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AUTOMATED STRIP-MINE AND RECLAMATION MAPPING FROM ERTS

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16. Abstract Computer processing techniques were applied to ERTS computer-compatible tape (CCT) data acquired in August 1972 on the Ohio Power Company's Coal Mining Operation in Muskingum County, Ohio. Processing results succeeded in automatically classifying, with an accuracy greater than 90%: (1) stripped earth and major sources of erosion, (2) partially reclaimed areas and minor sources of erosion, (3) water with sedimentation, (4) water without sedimentation, and (5) vegetation. Computer-generated tables listing the area in acres and square kilometers were produced for each target category. Processing results also included geometrically corrected map overlays, one for each target category, drawn on a transparent material by a pen under computer control. Each target category is assigned a distinctive color on the overlay to facilitate interpretation. The overlays, drawn at a scale of 1:250, 000 when placed over an AMS map of the same area, immediately provided map locations for each target. These mapping products were generated at a tenth of the cost of conventional mapping techniques.

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AUTOMATED STRIP-MINE AND RECLAMATION MAPPING FROM ERTS

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ABSTRACT

Using computer processing techniques, it is possible to produce geometrically-corrected maps of the coal strip mines in East-Central Ohio by utilizing ERTS-1 CCTs. Several target categories can be drawn by a computer-controlled pen on film that will accurately overlay a base map of any scale selected by the operator. For each overlay, the computer can generate a table that shows the area of each target category in square kilometers, acres, or percent of total area.

INTRODUCTION

The area encompassed by this investigation includes five counties in eastern Ohio that comprise nearly 3,000 square miles. The counties; Muskingum, Coshocton, Guernsey, Tuscarawas, and Belmont; have been disrupted by coal mining since the early 1800s. Strip mining, which generally began before the 1920s, has been practiced in all of them. The total area of stripping operations in each county was quite large during the period from 1914 to 1947, but was insignificant when compared to the area stripped from 1948 to the present time.

On-site examination of individual mines, and particularly older mines, is hindered by (1) a lack of adequate mine map coverage; (2) deeply eroded, non-existent, or blocked access roads; (3) lack of accurate or adequate records; (4) the great total size of the stripped area; (5) strip mine reclamation planting along roads that obscures adjacent barren land; and (6) dated aerial photographic coverage.

From the earliest days of mining until 1948, little thought was given to the detrimental effects of coal mining on the environment. However, reclamation techniques required by 1948 legislation resulted in some grading and planting of trees and forage on soil banks although, in some areas, the soil was too toxic for replanting. In view of the stricter laws passed by the state legislature in 1973, reclamation is proceeding, not only more rapidly, but much more effectively.

Various agencies within the Ohio state government collect certain types of coal-mining data. There is, however, little or no coordination between agencies; automatic data processing is non-existent; and various filing systems approach the choatic. Consequently, reports available to the public are severely dated, commonly inaccurate, and difficult to acquire.

ENVIRONMENTAL EFFECTS OF STRIP MINING

In addition to large areas that are disrupted to such an extent that they are no longer productive, strip-mining has caused severe ecologic effects. These include the erosion of bare or sparsely vegetated spoil banks and the discharge of highly mineralized water. Sediment eroded from mined areas tends to fill streams and reservoirs which, in turn, leads to flooding, decreased storage area, and the choking of vegetation. Water that discharges from spoil banks and underground mines generally has a low pH and is highly mineralized.

MAJOR TARGET AREA

Although several specific areas have been examined, a very large mine in Southeastern Muskingum County, owned and operated by the Ohio Power Company, was chosen for detailed examination. The mine, although very irregular, is nearly 14 km (9 miles) long and as much as 8 km (5 miles) wide (see Figure 1).

Mining and reclamation at this mine is proceeding at a very rapid rate. Air photographs indicate that there was no stripping in the area in 1950. By 1965, however, about 1.6×10^7 square meters (4,000 acres) had been disrupted and, by 1971, strip mining had devastated close to 4.5×10^7 square meters (11,000 acres) in a single mining area (see Figure 1). A similar pattern occurred in several other Ohio counties.

Because of the more stringent 1972 Ohio strip-mine bill, reclamation now proceeds, in many areas, at the same rate as the mining. In fact, grading equipment may be operating just behind the giant mining machinery.

Aerial photographs of the Northern part of the Ohio Power Company area were taken in May of 1972. The area was examined in the course of field work in June of 1973. In several parts of the mine, there is no comparison between the landscapes that appear on the 1972 photography and the condition that existed only 13 months later (see Figure 2). Many of the strip mine lakes had been filled, graded, and planted as a part of the reclamation program.

Examination of several water quality parameters in lakes, reservoirs, and streams throughout the region indicates a wide range in concentration, both in space and time (see Figure 2). Furthermore, the quality cannot be readily predicted from one area to another or, for that matter, from one impoundment to the next in the same mine. Consequently, a detailed regional analysis of water quality characteristics cannot be adequately accomplished without a monumental budget.

ERTS-1 DATA PROCESSING

Local, state, and federal agencies must have repetitive coverage of mining areas and the capability for rapidly evaluating each situation. They also must be able to quickly determine areas of mining reclamation and progress or viability of replanted vegetation, at least on an annual basis. This, presently, cannot economically be done by ground teams, and aerial photographs rapidly become outdated.

