NAS5-20832

LAND CLASSIFICATION OF SOUTH-CENTRAL IOWA FROM COMPUTER ENHANCED IMAGES

7.6-10.432
CR-148308

James R. Lucas
Principal Investigator
Research Division
~~Iowa Geological Survey~~
~~123 North Capitol Street~~
Iowa City, Iowa 52242

James V. Taranik
Principal Remote Sensing Scientist
Applications Branch
EROS Data Center
Sioux Falls, South Dakota 57198

Frederic C. Billingsley
Task Manager, Earth Observation Programs
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91103

February 3, 1976

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

(E76-10432) LAND CLASSIFICATION OF SOUTH-CENTRAL IOWA FROM COMPUTER ENHANCED IMAGES Progress Report, 3 Oct. 1975 - 3 Feb. 1976 (Geological Survey, Iowa City, Iowa.) 60 p HC $4.50 CSCL 08B G3/43

N76-28608

Unclas
00432

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
Report #4		

4. Title and Subtitle	5. Report Date
LAND CLASSIFICATION OF SOUTH-CENTRAL IOWA FROM COMPUTER ENHANCED IMAGES	FEBRUARY 3, 1976
	6. Performing Organization Code
7. Author(s) James R. Lucas, IGS; James V. Taranik, EROS; and Frederic C. Billingsley, JPL	8. Performing Organization Report No.
9. Performing Organization Name and Address Iowa Geological Survey Research Division 123 North Capitol Street Iowa City, Iowa 52242	10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt Road Greenbelt, Maryland 20771	13. Type of Report and Period Covered Type II Report 10/3/76 to 2/3/76 14. Sponsoring Agency Code

15. Supplementary Notes

Technical monitor: James Broderick

16. Abstract Certain land cover types in southern Iowa (commercial-industrial urban, strip mine-quarry, certain agricultural fields, etc.) appear to be dominated by blue-green hues on computer enhanced false color composites produced by the Jet Propulsion Laboratory. Analysis of the computer enhancement techniques, Optronics P-1500 Film Recorder characteristics, and photographic characteristics of the Vericolor II negative film and Ektacolor 37 RC photographic paper, suggest that the blue-green problem could be a function of: 1) digital contrast stretching with truncation of digital number (DN) values at histogram tails, 2) inability of the Optronics P-1500 Film Recorder system to record certain DN values, and 3) variations in the slope of the density versus digital number relationships of the Vericolor II negative and 37 RC photographic paper.

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

17. Key Words (Selected by Author(s))	18. Distribution Statement
Land Classification, South Central Iowa, Computer Enhanced Images, Image Processing	**ORIGINAL CONTAINS COLOR ILLUSTRATIONS**

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
		59	

Contents

Figures

Figures--Continued

Tables

Abstract

Certain land cover types in southern Iowa (commercial-industrial urban, strip mine-quarry, certain agricultural fields, etc.) appear to be dominated by blue-green hues on computer enhanced false color composites produced by the Jet Propulsion Laboratory. Analysis of the computer enhancement techniques, Optronics P-1500 Film Recorder characteristics, and photographic characteristics of the Vericolor II negative film and Ektacolor 37 RC photographic paper, suggest that the blue-green problem could be a function of: 1) digital contrast stretching with truncation of digital number (DN) values at histogram tails, 2) inability of the Optronics P-1500 Film Recorder system to record certain DN values, and 3) variations in the slope of the density versus digital number relationships of the Vericolor II negative and 37 RC photographic paper.

Introduction

In the November 3, 1975 Type II progress report for this investigation, two Jet Propulsion Laboratory (JPL) computer enhanced false-color composites were included for illustration and interpretation purposes. On the print (made on Kodak 37 RC paper) for the 29 August 1972 scene (ID 1037-16213), land cover categories such as commercial-industrial urban, strip mine-quarry, and agricultural land, in some places seem to possess the same blue-green color characteristics which make identification of land use categories, based solely on color, difficult or impossible. The blue-green hues on the imagery are produced by development of excess cyan dye in the photographic emulsion. Cyan dye subtracts red light. These blue-green hues were also present on the 15 April 1974 scene (ID 1631-16161), but to a lesser extent. In order to determine the cause of this phenomena, several aspects of digital image processing were examined. A careful analysis of contrast enhancement techniques was undertaken by using the Image 100 system at JPL and the EROS Data Center (EDC). The significance of truncating digital numbers (DN) in the contrast enhancement process was documented. Characteristics of the Optronics Film Recorder, which produces a black and white film product directly from digital numbers, were related to the sensitivity of the Kodak 2474 Shellburst film used in the recording system. Furthermore, digital number versus density curves were produced for the Vericolor II negative film and 37 RC photographic paper. Each of these probable contributors to the blue-green problem in urban areas will be discussed individually in the following text.

Linear Contrast Stretch with Truncation

To expand the distribution of digital numbers (DN) across the total eight-bit dynamic range of 256 steps, a method called contrast stretching is employed. Spectral data for Landsat bands are sometimes grouped into a small portion of the total possible dynamic range. To expand the distribution of brightness values of Landsat data, mathematical algorithms are implemented to transform existing digital numbers into new digital numbers so that the range of DN values are expanded across the entire dynamic range. To increase the limits over which the spectral data may be expanded, the end portions of the histograms of frequency of occurrence versus digital number, (usually 1½ to 3 percent of a band's total DN values), are transformed to digital numbers of 0 or 255 (corresponding to black and white, respectively, on a positive image). In many instances, however, the computer analysts determine what percentage of the total picture elements (pixels) will be transformed to white or black. This transformation of picture elements is known as truncation the end portions of the histograms. The term "stretch bounds" of a band refers to the end-point values on the histogram which are truncated to DN values of 0 to 255. This truncation of pixel DN values results in a greater range over which the remaining digital numbers may be expanded.

In image processing, the truncation of digital values is a very significant point, because this practice actually "throws away" data by converting picture element values to white and black. The losses of these extreme DN values through truncation result in loss of color and tones of urban areas, water bodies, and areas of high soil moisture on Landsat imagery and thus limit their detection and mapping by land planners.

To document these statements, the Image 100 systems at JPL and EDC were used to analyze the effects of truncation on two computer enhanced subscenes from JPL covering Wapello County, Iowa (Figure 1). Prints from both of these subscene's color composites with an interpretation were included in the November Type II Progress Report for this NASA contract. The dates and identification numbers for these subscenes are 1) 29 August 1972 (ID 1037-16213) and 2) 15 April 1974 (1637-16161).

The histograms for each wavelength band for both Wapello County subscenes are shown on Figures 2 and 3. All data for the spectral bands have been scaled-up to an eight bit dynamic range of 0 to 255 (256 steps or levels of gray). Table 1 summarizes the spectral data ranges for these figures.

The linear contrast bounds for both subscenes were arbitrarily chosen by the computer analyst to minimize the amount of truncation to each band. Even by following this procedure, however, a significant amount of tonal variation was lost, and key land cover classes were dominated by blue-green colors. Figures 4 and 5 portray the spectral histograms for both subscenes after a linear contrast stretch has been accomplished. Table 2 provides the contrast stretch bounds and percent pixels saturated for both subscenes within each band (4, 5, and 6) used for the production of the color composites. Figures 6 and 7 are location maps for both Wapello County subscenes which are to be used in conjunction with Figures 8 through 18 to show the exact

Figure 1

Location Map of the Eleven County Study Area and Wapello County

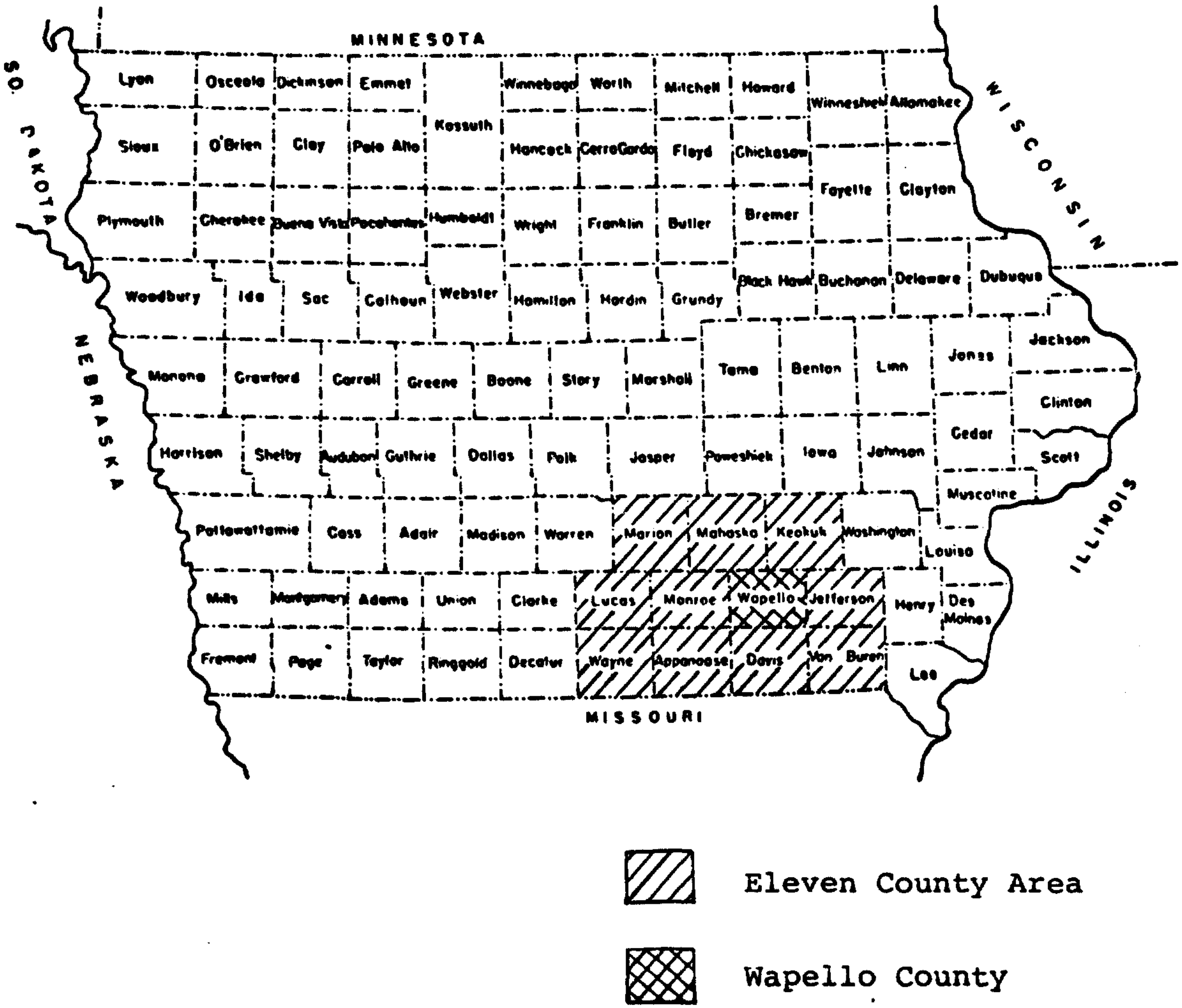
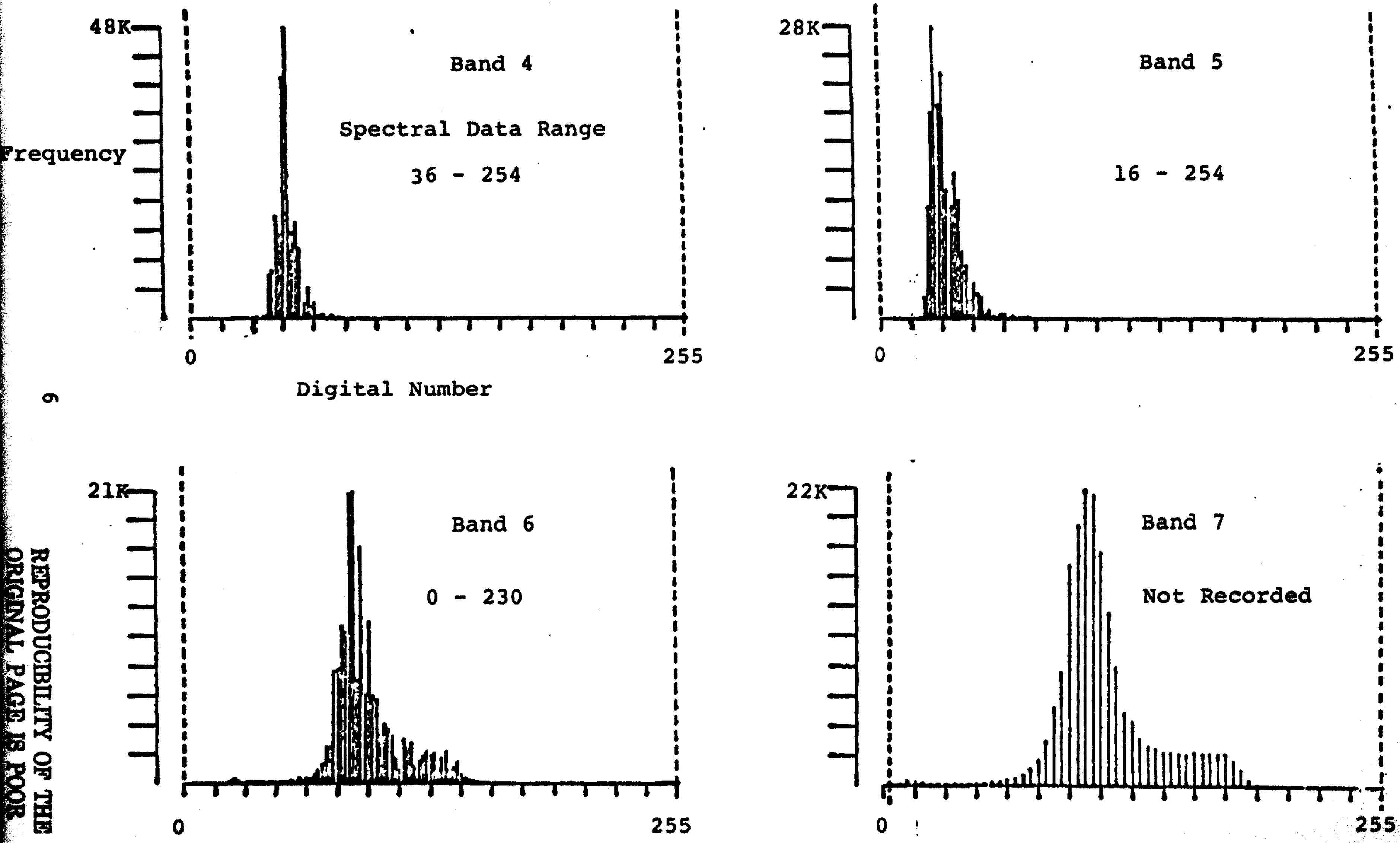


Figure 2

Histograms for Wapello County, Iowa

29 August 1972, LANDSAT 1 (Scene ID: 1037-16213)



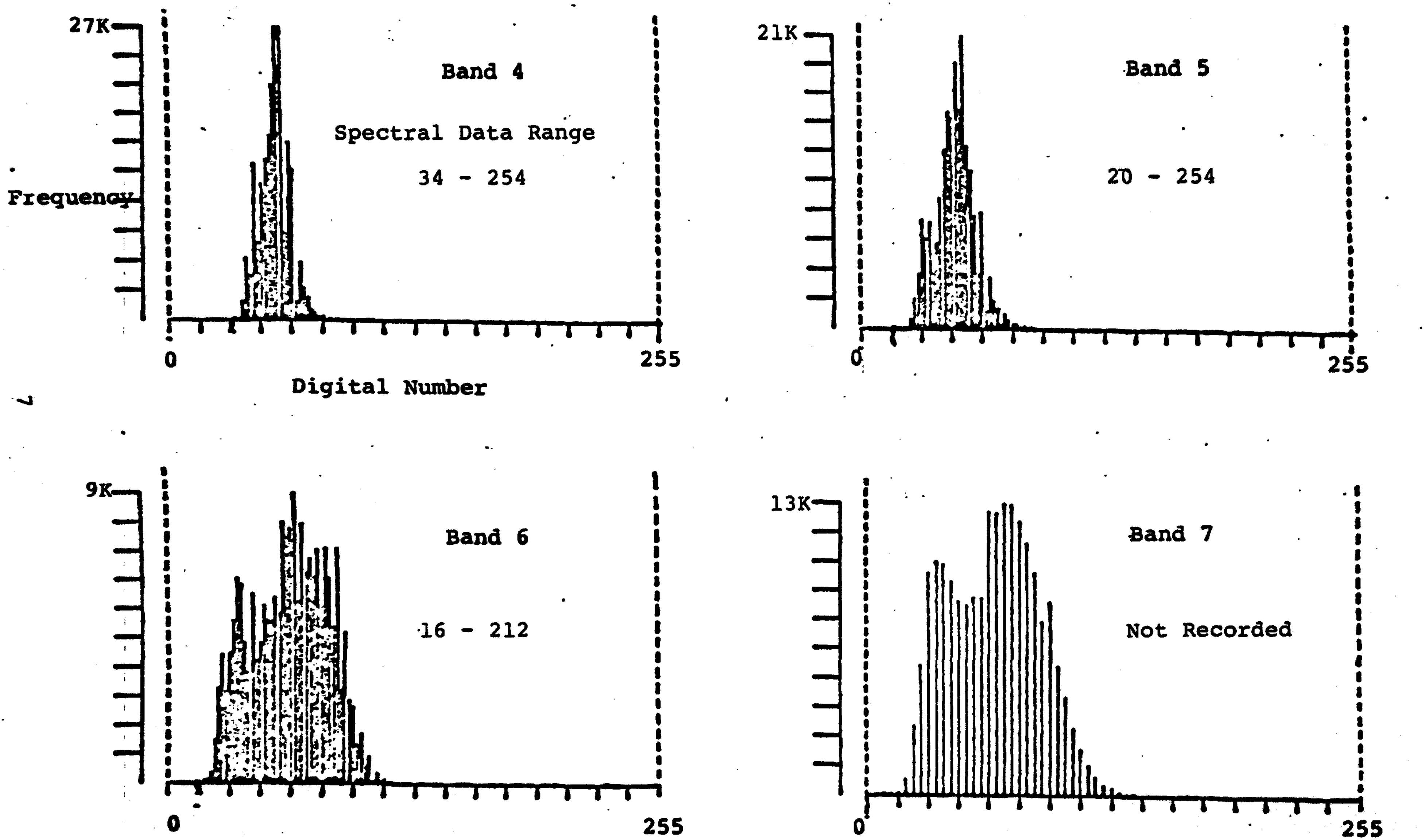
Histograms generated on the IMAGE 100
at the EROS Data Center, Sioux Falls, SD

