WASHINGTON STATE

DEPARTMENT OF ECOLOGY

LANDSAT APPLICATIONS FEASIBILITY STUDY

by Charles A. Gregory, Jr.

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Introduction

During August 1979, discussions were held between the Washington State Department of Ecology (DOE) and a representative of the Pacific Northwest Regional Commission (PNRC), Task Force for the Landsat application program, concerning the Landsat program and funding possibilities. A grant was received from the PNRC in September 1979. Further discussions were held between DOE and a member of the Task Force from NASA-AMES research center at Moffett Field, California, to delineate responsibilities and tasks to be performed.

Objectives

There was a need to develop accurate overlays and acreage measurements showing present water usage within the Deadman Creek Drainage Basin in Spokane County, Washington. There was also a need to develop a cost-effective methodology to monitor yearly increases in water usage and to verify surface water diversions for adjudication proceedings.

Accurate identification and measurement of the above-mentioned factors are needed for input into computer studies of the state's water resources. This study is to determine the feasibility and cost-effectiveness of using Landsat imagery for determination of water usage within Washington State. Included within the objective is the training of user personnel in all analysis techniques so that continuing operational use of the techniques will be provided, upon completion of the study, should accuracy levels and cost-effectiveness be proven.

These initial objectives were also used in a second test location within the total Landsat scene, but located in the Odessa ground water subarea in Adams County, Washington.

Informational Requirements

The following for both test locations:

1. Identification of various water uses
2. Determination of irrigated acreage
3. Identification and measurement of annual changes in irrigated acreages
4. Identification of sources for various water uses
5. Identification of crop type, measurement of crop type acreages, and water demand estimated
6. Determination of acreages for urban and nonirrigated lands

Initial Workshop

Four members of the Washington State Department of Ecology attended a workshop at Moffett Field, California in the NASA, AMES Research Center to determine the applicability of the technology to their various job requirements. The members of the team represented the Water Resources Policy Development Section, the Water Right Adjudication Section, the Water Resources Management Section, and the Eastern Regional Office. Landsat scene (E-30508-18025) of July 26, 1979 was used for all training, since it was cloud free over the Deadman Creek area. For computer purposes the test window of the Deadman Creek drainage basin was named SCAT 40N. Visual display of the image was accomplished through the use of the IDIMS system on a Cathode Ray tube (CRT).

NASA-AMES personnel generated two classifications of the test window, one of 20 groups and the other of 40 groups. This was accomplished by utilizing the spectral signature of each pixel and having the computer group the pixels into either 20 or 40 groups. Line printer maps of these clusterings were also generated so that distinct groups could be determined during analysis when not using the computer. The 40 clustering was used to classify the window, since the 20 clustering was determined to be too narrow. The 40 clustering was regrouped into 13 color-coded groups on the computer with color slides taken of each coding along with one dicomed of the entire test window and generation of new line printer maps of the new coding.

The total scene covered an area greater than expected by the team members. A second test window was chosen and named Lind Coulee. No prior data or printouts had been obtained so a quick supervised classification was obtained for analysis after departure from the workshop. Color slides and a line printer map of the new window were also generated for analysis. The ground truth for the new window was unknown except for the fact that center pivot irrigation was the subject of analysis of this window as opposed to that of the Deadman Creek window. Orientation within both windows was maintained by comparison with color infrared positive photos flown by a U-2 aircraft on July 13, 1978.

Initial Products Received

Transparencies of bands 4, 5, 6, 7, a false color composite and large prints of the false color composites for scenes E-21619-17562 and E-30508-18025 along with a line printer map of the Deadman Creek window were distributed by the NASA-AMES personnel. A roll of U-2 color infrared transparencies which covered most of Eastern Washington was received and used for comparative analysis. Colored 35 mm transparencies of the color-coded computer enhanced window images were taken by the NASA-AMES analyst for continued analysis.

The analysis consisted of verifying acreage estimates of each classification by using 7.5 minute quadangle maps, the U-2 positives, the large false color composite photograph and the slides of the Deadman Creek Basin. The line printer map was colored as to the regrouping symbols of the spectral signature of the groups which was then compared with the slides, and quad maps for correct area coverage and inconsistencies

caused by topographical changes. It was decided that a pixel count by class was necessary to determine the quantification of acreages per cluster group within the classification. Analysis of the slides taken of Lind Coulee consisted of obtaining a ground truth of the area and matching this information to the slides.

Second Workshop

During a second workshop, a printout of the pixel count by group was obtained for the Deadman Creek drainage basin. A pixel represents approximately .803 of an acre. By multiplying the pixels per grouping by .803, the number of acres per group was determined to be:

Irrigated acreage	147 acres	Pasture	6,315 acres
Conifer trees	48,354 "	Dryland crops	15,172 "
Deciduous trees	1,548 "	Urban	194 "
Scrub pine	3,276 "	Water	55 "
Bare soil	3,198 "	Subirrigation	459 "

The Lind Coulee test window consisting of 1,024 pixels to a side was classified using a ground truth obtained from an agronomist managing the cropping within a subwindow called Phillips, the NASA-AMES personnel had obtained a line printer map based on an unsupervised classification using a 30 classification. The line printer map was used to determine the boundaries for the subwindow (scene coordinates 415, 715, 210, 210). The EDITOR system was used to determine the shades of gray which resulted in a printout which helped to determine the reflectance variation between the crops being grown.

