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CR - 130023

TYPE I PROGRESS REPORT

For Period Ending 1 February 1973

(E73-10077) EVALUATION OF THE APPLICATION OF ERTS-1 DATA TO THE REGIONAL LAND USE PLANNING PROCESS Progress Report, period ending (Wisconsin Univ.) 24 p HC $3.25 CSCL 08M
N73-17290
Unclas
G3/13 00077

A. Title of Investigation:

Evaluation of the Application of ERTS-1 Data to the Regional Land Use Planning qrocess, Proposal #058, Contract #NAS 5-21754.

B. GSFC Identification Number of Principal Investigator:

James L. Clapp, UN 040

C. Statement of Any Problems Impeding Progress of Investigation:

As reported in the Type II Progress Report for June-December, and in the Type I Progress Reports for October and August, we have not received any retrospectively ordered color composite imagery either precision or bulk. As noted before, it was thought at the initiation of this project that a "quick look" would be performed on the bulk black and white imagery as it was received. These "quick looks" would identify which images should be ordered retrospectively in either bulk or precision processed color format. It was intended that this retrospectively ordered imagery would be used to interpret and extract types of information to be correlated with existing data sources. The investigators have submitted retrospective data request forms for color products (first was submitted on 12 September). Additional requests for color composites have been submitted through 24 January (see Appendix 3 for Data Request sent since last Progress Report). It is realized that the facilities for handling data requests are over-burdened. However, it is felt that significant comparisons will be possible upon receiving such imagery.

D. Discussion of Accomplishments During Reporting Period and Those Planned for Next Reporting Period:

To date, the project has received ERTS images from the following dates: August 9, 12, 27, 28, 29, 30, 31;

Original photography may be purchased from:
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

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September 14, 15, 16, 17, 18; October 1, 2, 4, 6, 20, 23; November 6, 24, 28, 29; and December 13, 14, 15, 16, 17. This continuum of dates and the receiving of data in the format requested in our Standing Orders (an unrectified problem until January), in addition to receiving black and white imagery (9.5" for certain dates) retroactively requested has allowed us (during the last two weeks) to begin to finally analyze data as we desired to.

As identified in both the contract and the Type II Progress Report, this investigation is examining three geographical areas. Correlations with existing data bases are a principal goal. Because geographical regions 1 and 2 have computer data bases, initial work has begun with these regions. The Type II Progress Report noted that, due to lack of imagery at that time, correlation methodologies were established to compare RB-57 imagery (data that was on hand) and the REMAP I and II computer stored data. (NOTE: As described in the Type II Progress Report, this was done for two sample areas representing 600 km within the spatial data bank.) Although correlations with RB-57 and the data banks were initially undertaken while we were waiting for ERTS data, it provided a unique opportunity to spatially compare for sample areas; the ERTS data, the RB-57 data, and the data presently stored in the computer data bank (from conventional sources, i.e. USGS, soils data, etc.).

At the present time, we have 9.5" ERTS imagery of the area covered by the REMAP I and II data bank for the dates of 9 August, 14 September and 13 December (the 9.5" imagery is needed in the interpretation/extraction process).

We have developed a computer program enabling us to spatially compare data extracted from the ERTS imagery available (by selecting the most appropriate date and

MSS band), data extracted from the RB-57 photography and the existing data bank. Appendix 1 illustrates preliminary results of this analysis for the data variable "open swamp" and the Sheboygan sample area (10x30 km). Each sample area illustrates the spatial distribution and the percent of occurrence of "open swamp" within each 1 km cell. (NOTE: Symbols and levels: Level 1 = 0-10% occurrence; Level 2 = 10-20%, etc.) Initial ground truthing of the distribution of open swamp in the sample area has indicated that many of the areas indicated in the I57/REMAP I data bank have disappeared, suggesting that the RB-57 and the ERTS are a closer approximation of reality (more ground studies will be conducted in the spring; during which time we also will have been able to analyze additional ERTS data and perhaps color).

During the next reporting period we will analyze spatially the relationships between ERTS, RB-57 and I57 REMAP I and II data bank for both sample areas (Sheboygan and Green Bay) as illustrated in Appendix 1, for the following data:

- Agricultural
- Beach Ridge
- Communications, Airfields
- Drumlins
- End Moraine
- Esker
- Escarpment
- Forest, Lowland
- Forest, Upland
- Forest, Coniferous
- Forest, Deciduous
- Forest, Deciduous/Coniferous
- Glacial Lake, Bed
- Ground Moraine
- Interchanges
- Lakes

Lake Michigan
Lakes, Less 50 Acres
Limited Access Highway
Marsh
Open Swamp
Residential, Rural
Residential, Suburban
Residential, Urban
Rivers
River or Lake Zoning
Roads
Sand Dunes
Shrub Carr
Stream
Stream, Intermittent
Terraces
Utilities - Railway Lines

Additionally these data can be analyzed by the CROSTAB techniques described in the Type II Report. Those data illustrating significant correlation will then be interpreted for the entire region (5000 one-km cells) from appropriate ERTS imagery. We hope the results can then be reported in the weekly abstract.

Since having an appropriate image (i.e. black and white color, band, date, etc.) is of such obvious significance to our work, a matrix comparing available imagery to the REMAP I and II data was developed. These matrices (Appendix 2) analyze all the available dates (regardless of available format, 9.5" or 70mm) that would include coverage over the geographic region of the I57 REMAP data banks relative to the list of data presented above. As can be seen in the Appendix 2, information is recorded on date, % cloud cover, MSS band 4, 5, 6 or 7 and C (for color composites which at present we do not have except for images we manually combined, or processed with the I^2S color additive viewer maintained by the Iowa State

Geological Survey). We are planning additional trips to use the Iowa facility because of our belief in the value of color for this type of investigation. However, since we had no images processed by NASA we did not feel we could include that data in the matrices.

It is felt that, over time, these matrices will allow us to quickly determine optimum date and image format for identifying a given variable. The matrices included in the appendices are updated to our most recently acquired image of the area and will be continuously updated as new imagery arrives.

We are also developing two additional matrices that will examine the other geographic regions of the entire state of Wisconsin. These matrices, which will be updated on a 2 month basis (coinciding with progress reports), will examine: a) the list of variables from the ERTS descriptor list applicable to the state of Wisconsin; b) the list of variables that are stored in other data systems besides REMAP I and II and the data that we feel is part of the Wisconsin resource scene but not on other lists. It is felt that, over time, these matrices will enable us to make a solid contribution to the NASA-requested ERTS descriptor forms (which we were unable to respond to previously due to insufficient data), in addition to recognizing data inputs that ERTS could provide to regional planning in the entire state of Wisconsin.

We have begun to construct a ERTS mosaic for the entire state (to be finished by the next reporting period). This will be done with the imagery from December 13, 14, 15, 16 and 17; the first complete coverage we have obtained for the state with minimum cloud cover. To illustrate to the state of Wisconsin the validity of ERTS data, we intend to trace onto mylar an interpretation of a resource that has been identified as both in a critical state and not available from conventional sources (e.g. wetland classification - the exact number and types of data have not been determined).

In essence, we see the next reporting period as being one in which a number of significant results dealing with the application of ERTS-1 to the regional land use planning process can be identified.

On 6 February 1973 we received a letter from Stanley Freden (dated 31 January 1973) requesting information on the use of aircraft support to our ERTS program. Specifically three questions were requested: a) adequacy of support; b) data processing and quality; and c) specific use of the aircraft data. It was requested that this information be supplied with the periodic progress reports or regerences to past reports.

1. At the present time the coverage provided by RB-57 underflights is adequate to our needs and available personnel.

2. As reported in our Type I Progress Reports of August and October 1972, and the Type II Report for the June-December period, quality of the imagery is excellent but we felt there existed certain data handling problems. Cooperation between NASA personnel in confirming flight plans was also excellent. Unfortunately our June 4th flight provided complete coverage of one of our study areas while the September 22 flight provided us with less than 1/3 coverage due to a lack of fuel. We also noted some delay in getting the processed imagery to us.

3. Our principle use of the data is as ground truth to our ERTS investigation. Preliminary ground studies have illustrated that certain data existing in our computer data bank (from conventional sources) is not as accurate as interpretations that can be made from the RB-57 aerial imagery. We are still investigating this phenomena.

In our Type II Progress Report we specifically illustrated the methodology being used to compare RB-57 derived data with the data stored in the computer data bank. Crostabs were illustrated of 4 types of data and spatial comparisons of the same data was also shown. The present progress report for February illustrates our present use of RB-57 data in Appendix 1: the spatial comparison of ERTS, RB-57 and stored data for the variable "open swamp". This procedure as indicated will be prepared during the next reporting period on 33 other data (see page 3).

We have examined many images of Lakes Michigan and Superior for indications of turbid near-surface water. Several of the images show very turbid water along the Wisconsin shore of Lake Michigan, and near Duluth, in the western arm of Lake Superior. We are now searching for ground truth for those days (i.e. in situ turbidity measurements). Some has been found already (e.g., 12 August, near Duluth).

Because of the tremendous impact such data may have on litigation involving water quality, it is quite possible that we (and the data) will be subpoenaed in connection with such litigation.

E. <u>Discussion of Significant Results</u>:

None at this time.

F. <u>Listing of Published Papers, Articles</u>:

McCarthy, M.M., B.J. Niemann, Jr., and R.A. Boots, 1973. Remote Sensing of Infrared Energy: Critical Data for Land Use Decision Making, <u>Landscape Architecture</u>, Vol. 63, No. 2, pp. 133-143.