Figure 3

Histograms for Wapello County, Iowa

15 April 1974, LANDSAT 1

(Scene ID: 1631-16161)



Histograms generated on the IMAGE 100
at the EROS Data Center, Sioux Falls, SD

Table 1

Spectral Data Range for Histograms Shown in Figures 2 and 3

29 August 1972 Scene (ID #1037-16213)

Band	Lower Data Bound	Upper Data Bound
#4	36	254
#5	16	254
#6	0	230

15 April 1974 Scene (ID #1631-16161)

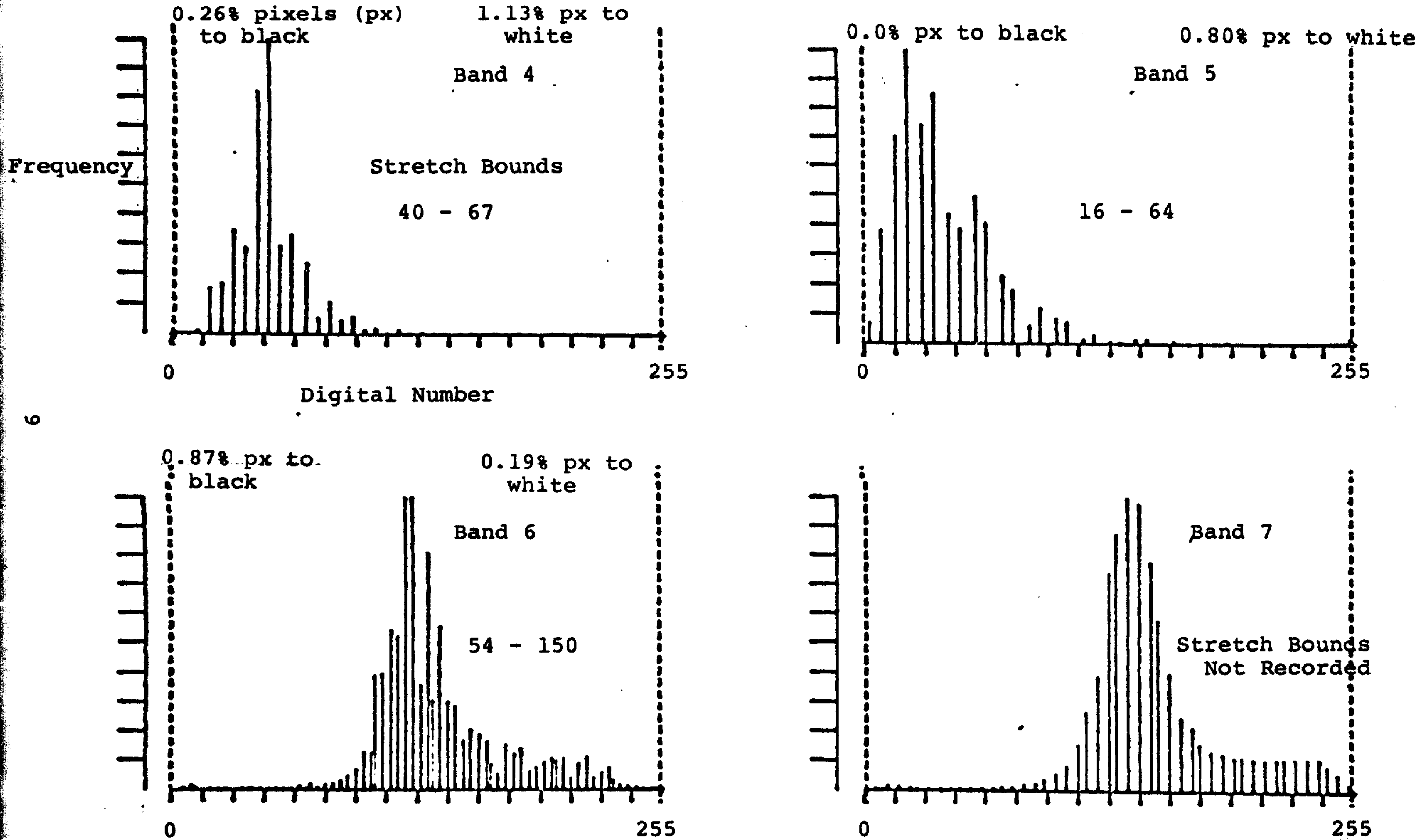
Band	Lower Data Bound	Upper Data Bound
#4	34	254
#5	20	254
#6	16	212

Figure 4

Histograms After Linear Contrast Stretch for Wapello County, Iowa

29 August 1972, LANDSAT 1

(Scene ID: 1037-16213)



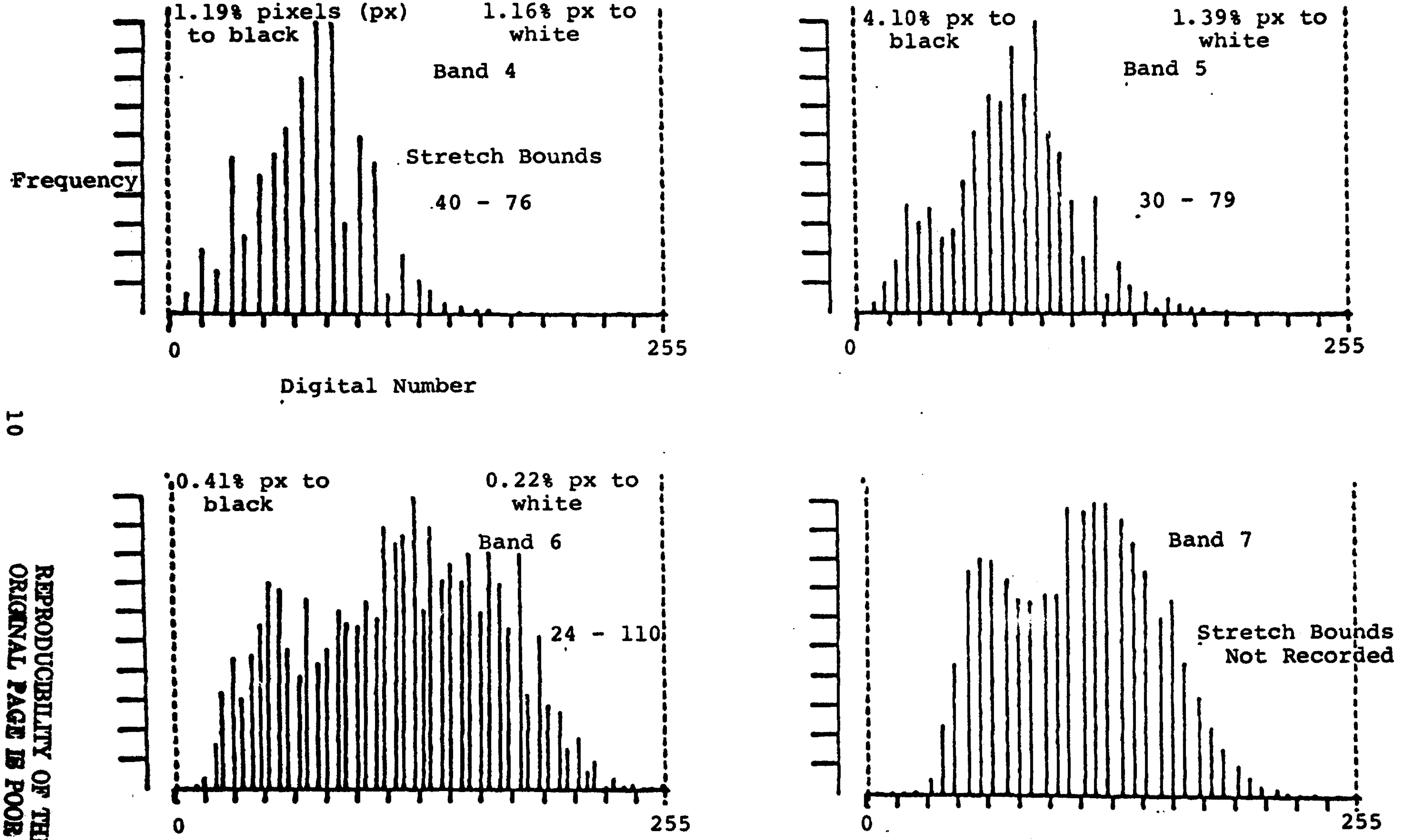
Histograms generated on the IMAGE 100 at the EROS Data Center, Sioux Falls, SD

Figure 5

Histograms After Linear Contrast Stretch for Wapello County, Iowa

15 April 1974, LANDSAT 1

(Scene ID: 1631-16161)



Histograms generated on the IMAGE 100 at the EROS Data Center, Sioux Falls, SD

Table 2

Contrast Stretch Bounds and Percent Pixels Saturated for the Histograms Shown in Figures 4 and 5

Band	Lower Stretch Bound	% Pixels Sat.	Upper Stretch Bound	% Pixels Sat.
<u>29 August 1972 Scene (ID #1037-16213)</u>				
#4	40	0.26	67	1.13
#5	16	0.00	64	0.80
#6	54	0.87	150	0.19
<u>15 April 1974 Scene (ID #1631-16161)</u>				
#4	40	1.19	76	1.16
#5	30	4.10	79	1.39
#6	24	0.41	110	0.22

Figure 6

Location Sketch for Wapello County, Iowa Subscene
29 August 1972 (ID #1037-16213)

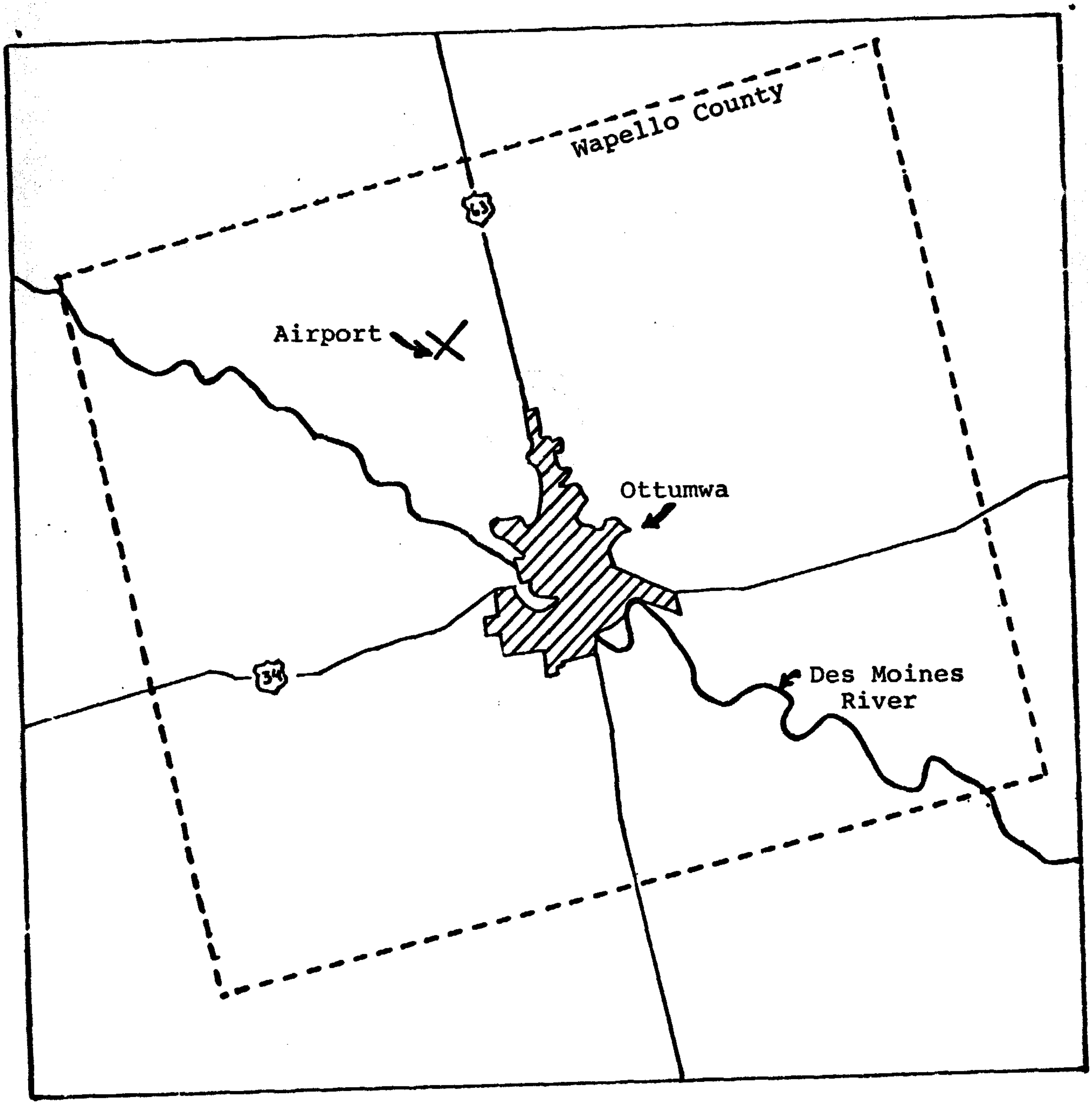


Figure 7

Location Sketch for Wapello County, Iowa Subscene
15 April 1974 (ID #1637-16161)

