CCF - computer compatible tape.

Channel - there are 6 channels (scan line detectors) per MSS spectral Bands 1, 2, 3, and 4; hence the MSS is a 24-channel scanner on LANDSAT 1 and 11.

Digital Subsystem (formerly Special Processing Subsystem) - receives digitized image data from system correction and scene correction processing and produces digital image data in 7-track and 9-track, computer-compatible, magnetic-tape format.

EBIR - Electron Beam Image Recorder - A device using an electron beam to record digital MSS data on photographic film.

ERTS - EARTH RESOURCE TECHNOLOGY SATELLITE A and B, now termed LANDSAT 1 and 11.

Format Center - the center of the RBV and MSS total image writing area. In Bulk Processing MSS Format Center is identical to RBV Format Center, defined as the intersection of the film registration mark diagonals. The image is corrected so that the geometric extension of the spacecraft axis to the earth's surface occurs at the Format Center.

Geometric Accuracy

Geographic (Latitude-Longitude) - based on the standard earth-fixed coordinate reference system, which employs latitude and longitude.

Registration - the ability to locate a point in an image with respect to a star.

Scene Registration - the ability to superimpose the same point in two images of a scene taken at the same time (different spectral bands).

Temporal Registration - the ability to superimpose a point in two images of the same scene taken at different times (same or different spectral bands).

Ground Control Point - any point that has a known location on the earth's surface which can be identified in IRIS imagery.

Ground track/trace - the locus of earth surface points which pass directly under the vehicle as it orbits the earth.

Hue - that aspect of the perception of light that varies when the wavelength is changed.

Image/trace - that data from one spectral band of one sensor for a nominal framing area of the earth's surface.

Image Processing Subsystem - receives video data, image annotation, and correction data to produce both film imagery and digital image data.

Initial Image Generating Subsystem (formerly Bulk Processing Subsystem) - converts all video data from RBV and MSS sensors to 55 by 55 (or 53) mm annotated and corrected images on 70 mm film.

LANDSAT - as of May 1975, the name applied to the Earth Resources Technology Satellite System. LANDSAT 1 was launched in July 1972 and LANDSAT was launched in January 1975.

LBIR - Laser Beam Image Recorder, a device using a Laser Beam to record MSS images on photographic film.

NASA - National Aeronautics and Space Administration.

Nadir - the intersection with the earth's surface of a line from the spacecraft perpendicular to the nearest plane tangent to the earth ellipsoid.

Negative - a photographic image on film, plate, or paper, in which the tones are reversed.

Negative colour - a photographic image on film, plate, paper, in which the colours appear as the complements of those in nature.

Noise - any signal, manifested in any form of energy, that occurs irregularly with respect to the signal of interest, and tends to obscure that signal.

Map - a graphic representation of the earth's surface, showing the relative positions of features and objects, and the shape and size of the earth's surface.

Map projection - a mathematical transformation of the earth's surface onto a flat surface, such as a map.

Observation/scene - the collection of the image data of one nominal frame/area of the earth's surface; this includes all data from each spectral band of each sensor.

Orthophotograph - a photograph of the earth showing images of objects in their true orthographic positions. Orthophotos are produced from perspective images by correcting for distortions which occur due to different angles of projection and relief.

Pixel - the instantaneous field of view of a detector in a Multispectral Scanner.

Platform - a data collection, sensor package on the earth's surface.

Precision Processing Subsystem - see Scene Correcting Subsystem.

Precision Processing Subsystem (PPS) - the PPS receives user-selected, full process imagery and produces precision-located and corrected imagery on 9-1/2 inch (241.3 mm) film.

Principal point - the intersection with the earth's surface of the line which is an extension of the optical axis of an lens camera. This point differs from the format center by the bore-sight angle error from nominal alignment.

Radioelectric - concerned with the combined electronic and optical transmission of data.

RBV - Real Time Beam Vidicon camera system.

Registration Marks - locations on the film plane outside the image writing area of full processing; there are four marks, one outside each corner of the writing area, fixed in position such that their diagonals intersect at the format center, or center of the tick mark coordinate center.

Reseau - the rectangular grid pattern inscribed on the RBV faceplate to facilitate geographic identification.

Saturation - that aspect of the perception of a patch of light that varies as more and more white light is added to a monochromatic light.

Scene Correcting Subsystem (formerly Precision Processing Subsystem) receives user-selected, system-correcting imagery and produces precision-located, scene-corrected imagery on 9-1/2 inch (241.3 mm) film.

Sensor/Band Identification - the ERTS spectral bands are identified as Bands 1, 2, and 3; the MSS as Bands 1, 2, 3, 4, and 5.

Skew - image distortion caused by scanning the scene in a direction non-parallel to the plane formed by the spacecraft and the instantaneous ground track velocity vector.

Special Processing Subsystem (SPS) - the SPS receives digitized image data from Full and Precision Processing and produces digital image data in a computer-compatible format.

Subsatellite Point - the intersection with the earth's surface of a line from the spacecraft to the center of the earth.

Sun Azimuth Angle - angle in degrees measured in the horizon plane from true north to a vertical circle passing through the sun.

Sun Elevation Angle - angle of the sun above the horizon measured in degrees.

Swath - the dimension on the ground seen as transverse to spacecraft velocity, within the sensor field of view (FOV).

Temporal - that which exists in the physical world as it relates to time but is not spatial, such as telemetry information.

Tick Marks - positional marks placed on imagery to enable a locational grid coordinate system to be constructed.

Tone - each distinguishable shade variation from black to white.