NOTE: This article was reported in the December 1972 Type II Progress Report. We have again included copies with this report as we are now able to include the finished copy (the previous copy was only a typewritten draft). Note the ERTS illustration/discussion on pages 134-135.

G. Recommendations:

None at this time.

H. Standing Order Changes:

None at this time.

I. ERTS Image Descriptor Forms:

None at this time (see comments on p. 5).

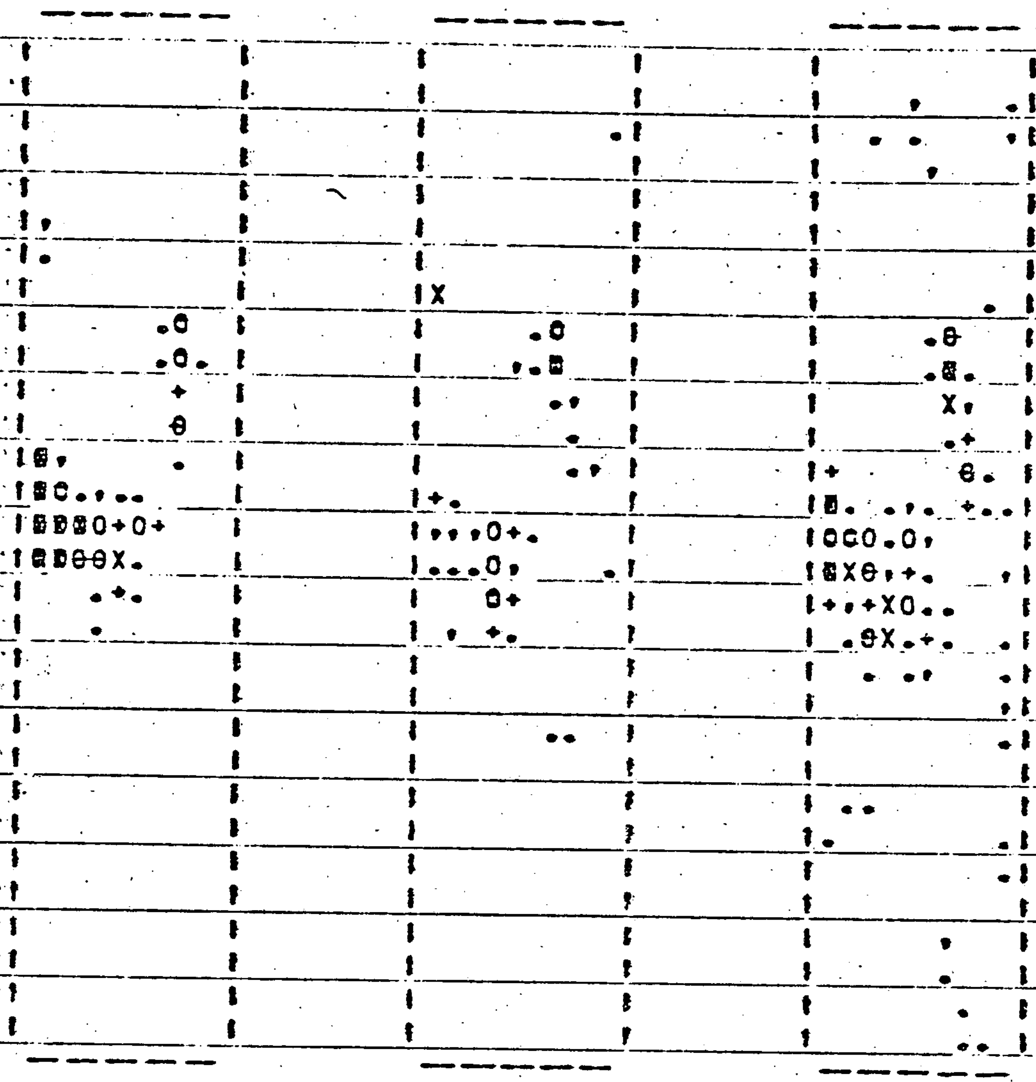
J. Data Request Forms Submitted During Reporting Period:

See Appendix 3.

APPENDIX I.

SHEBOYGAN

OPEN SWAMP



LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	••••••	,,,,,,	••••••	++++++	XXXXXX	OOOOOO	θθθθθθ	000000	[illegible]	[illegible]

PRELIMINARY DRAFT. APPENDIX 2

CODE

MATRIX: DATA:

Data can be identified

- Data item easily identified . . . . /
- Data item identified with difficulty . . . —
- Image format most appropriate for identification . . . //

Data cannot be identified

- Not available . . . . N
- Quality too poor for interpretation . . . . P
- Data item unable to be identified C

ERTS/REMAP I & II DATA BANK

DATE % CLOUD COVER	AUG. 9 / 20%					AUG 27 / 70%					SEPT 14 / 10%				
	4	5	6	7	C	4	5	6	7	C	4	5	6	7	C
AGRICULTURAL	—	//	C	C	N	ALL DATA					—	//	C	C	N
BEACH RIDGE	—	//	C	C	N	POOR QUALITY					—	//	C	C	N
COMMUNICATIONS, AIRFIELDS*	—	//	C	C	N	—	P	—			/	//	C	C	N
DRUMLINS	—	//	—	—	N	NO DETERM.					—	//	—	—	N
END MORAINE	—	//	C	C	N	POSSIBLE					—	//	C	C	N
ESKER	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
ESCARPMENT	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
FOREST, LOWLAND	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
FOREST, UPLAND	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
FOREST, CONIFEROUS*	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
FOREST, DECIDUOUS*	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
FOREST, DECIDUOUS/CONIFEROUS*	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
GLACIAL LAKE, BED	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
GROUND MORAINE	—	—	—	—	N	P	P	P	P	P	—	—	—	—	N
INTERCHANGES	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
LAKES	/	/	/	//	N	P	P	P	P	P	/	/	/	//	N
LAKE MICHIGAN	//	/	/	/	N	P	P	P	P	P	//	/	/	/	N
LAKES, LESS 50 ACRES	/	/	/	//	N	P	P	P	P	P	/	/	/	//	N
LIMITED ACCESS HIGHWAY	—	//	C	C	N	P	P	P	P	P	—	//	C	C	N
MARSH*	/	//	//	/	N	P	P	P	P	P	/	//	//	/	N
OPEN SWAMP	/	//	//	/	N	P	P	P	P	P	/	//	//	/	N
RESIDENTIAL, RURAL	/	//	C	C	N	P	P	P	P	P	/	//	C	C	N
RESIDENTIAL, SUBURBAN	/	//	C	C	N	P	P	P	P	P	/	//	C	C	N
RESIDENTIAL, URBAN	/	//	C	C	N	P	P	P	P	P	/	//	C	C	N
RIVERS	—	—	/	//	N	P	P	P	P	P	—	—	/	//	N
RIVER OR LAKE ZONING	—	—	/	//	N	P	P	P	P	P	—	—	/	//	N
ROADS	—	//	C	C	N	P	P	P	P	P	—	//	C	C	N
SAND DUNES	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
SHRUB CARR*	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
STREAM	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
STREAM, INTERMITTENT	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
TERRACES	C	C	C	C	N	P	P	P	P	P	C	C	C	C	N
UTILITIES - RAILWAY LINES	—	//	C	C	N	P	P	P	P	P	—	//	C	C	N

*REMAP II Data (all other listed data from REMAP I)

CODE PRELIMINARY DRAFT

APPENDIX 2

MATRIX:
DATA:

Data can be identified

Data item easily identified	/
Data item identified with difficulty	—
Image format most appropriate for identification	//

Data cannot be identified

Not available	N
Quality too poor for interpretation	P
Data item unable to be identified	C

ERTS/REMAP I & II DATA BANK

DATE / % CLOUD COVER	OCT. 2 / 20%					OCT 20 / 30%					NOV. 7 / —				
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AGRICULTURAL	/	//	C	C	N	/	//	C	C	N	N	N	N	N	N
BEACH RIDGE	—	//	C	C	N	—	//	C	C	N	N	N	N	N	N
COMMUNICATIONS, AIRFIELDS*	/	//	C	C	N	/	//	C	C	N	N	N	N	N	N
DRUMLINS	—	//	—	—	N	/	//	—	—	N	N	N	N	N	N
END MORAINE	—	//	C	C	N	—	//	C	C	N	N	N	N	N	N
ESKER	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
ESCARPMENT	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
FOREST, LOWLAND	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
FOREST, UPLAND	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
FOREST, CONIFEROUS*	C	C	—	//	N	C	C	—	//	N	N	N	N	N	N
FOREST, DECIDUOUS*	C	C	—	//	N	C	C	—	//	N	N	N	N	N	N
FOREST, DECIDUOUS/CONIFEROUS*	C	C	—	//	N	C	C	—	//	N	N	N	N	N	N
GLACIAL LAKE, BED	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
GROUND MORAINE	—	//	—	—	N	—	//	—	—	N	N	N	N	N	N
INTERCHANGES	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
LAKES	/	/	/	//	N	/	/	/	//	N	N	N	N	N	N
LAKE MICHIGAN	//	/	/	/	N	//	/	/	/	N	N	N	N	N	N
LAKES, LESS 50 ACRES	/	/	/	//	N	/	/	/	//	N	N	N	N	N	N
LIMITED ACCESS HIGHWAY	/	//	C	C	N	/	//	C	C	N	N	N	N	N	N
MARSH*	/	//	//	/	N	/	//	//	/	N	N	N	N	N	N
OPEN SWAMP	/	//	//	/	N	/	//	//	/	N	N	N	N	N	N
RESIDENTIAL, RURAL	/	//	C	C	N	/	//	C	C	N	N	N	N	N	N
RESIDENTIAL, SUBURBAN	/	//	C	C	N	/	//	C	C	N	N	N	N	N	N
RESIDENTIAL, URBAN	/	//	C	C	N	/	//	C	C	N	N	N	N	N	N
RIVERS	—	—	/	//	N	—	—	/	//	N	N	N	N	N	N
RIVER OR LAKE ZONING	—	—	/	//	N	—	—	/	//	N	N	N	N	N	N
ROADS	—	//	C	C	N	—	//	C	C	N	N	N	N	N	N
SAND DUNES	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
SHRUB CARR*	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
STREAM	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
STREAM, INTERMITTENT	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
TERRACES	C	C	C	C	N	C	C	C	C	N	N	N	N	N	N
UTILITIES – RAILWAY LINES	—	//	C	C	N	/	//	C	C	N	N	N	N	N	N