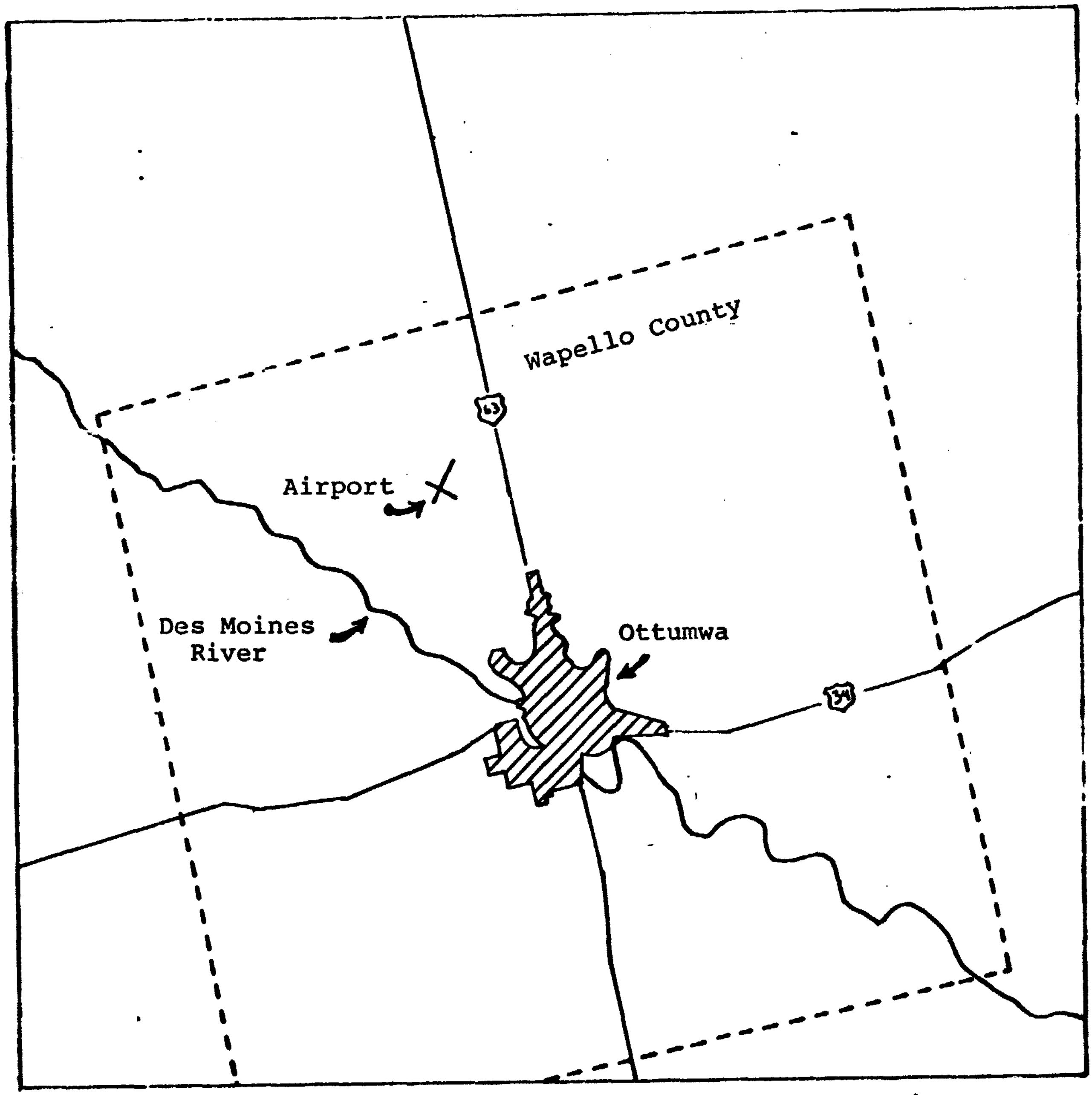
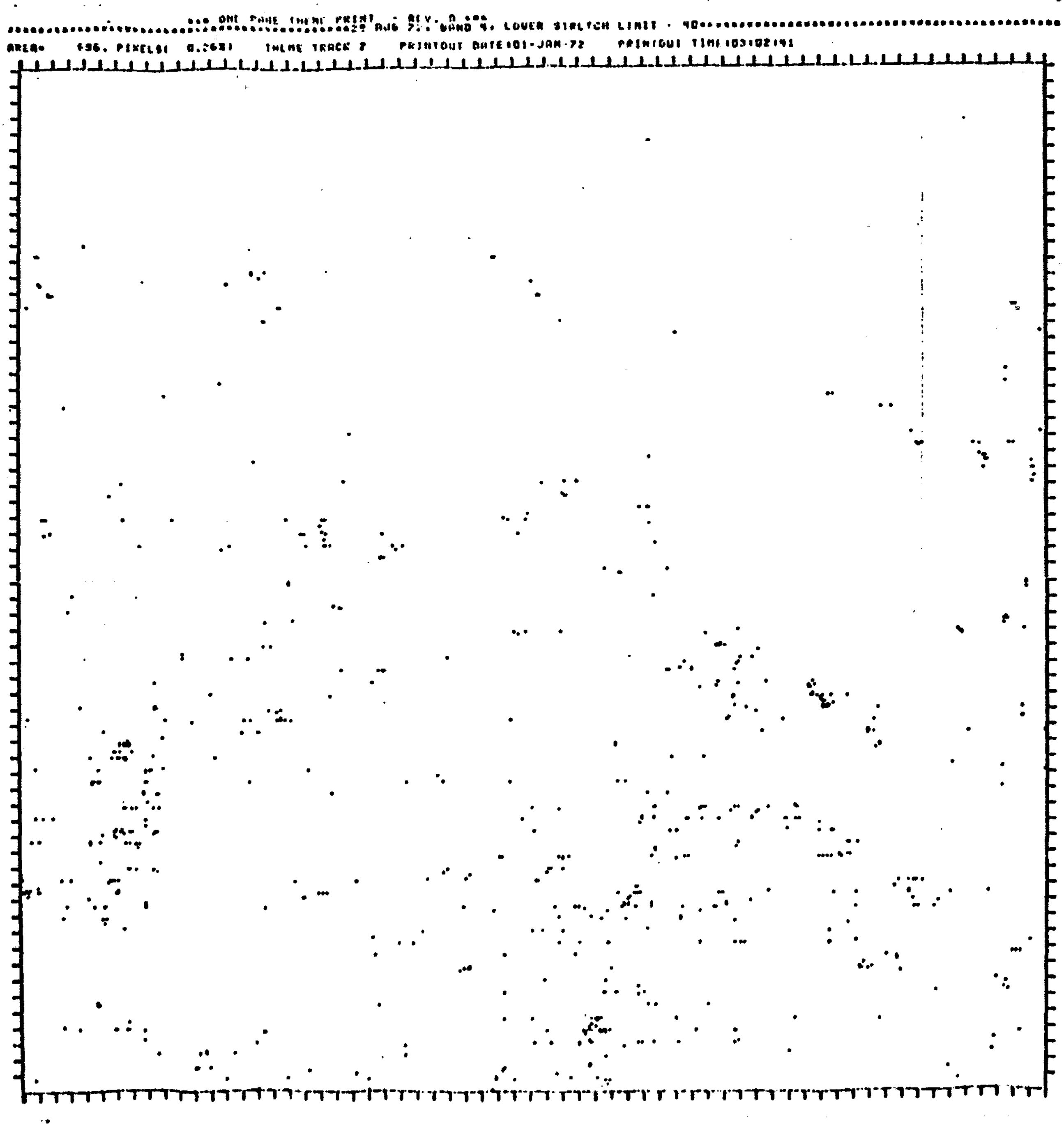


Figure 8

Pixels Saturated to Black in Lower Contrast Stretch for Wapello County, Iowa, Band 4, 29 August 1972 (ID #1037-16213)

Lower Spcetral Data Limit--DN 6
Lower Stretch Range--40 to 0
DN Values 6 to 40 Saturated to Black (0.26% of Total Pixels)

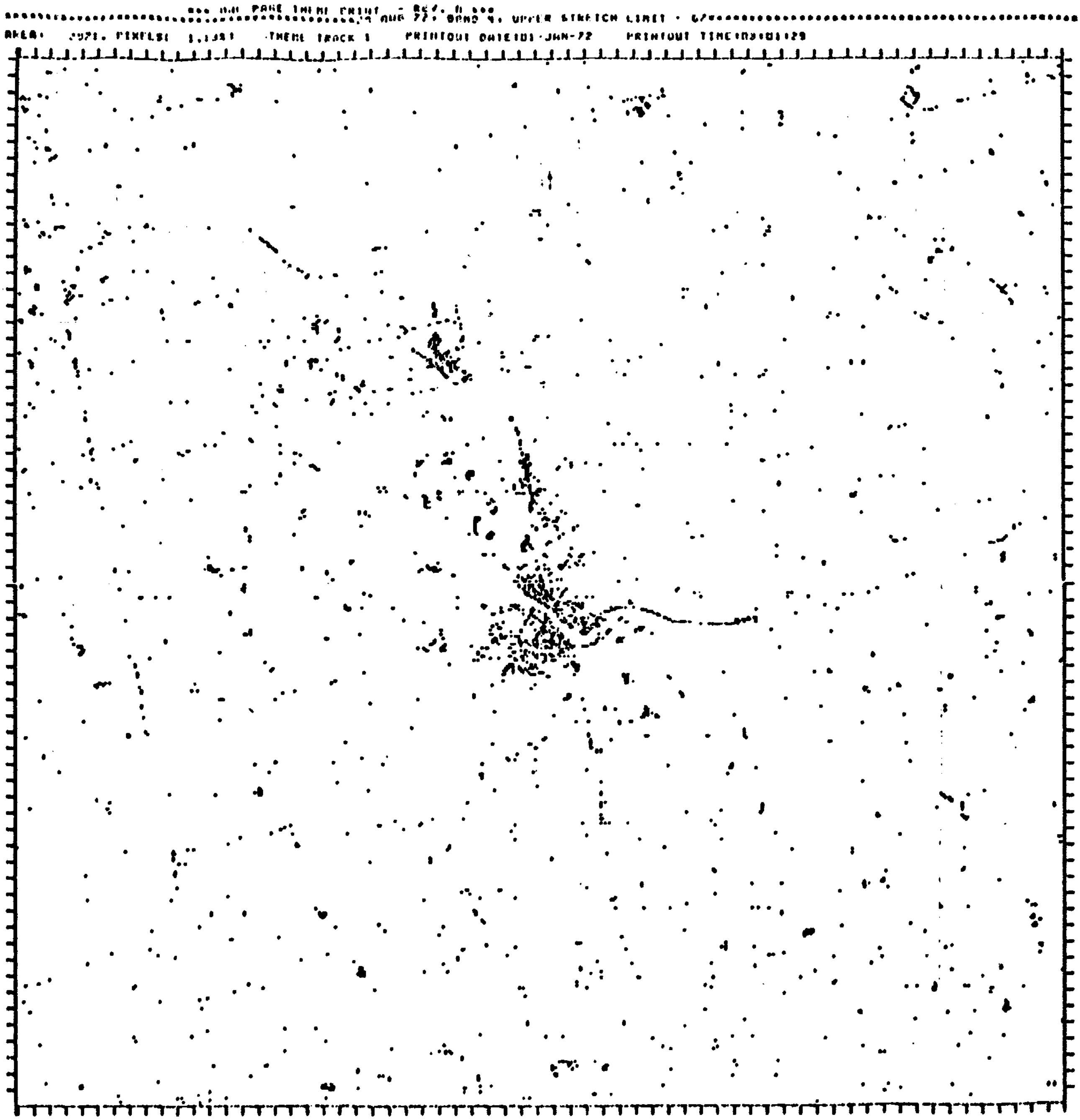


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 9

Pixels Saturated to White (Displayed in Black) in Upper Contrast Stretch Limit for Wapello County, Band 4, 29 August 1972 (ID #1037-16213)

Upper Spectral Data Limit--DN 254
Upper Stretch Range--67 to 255
DN Values 67 to 254 Saturated to White (1.13% of Total Pixels)

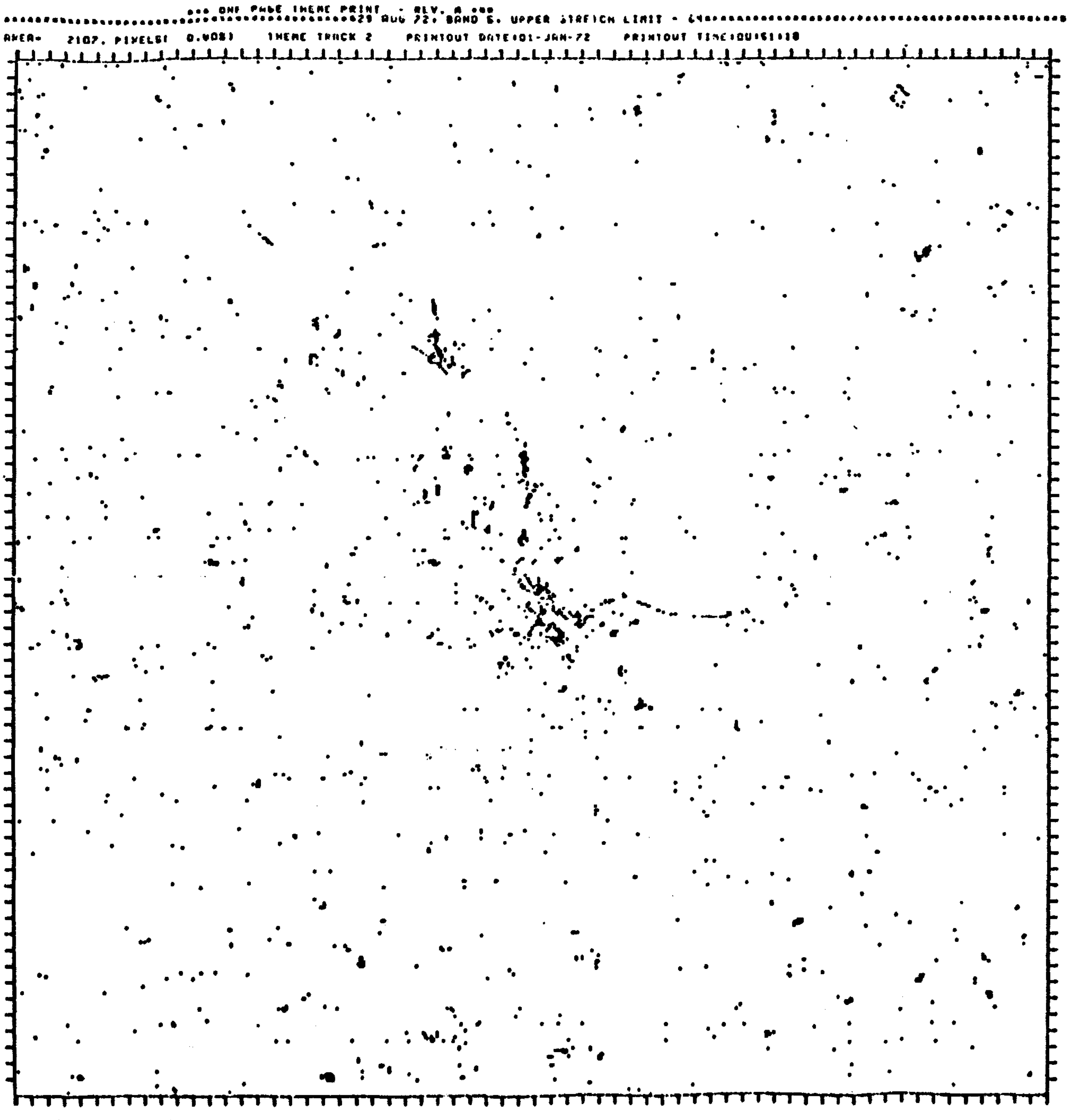


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 10

Pixels Saturated to White (Displayed in Black) in Upper Contrast Stretch Limit for Wapello County, Band 5, 29 August 1972 (ID #1037-16213)

Upper Spectral Data Limit--DN 254
Upper Stretch Range--150 to 255
DN Values 150 to 254 Saturated to White (0.19% of Total Pixels)

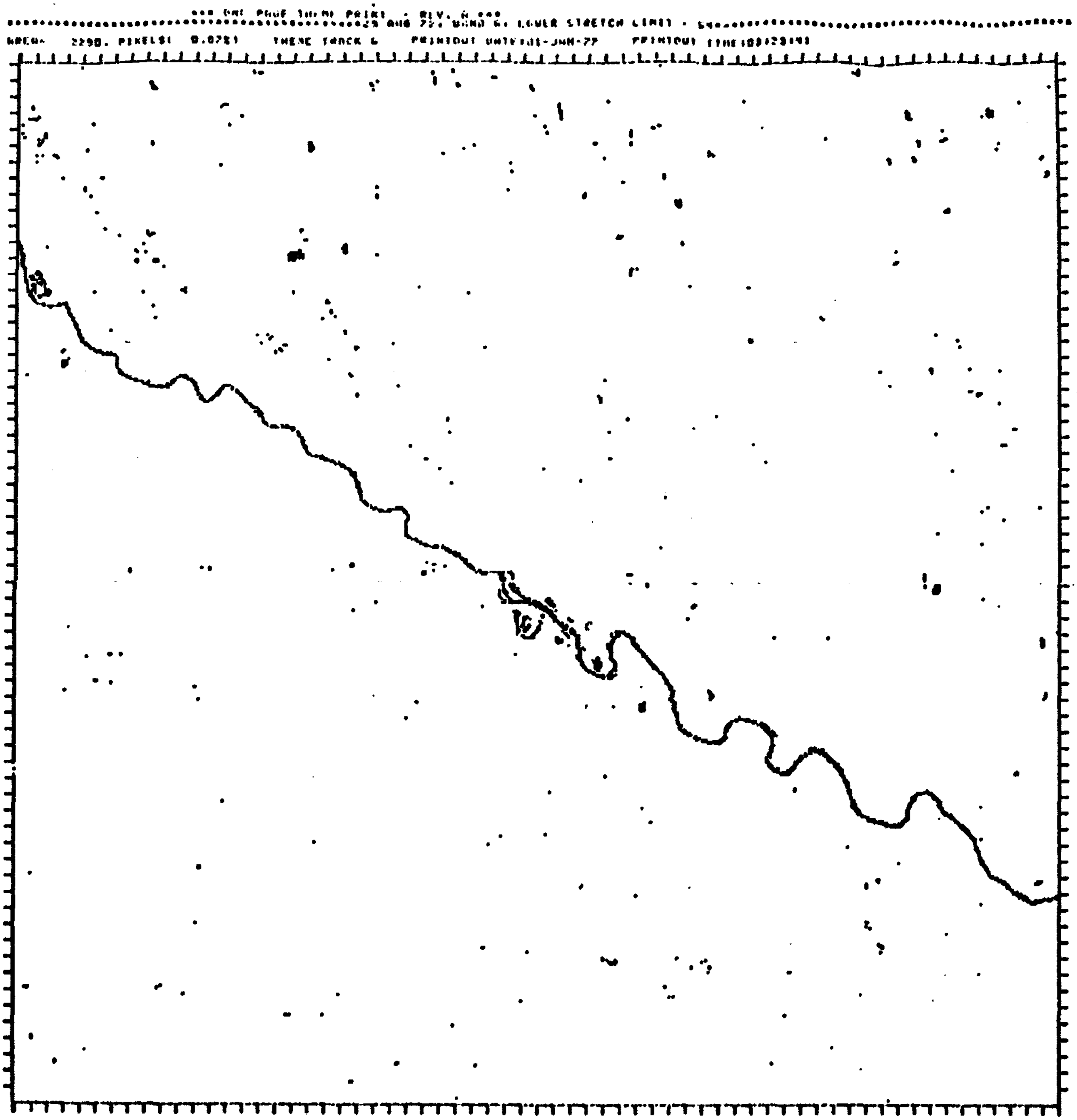


Saturation Prints Generated on the Image 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 11

Pixels Saturated to Black in Lower Contrast Stretch for Wapello County, Iowa, Band 6, 29 August 1972 (ID #1037-16213)

Lower Spectral Data Limit--DN 0
Lower Stretch Range--54 to 0
DN Values 0 to 54 Saturated to Black (0.87%of Total Pixels)