A supervised classification of the Phillips window was conducted using the 30 classification and grouping these reflectance levels into like groups which became 10 categories with each category being designated by a unique color. The 10 categories were matched to the ground truth and fit it exactly.

The subwindow was moved to scene coordinates 127, 411, 400, 415 which was named Schrag. The computer was given the same commands as for the Phillips subwindow. The colors appeared on the CRT and were checked against a ground truth of area under scrutiny. The match was perfect, except for one circle which had not been classified in the Phillips subwindow, because the crop did not exist in that ground truth.

The additional subwindows were selected and classified from the Lind Coulee window, so that a detail of the entire window could be obtained. They were named Providence (scene coordinates 510, 315, 430, 120), Moody (scene coordinates 1,513, 285, 512) and Wheeler (scene coordinates (1,1,285,512), respectively.

The entire window was shifted north 1,024 pixels and named Odessa. The computer was told to classify the window according to the categories obtained for Phillips. The computer colored the CRT as directed and the amount of a crop type known to be grown in this area was quite reduced from the amount anticipated. A reclustering from one category to another was accomplished with the resultant change on CRT of the window being in

an amount nearer to that anticipated. Dicomed positives, negatives, and polaroids were taken of each classification of this window along with each subwindow and window of Lind Coulee.

Products Received

A line printer map of the Phillips subwindow was used to determine the actual boundaries of the ground truth. Dicomeds of each window and subwindow were printed and enlarged for a more detailed analysis. A printout of the pixel count by category by subwindow was obtained for varification with the dicomeds.

Analysis (Refer to dicomeds attached or as listed in acknowledgments)

The pixel count by land-cover type by subwindow computed out to be as follows:

Color	Cover	Phillips Acreage	Schrag Acreage	Providence Acreage	Wheeler Acreage	Moody Acreage
Green	Potatoes	971	2,634	7,853	3,482	463
Blue	Wheat	4,768	11,966	19,163	23,973	2,670
Yellow	Sunflowers	1,073	1,267	3,669	1,601	260
Violet	Ripened wheat	161	793	1,009	607	560
White	Irrigated pasture	141	1,013	5,942	5,076	141
Sand	Dryland wheat	12,206	47,106	57,534	33,112	44,375
Red	Summer fallow	14,102	56,838	31,755	30,513	58,678
Gray	Water	45	50	1,528	988	27
Brown	Alfalfa	159	1,025	7,563	6,382	454
Black	Scablands	1,787	10,608	9,006	11,439	9,546
	Total Subwindow	35,413	133,300	145,022	117,173	117,174

The initial analysis of the dicomed as matched to the computer printout of pixel count substantially confirmed the ground truth for subwindow Phillips. However, it was noted when the enlargements were made that bright yellow did not print, so that it was necessary to draw circles with black ink to locate the center pivot irrigation of sunflowers on the dicomeds. The other subwindows were analyzed by comparing dicomed to computer printout and substantially agreed with each other. Some of the circle irrigation shown on the dicomeds did not print in a homogenous manner. Initially this interference was thought to be caused by improper farming techniques. Closer scrutiny using U-2 imagery in conjunction with the dicomeds indicated that this was probably not true. The interference between the pixels could possibly have been caused by the crop being lodged (laid down), the growth habit of the crop, elevational changes in the topography, cropping pattern, or improper pixel classification by the interpretation team.

Further interpretation revealed several center pivot irrigation systems that were grouped into the dryland wheat category. The failure to classify these circles into the irrigated crops was most probably caused by improper pixel grouping by the interpreters, lack of crop knowledge due to incomplete or faulty ground truth, or possibly elevation changes.

These center pivot acreages are delineated on the dicomeds in green ink. The blue ink circle on the Schrag and Lind dicomeds delineates a known irrigated onion crop that was not given a color designation by the interpreters as an oversight. Not all incorrectly classified center pivot systems will be shown by the ink circles, just selected or obvious circles. The crops grown on these circles could be onions, corn, or peas as examples.

The two dicomeds for the area named Odessa show that a reclustering of the pixels into the wheat category makes significant changes between the two dicomeds. Odessa No. 1 is the dicomed colored according to Phillips. In the approximate center of the frame are two groups of circles which do not classify as wheat. Odessa No. 2 is the reclustered dicomed which shows large additions of wheat across the window.