*REMAP II Data (all other listed data from REMAP I)

CODE PRELIMINARY DRAFT. APPENDIX 2

MATRIX: DATA:

Data can be identified		Data cannot be identified	
Data item easily identified	/	Not available	N
Data item identified with difficulty	—	Quality too poor for interpretation	P
Image format most appropriate for identification	//	Data item unable to be identified	C

ERTS/REMAP I & II DATA BANK

DATE % CLOUD COVER

	NOV. 25 –					DEC. 13/0%									
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AGRICULTURAL	N	N	N	N	N	C	C	C	C	N					
BEACH RIDGE	N	N	N	N	N	—	—	—	//	N					
COMMUNICATIONS, AIRFIELDS*	N	N	N	N	N	C	C	C	C	N					
DRUMLINS	N	N	N	N	N	/	/	/	//	N					
END MORAINE	N	N	N	N	N	/	/	/	//	N					
ESKER	N	N	N	N	N	C	C	C	C	N					
ESCARPMENT	N	N	N	N	N	/	/	/	//	N					
FOREST, LOWLAND	N	N	N	N	N	—	—	—	//	N					
FOREST, UPLAND	N	N	N	N	N	—	—	—	//	N					
FOREST, CONIFEROUS*	N	N	N	N	N	/	/	/	//	N					
FOREST, DECIDUOUS*	N	N	N	N	N	/	/	/	//	N					
FOREST, DECIDUOUS/CONIFEROUS*	N	N	N	N	N	/	/	/	//	N					
GLACIAL LAKE, BED	N	N	N	N	N	C	C	C	C	N					
GROUND MORAINE	N	N	N	N	N	—	—	—	//	N					
INTERCHANGES	N	N	N	N	N	C	C	C	C	N					
LAKES	N	N	N	N	N	—	—	—	—	N					
LAKE MICHIGAN	N	N	N	N	N	//	/	/	/	N					
LAKES, LESS 50 ACRES	N	N	N	N	N	C	C	C	C	N					
LIMITED ACCESS HIGHWAY	N	N	N	N	N	—	—	—	—	N					
MARSH*	N	N	N	N	N	—	—	—	—	N					
OPEN SWAMP	N	N	N	N	N	—	—	—	—	N					
RESIDENTIAL, RURAL	N	N	N	N	N	C	C	C	C	N					
RESIDENTIAL, SUBURBAN	N	N	N	N	N	C	C	C	C	N					
RESIDENTIAL, URBAN	N	N	N	N	N	—	—	—	—	N					
RIVERS	N	N	N	N	N	—	—	—	//	N					
RIVER OR LAKE ZONING	N	N	N	N	N	—	—	—	—	N					
ROADS	N	N	N	N	N	—	—	—	—	N					
SAND DUNES	N	N	N	N	N	C	C	C	C	N					
SHRUB CARR*	N	N	N	N	N	C	C	C	C	N					
STREAM	N	N	N	N	N	C	C	C	C	N					
STREAM, INTERMITTENT	N	N	N	N	N	C	C	C	C	N					
TERRACES	N	N	N	N	N	—	—	—	//	N					
UTILITIES – RAILWAY LINES	N	N	N	N	N	C	C	C	C	N					

*REMAP II Data (all other listed data from REMAP I)

APPENDIX 3

NDPF USE ONLY
D ______
N ______
ID ______
DTM ______
TM ______
TM APP. ______

ERTS DATA REQUEST FORM
560-213 (7/72)

1. DATE 24 January 1973

2. USER ID UN 040

4. SHIP TO:

ADDRESS Dr. James Clapp ☐ NEW
1204 Engineering Bldg.
University of Wisconsin
Madison, Wisconsin 53706

5. TELEPHONE NO. 608-262-1978 ☐ NEW

6. CATALOGUES DESIRED

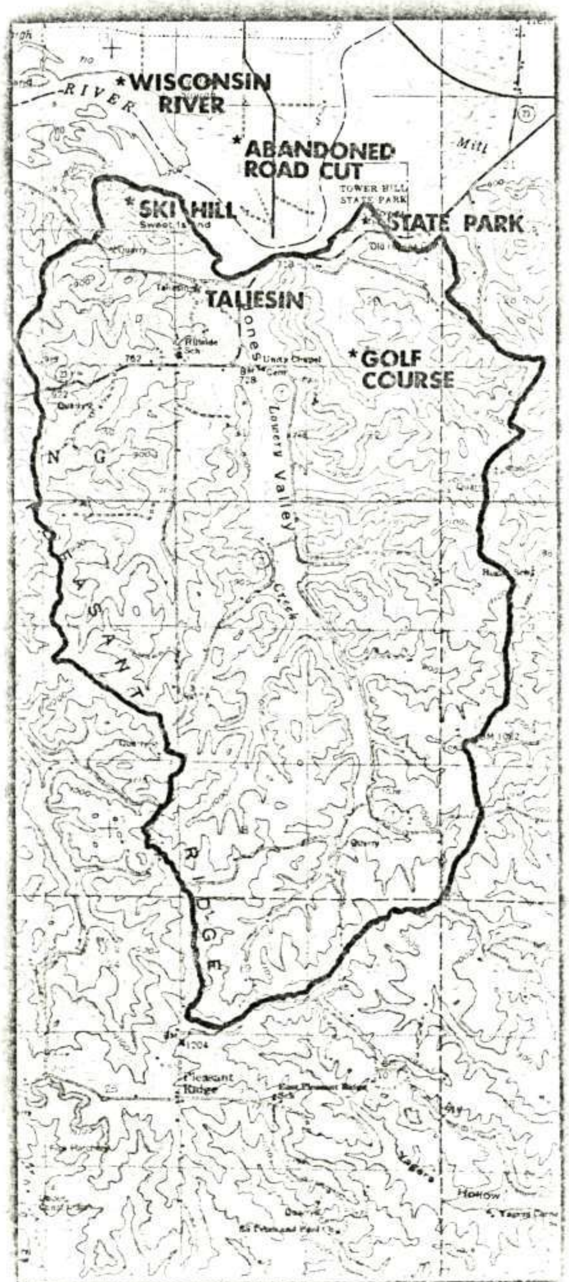
STANDARD ☐ U.S. ☐ NON-U.S.

DCS ☐

MICROFILM ☐ U.S. ☐ NON-U.S.

ADDDHHMMS OBSERVATION IDENTIFIER	C CENTER POINT COORDINATES	B SENSOR BAND	P PRODUCT TYPE	F PRODUCT FORMAT	T TICK MARKS	NN NUMBER OF COPIES	A AREA
1053-16090	N44-32 W87-34	7	B	T		2	
1053-16093	N43-07 W88-14	7	B	T		2	
1089-16093	N44-32 W87-41	7	B	T		2	
1143-16095	N44-26 W87-46	7	B	T		2	
1143-16102	N43-01 W88-18	7	B	T		2	

LANDSCAPE ARCHITECTURE



Remote Sensing of Infrared Energy: Critical Data for Land-Use Decision-Makers

By Michael M. McCarthy, Richard A. Boots, Bernard J. Niemann, Jr.

ACKNOWLEDGEMENTS

Credit for any interdisciplinary effort is diverse. The authors wish to especially recognize the support, both moral and financial, provided by Dr. James Clapp, Program Leader of the Environmental Monitoring and Data Acquisition Group (EMDAG) of the Institute for Environmental Studies (IES) at the University of Wisconsin—Madison. In addition, we acknowledge support from the National Aeronautics and Space Administration (NASA), National Center for Atmospheric Research (NCAR), the Graduate School and the Department of Landscape Architecture/Environmental Awareness Center (University of Wisconsin—Madison).

Understanding the environment as a complex interactive entity has historically been neglected, disregarded, or not understood by land-use decision-makers such as landscape architects and others responsible for altering or preserving the physical environment.

Contributing to the present difficult process of intelligent land-use decision-making are slow and antiquated data-inventory techniques that may or may not produce information (often static and archaic). Planners typically lack pertinent basic information about the use, composition, character, and temporal dynamic qualities of landscape change. This includes such forms of data as the extent and variation of vegetation cover, wetland distribution, dynamic perception of urban growth patterns, the state of the landscape in respect to existing impact levels, and general character of the landscape. But this data is not impossible to obtain. Most plans of landscape alteration do not recognize or utilize changes in microclimate; even if they are understood to occur, their perception, until the very recent past, was virtually impossible. Now the development of thermal infrared scanners and color-enhancing devices makes it possible to compare surface temperatures of large geographical areas.