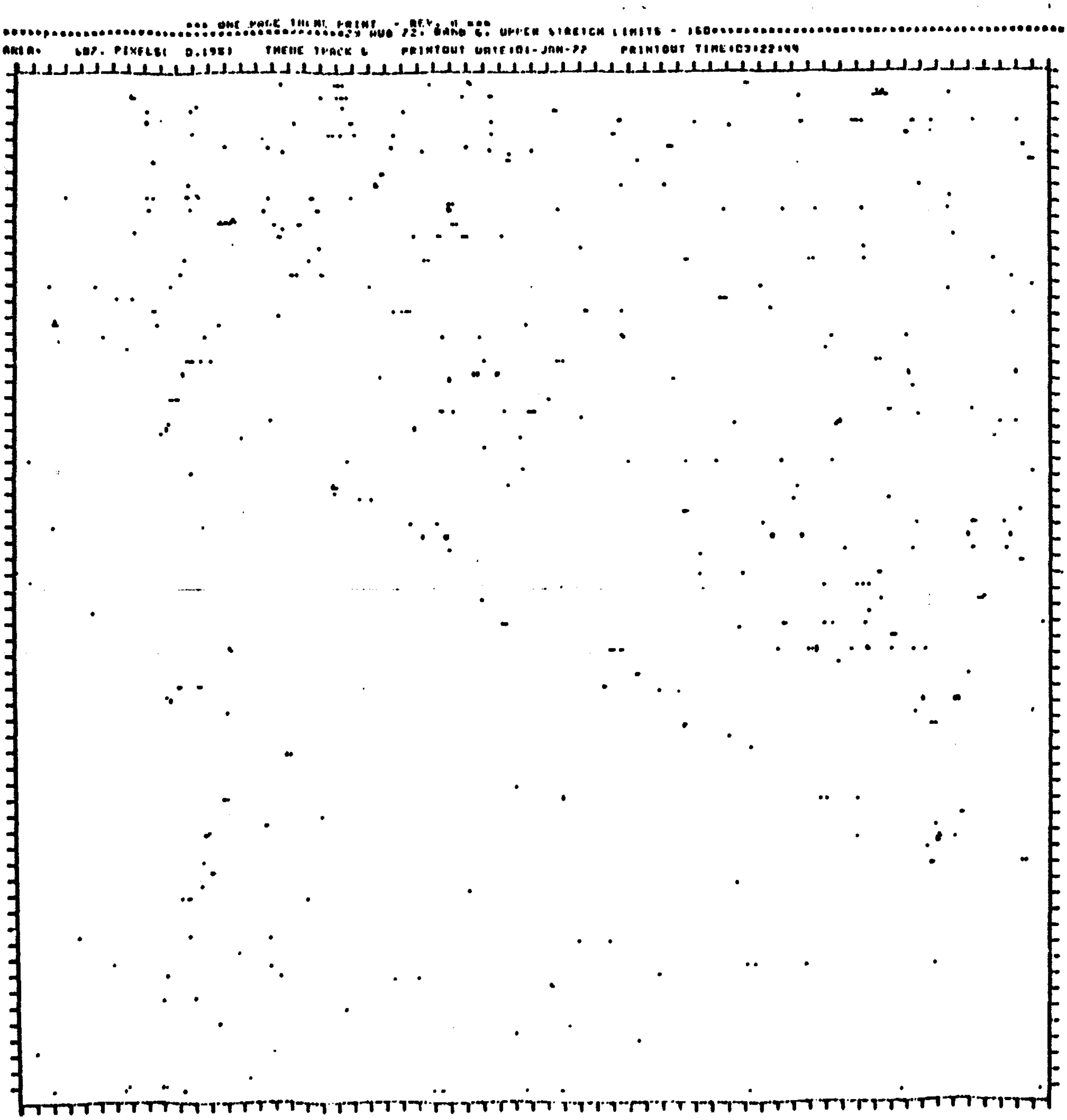


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 12

Pixels Saturated to White (Displayed in Black) in Upper Contrast Stretch Limit for Wapello County, Band 6, 29 August 1972 (ID #1037-16213)

Upper Spectral Data Limit--DN 230
Upper Stretch Range--150 to 255
DN Values 150 to 230 Saturated to White (0.19% of Total Pixels)

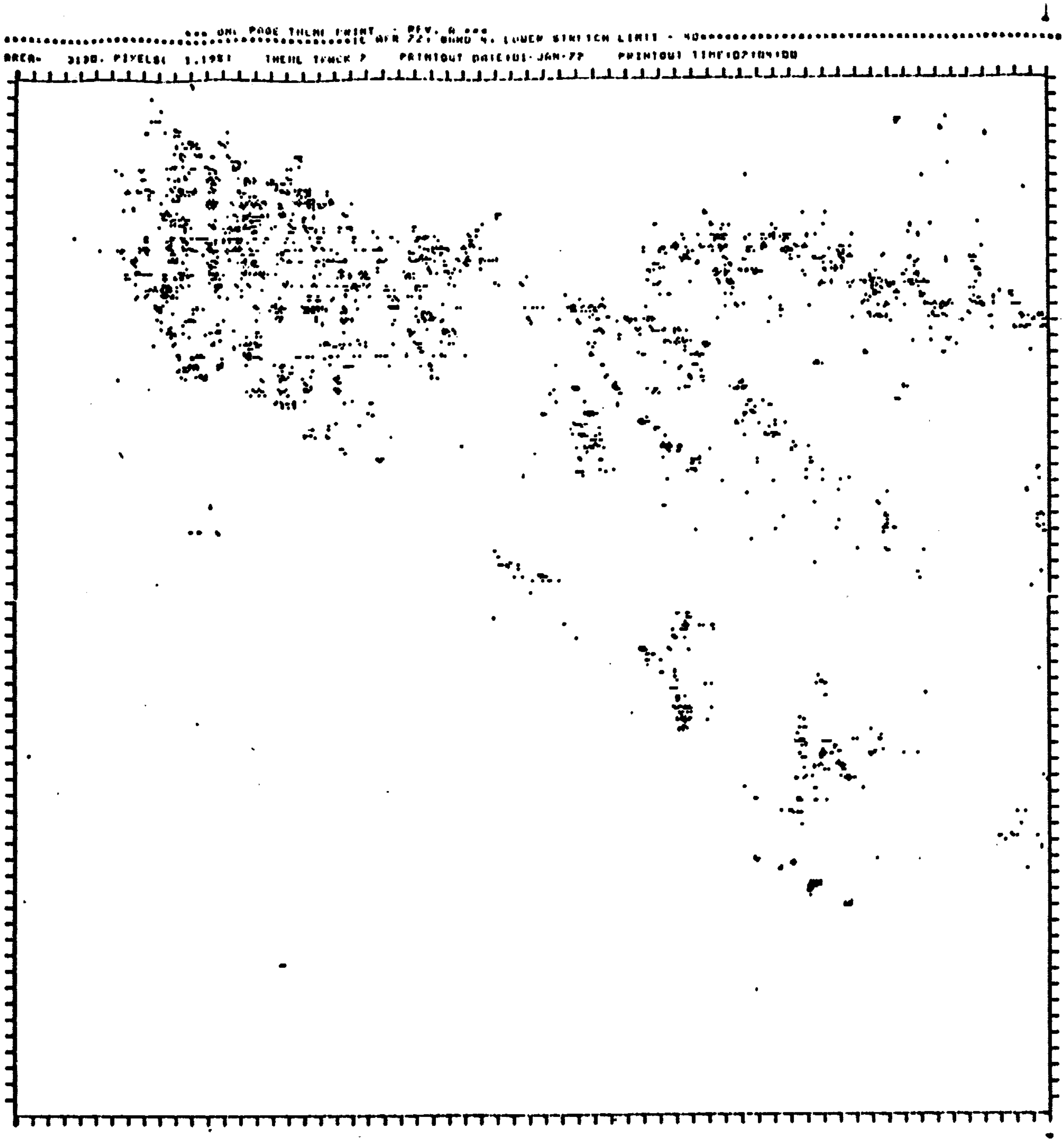


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 13

Pixels Saturated to Black in Lower Contrast Stretch Limit for Wapello County, Iowa, Band 4, 15 April 1974 (ID #1631-16161)

Lower Spectral Data Limit--DN 34
Lower Stretch Range--40 to 0
DN Values 34 to 40 Saturated to Black (1.19% of Total Pixels)

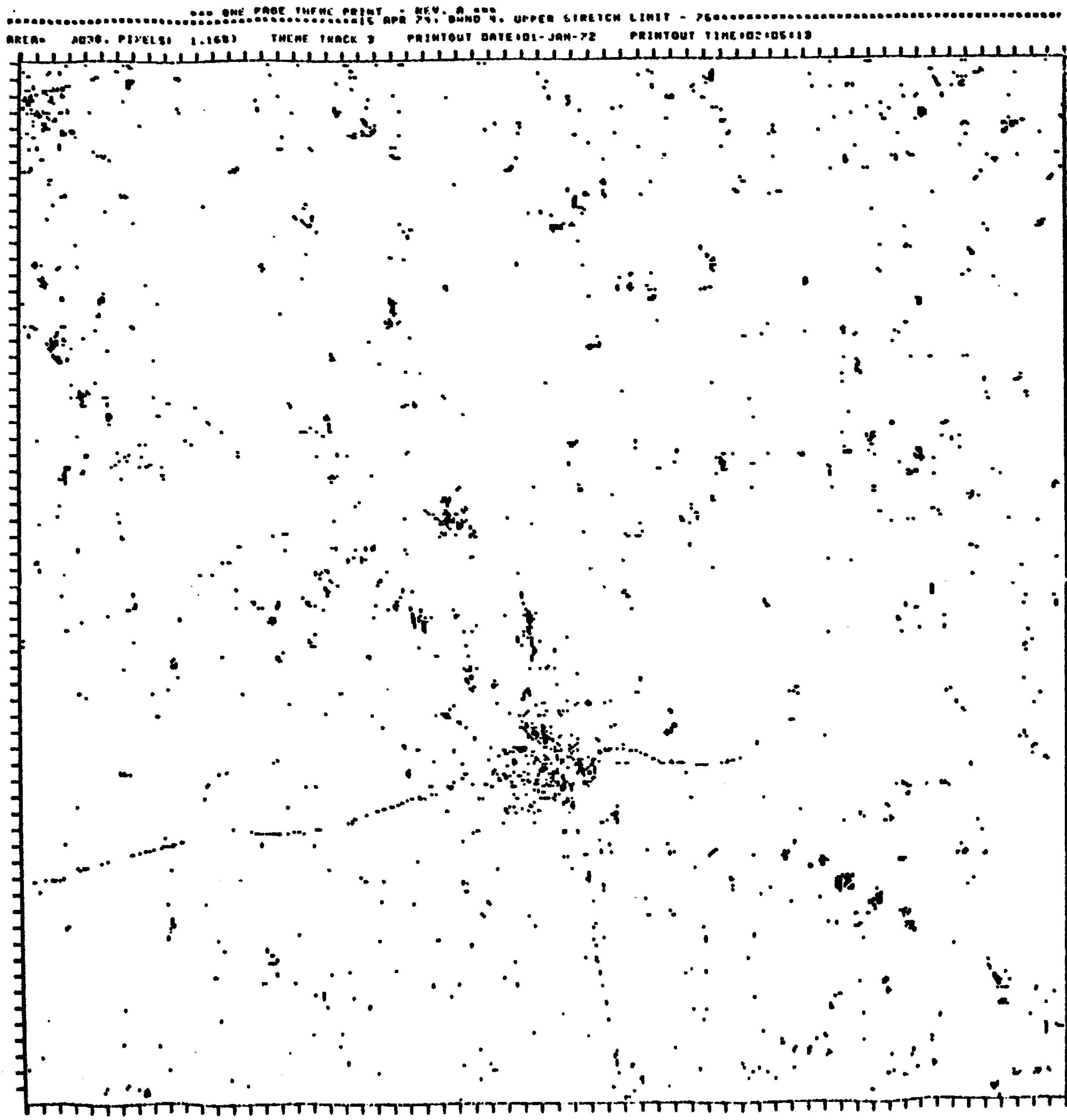


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 14

Pixels Saturated to White (Displayed in Black) in Upper Contrast Stretch Limit for Wapello County, Band 4, 15 April 1974 (ID #1637-16161)

Upper Spectral Data Limit--DN 254
Upper Stretch Range--76 to 255
DN Values 76 to 254 Saturated to White (1.16% of Total Pixels)

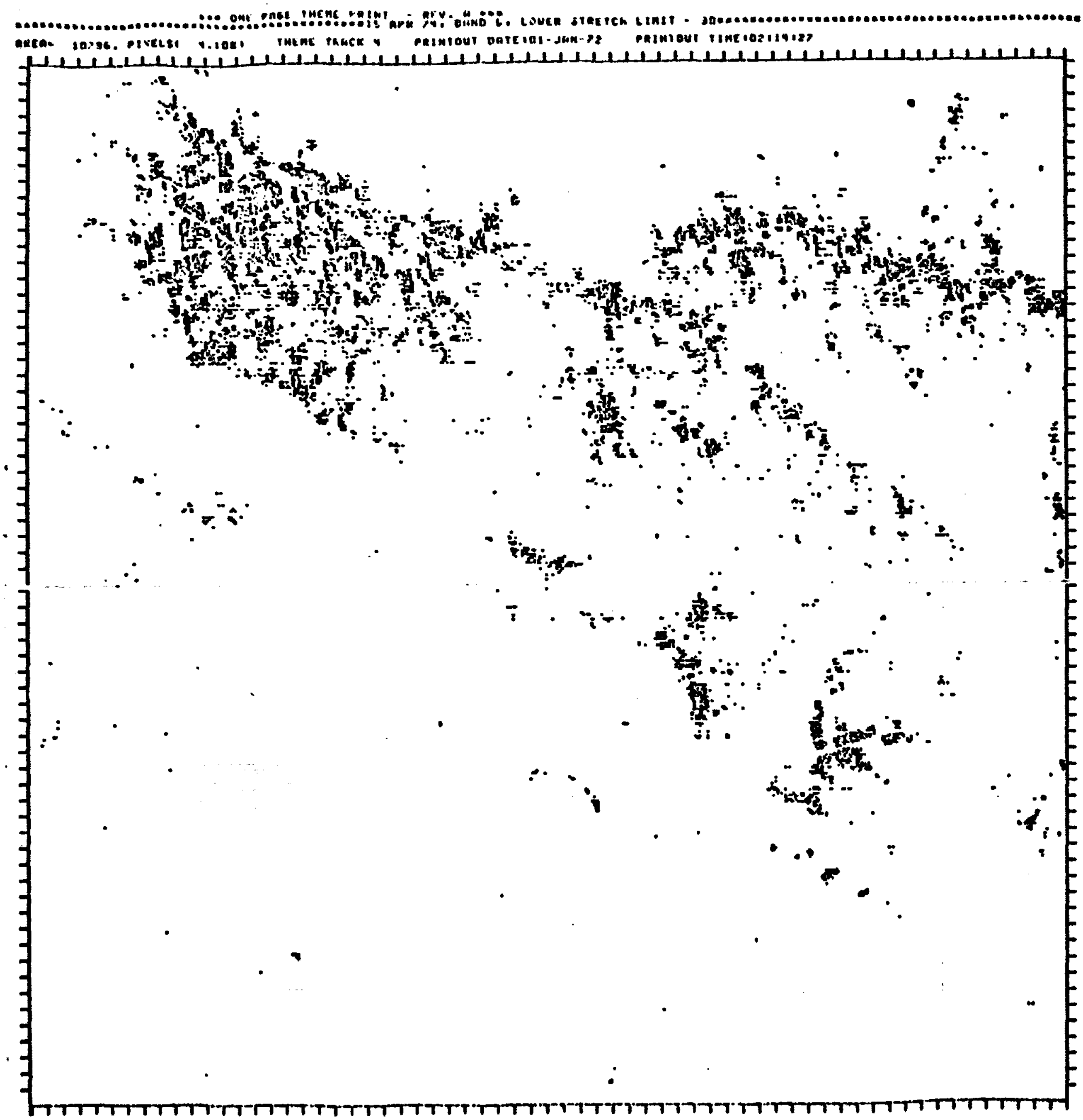


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 15

Pixels Saturated to Black in Lower Contrast Stretch for Wapello County, Iowa, Band 5, 15 April 1974 (ID #1637-16161)

Lower Spectral Data Limit--DN 20
Lower Stretch Range--30 to 0
DN Values 20 to 30 Saturated to Black (4.10% of Total Pixels)