Deficiences Noted During Analysis

1. Clustering not as specific as required to identify crops accurately

2. Interference between pixel not rectified

3. Interpretation of imagery not as detailed as was necessary for complete accuracy of ground cover types

4. Complete and extensively detailed ground truth necessary prior to attempting to classify landsat scene

5. Interpreters should have a statistical analysis background

6. Interpreters should have photo interpretation background

Landsat Applications by Represented DOE Section

Adjudication Section: Landsat could be used for large projects to identify irrigated acres, identify crop type and convert to water consumption, and discern between ground water or surface water irrigation. Within small basins, Landsat would take more time due to ground truth requirements, because when field investigations are complete, the information needed would be complete. The best method for using Landsat within this section would be for the estimation of time requirements for planning purposes and field involvement.

Eastern Regional Office: Landsat could be used to determine irrigated acreages and crop types which could then be computed into a consumption figure, which would in turn compute into an average withdrawal figure for a particular basin. Used in conjunction with present field operations, Landsat could assist in determining nonregulated expansion of irrigated lands.

Water Resources Management Section: Landsat imagery could assist in the determination of irrigated acres as to source of water. Crop types could be determined which in conjunction with annual application rates would give an amount of water use. Current field methods and U-2 imagery interpretation could be augmented by Landsat data verifications.

Water Resources Policy Development Section: Our own initial efforts indicate that Landsat does provide reliable data on irrigated land area and crop types leading to accurate estimates of existing water use. Existing use quantities, together with minimum flow information and other hydrologic data, is used to determine the quantities of water available on a firm basis for further allocation in basin management plans.

In addition, the use of landsat scenes as visual aids in meetings, workshops, and hearings has been found to be beneficial for general information. These scenes, when properly interpreted, help provide an understanding of the spatial relationship of water and land resources and their various uses.

Costs of Landsat

Computer compatible tape of Landsat scene	$200 each
Dicomed of scene produced from CRT	40 each
EDITOR	7/min.
IDIM	40/hr.
IDIMS w/analyst	80/hr.
U-2 Flight	2,000/hr.
U-2 Photos	2/lin. ft.
U-2 Photo single-frame	15 each
Enlarged false color image print	50 each

Project Cost (not including per diem, travel, salaries, or match):

1 Computer compatible tape	200.00
20 Dicomeds	800.00
10 Min Editor	70.00
30 hr. IDIMS 2/analyst	2,400.00
1 roll U-2 Photos (no flight)(approx. 184 ft.)	368.00
10 sets Dicomed enlargements	1,144.50
2 False color images	100.00
	$5,082.50

Summary

Based upon this study, the use of Landsat scenes to provide data on water use within Washington State is feasible. Landsat can provide the data necessary to accomplish the objectives of the represented offices, as long as a current, correct, and detailed ground truth is available. An initial unstated objective of the study was to cut down the amount of field time necessary to accomplish the objectives within each office. Had this objective been met, per diem and travel expenses would have been reduced with the appurtenant savings offsetting the cost of Landsat. The ground truth requirement does not change the amount of field time required, so that costs would be higher using Landsat for verification of field data. This does not preclude the use of Landsat as a valuable tool for the collection of water use data for planning, managing, or legal purposes.

ACKNOWLEDGMENTS AND NOTES

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Don Wilson	Technology Applications Branch, NASA-AMES
Bob Wrigley	Technology Applications Branch, NASA-AMES

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C. A. "Greg" Gregory, Jr.	Water Resources Management Section, Olympia
Jim Lyerla	Eastern Region Office, Spokane
Ken Slattery	Water Resources Policy Development Section, Olympia
W. Ben Turner	Water Right Adjudication Section, Olympia
Dannie Weis	Eastern Regional Office, Ephrata

The cost of including prints of the dicomeds with each copy of the study prohibited their inclusion. Copies of the dicomeds can be reviewed at the following locations:

Technology Applications Branch	NASA-AMES Research Center Moffett Field, California
Pacific Northwest Regional Commission	700 East Evergreen Blvd. Vancouver, Washington
Headquarters, Department of Ecology (WRMS)	St. Martins College Olympia, Washington
Eastern Regional Office, DOE	East 103 Indiana Spokane, Washington

GLOSSARY

Bands 4,5,6,7 - Multispectral Scanner Data for the Electromagnetic Reflectance of Energy for Colors: Visible Green (Band 4), Visible Red (Band 5) Invisible Solar IR (Band 6) and Invisible Solar IR (Band 7).

Clustering - The Grouping or Sorting of Pixels into Corresponding Multispectral Reflectance.

Dicomed - An Image Produced by Dicomed 47 Image Recorder.

False Color Composite - The Superposed Color-Coded Layers in the Film Emulsion, Each Representing a Separate Spectral Wavelength of Electromagnetic Radiation Detected by the Sensor.

Ground Truth - The Knowledge of What was Present on the Ground in the Area of the Scene at the Time of Flyover.

Landsat - Originally Named Earth Resources Technology Satellite. Renamed Landsat in 1975.