Interdisciplinary personnel at the University of Wisconsin—Madison are contributing to improved decision-making through better identification, analysis, and understanding of landscape elements by conducting research into the use of remote-sensing techniques for acquiring data not usually available in land-use planning. Remote sensing is defined as the gathering, detecting or recognition of information about objects in our environment, using a device not physically in contact with the object.* Use of specific sensing techniques is based on the fact that all objects in the environment inherently emit or reflect some form of electromagnetic radiation and that the magnitude of this emitted or reflected electromagnetic energy is unique for specific objects.

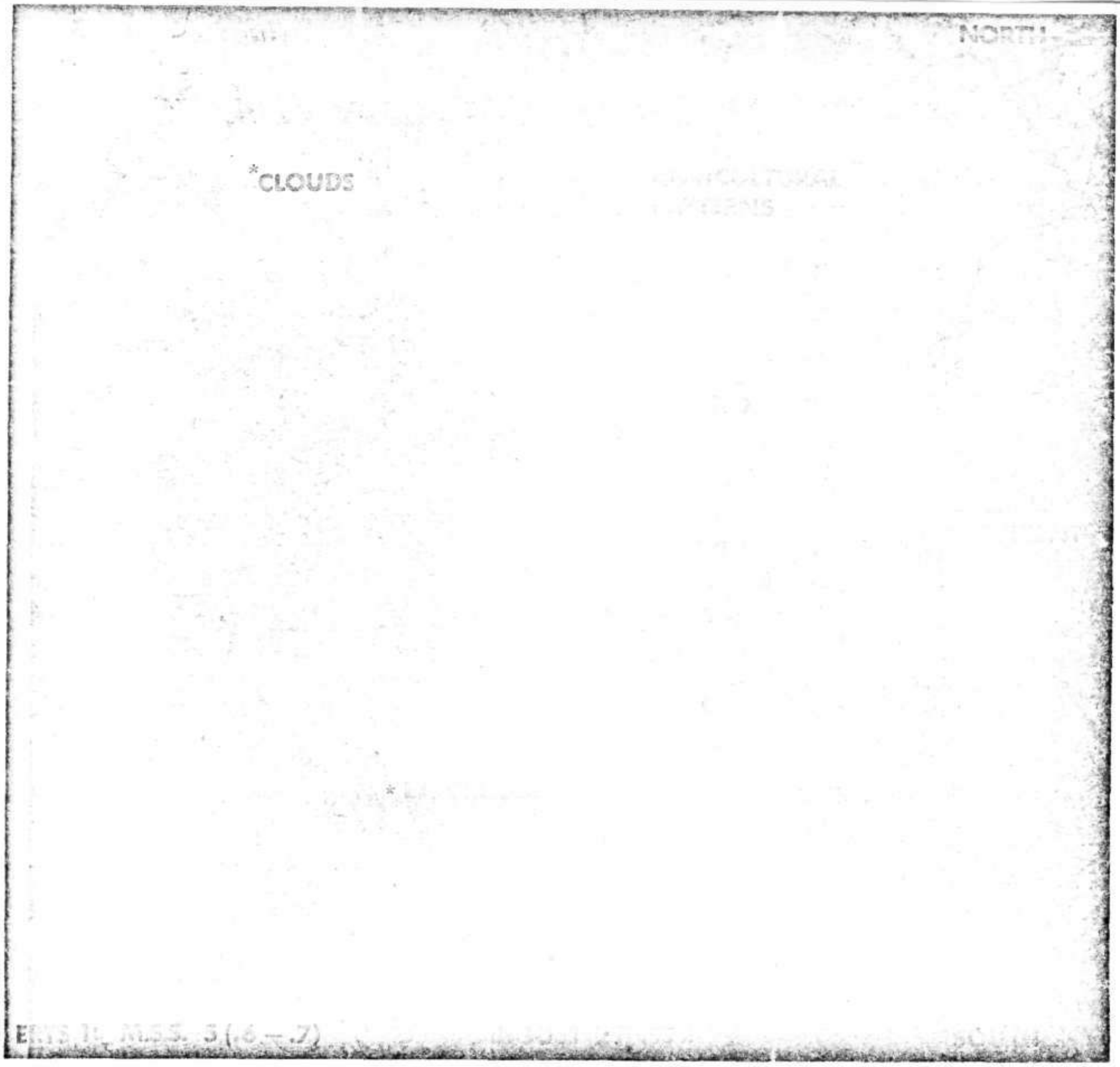
Within the electromagnetic energy spectrum there exists a range from .7 to 20 microns of infrared energy. This radiation cannot be seen by man (whose visual abilities

*The general applications of remote sensing were discussed in LAQ, Oct. '70 (Niemann, McCarthy, Dunn).

About the Cover

(Continued from Cover) . . . other at 3:30 p.m. on 24 August 1970. The images are created by inputing the magnetic tape responses obtained from the scanner into a color TV display system for enhancement, and 70mm photographic recording. The hierarchy of colors represent a continuum of temperature (red warmest, blue-magenta coolest). The 5:30 a.m. image indicates that the open fields (blue and magenta) are the cool and the water and woodland vegetation is warm (yellow and green). Exposed bedrock and steep slopes are the warmest (red). The image obtained at 3:30 p.m. indicates a very different thermal relationship. In this case the open fields and woodland vegetation are warm (yellow and green) and the water becomes coldest landscape element (blue and magenta).

Alterations to the environment can be identified by areas exhibiting major color changes. Examples of such change can be noted at the ski hill in the 5:30 a.m. image (see USGS for location of features). Another example also in the 5:30 image is the altered ecosystem that resulted from an abandoned road cut. The color-enhanced thermal imagery dramatically indicates the complex thermal changes which take place in the environment wthin a 24 hour period. The color-enhanced imagery was provided by Daedalus Enterprises, Inc. of Ann Arbor, Mich., through their "DIGICOLOR™" color enhancement process.



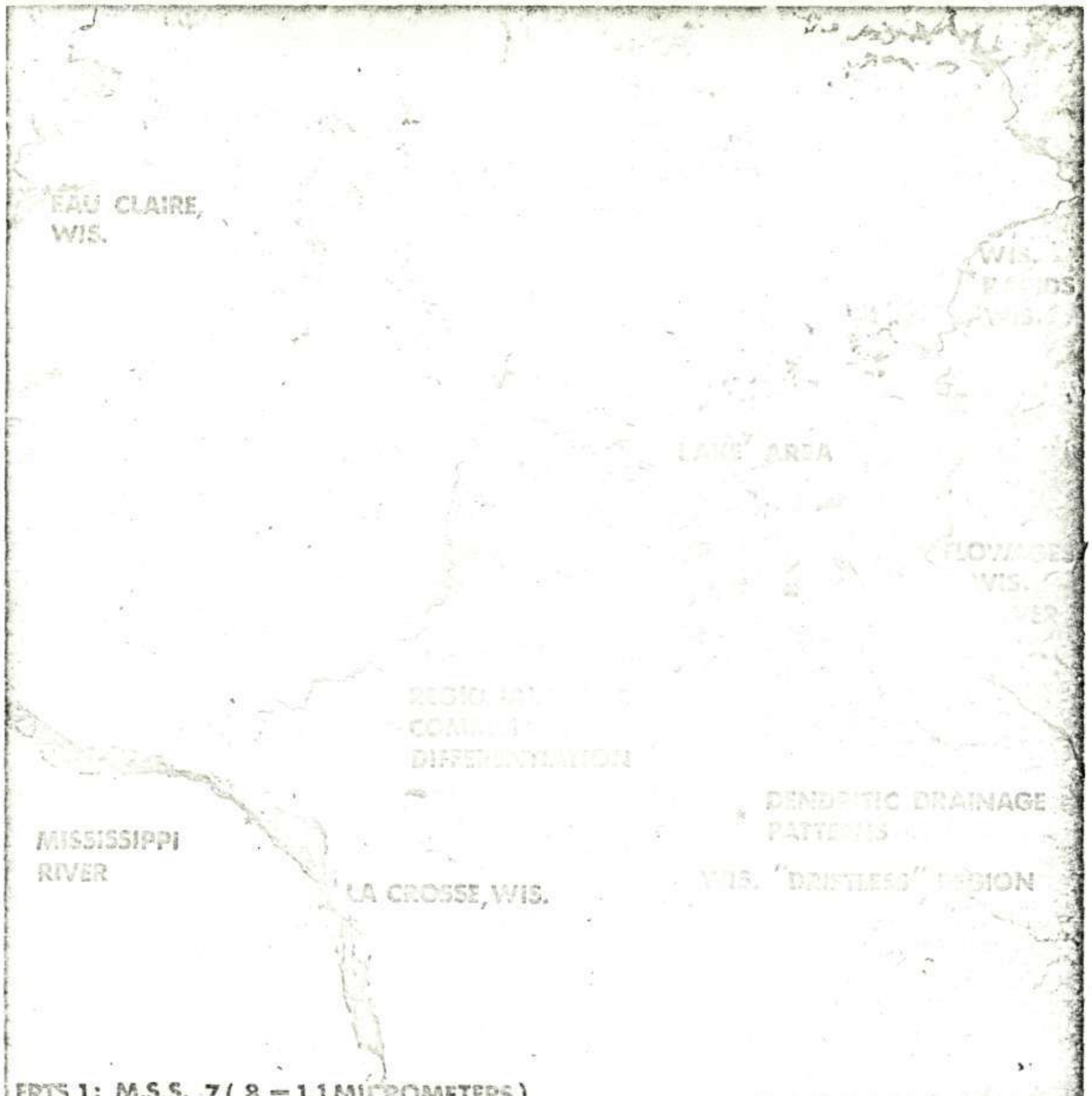
are limited to a range of .4 to .7 microns) and therefore offers a new potential in the presentation of environmental information. The use of remote sensing technologies to gather this information thus becomes a dynamic means of obtaining new and unique data.