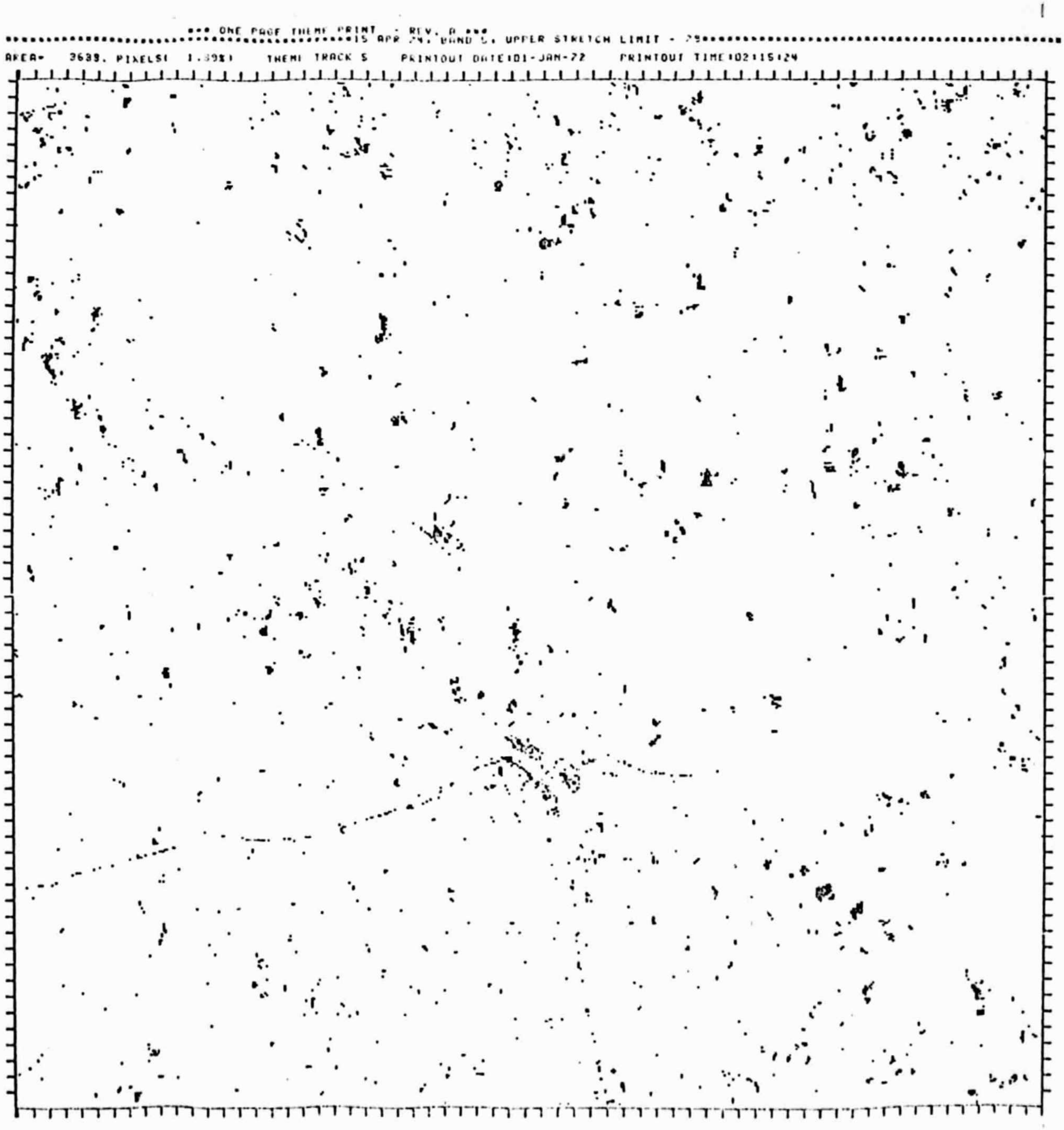


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 16

Pixels Saturated to White (Displayed in Black) in Upper Contrast Stretch Limit for Wapello County, Band 5, 15 April 1974 (ID #1637-16161)

Upper Spectral Data Limit--254
Upper Stretch Range--79 to 255
DN Values 79 to 254 Saturated to White (1.39% of Total Pixels)

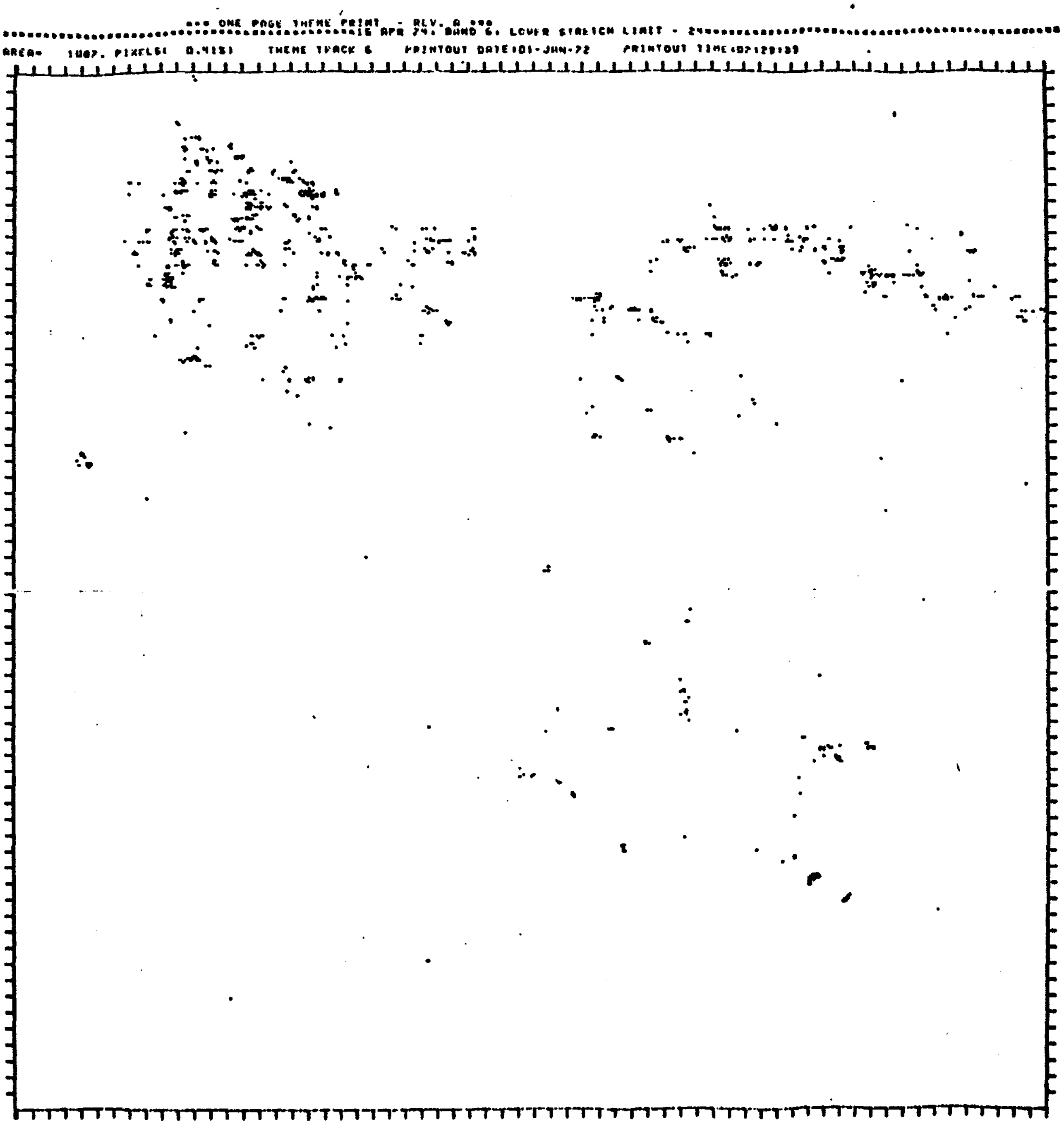


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

Figure 17

Pixels Saturated to Black in Lower Contrast Stretch Limit for Wapello County, Iowa, Band 6, 15 April 1974 (ID #1631-16161)

Lower Spectral Data Limit--DN 16
Lower Stretch Range--24 to 0
DN Values 16 to 24 Saturated to Black (0.41% of Total Pixels)

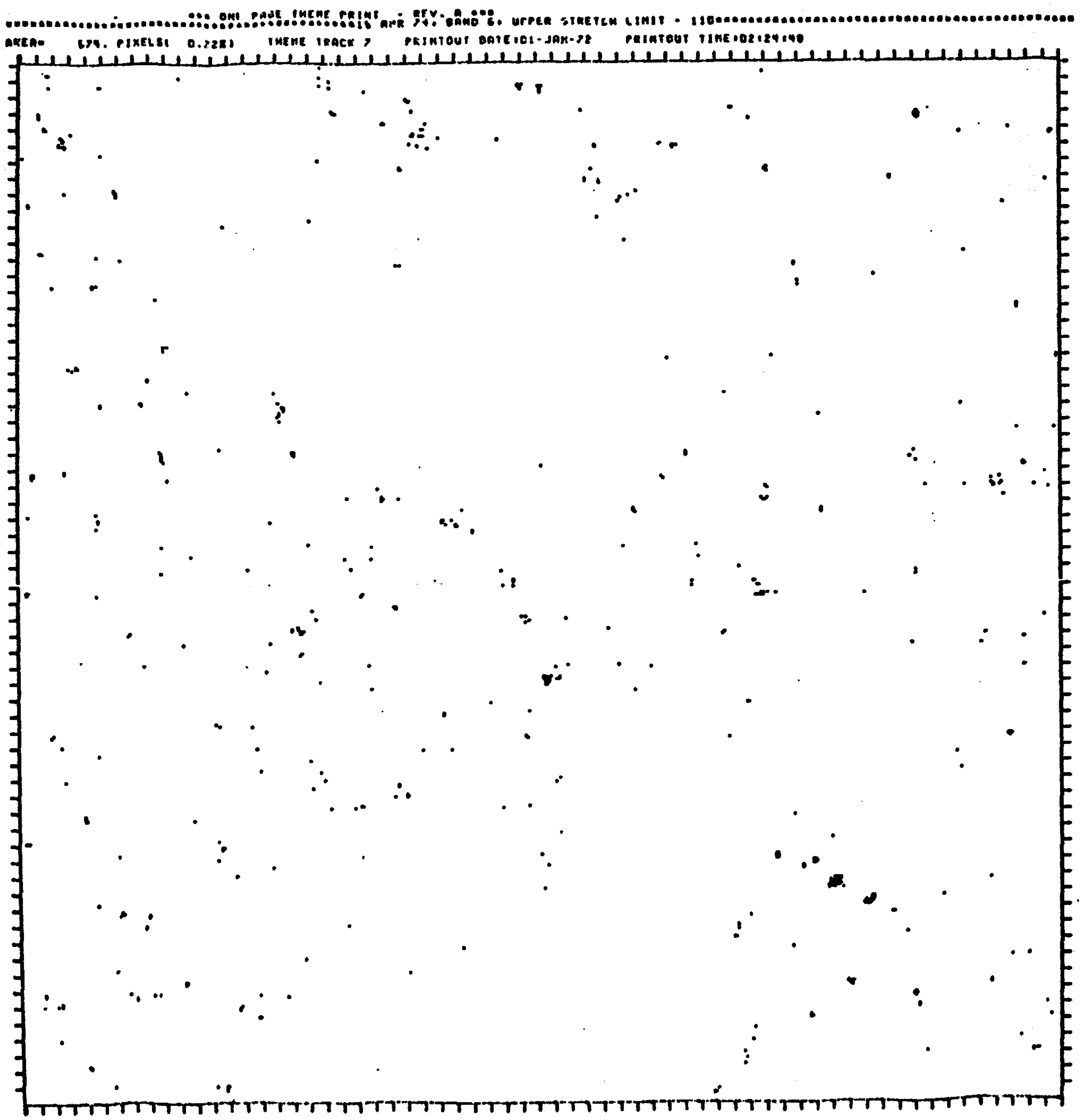


Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, Califorina

Figure 18

Pixels Saturated to White (Displayed in Black) in Upper Contrast Stretch Limit for Wapello County, Band 6, 15 April 1974 (ID #1637-16161)

Upper Spectral Data Limit--DN 212
Upper Stretch Range--110 to 255
DN Values 110 to 212 Saturated to White (0.22% of Total Pixels)



Saturation Prints Generated on the IMAGE 100 at the Jet Propulsion Laboratory, Pasadena, California

number of pixels which have lost their tonal variations by being truncated either to black or white.

To summarize this discussion on truncation, band 5 from the 15 April 1974 scene will be used as an example. Figure 6 is a general location map with which Figures 14 and 15 may be compared. The lower contrast stretch bounds which have been truncated to black are shown in Figure 15. The data range for band 5 is DN 20 to DN 254. The DN range 20 to 30 was saturated to black (4.10% of the total pixels). Pixels truncated to black are shown in Figure 14. The picture elements shown in this figure relate mostly to the highly organic soils in Wapello County which are plowed and/or are wet in early spring. All of these pixels have the same tonal variation after this linear contrast stretch.

The upper bound of spectral data for band 5, on the other hand, is DN value 254. The upper stretch bound for this band is DN 79 to 255. All pixels with DN values between 79 and 254 are truncated to white (1.39% of the subscene's total pixels). These pixels that have been changed to white by the truncation process, are displayed in black on Figure 15. These pixels relate to high reflectance such as roof tops, concrete roads, and in some places strip mines and quarries.

Conclusions to Contrast Stretching with Truncation

Even when very small portions of a spectral histogram are truncated (less than 1% of the total pixels), the tonal variations which are lost for land cover classes having high reflectance values, (urban, strip mine-quarry, water soils, etc.) prove to be critical when the individual bands are combined together to produce a false-color composite. The resulting photographic color product consequently has much larger areas represented in both high and low reflectance values than does a scene which has not been truncated during a contrast stretch. The implication is that for southeastern Iowa, a contrast stretched scene with truncation (even though the truncation is very slight) will possess less tonal detail in critical land cover categories than will a scene which possess all of the original spectral data.

Optronics Film Recorder Characteristics

The Optronics Photowrite Model P-1500 Film Recorder is a precision digital film-writing system which produces a hard-copy photographic product from digital numbers. The system consists of an unexposed sheet of Kodak Linograph Shellburst 2474 Film clamped to the outside of a circular rotating drum. A beam of light, modulated by the digital data, exposes the film through an optical system consisting of a red-light emitting diode (LED) source, an adjustable aperture, and lens system to focus the light beam onto the film. The drum, film, and optical path are enclosed in a light-proof enclosure which may be removed for developing the film. As the red-light emitting diode is pulled across a rotating sheet of Kodak 2474 film, the picture elements are exposed according to the assigned DN value.

The Kodak 2474 Shellburst Film is a thin, mylar-based, high contrast, red sensitive film. Its dynamic density range is approximately 2.5 optical density units with an associated fog level of 0.11 to 0.19 density units. The term "fog" is defined as the optical density on a film after development without exposure. The fog level of the film is important to note because the Optronics Film Recorder uses a red LED whose intensity is not sufficient to raise a signal above the film's fog level until a DN value of approximately 231 is reached when a positive image is being formed (Figure 19). This means that film densities corresponding to DN values of 231 to 255 cannot be differentiated on a standard JPL Optronics film product. In addition, the curve indicates that the lower reflectance values from DN of 0 to approximately 24 also cannot be uniquely recorded on the film because of the operational characteristics of the film and recorder.

Conclusions on the Use of the Optronics P-1500 Film Recorder

The hardware and film characteristics of the Optronics have led to a strategy of contrast stretching a scene which, through a table look-up procedure, reassigns the DN values to a range which can be fully recorded on the 2474 film. This range (which is estimated very conservatively) falls between DN of 32 and 210. Figure 19 displays the relationship of digital number versus transmission density for a 32 step density wedge generated on the P-1500. The procedure which is followed to utilize this contrast range of DN 32 to 210 after a linear stretch is performed, the DN value of 0 is reassigned to the DN value of 32; the DN value of 255 is reassigned to "fit" within this compressed dynamic range. According to the JPL P-1500 Optronics Film Recorder characteristics, all of these

Figure 19

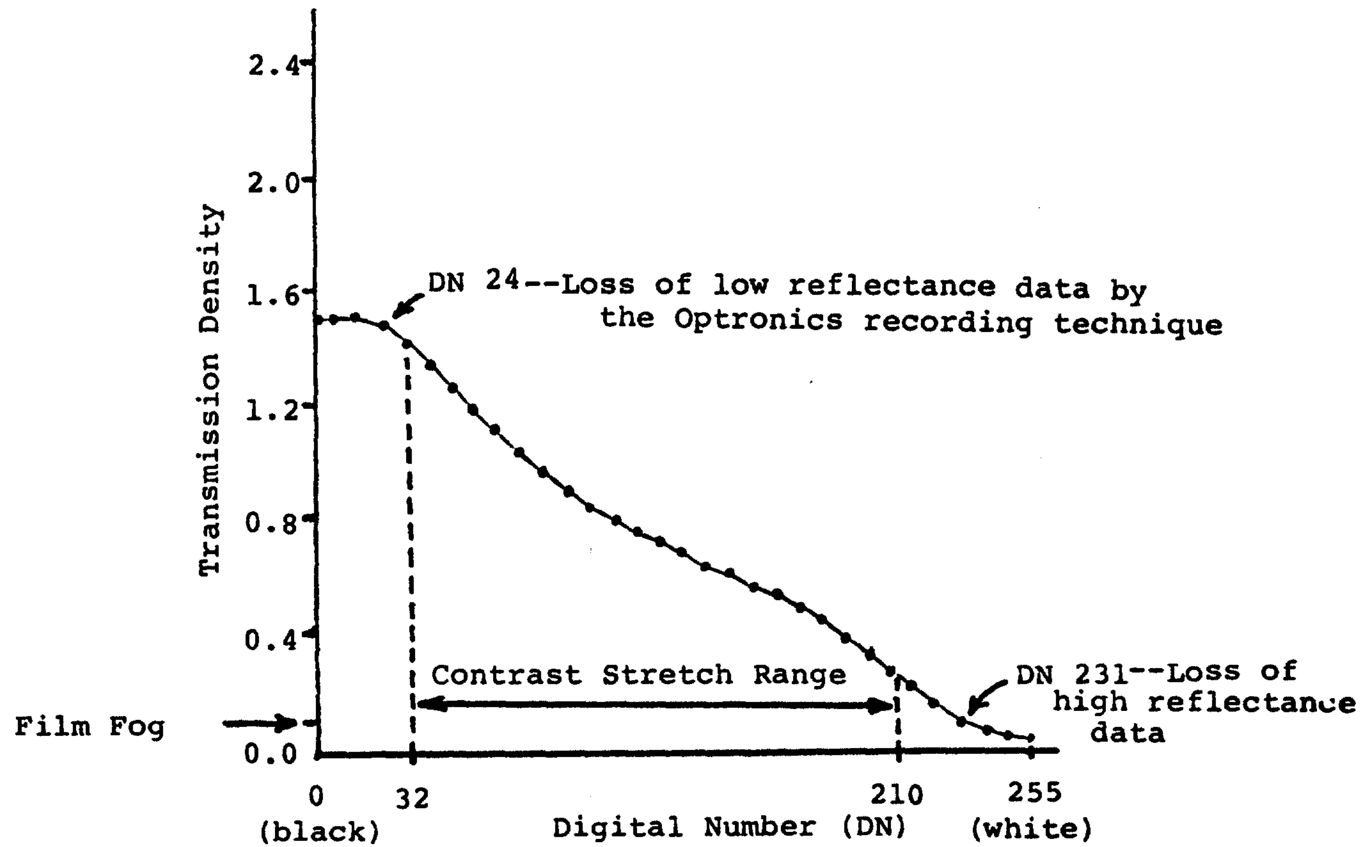
Digital Number versus Transmission Density for Linograph Shellburst Film 2474 for Positive Step Wedge Exposed on an Optronics P-1500 at the Jet Propulsion Laboratory