Line Printer Map - A Computer Generated, Number Coded Distribution of Pixel Reflectances Produced as a Printout to be Used for Comparison with Quad Maps.

Pixel - A Picture Element of the Landsat Scene Covering Approximately .803 Acres on the Ground.

Reflectance Levels - The Various Levels of Electromagnetic Radiation as Reflected by the Earth's Surface or Land Cover.

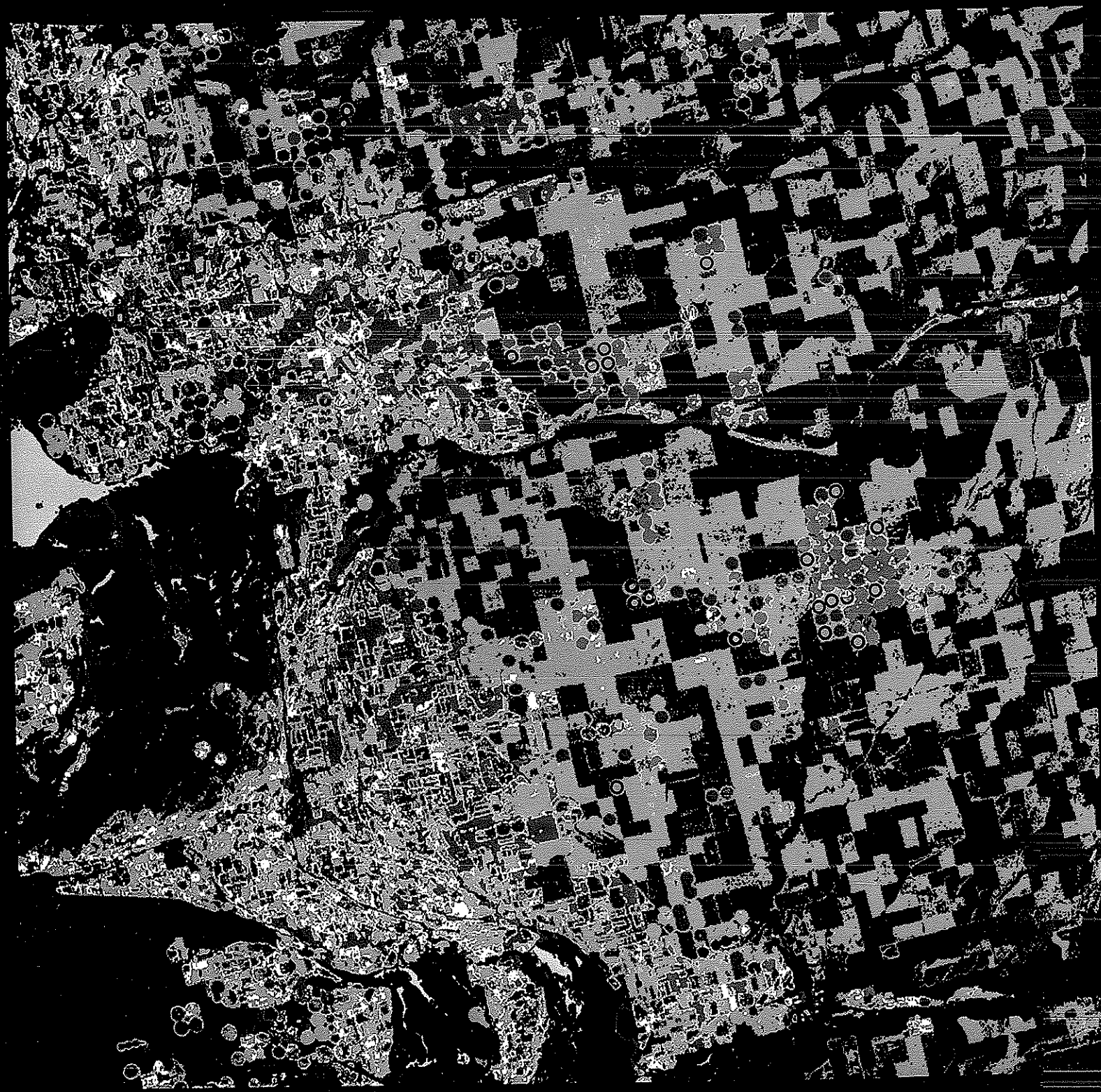
Scene Coordinates - The Digitized Coordinates Used Within the Scene by the Computer to Locate the Corner of a Test Window or an Individual Pixel.

Spectral Signature - The Level of Reflectivity or Emissivity of a Particular Pixel When Compared to Others Within the Scene.

Supervised Classification - An Analyst Controlled Computer Classification Based Upon Obtained Ground Truth.

Test Window - A Training Field Within the Total Landsat Scene Used to Determine the Statistical Characteristics of the Represented Pixels.