Land allocation decisions require specific information. Remote sensing of infrared energy (.7 to 20 microns) provides such information. Both infrared photography (.7 to .9 microns — reflected energy) and infrared imagery (1 to 20 microns emitted energy) provide a great amount of data that can be applied to land use allocation problems.

While many decisions are aided by the simple addition of updated information that remote sensing techniques provide, the most important use of this technique is for acquiring data not available by conventional means. There is little doubt that landscape architects as synthesizers of cultural and natural data should look to remote sensing as a means of providing an entire continuum of types of information. The ability to analyze new forms of types of information such as biological or climatic data can only increase the efficiency of the landscape architect and the decisions he must make.

Remote sensing is not a panacea, however. Certain considerations must be understood. In studying it, we believe that the two most critical considerations of the technique are scale and timing. Our studies have principally been conducted within one geographical region and therefore we must partially qualify our results, but we feel strongly that many of the concepts reported here are universally applicable. The insert accompanying this article illustrates various aspects of the importance of timing and scale to color infrared photography.

Within this insert, illustrations A and B represent photography at two different scales. Illustration A is a low altitude (3000′ above ground) color infrared photo. Illustration B is a high altitude photo (60,000′ above ground). Figures 1 and 2 are images taken from the recently launched Earth Resource Technical Satellite (ERTS-1) (500 miles above ground). Figures 1 and 2 are from a multispectral scanner, illustrating two different infrared wavelengths that can be sensed by satellite and photographically reproduced. Figure 1 is from .6-.7 microns and Figure 2 is from .8 to 1.1 microns. The optimum scale utilized is a variable that will be dependent on the extent of detail necessary for interpretation and analysis to be maximized. The scale must therefore be compatible with the level of decision to be made. Low altitude infrared photography presents very detailed information. The scale of illustration A is approximately 1″ = 500′. It can be utilized very effectively in management decisions. Examples of the types of interpretation that can be made are: use area recognition, vegetation



ERTS 1: M.S.S. 7 (.8 — 1.1 MICROMETERS)

definition, small scale pattern delineation, predominant and specific species identification, specific land use identification, and biotic diversity and distribution. Low altitude IR photography represents greatest image resolution but presents a problem when large areas are to be studied. Inherent photogrammetric distortions are greater in low altitude photography. Because cost to information ratio is high, this means of data acquisition should be used only when specific study areas are known and it is to be utilized for detail quantification of the acquired data. Examples of the types of interpretations that can be made are illustrated on the insert.

A high altitude platform of image acquisition enables large areas to be imaged (illustration B). A unique advantage of IR photography at this altitude is the ability to spatially relate data from a common reference point. The lack of distortion allows this imagery to be used as "corrected" similar to a map. Surprisingly high image resolution can be achieved and although interpretation of specific detailed patterns can be more difficult, the wide area coverage and high resolution could make it the only required data source for land use classification schemes if the categories required are structured so as to allow direct interpretation.

Although many specific resource forms cannot be identified, the differentiation of various ecosystems by vegetation communities such as savanna, aquatic, grassland, meadow, and shrub and forests can be easily discerned. One can also differentiate herbaceous plants, conifers and hardwoods, as well as certain moisture conditions and canopy density ranges. A large number of cultural variables can be identified, too, such as urban expansion, roads, rail systems, energy/utility networks. Illustration B depicts types of interpretation that can be made. The wide-area coverage as well as high resolution provided by a high altitude image* makes it a most useful data source for regional land use planning.

Satellite platform IR photography as it relates to land-use decision making is in its infancy. The inherent characteristics of a satellite image (such as that acquired from ERTS 1) lends itself primarily to regional level decisions. The extreme area coverage of this scale image, plus the fact that this data will be available on a continuous basis, can greatly enhance the potential of monitoring urban growth patterns. The potential of ERTS-1 data for sensing major ecological units as well as large land use patterns can

*For more information on high altitude photography write the Department of Landscape Architecture, University of Wisconsin, for "The Utility of RB-57 High Altitude Photography in the Regional Land Use Decision Making Process" by Edward L. Kuhlmey and Bernard J. Niemann.

be of extreme value to the land use planner. Large biotic communities and certain circulation patterns are easily discernable on an image of this scale. Also of interest to the decision maker is the value of satellite IR photography for detecting areas that warrant more intense study and investigation. Satellite IR photography from ERTS-1 will offer the opportunity to monitor sequentially temporal change as it occurs in the environment. As noted, Figures 1 and 2 are satellite images of Wisconsin taken recently. Certain of the types of information that are available at this scale are indicated on the imagery.

Perhaps the most unrecognized attribute of satellite data is its repetitiveness: every 18 days over the same area. Leith (1970), in an article on phenology and productivity studies, inadvertently noted the very types of information that ERTS satellites will be able to provide:

- Duration of growth and vegetation periods
- Appropriate bases for calculation of ecological efficiencies
- Quantitative data on growth and development
- Migration patterns of various animals
- Quantitative data about the development of populations in time and space
- Relations of population growths to food resources
- Correlations with macroclimatic variables
- Environmental influences resulting from combined climatic and edaphic characteristics
- Relations between phenological events and environmental conditions

This very list aptly illustrates a basic belief of the authors: Remote sensing is best used in bringing and identifying new types of data into the land allocation process. The analysis of various scales has shown how specific scales relate to the acquisition of specific data. Timing must also be determined when measuring the compatibility of information to decision, since data acquired at different times of the year will provide different information.

On the enclosed insert are three images representing sequential change. Illustrations C, D and E of the color insert are color-infrared photographs of the same area taken at the same scale, with identical photographic equipment during different times of the year (constant: northeast corner of Lowery Creek Watershed, Iowa County, Wisconsin, at a scale of 1″ = 1000′, altitude 6,000′, aerial mapping camera film #8443, #12 filter). Illustration C was taken in April, 1970; illustration D in July, 1969; and E in October, 1969.

Even the casual observer can readily see that there exist different types of information in each image. Each example is capable of transmitting different and unique information along with the more basic natural and cultural data necessary to maximize environmental decisions. An image secured in early spring (illustration C) offers the advantage of minimal vegetative cover. Also, the early-spring image is superior for determining soil moisture conditions. Since vegetation canopies have not yet emerged, IR photography secured at this time better indicates existing ground conditions. Specific phenological information — early emergence of exotic understory, ground layer species, etc. — can be identified. Soil texture characteristics and initial soils analysis are also best supported by imagery taken at this time. Early spring photography will detect emergence of disturbed plants that indicate a previous site impact, allowing the decision maker to actually quantify areas and the reasons for occurrence of the disturbance. This can provide an effective means of monitoring existing levels of environmental impact (McCarthy, 1972). Stream patterns are more discernable on early spring images, because of the absence of appreciable canopy cover. Additional information that can be interpreted is illustrated on the insert.

Summer images (Figure C) can assist in the determination of certain features (as indicated on Figure C), but there exists too much vegetative masking of image photo tone to permit accurate interpretive analysis of many features. This is because all vegetation is at the height of its growing season, resulting in strong infrared reflectance. Summer photography, however, is standard practice for many areas and is often recommended by aerial survey teams. Examining illustrations B, C and D, one can see that many features identified on B or D cannot be found on C because of the vegetative masking. Other features, while being identifiable on all three images, are definitely "enhanced" in either B or D. We believe that times of stress for biological resources (such as spring or fall in the region of Wisconsin) provide the most information.

The autumn period, in the region studied, offers maximum sensing information for a given flight (other times may produce a specific need). Because plants enter dormancy at different rates, the low IR reflectance produces images with many tones. D illustrates some of the features that may be interpreted. Definition of clarity on fall images comes as a result of a greater period of time in which low haze conditions are predominant; this allows one to pick an exact time for flights based on plant changes one can monitor. Resource knowledge of the specific study area allows one to uniquely identify plant genus/groups and certain specific species. Information on wildlife patterns can be obtained using fall images since certain vegetation edge patterns appear. By observing these edge effects one can infer variations in biological complexity which lead to the quantification of species diversity and distribution.

An example of the value of unique species identification as determined by the use of color infrared photography taken in the fall is the indication — through tonal variation on the image of an area — of the predominant presence of Rhus typhina. In the Wisconsin region the presence of this plant species indicates an area associated with dry conditions, inferring strong suitability toward development forms that require such conditions. Another easily identified indicator, Populus tremuloides, can be used to recommend certain wildlife management techniques (Gullion, 1968).

Landscape architects and other environmental planners can appreciate having available this unique data. All sequential images have value, some seasonal images more valuable than others. If a time must be selected for image acquisition the following sequence provides the most information for our studies: 1) fall, 2) fall-early spring, 3) fall-early spring-late spring, and 4) fall-early spring-late spring-summer.