2474 Film Processed in D-76 for 11 minutes at 68°F.

Data Used for Curve

DN	Density
0	1.49
8	1.50
16	1.50
24	1.47
32	1.41
40	1.34
48	1.26
56	1.18
64	1.11
72	1.03
80	0.96
88	0.89
96	0.84
104	0.79
112	0.76
120	0.72
128	0.68
136	0.64
144	0.61
152	0.57
160	0.53
168	0.49
176	0.44
184	0.39
192	0.34
200	0.27
208	0.21
216	0.15
224	0.10
232	0.07
240	0.05
248	0.05
255	0.05

Photographic Curve Generated By Ron Wichelman at JPL



transformed DN values would be recorded on the Kodak 2474 film. This procedure slightly compresses the dynamic range of the spectral data from 256 to 178 levels of gray. The advantage of having the ability to display all levels of gray without data loss outweighs the disadvantage of assigning a smaller dynamic range to the spectral data. The problems of the smaller dynamic range could be circumvented by the implementation of a table look-up program in the P-1500's mini-computer. This operation is routinely done in the Data Analysis Laboratory of EDC (Waltz, personal communication, 1976). A table look-up program would allow the DN values for the 8-bit dynamic range to be "fit" into the straight line portion of the DN/transmission density curve before the data is actually recorded on the 2474 film. This procedure would eliminate the need for amending contrast stretch output.

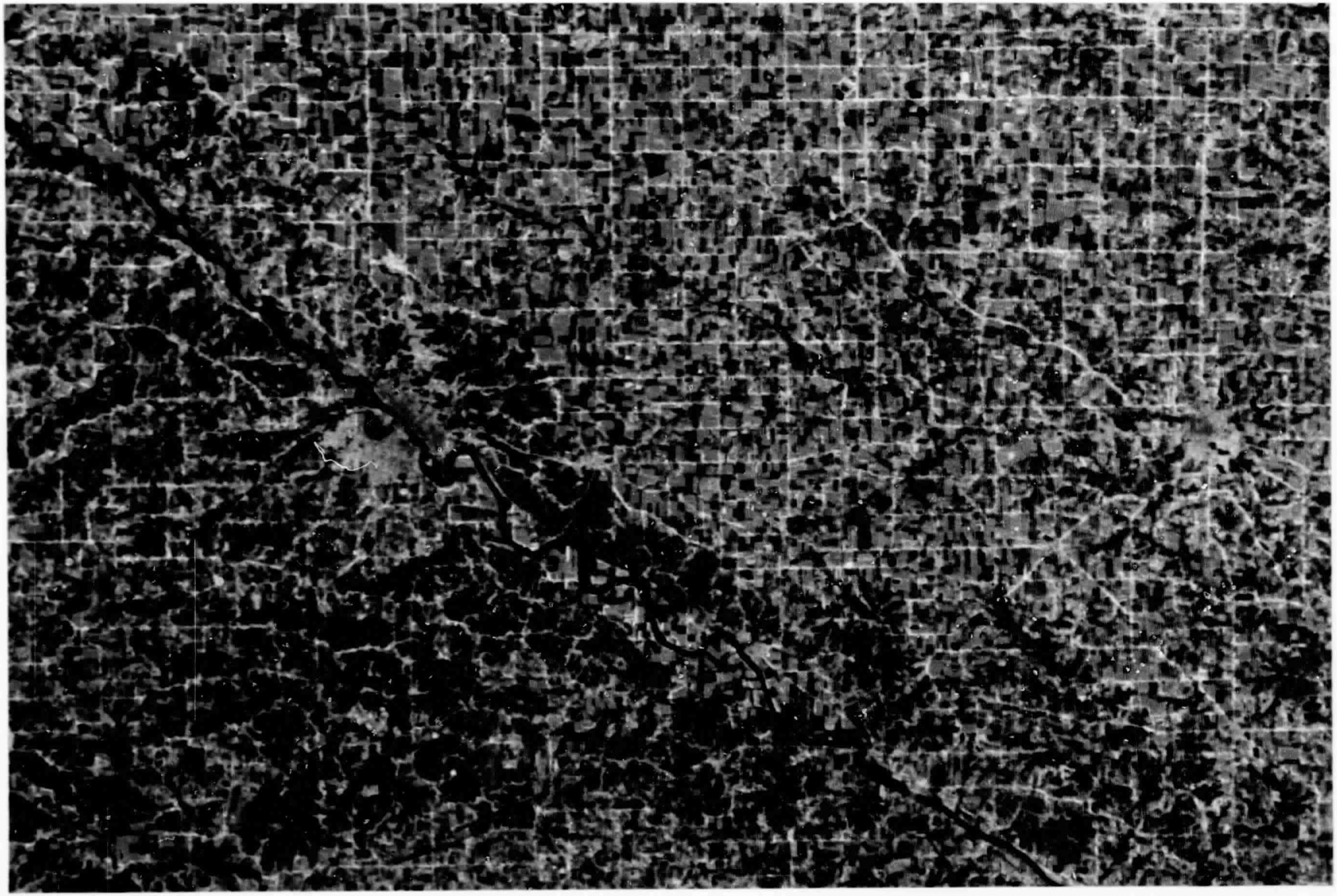
Examples of Color Composites with No Optronics Saturation

Figure 20 and 21 are examples of JPL computer enhanced false color prints which have been linear stretched (with minimal saturation) and compressed to fit within the DN 32 to 210 range of the Optronics film curve. In addition to contrast enhancement, both of these images have been geometrically rotated north/south. Figure 22 is a general location map for the JPL image illustration area; Figure 23 is a larger scale location map taken from the USGS 1:250,000 scale NK series topographic maps.

Figure 20

N

Southeastern Iowa, 29 August 1972 (Scale 1:250,000)
JPL Computer Enhanced LANDSAT-1 False Color Composite (ID #1037-16213)



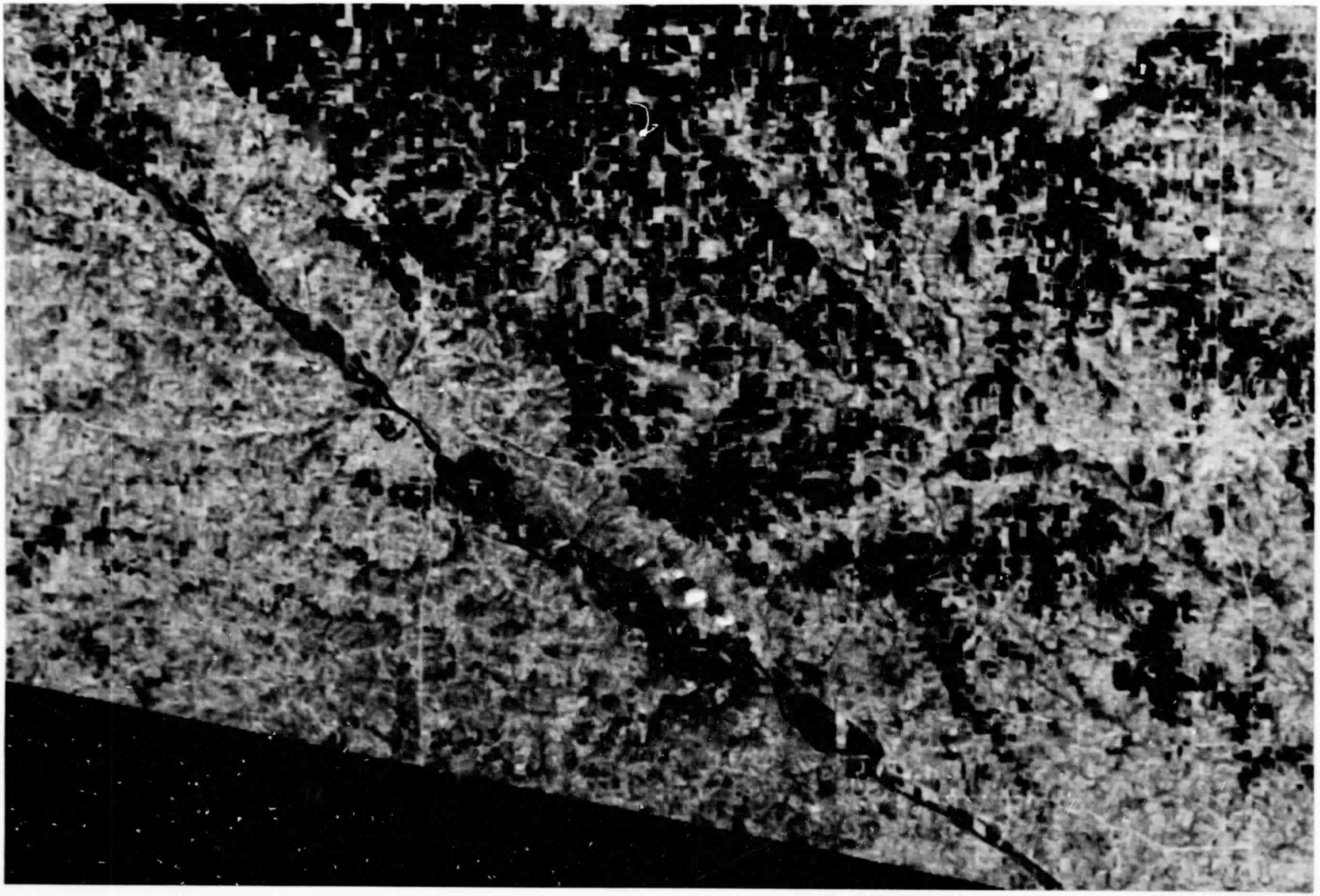
Linear Table Contrast Stretch
Geometrically Rotated North/South

Computer work by: Andree Y. Smith (JPL)
Color Photographic Printing by: J. Lucas (IGS)

Figure 21

N ↑

Southeastern Iowa, 15 April 1974 (Scale 1:250,000)
JPL Computer Enhanced LANDSAT-1 False Color Composite (ID #1631-16161)



Linear Table Contrast Stretch
Geometrically Rotated North/South

Computer Work by: Andree Y. Smith (JPL)
Color Photographic Printing by: J. Lucas (IGS)

Figure 22

Location Map of the Eleven County Study Area and
JPL Image Illustration Area

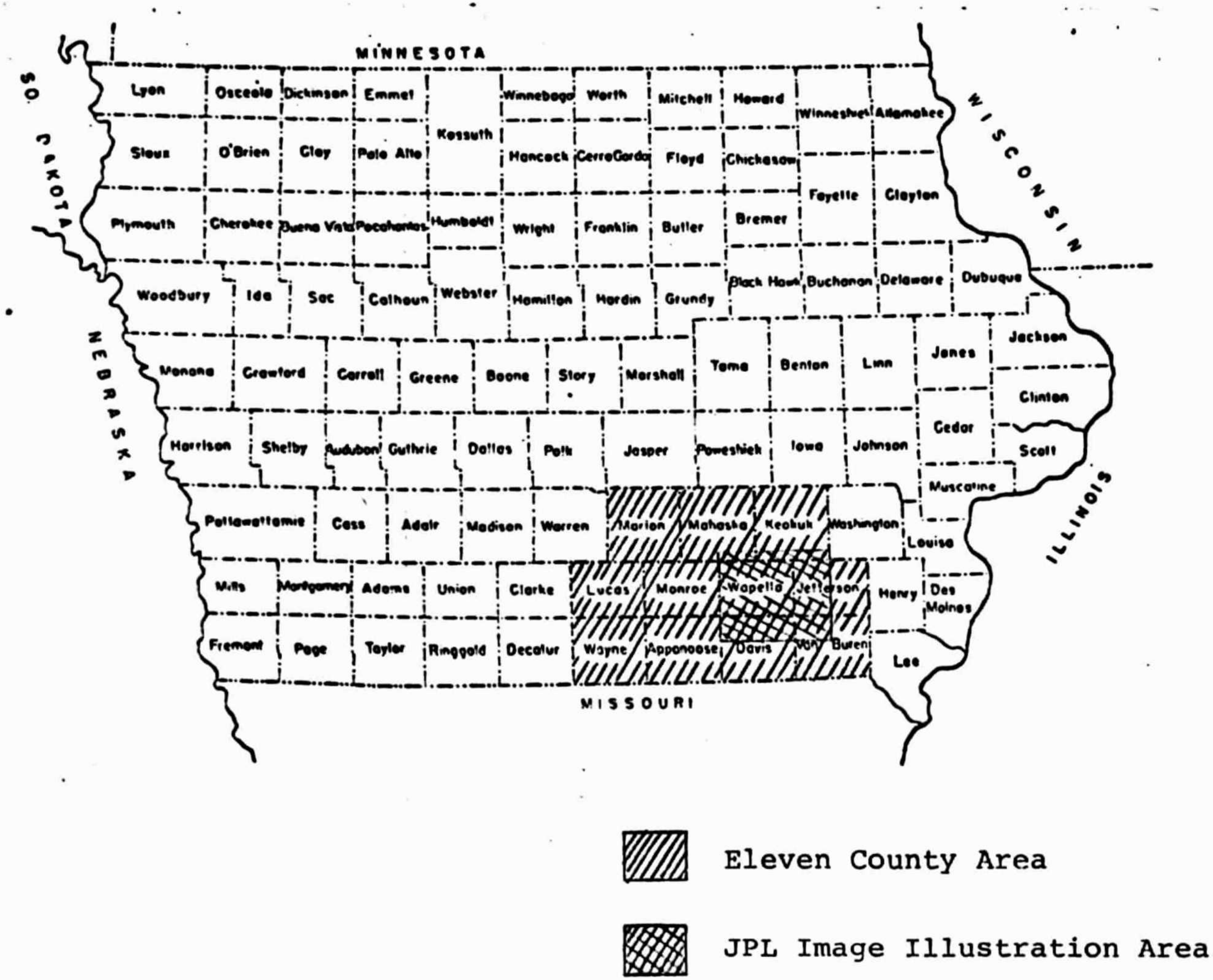
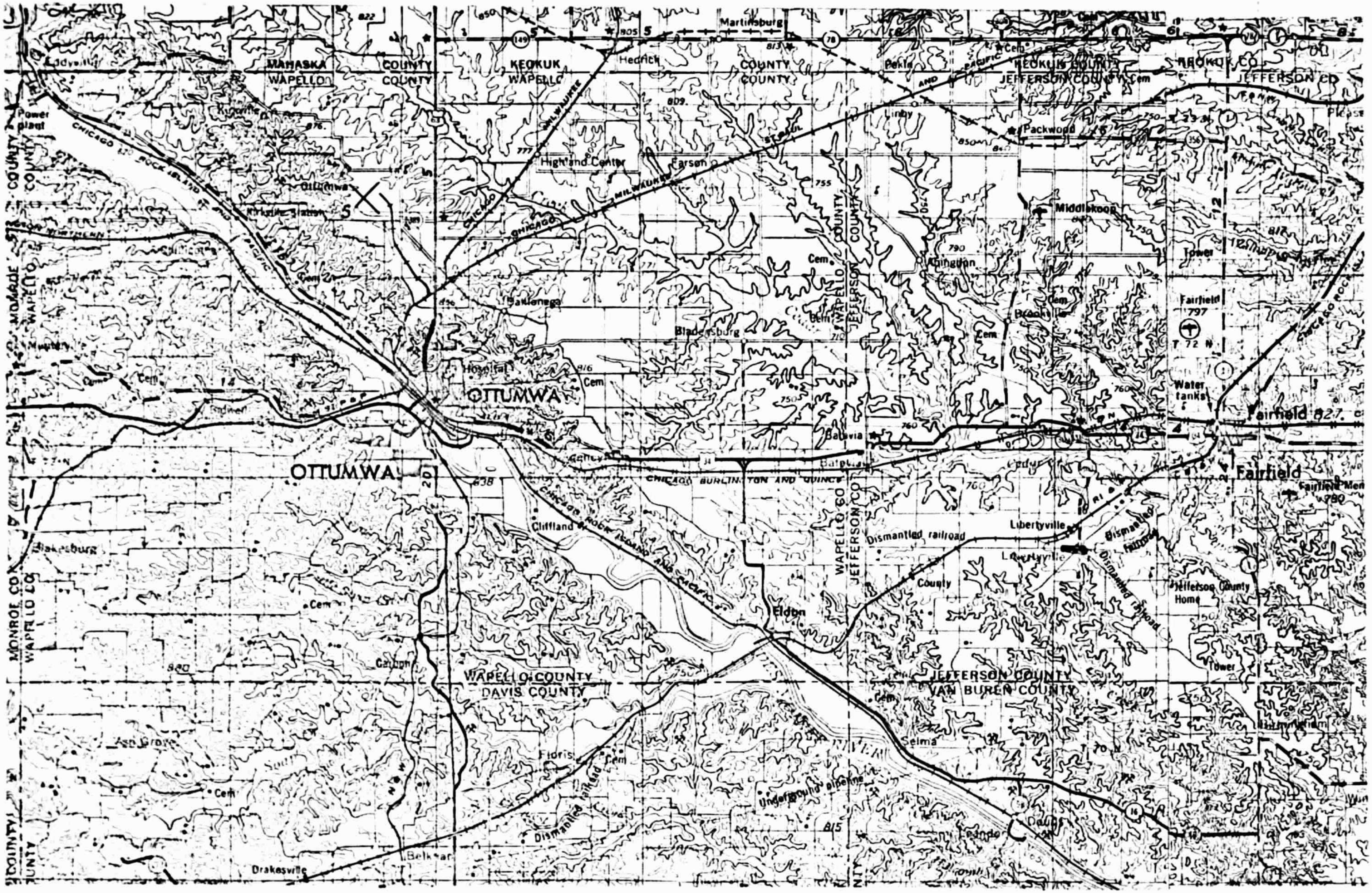