30 Classification - A Computerized Classification of the Test Window Without Ground Truth Knowledge or Analyst Input, Other Than Instructions to Classify Window to 30 Groups of Pixels and to Continue Iterations Until Instructions are Completed.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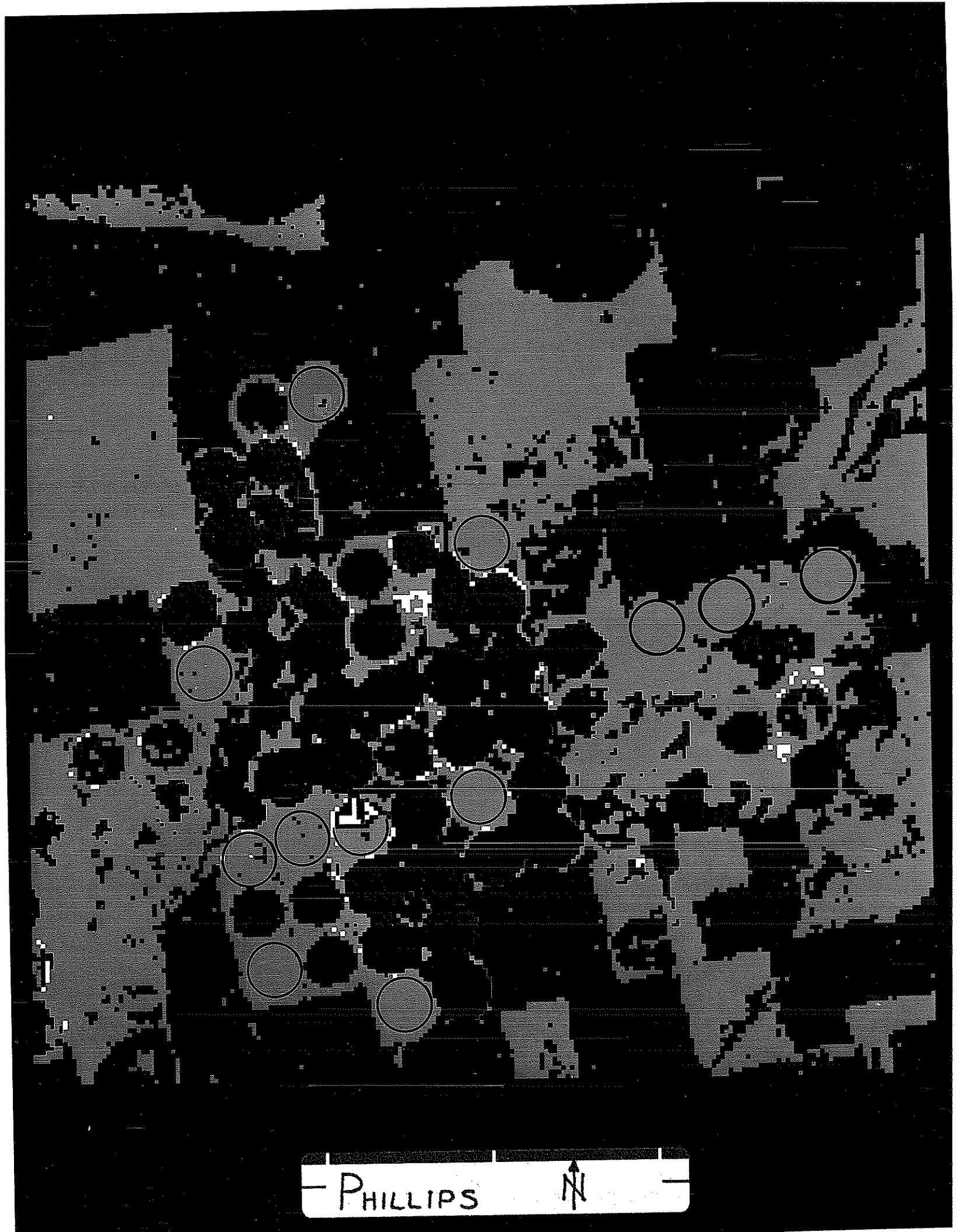
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