Reflected infrared energy can be acquired by photography, using film sensitive to the infrared region. Since photographic sensors are not capable of detecting electromagnetic energy beyond that of the film's sensitivity, special sensing devices are necessary to record the infrared energy beyond the range of film.

Two means exist of detecting emitted infrared energy in the thermal region of 8-14 microns: thermal

TOWER HILL STATE PARK

FIGURE: 3

WISCONSIN RIVER

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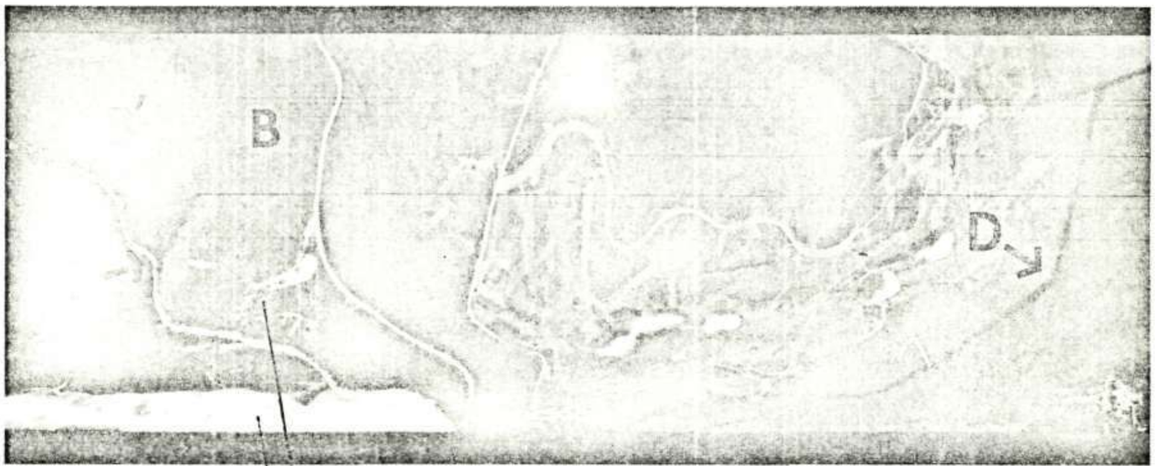

TOWER HILL STATE PARK

FIGURE: 4

WISCONSIN RIVER

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scanners, capable of detection in the approximate wavelength ranges of 3-5 microns and 8-14 microns, and multispectral scanner systems, capable of extending from .3 microns to around 20 microns. The multispectral system is essentially the combination of the photographic systems with that of the thermal scanner. The thermal imagery examples with this article are a product of a thermal scanner sensitive to the 8-14 micron range. It must be emphasized that thermal infrared imagery is not a photograph but instead a contiguous strip of film that represents the emitted heat energy (temperature variations) of the earth's surface. The scanner, by sensing and recording the changes in infrared emission, provides the opportunity to gather unique data on micro-climatic patterns, since relative change in emission indicates relative micro-climate changes. These temperature gradients are recorded on 70mm imagery as a variation and levels of tonal values of gray, thus relating the imagery tonal values directly to surface temperature and allowing for the identification of surface temperature anomalies that may exist. In identifying these tonal values and their association with temperature gradients the convention used is that light tones indicate warm areas and dark tones indicate cold areas. (Tonal variations are produced by the changes in surface temperatures during a diurnal cycle).

Analysis indicates that our environment exists in relative harmony and that where natural or man-made impact has been introduced an alteration of this harmony occurs. Thermal imagery is a means of detecting this change by measuring micro-climate differences.

As is the case with reflected infrared energy, analysis of the best times for imagery acquisition as a means for maximizing data must be investigated. Direct solar radiation during the day will raise the total surface temperature so that imagery taken at this time not only is influenced by the emitted energy from the earth's surface but also strongly influenced by the reflected energy of the sun. At night as the earth's surface begins to cool, this heat balance shifts and the energy detected is that outgoing radiation yielded by the earth's surface. It is this energy that is critical to the thermal properties of the landscape. The type of information desired dictates timing of image acquisition. For detection of micro-climatic patterns not concerned with cyclic change the thermal image should be made at night. It was specifically determined that in the region studied, imagery secured between 10 p.m. and 12 midnight was most valuable in ascertaining information concerning the thermal properties of the terrain.

Of extreme value in analyzing thermal imagery is that the relative gray tones (variations in temperature gradients) are a function of the various density levels of the imagery. This allows the decision maker, through various mechanical means, to **quantify** the data. The image area to be analyzed is broken into its various density level components. Variation in the amount of change in density levels is analyzed and indicates the magnitude of change in temperature variations on the imagery. Initial analysis of thermal imagery indicated very clearly that there exists in the environment a great diversity of temperature levels; variations, however, seem to flow smoothly with few abrupt changes, except in obvious land-water interfaces. This indicates the compatabilities of the many co-existing complex systems. This gradual transition of micro-climate patterns becomes a critical constraint affecting maximization of management policies. If these systems are not compatible, alterations in design and management practices can be made to begin and establish compatibility.

Individual analysis of thermal infrared imagery clearly indicates the uniqueness of the information that can be secured. In comparing Figure 3 (taken 17 September 1971, 3 p.m., H = 2,000′ above ground) with Figure 4 (taken 18 September 1971, 2 a.m., H = 2,000′ above ground), an obvious tonal change becomes evident in areas A and B. Further investigation indicated that this change is due to a difference in vegetation communities. The dark or cool areas (Figure 4, area B′) are associated with moist lowland communities; the light and warmer tones (Figure 4, area B) are upland associations. The relationship cannot be as clearly detected on photographic infrared images. Time of year was not a constraint in acquiring this data as would be the case with infrared photography. Figure 4 displays the value of night thermal infrared imagery in the detection of stream channels (indicated by arrow C) that may be somewhat obscured by overburden of vegetation. The streams' high emittance of radiated energy makes them appear warm in contrast to the cooler lowland vegetation. Being able to secure this type of community identification can be very valuable when it comes time to infer land-allocation decisions.

Another application of night acquisition of thermal imagery is the indication of magnitude of micro-climatic temperature variation as a result of electrical transmission line cuts. Figures 3 and 4 both indicate the dynamic change in temperature variations from day to night (areas D and E). Area D on the night image appears very cold in comparison to the surrounding micro-climate patterns. This situation is reversed during daylight hours (area E). Management policies affecting land-use decisions are related to the effect this change might have on wildlife habitat. Certain wildlife species have been known to be very sensitive to variations in micro-climates; they may adapt to specific environments because of prevailing micro-climatic conditions. It can be implied that extreme temperature variations caused by transmission line cuts may act as a barrier to wildlife migration patterns. Quantification of this type of micro-climatic data (analysis and quantification techniques indicate a temperature change approaching the magnitude of 6°C) will play a critical role when the landscape architect/planner writes environmental impact statements.

Magnitude of sequential temperature variations as monitored by the use of thermal infrared is illustrated in Figures 5 through 8, showing a sequence of images of a ski area development. Change in temperatures of the cleared areas becomes readily apparent. In Figure 5 (taken 18 September 1971, 10 a.m., H = 2000′ above ground) and Figure 6 (taken 17 September 1971, 10 p.m., H = 2000′ above ground) the cleared areas indicate cool at night and warm during the day. In Figure 7 (taken 5 April 1972, 12 noon, H = 2000′ above ground) and Figure 8 (taken 13 April 1972, 3 p.m., H = 2000′ above ground) micro-climate indication is of extreme cold, even though both were daytime images. Sequential monitoring of this area (Figures 7 and 8) indicates dramatic micro-climate change on the ski runs (arrow A and B). Figure 7 (Arrow A) shows the open areas of the ski hill as being extremely cold (due primarily to snow cover on the north facing slopes at this time of year), whereas Figure 8 (Arrow B) begins to show areas that are warming faster than others. This phenomenon appears to relate to the fact that these are areas of less degree slope. Thus in ski-area design one may be able to alter micro-climatic conditions by variation of degree of slope of individual ski runs.

In the development of ski areas micro-climate data could be of extreme value in determining optimum ski run orientation and design of ski lifts. The impact caused by clearing an area for a ski run is indicated by the magnitude of temperature change appearing on Figures 5 through 8 — or a tow line can be quantified, as was the case with the impact caused by introduction of an electrical power transmission line. Management and design criteria can minimize this impact. Planting of vegetative masses can influence and possibly minimize these great variations in temperature. Micro-climatic data will also aid in determination of optimum housing sites at ski area developments.

Figures 5, 6, and 7 indicate another application and value of micro-climate data. In area C of Figure 5, there appears to be very little indication of slope orientation, whereas in area E, Figure 7 (same general area), slope orientation becomes very discernible. At the time this image was flown (5 April 1972) the cool, north-facing slopes were still snow-covered, showing extreme magnitude of micro-climatic temperature variation from the north side of the slope to the south. Figure 6 (area D) taken at night in September does appear to indicate micro-climatic temperature change due to slope orientation. Sequential monitoring of these slope-oriented, micro-climatic patterns indicated a reversal of micro-climate on the south-facing slopes. Fall nights (September) indicated the south-facing slopes as having relatively cool temperature values; early spring nights (April) indicated these same slopes with relatively warm temperature values. Landscape architects as site planners must be aware of these temperature variations caused by slope orientation.