Figure 23 Location Map for Figures 20 and 21



USGS NK Map Series
Scale 1:250,000

Quadrangles used to produce this map: Centerville (NK 15-11), Des Moines (NK 15-8), Burlington (NK 15-12), and Davenport (NK 15-9)

Because a detailed discussion for different versions of these scenes were presented in the November 3, 1975 Type II report, only a brief discussion of the imagery will be presented here. A 29 August 1972 color print for southeastern Iowa scene is displayed on Figure 20. The image is roughly divided by the Des Moines River into two regions. The northeastern region is characterized by rolling topography which is highly productive farmland. The southwestern portion of the scene is composed mostly of hilly terrain developed on glacial till. Because this land is much less productive agriculturally, more forest and pasture land are present. Two major urban areas within this scene are Ottumwa (pop. 30,000) and Fairfield (pop. 8,000). Figure 21 contains a 15 April 1974 color print roughly covering the same area as Figure 20. This print distinctly displays some of Iowa's highly productive agricultural land. The dark bluish-black patterns are areas of flat farmland which have dark organic soils high in soil moisture. Farms in these highly productive areas are presently selling for over $2,000 an acre!

The major point of concern for both of these images, however, is that they have dominant blue-green hues within urban areas. They have blue-green hues because red has been subtracted by an abundance of cyan dye formed in the "red layer" of emulsion. Also, on the 29 August 1972 scene there are areas of strip mines, northeast of Ottumwa, that appear to have the same blue-green hue as certain agricultural fields. Because both of these scenes were processed to minimize the Optronics Film Recorder saturation, they demonstrate that the blue-green saturation problem is not related to the Optronics hardware and 2474 film characteristics.

Discussion and Summary of the Blue-Green Saturation Problem

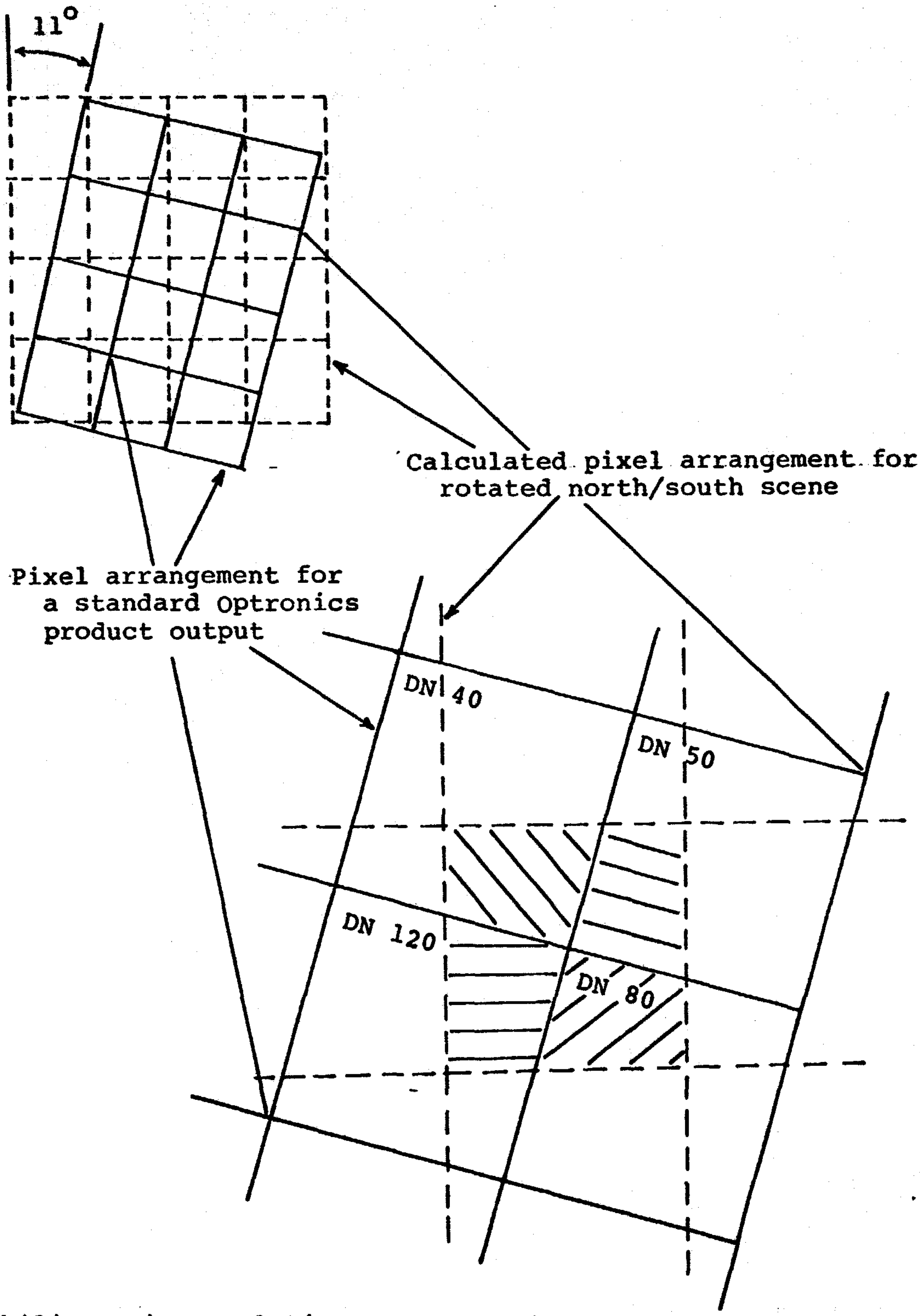
The blue-green saturation problem is a result of the characteristics of the black and white film products which are printed onto the color composite film. When bands 4 and 5 are contrast stretched with the upper reflectance values being truncated to white, the resultant black and white film products display urban areas as low optical density land cover. Concrete and light colored roof tops account for the high reflectance nature of these cultural features. Bands 6 and 7, however, record low reflectance values for these same cultural features. The film densities recorded for the urban areas are much greater on the black and white film positives for the same urban areas. When a false-color composite is generated from these black and white positives, the bands are registered and individually printed onto a sheet of color film. Band 4 is printed with blue light, band 5 is printed with green light, and band 6 (or 7) is printed with red light. For the urban areas on bands 4 and 5, much silver halide will be activated in the corresponding emulsion layers, meaning that not much yellow or magenta dyes will be formed. Band 6 (or 7), which displays urban areas as dark tones, prevents red light from reaching the "red emulsion layer". Consequently little silver halide is activated and much cyan dye is produced. Because little yellow and magenta dyes are produced for the urban areas, much blue and green light will be reflected from a color print. The cyan dye for band 6 (or 7) will absorb the red light being reflected from a color print, thereby causing the urban areas to be dominated by blue-green colors. A summary of this discussion is outlined on Figure 23-A (p. 47).

Computer Rotation North/South of a Landsat Scene

Both scenes shown in Figures 20 and 21 have been geometrically rotated north/south during the image enhancement process. In the JPL VICAR (Video Image Communication And Retrieval) System the program ROTATE2 was utilized to accomplish the rotation. The angle of rotation was determined by hand measuring with a protractor the angle which scene cultural features deviate from north. This angle (11 degrees for the southeastern Iowa scenes) was used as the rotation angle parameter by the computer to superimpose a new grid or pixel network over the original JPL picture element arrangement (see Figure 24). Through a bilinear interpolation process, new digital numbers were calculated for all the pixels in the rotated scene. Each new DN value was determined by assessing the digital number values of the four nearest picture elements contained in the original JPL scene. In Figure 24 the solid lines of the grids represents the pixel arrangement for the standard JPL scene. The dashed lines represent the pixel arrangement for the rotated north/south Landsat scene. In the enlarged portion of the pixel arrangements, the picture element which is cross-hatched is used to demonstrate how the four surrounding pixels are used to determine the value of the rotated picture element. The bilinear interpolation technique weights by area the contribution of

Figure 24

Pixel Arrangements for a Computer Rotated North/South LANDSAT Scene



The bilinear interpolation process weights by area the contribution of the four surrounding pixel's DN values in order to calculate the DN value for the rotated pixel (shown in different cross-hatch patterns).

these four pixels (DN 40, 50, 120, and 80) to calculate the DN value for the rotated pixel (DN 75). To accomplish this rotation for a full frame JPL scene, this operation of utilizing four pixel values to calculate one rotated value pixel value must be carried out on a 2340 by 2340 matrix for each spectral band.

Although the geometrically rotated north/south scenes are aesthetically pleasing, there are disadvantages which must be considered. 1) The recalculation of all DN values through the bilinear interpolation process consumes much computer time thereby making this operation relatively expensive. 2) Because the original spectral data is lost through the recalculation of DN values, it is questionable whether machine classification results will be valid. 3) The bilinear interpolation process causes road networks to become less distinct than on a standard JPL enhanced product. 4) Pixel drops (which are the small yellow dots on the 29 August 1972 scene--Figure 20) are enlarged by the recalculation process to cover from 2 to 4 pixels instead of one. 5) The reaction of the regional planners at the Area XV Regional Planning Commission in Ottumwa, Iowa was that a photographically oriented north/south scene is just as useful for their purposes as a computer rotated scene.

Photographic Consideration in the Production of a Landsat False Color Composite

Before a false-color negative can be printed, the Optronics black and white positive transparencies must be registered as a set. To facilitate registration, images are processed by a

VICAR applications program called MASK which adds a scene border with registration tic marks, gray scale, and annotation. Because only bands 4, 5, and 6 are used to produce the images in this report, band 7 was not registered. The equipment for registering transparencies consists of a light table, registration punch, and a magnifying eyepiece. The black and white positive transparencies are individually registered to the VICAR generated mask, punched, and removed from the light table.

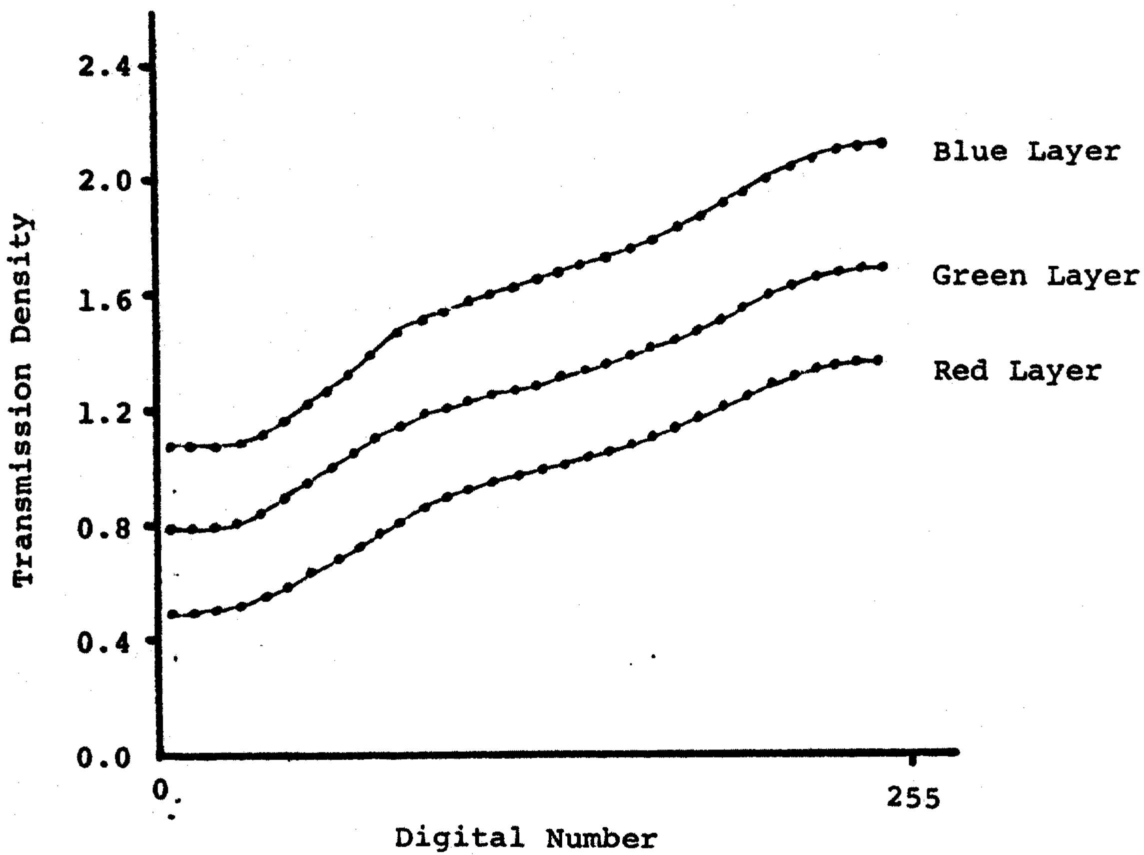
The printing of the black and white transparencies onto color negative film is accomplished at JPL by using a contact frame with registration pins mounted on the bed, a point-light source with a filter wheel, three primary filters and filter selector, and a timer for the light source. The first step, however, in producing a false color negative requires the registration of the MSS band 4 (green spectral band) to the contact frame via the mounting pins on top of a sheet of Kodak 4108 Vericolor II--Type L film. The film and the black and white transparency are exposed for a predetermined time to blue light through a Wratten #47B primary filter. Band 4 is removed from the contact frame and is replaced by band 5 (red spectral band) which is registered and exposed to green light through a Wratten #61 green filter. Band 5 is then removed, being replaced by band 6 or 7 (infrared spectral band), which is registered and exposed to red light through a Wratten #29 red filter. When this procedure is completed, the exposed Vericolor II film is removed and processed to form a color negative transparency.

To determine the response of the Vericolor II film to the Shellburst 2474 film, a 32 step density wedge was produced on the JPL P-1500 Optronics. The 32 densities which were produced on the step wedge corresponded to specific digital numbers starting with DN 0 and sampling every eighth DN value to DN 255. This black and white positive wedge was printed onto a Vericolor II, Type L color negative film. Figure 25 displays the digital number versus transmission density relationship for this film (Table 3 lists the data used to generate these curves). Although all three layers do not possess an exact linear relationship between densities and digital numbers, the response of the Vericolor film will allow the recording of all densities found on the Kodak 2474 film. In other words, no spectral data is lost from printing the Optronics black and white film product onto the Vericolor II, Type L color negative film.