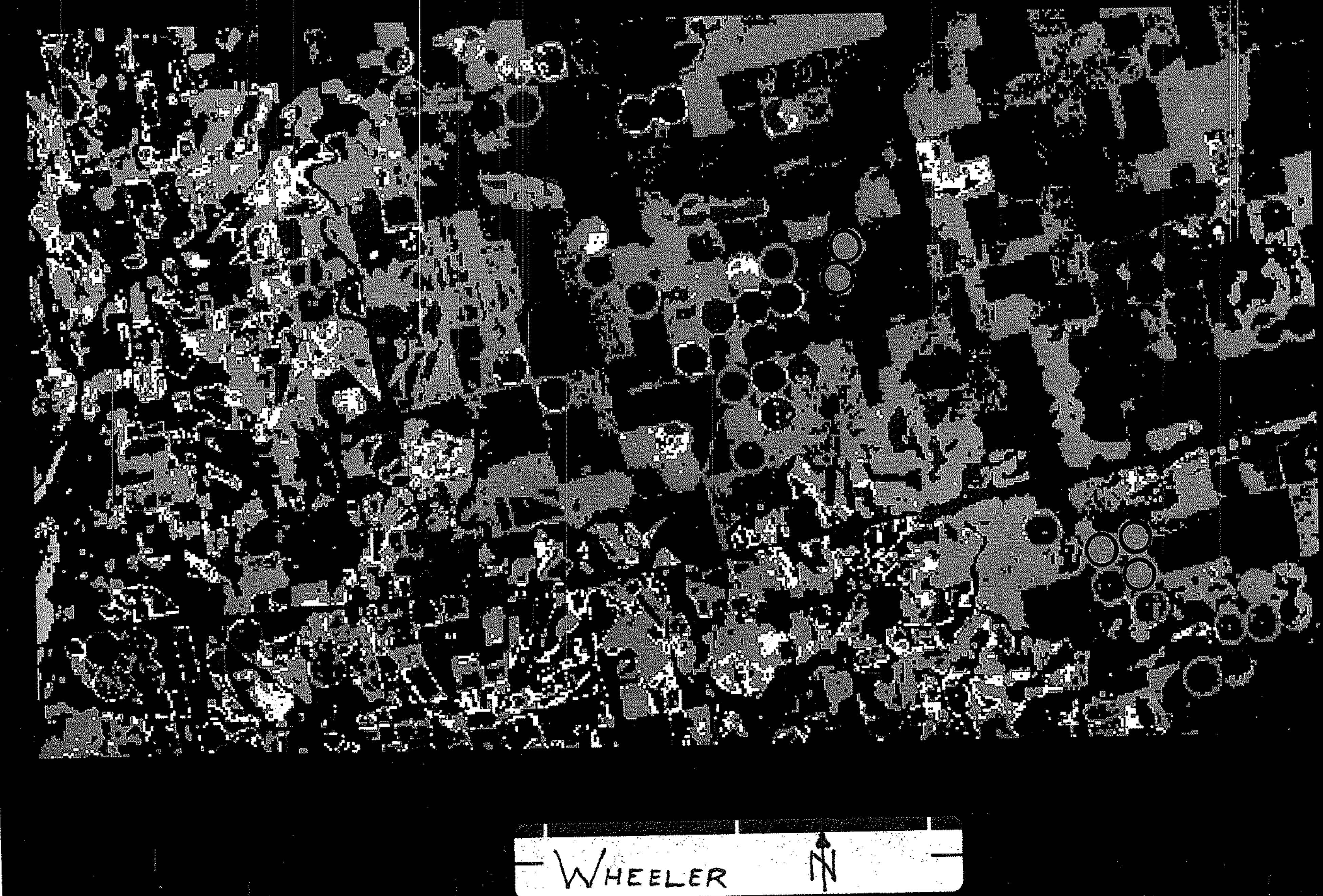
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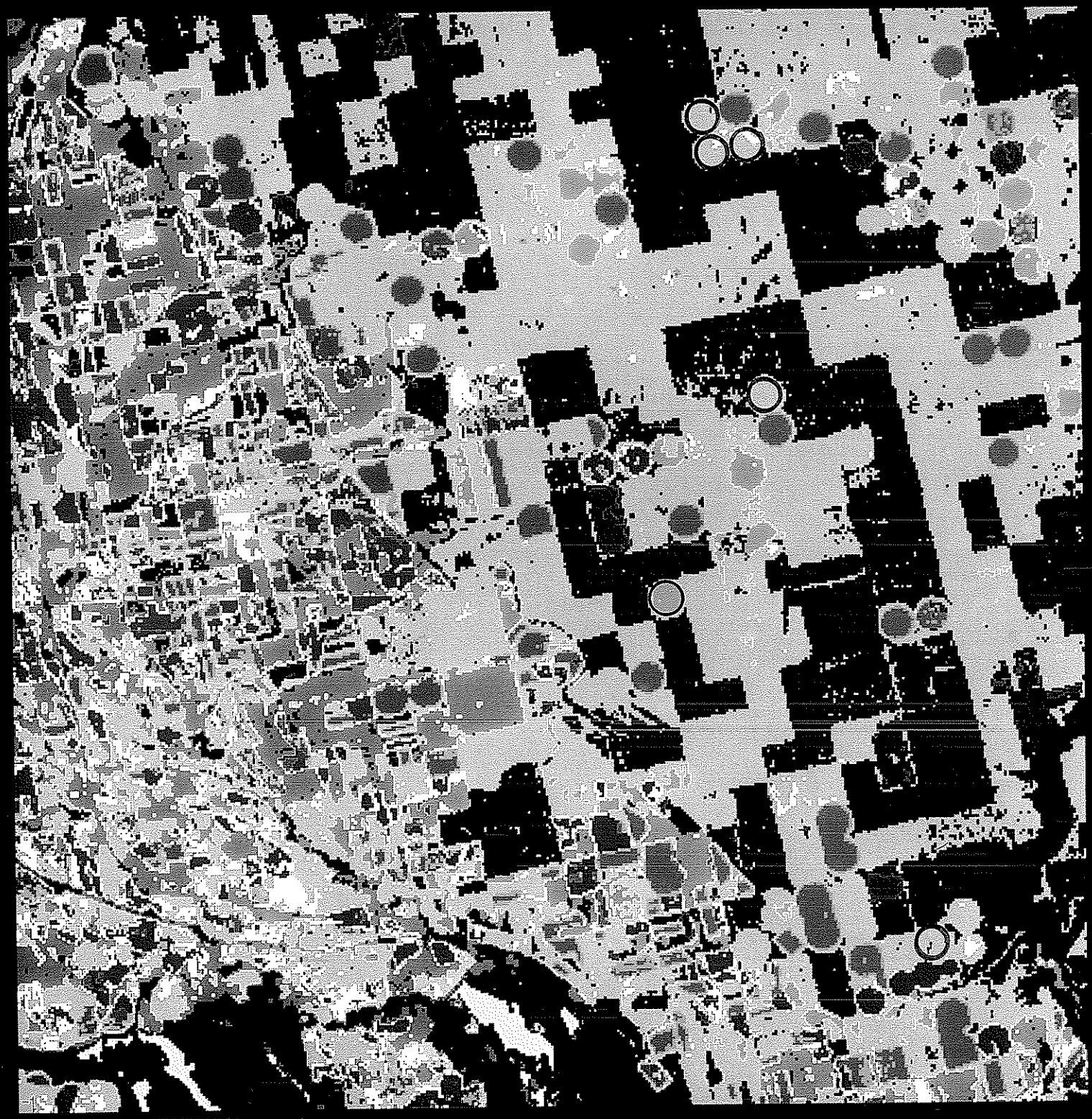