The front cover of this issue of Landscape Architecture illustrates thermal imagery enhanced by color. Color tone reversal between the two images is readily apparent: hilltops are cool and the valley floors warm during the day, with the reverse occurring at night. This condition presents confirming evidence of cold air troughs which appear characteristic of steep topography during night hours. The use of "DIGICOLOR™" gives unique information on thermal characteristics of the environment, easily discernible on imagery from 6000′. Use of this process allows for much more accurate interpretation and pattern delineation of the many co-existing environmental similarities and dissimilarities.

The most important aspect of color-enhanced imagery for landscape architects/planners is the ease with which an area can be analyzed; i.e. the amount of data that can be interpreted quickly. The range of colors assigned

The following pre-printed insert was supplied through the collaboration of the authors and the University of Wisconsin at Madison.

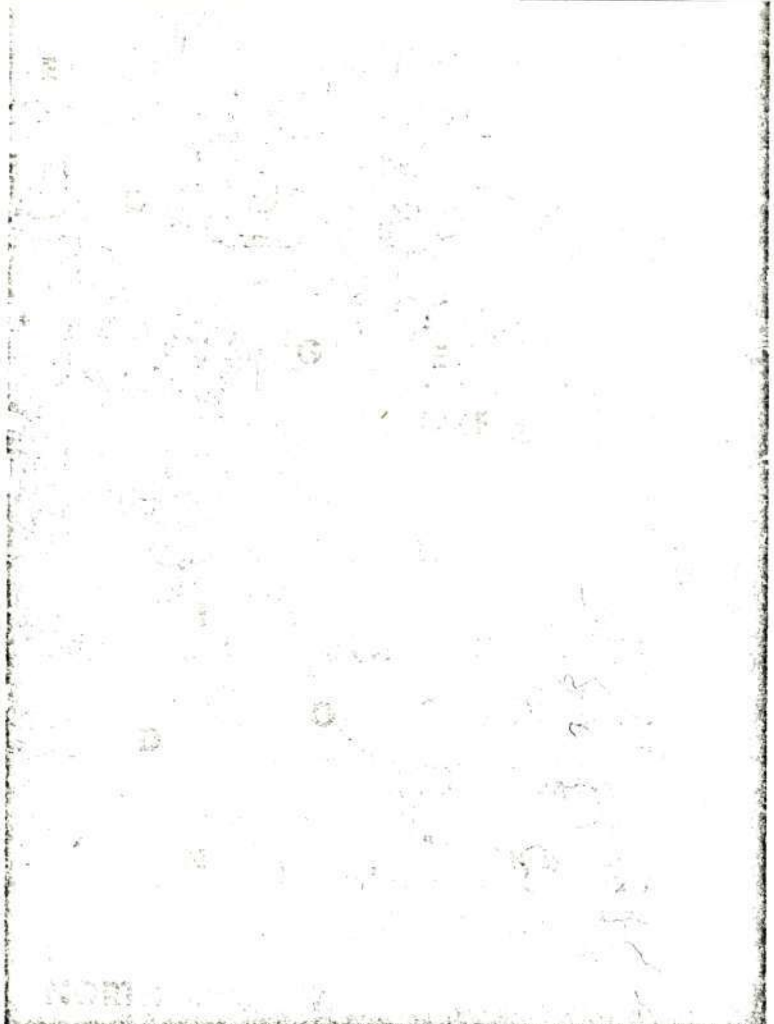


ILLUSTRATION A

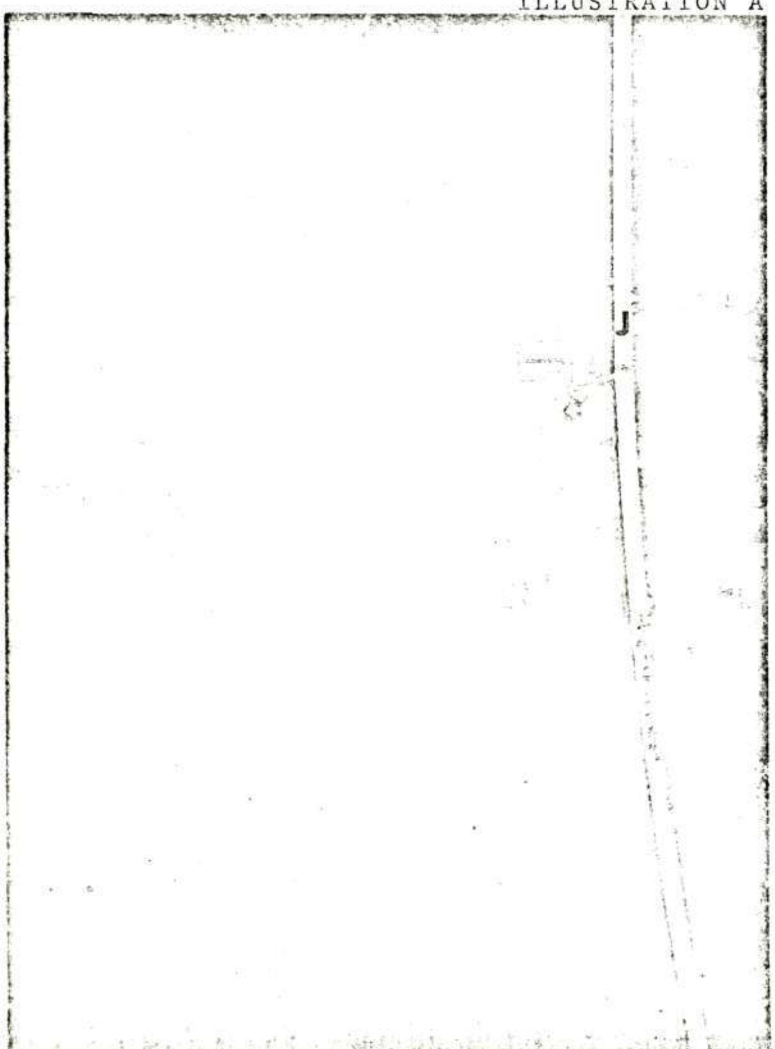


ILLUSTRATION B

ILLUSTRATION

ILLUSTRATION

ILLUSTRATION

ILLUSTRATION A

Location: Columbia County, Wisconsin
Film: Kodak Color Infrared No. 2443.
Date: October 1971

Example Interpretation:

A. Sedge meadow plant community (various species dominating as indicated by different tones)
B. Aspen (Populus) species
C. Abandoned/old field community
D. Glaciated landscape—agricultural crops
E. Fence line
F. Drainage ditch
G. Pothole
H. Southern dry/dry mesic (upland) forest; principally oak (Quercus) species—Black (Q. Velutina), White (Q. Alba), Red (Q. Borealis)
I. Driveway
J. Two-lane highway
K. Residence
L. Man-made lake/stream
M. Small natural lake
N. Algae/emergent aquatics in lake
O. Pine (Pinus) plantation
P. Agricultural crop—corn

ILLUSTRATION B

Location: Menominee/Oconto County, Wisconsin
Film: Kodak Color Infrared No. 2443
Date: September 1971

Example Interpretation:

A. Braided stream patterns
B. Creek
C. Meander/oxbow patterns
D. Northern wet (lowland) forest, principally Tamarack (Larix), Spruce (Picea), Fir (Abies), Cedar (Thuja)
E. Glaciated landscape; agricultural land use (note patterns of individual farms and road net)
F. County line (between Menominee-west and Oconto-east; until recently Menominee County was an indian reservation; the county line is a valid representation of differences in land management techniques between different cultures)
G. Aspen (Populus) species with associated hardwoods
H. Logging roads in area of Jack Pine (Pinus Banksiana)
I. Red and white pine (Pinus Resinosa and P. Strobus) and associated hardwoods
J. Established recreational/strip development
K. Pine (Pinus) plantation
L. Undeveloped lakes
M. New construction: recreational development
N. Northern dry mesic (upland) forest (principally red oak (Quercus Borealis) in this example).

ILLUSTRATION C

Location: Iowa County, Wisconsin (including Tower Hill State Park as indicated on cover)
Film: Kodak Color Infrared No. 8443
Date: April 1970

Example Interpretations:

A. Flood plain
B. Sloughs (created by the action of the river)
C. Mill Creek
D. Abandoned channel of Mill Creek
E. Impacted area (compaction/grazing as indicated by presence of early emerging exotic and opportunistic plants)
F. Burned area
G. Sedge meadow plant community
H. Meander/Oxbow patterns (these are considerably older geological time than the channel pattern of "D")
I. Agricultural fields
J. Paved roads
L. Access road for agricultural field (unpaved)
M. Red and white pine (Pinus Resinosa and P. Strobus) indicated by red tone
N. State Park Trail
O. State park parking lot

ILLUSTRATION D

Location: Iowa County, Wisconsin (including Tower Hill State Park)
Film: Kodak Color Infrared No. 8443
Date: July 1969

Example Interpretations:

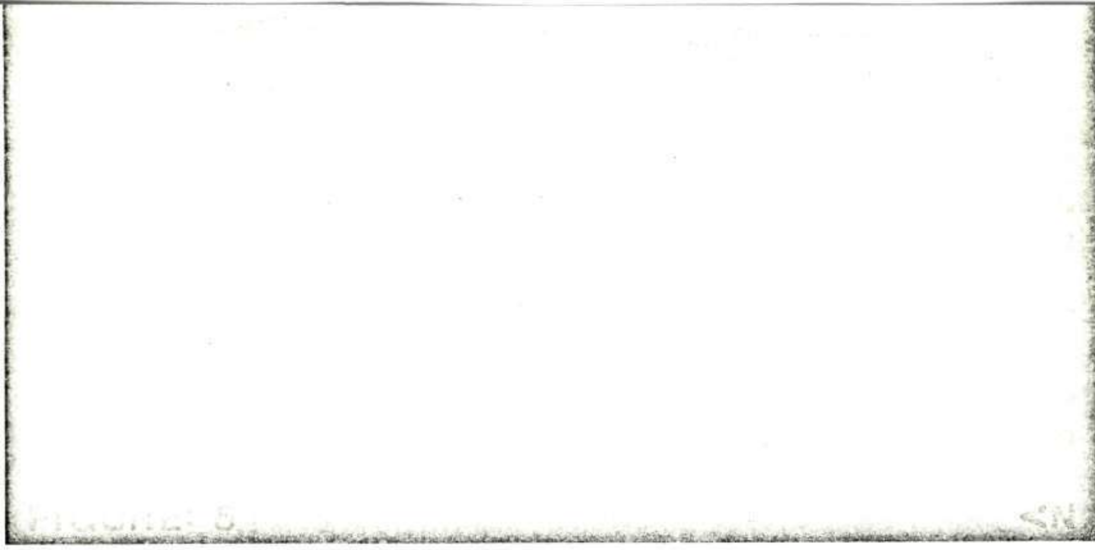
A. Savanna plant community (as compared to a forest community)
B. Sloughs
C. Mill Creek
D. Meander/Oxbow patterns
E. Shrub community (as indicated by size of crowns)
F. Areas of high percentage of early successional woody plants (this is indicated by the brightness of red—which during the summer is related to the increased IR reflectance of such plants)
G. Agricultural fields
H. Paved roads

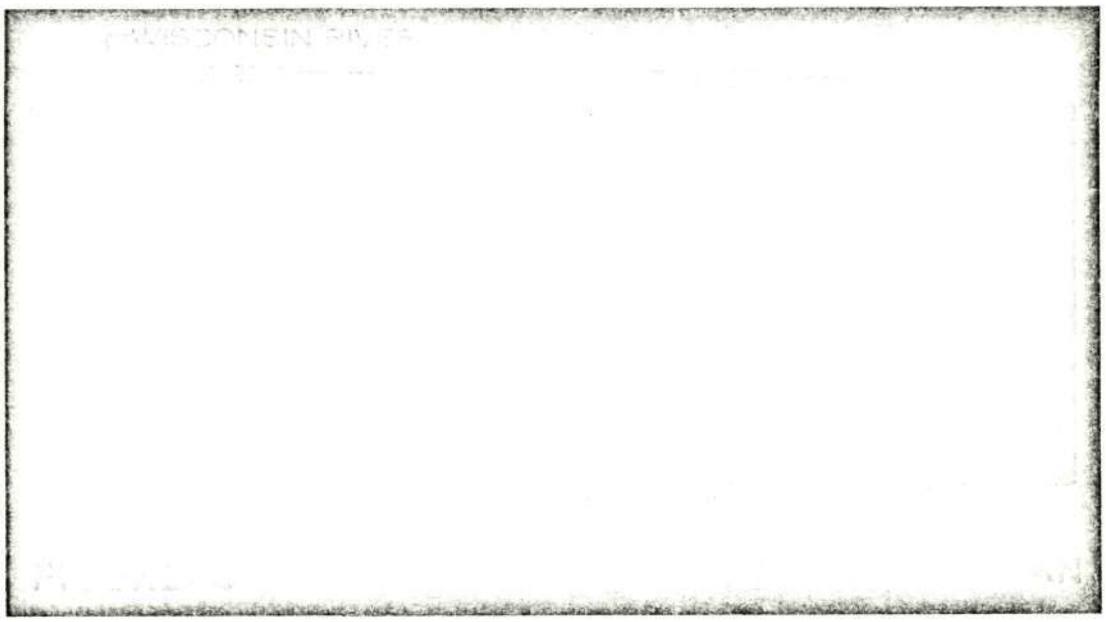
ILLUSTRATION E

Location: Iowa County, Wisconsin (including Tower Hill State Park)
Film: Kodak Color Infrared No. 8443
Date: October 1969

Example Interpretations:

A. Southern wet (lowland) forest community (principally Silver Maple (Acer Saccharinum) and Swamp White Oak (Quercus Bicolor)
B. Fence line (indicating different land management practices)
C. Sedge meadow plant association
D. Meander/Oxbow patterns
E. Shrub community
F. Southern dry/dry mesic (upland) forest principally oaks (Quercus), White (Q. Alba), Black (Q. Velutina) and Red (Q. Borealis)
G. Residences
H. Agricultural Crops
I. Paved Road
J. Mill Creek
K. State park parking lot
L. Trails (presumably deer runs)





in the "DIGICOLOR™" process (red, hot, magenta, cold) allows for quick analysis of an entire area (Lowery Creek Watershed is approximately 25 square miles) to begin to understand the natural changes that occur in a 24-hour period, and speculate on the changes over months. Such understanding is coupled with formats that can be quantified.

In establishing data variables critical to land-use allocation it must be recognized that the data discussed here are only a small number in a continuum. They constitute the development of analysis systems to understand and use in decisions about natural and cultural resources. It must also be understood that many of our conclusions are regionally derived and not universally applied, although we feel the concepts are. Hopefully, inputing this unique data gathered by remote sensing techniques into these systems will aid in optimum land-use planning. The process of environmental decision-making is critical to controlling the tremendous amount of environmental impact on landscape from urban and social population pressures.

In future, numerous land uses will place such high demands on our physical environment that this means of monitoring existing, unique data will be necessary for management decisions. And management and land-use decisions are imperative to establish and maintain compatible relationships in our diverse environment. To make accurate and feasible decisions for land-use and management policies, decision-makers must analyze as many critical data variables as can be input into analysis systems and not rely on subjective judgments alone.

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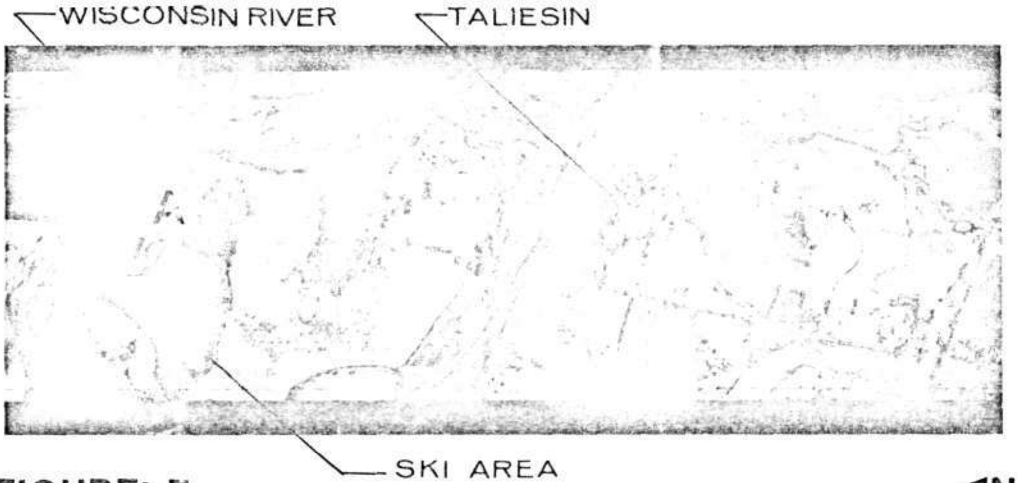

FIGURE: 7

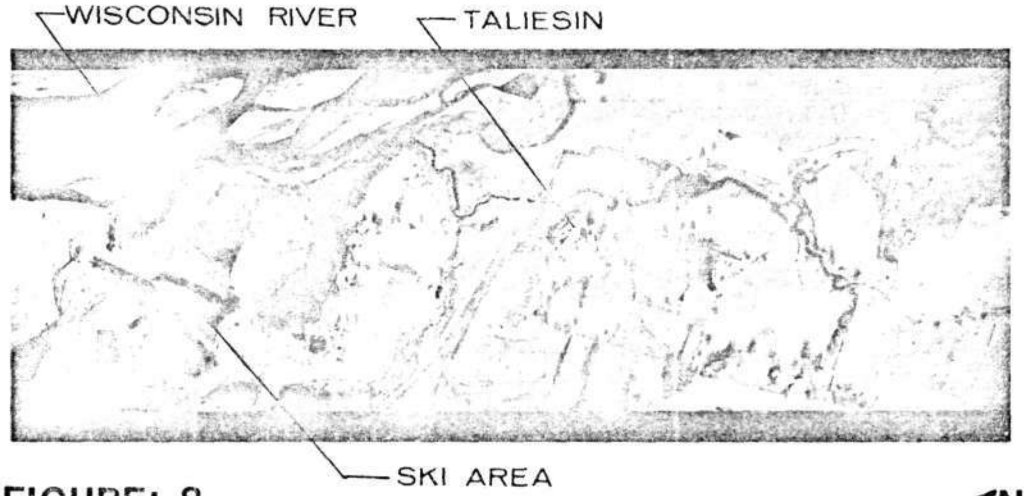

FIGURE: 8

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