The 32 density step wedge which was printed onto the Vericolor II film was in turn printed onto the Kodak 37 RC color photographic paper. Figure 26 illustrates the digital number versus reflection density relationships for this paper (Table 4 displays the data used to generate these curves). The 37 RC paper displays almost the same saturation characteristics (that is, the same lack of discernable density variation with change in digital number) as the Kodak 2474 film used in the Optronics film recorder (see Figure 19). For low reflectance values, saturation occurs from DN 0 to about 32, while at the high reflectance end of the curve the saturation begins at approximately DN 231 extending to 255. A comparison of the 37 RC and

Figure 25

Digital Number versus Transmission Density for the Optronics P-1500 Positive Step Wedge Printed onto Vericolor II, Type L Color Negative Film



Photographic Curve Generated by Ron Wichelman at JPL

Table 3

Data for Figure 25, Digital Number (DN) versus Transmission Density for the Optronics P-1500 Positive Step Wedge Printed onto Vericolor II, Type L Color Negative Film

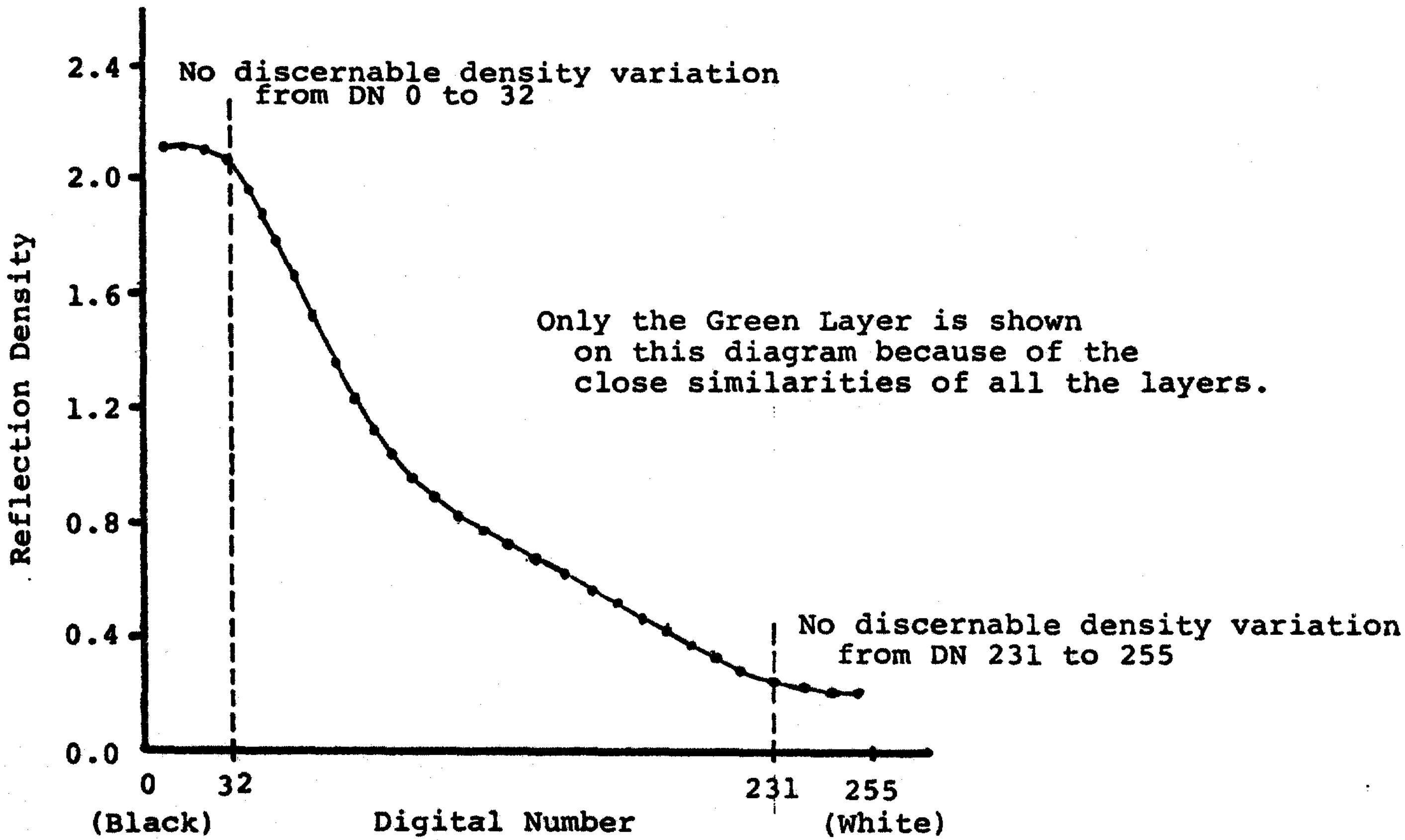
Data Used for Curve

Data Generated By
Ron Wichelman at JPL

Digital Number	Transmission Density		
	Red Wratten #29	Green Wratten #61	Blue Wratten #47B
(Base + Fog)	0.10	0.38	0.67
8	0.49	0.79	1.08
16	0.50	0.79	1.09
24	0.50	0.79	1.08
32	0.52	0.81	1.08
40	0.54	0.84	1.12
48	0.58	0.89	1.17
56	0.63	0.95	1.23
64	0.67	0.98	1.27
72	0.73	1.05	1.34
80	0.78	1.10	1.42
88	0.82	1.14	1.48
96	0.86	1.18	1.52
104	0.90	1.20	1.55
112	0.92	1.23	1.59
120	0.95	1.25	1.61
128	0.97	1.27	1.63
136	0.99	1.29	1.66
144	1.01	1.32	1.69
152	1.03	1.33	1.71
160	1.06	1.36	1.74
168	1.08	1.39	1.77
176	1.10	1.41	1.80
184	1.14	1.44	1.84
192	1.17	1.47	1.87
200	1.20	1.50	1.91
208	1.25	1.55	1.96
216	1.29	1.59	2.01
224	1.32	1.63	2.04
232	1.35	1.66	2.08
240	1.36	1.67	2.11
248	1.37	1.68	2.12
255	1.37	1.69	2.12

Figure 26

Digital Number versus Reflection Density for the Vericolor II, Type L 32 Step Wedge Printed onto Ektacolor 37 RC Photographic Paper



Photographic Curve Generated by Ron Wichelman at JPL

Table 4

Data for Figure 26, Digital Number (DN) versus Reflection Density for the Vericolor II, Type L 32 Step Wedge Printed onto Ektacolor 37 RC Photographic Paper

Data Generated By Ron Wichelman at JPL

Digital Number	Reflection Density Red Wratten #29	 Green Wratten #61	 Blue Wratten #47B
8	200	214	221
16	200	212	221
24	198	210	221
32	196	207	220
40	186	195	210
48	172	179	195
56	158	164	177
64	146	150	163
72	131	134	144
80	114	117	124
88	101	104	109
96	91	96	98
104	83	90	92
112	75	83	83
120	70	78	79
128	66	75	74
136	59	69	69
144	55	65	63
152	51	61	59
160	46	57	55
168	42	53	51
176	38	48	44
184	33	44	40
192	30	40	36
200	26	35	32
208	22	31	29
216	19	28	26
224	18	25	24
232	17	23	23
240	17	22	22
248	16	21	21
255	16	22	22

2474 density versus digital number curves is shown on Figure 27. It is interesting to note that the 37 RC curve indicates that the color photographic paper has a greater contrast range for lower reflectance digital numbers than for high reflectance values. Lower reflectance land cover should consequently possess greater tonal variations than high reflectance cover.

Contrast Stretch Strategy to Eliminate the Blue-Green Saturation Problem

In order to fully eliminate the blue-green saturation problem, contrast stretching with no saturation must be employed. This means that no original data will be thrown away through truncation. To assess the full Landsat band data distribution, the spectral histograms must be examined. In some instances, however, the full data distribution may not represent the correct data range for the scene in question. If picture elements in a computer tape are "bad", that is they are not real spectral reflectance values but are dropped values that were introduced during the generation of the computer tape itself, they appear as extreme values--DN's of 0 or 255. These pixel drops obviously should not be included in assessing the spectral data range. Once the data range is determined, it is recommended that the stretch bounds be set at DN 1 to DN 254. The assessed data range should then be expanded only to fill the entire dynamic range without truncating any DN values.

The data range for the bands of 29 August 1972 scene are listed below:

Band 4	DN 36 to 254
Band 5	DN 16 to 254
Band 6	DN 0 to 230.

Figure 27

Comparison of 37 RC and 2474 Density Versus Digital Number Curves

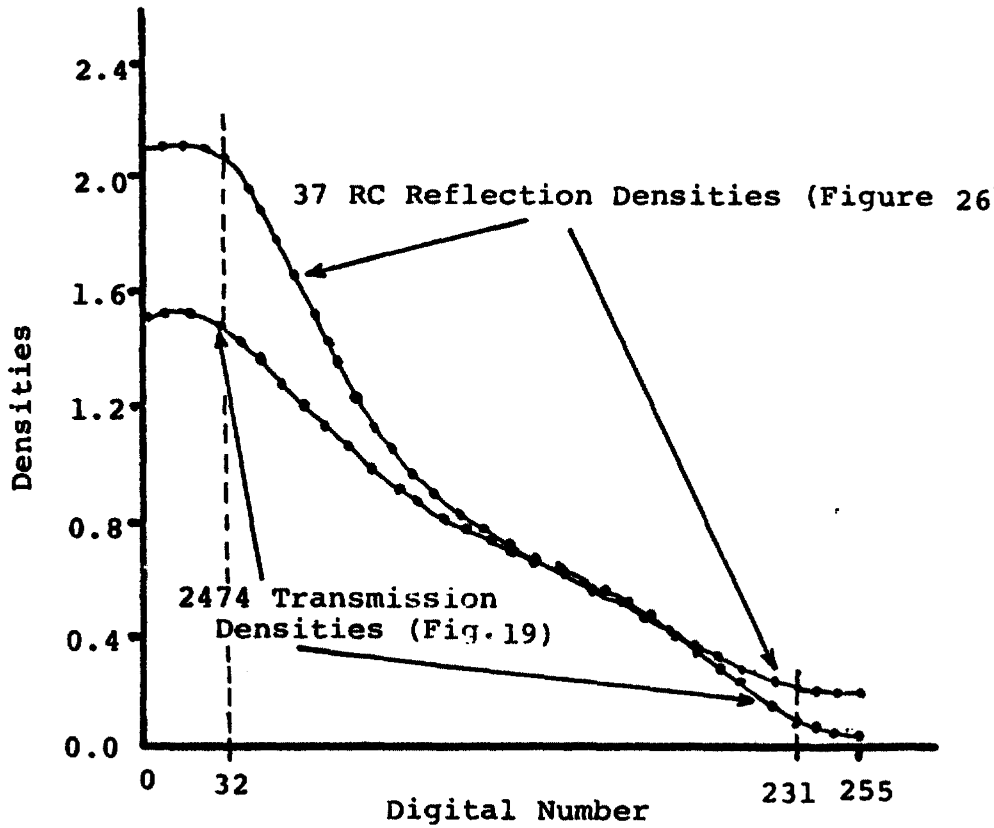


Figure 23-A

Illustration of the Blue-Green Color Domination for Urban Areas on a Computer Enhanced Satellite Image

Landsat Spectral Band	Urban Scene Characteristics on enhanced Landsat black and white film products	Colors Produced on color film dye layers for urban areas when a color composite is generated from black & white film products	Light Reflected from color print for urban areas
#4	Light (little density)	Little Yellow Dye Formed	Lots of Blue Light Reflected
#5	Light (little density)	Little Magenta Dye Formed	Lots of Green Light Reflected
#6 (or 7)	Dark (lots of density)	Lots of Cyan Dye Formed	Little Red Light Reflected

RESULT: BLUE-GREEN DOMINATION IN URBAN AREAS

The contrast stretch bounds for all bands will be DN 1 to 254. Because the upper limit (254) is filled in bands 4 and 5, only the lower stretch bound has to be employed. In band 4, DN 36 is stretched to DN 1, while in band 5, DN 16 is stretched to DN 1. Band 6's data range shows that only the upper stretch limit must be employed--DN 230 stretched to 254.

The resulting images which will be produced by utilizing this contrast and bands 4 and 5 with more tonal detail in the high reflectance areas than the bands that were produced with truncation of data. It is anticipated that the color composite generated from these black and white bands will not possess the blue-green saturation problem.

Support of NASA's Landsat Program by Director of Area XV Regional Planning Commission

Although the major objective of the NAS5-20832 contract is to generate a series of land classification maps for southeastern Iowa from computer enhanced images, the ultimate success of the project depends on the adoption and use of these Landsat derived products by regional planners. Included in this report is a letter from Bruce Bullamore, Director of the Area XV Regional Planning Commission, to Richard Blackwell, Acting Task Manager of the Earth Observation Programs at the Jet Propulsion Laboratory. The contents of this letter are self-explanatory.

Funds Expended

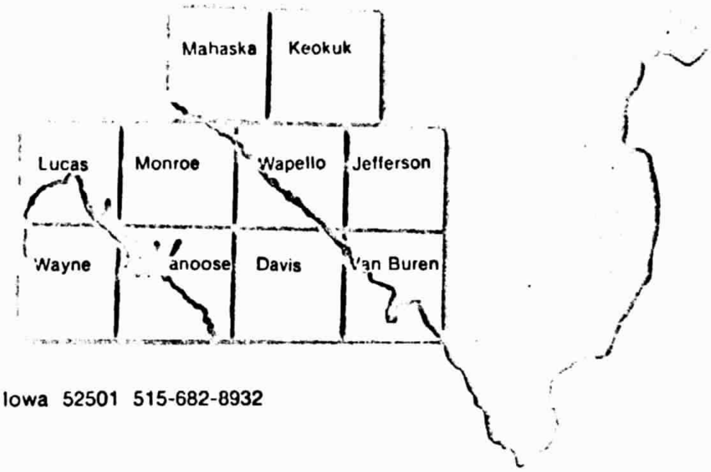
Table 5 summarizes the budget allotted by NASA and the funds expended in execution of contract NAS5-20832. The total funds expended by the Iowa Geological Survey during the first

AREA XV

REGIONAL

PLANNING

COMMISSION



Building #46 Ottumwa Industrial Airport Ottumwa, Iowa 52501 515-682-8932

June 18, 1976

Mr. Richard Blackwell
Acting Task Manager
Earth Observations Program
Jet Propulstion Laboratory
4800 Oak Grove Dirve
Pasadena, California 91103

Dear Mr. Blackwell:

The Area XV Regional Planning Commission would like to express its deepest appreciation for the Land Classification Study which used enhanced Landsat image that are being conducted in our area. As a result of this study, not only has our staff expanded its appreciation of the Landsat programs and their applications, but we have been able to come up with techniques for using Landsat information in our long-range and day-to-day planning programs which makes it possible to make rational decisions concerning land use planning and management from a set of relatively complex data bases. The major advantage of the Landsat information is that it allows us to inexpensively evaluate changing conditions and to portray those changing conditions through the use of imagery to relatively non-technically oriented policy makers. Thus we are able to develop a heuristic model capable of dealing with issues in land management in a relatively inexpensive manner.

In my opinion, if regional planners and aerospace scientists could sit down to decide how to fully utilize those Landsat processes which are already proven and how to integrate them with other natural inventory data systems, the resulting system based on Landsat imagery could revolutionize land use planning in this country. Perhaps the two reasons planners have not fully utilized Landsat information sytems is the lack of technically understandable systems on the part of planners themselves; and the somewhat indefinite nature of the availability of NASA information to state and local agencies.

Certainly a formal committment by the federal government to follow on Landsat programs would do much to alleviate this. But beyond that, there is a need for a definable set of policies as to what role NASA, JPL, and the EROS Data Center might play in assisting regional and state agencies in developing their own Landsat systems.

I think future demonstration projects in the nature of this one could be conducted in other regions in the United States with the assistance of people like Jim Lucas, who obviously has an understanding of the technical aspects of the Landsat system. People such as Mr. Lucas are extremely helpful in getting broader recognition and eventually broader applications for the Landsat systems.

As a side note, I would like to point out that one factor which is centrally important in expanded applications of Landsat systems is that of appreciation of key state agencies of the Landsat system and what they have to offer. Since most of the hardware and software equipment needed to carry on Landsat analysis on an ongoing basis is beyond the capability of the majority of regional planning commissions the key to further use has to lie with state agencies, or perhaps state associations of regional planning commissions. In this respect there is a great need for further intensive application training sessions with state officials. This should be conducted by people from the JPL, EROS Data Center, or other NASA agencies.

What I hope is that this study can be reviewed, not as a highly technical document pointing out the ultimate applications of Landsat imagery and land use planning, but as a document that would show the possible types of advantages and applications that the Landsat information system would have in local planning.

This agency, for one, is deeply appreciative of the services which NASA and JPL have rendered us in allow these studies to be conducted here.

Sincerely,

Bruce W. Bullamore
Executive Director

BB:kb

TABLE 5
BUDGET ALLOTTED BY NASA AND FUNDS EXPENDED BY IGS

Contract NAS5-20832

Land Classification of South-Central Iowa from Computer Enhanced Images

Contractor:

Iowa Geological Survey
123 North Capitol Street
Iowa City Iowa 52242

Element of cost	Budget Allotted by NASA	Expended Funds by IGS to Date
Salary for Project Manager Based on 16 months	$16,874.00	$12,328.00
Employee Benefits for Project Manager	2,038.00	1,339 48
Travel Related to Project-Transportation	2,400.00	1,386.27
-Per Diem	1,600.00	842.73
Expendable Materials and Photographic Supplies	863.00	696.36
Publication Expense	5,000.00	3,034.68
Subtotal	$28,775.00	$19,627.52

Funding to the Jet Propulsion Laboratory (JPL) by NASA

Salary for JPL Scientific and Technical Staff and Computer Processing Time	20,000.00	Billed to NASA by JPL directly
Total Funding by NASA for Contract NAS5-20832	$48,775.00	

Payments Received to February 3, 1976 by IGS from Government..........$19,627.52

4 quarter are $19,627.52. IGS has been reimbursed for the total amount by the government.

Conclusions Concerning the Cyan Saturation Problem for the JPL Computer Enhanced Products

1. Contrast stretching techniques that involve saturation portions of the spectral histogram should be used very carefully if at all. Very small portions of extreme reflectance values provide much tonal detail in critical land cover categories such as urban areas.
2. The System P-1500 Optronics Photowrite should be used so that low and high DN value discrimination can be recorded on the 2474 film. This means that a smaller dynamic range will have to be used to assure that all densities will be recorded on the 2474 film. Also, by using this compressed dynamic range, all density values recorded on the Optronics black and white film can be printed on the 37 RC paper.
3. The blue-green saturation problem can be eliminated by contrast stretching the spectral bands without truncation of data. In order to determine the data range for this type of contrast stretch, it is imperative that spectral histograms be provided for the original data. The resulting enhanced images should have less contrast for the IR bands (both 6 or 7), and more tonal detail in high reflectance area for bands 4 and 5. The color composites produced from these black and white positive film products should not have the blue-green saturation problem.