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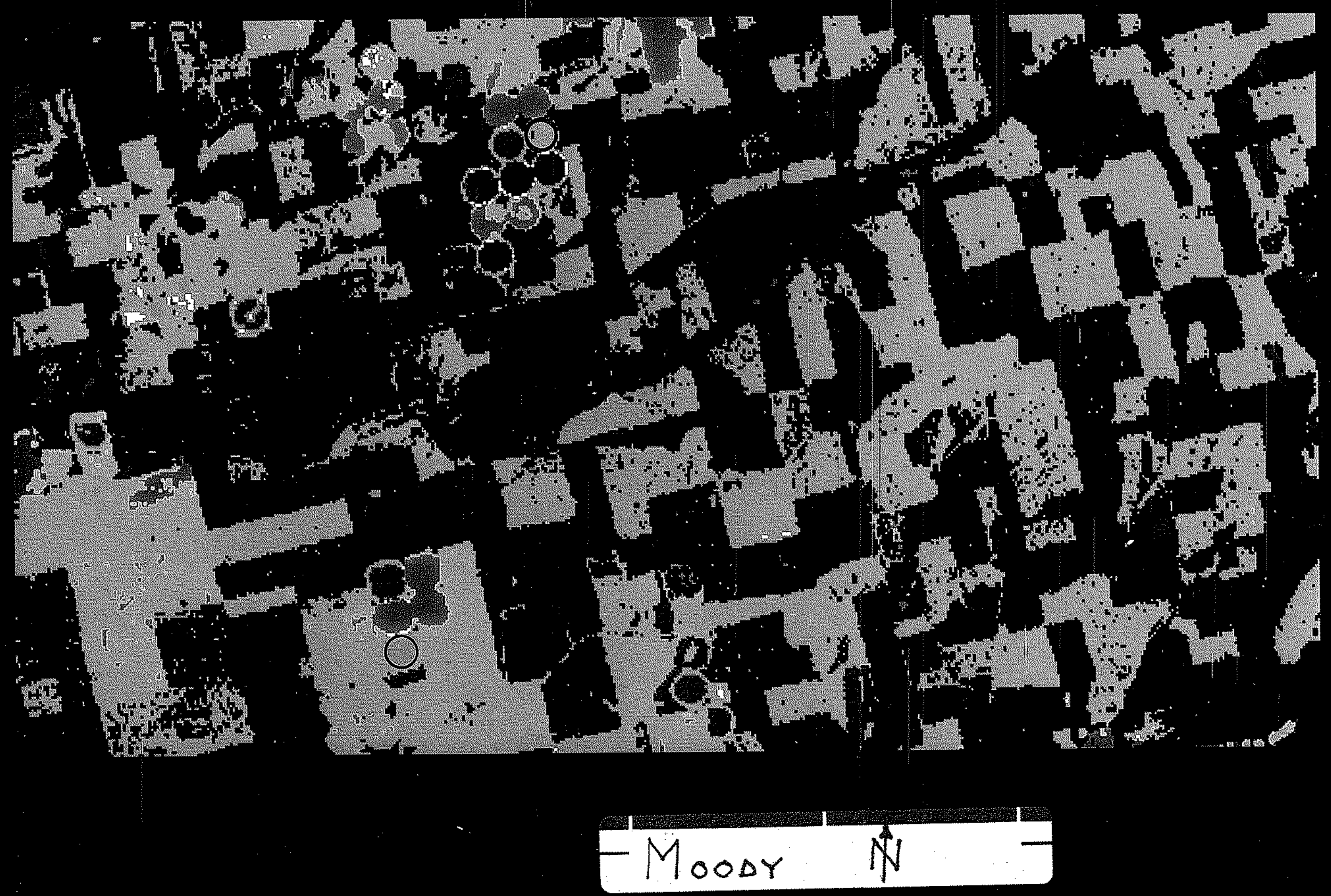
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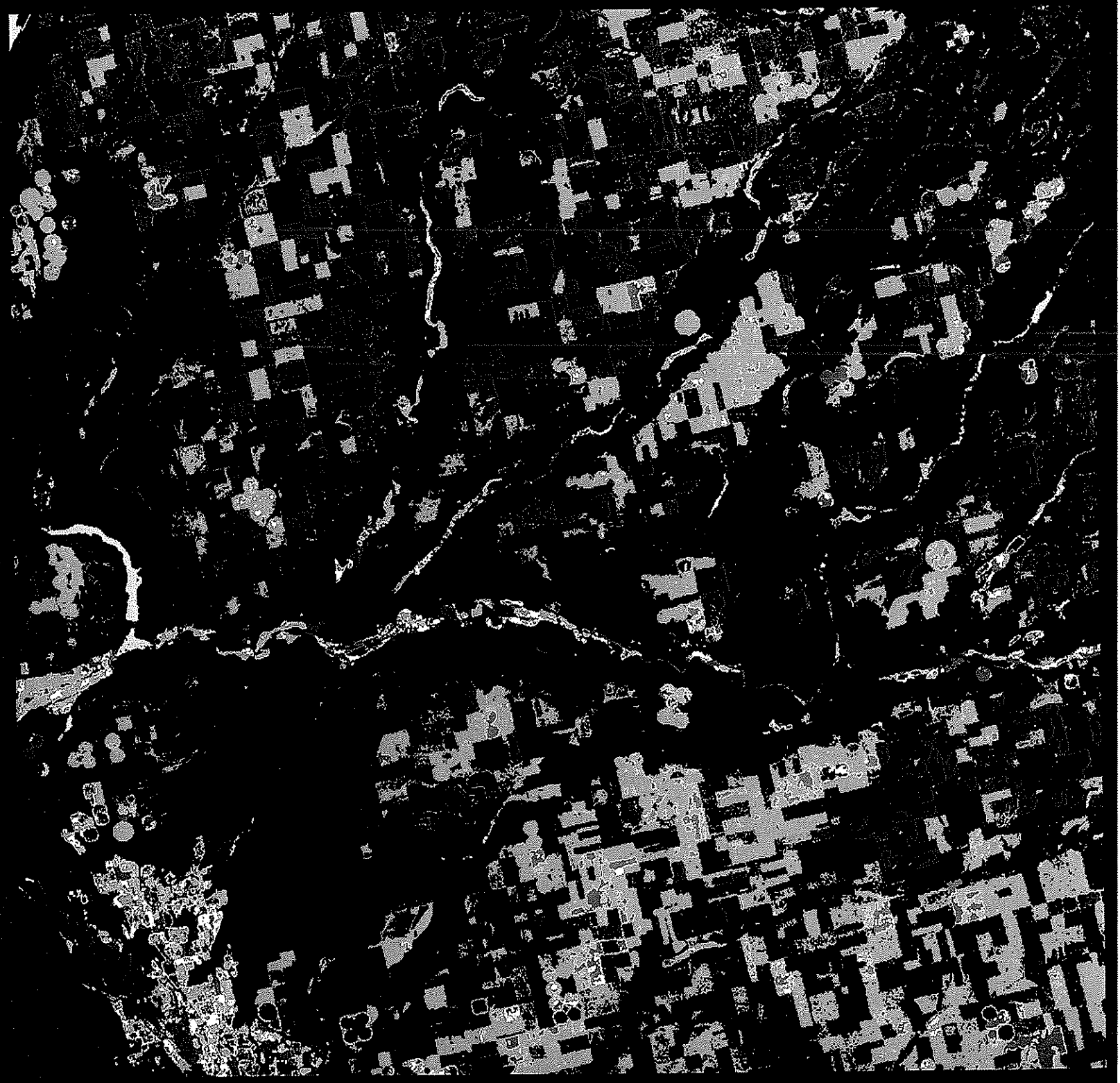

ODESSA #1

ODESSA #2 N