In response to the urgent need for a faster and more economical means of generating strip mine and reclamation maps, this study is evaluating the suitability of using ERTS computer compatible tape (CCT) for automatic mapping. The procedure uses computer target "spectral recognition" techniques as a basis for classification. To implement these techniques, a computer is provided with a number of samples of ERTS measurements (training sets) for each target category of interest.

Once the numerical descriptions which define the spectral characteristics of each target category are determined, the operator executes the "canonical analysis" program. The program derives, for each target category being sought, a set of "canonical coefficients". In the decision processing phase, the coefficients are used by the computer to form a linear combination of the ERTS measurements to produce a "canonical variable" whose amplitude is associated with the probability of an ERTS measurement being from the target sought. A set of canonical coefficients are derived for each target category of interest.

In decision processing, the probability of an ERTS measurement arising from each one of the different target categories of interest is computed for each ERTS spatial resolution element, and a decision based on these computations is reached. If all probabilities are below a threshold level specified by the operator, the computer is permitted to decide that the target viewed is unknown (an unclassified category).

Before producing decision data on a large amount of ERTS data, a number of tests are applied to evaluate the computer's capability of performing the desired target classification. The tests include generating scatter diagrams, generating classification accuracy tables, and viewing the results of processed data on a TV monitor. In the test site, the classification accuracy was greater than 95% (see Table 1).

Table 1. Classification Accuracy Table

CLASSIFICATION TABLE 12-OCT-73 10:11:59

REJECTION LEVEL = 0.100000 PER CENT

TNG SET	PER CENT CLASSIFIED AS GROUP 0	1	2	3	4	5
1	0.000	97.872	0.000	2.128	0.000	0.000
2	0.000	1.587	98.413	0.000	0.000	0.000
3	0.000	4.545	0.000	95.455	0.000	0.000
4	0.000	0.000	0.000	0.000	100.000	0.000
5	0.000	0.000	0.000	0.000	0.000	100.000

PROGRAM RUN TIME = 00:00:21

Designation	Target
1	Stripped earth
2	Water with sedimentation
3	Partially reclaimed earth
4	Vegetation
5	Water without sedimentation

DECISION DATA PRODUCTS

Decision products developed for this investigation, using the 21 August 1972 ERTS-1 CCTs, include a printout table showing the area covered by each target category, decision imagery, and decision map overlays. The target classifications include stripped earth and major areas of erosion, partially reclaimed earth and minor areas of erosion, vegetation, deep (clear) water, shallow (turbid) water, and unclassified areas. Decision imagery, although not geometrically-correct, is produced rapidly and provides an immediate view of the processed scene. Decision-map overlays are geometrically-corrected and will directly overlay a UTM map coordinate system at any scale selected by the operator.

The canonical coefficients defining each of the five categories was applied to process that portion of the CCTs covering the Ohio Power Company's surface mining operation. The first step in the decision processing resulted in a new or processed CCT, which contains a code for each spatial element designating it as one of the categories. From this processing, Table 2 was generated, showing the area coverage of each category in terms of percent of total area processed, square kilometers, and acres.

Table 2. Area Table

ERTS PROCESSOR 15-OCT-73 09:01:32

ERTS SCENE 10 - 1029-15361
DATE OF SCENE - 21 AUG 72
CENTER OF SCENE - N39-25/W081-00
SUN COORDINATES - EL53 DEGREES
AZ130 DEGREES
SPACECRAFT HEADING - 191 DEGREES
TAPE NUMBER - 1
STARTING SCAN LINE = 450
ENDING SCAN LINE = 950

CATEGORY	PERCENT OF TOTAL	ACRES	SQ. KM.
UNCLASSIFIED	4.47	20293.15	82.12
STRIPPED EARTH	0.74	3343.62	13.53
DIRTY WATER	0.80	3610.80	14.61
RECLAIMED EARTH	3.95	17928.80	72.55
VEGETATION	89.67	406771.91	1646.13
CLEAN WATER	0.38	1704.79	6.90
TOTALS	100.00	453653.06	1835.84

PROGRAM RUN TIME = 00:23:23

Notable, on the list of categories shown, are the two water and two disturbed-earth categories. Water without sediment includes deep or clear water such as that found in reservoirs; water with sediment represents shallow or murky water, characteristic of shallow rivers and strip-mine-associated lakes. The two disturbed earth categories, stripped earth and partial reclamation, need little explanation except for some definition of partial reclamation. Partially reclaimed land may represent areas where reclamation, either natural or man-made, is proceeding very slowly, and usually less than 40% of the area is covered with vegetation. It also may represent recently mined areas where there has been a significant amount of spoil-bank grading, as well as planted sites where the vegetation may cover 0 to 100% of the area.

Table 2 also shows that stripped earth makes up 0.74% of the total area processed or 13.53×10^6 square meters (3,344 acres). It can readily be seen that this type of data product could be especially valuable when a quantitative measure for new stripping is needed, to determine progress of reclamation, and to measure changes brought about by surface mining.

The tape produced for decision processing was also used to generate 70-mm imagery wherein each image shows only a specified category at a scale of 1:1,000,000. This imagery is geometrically (spatially) identical to the data on the decision CCT and on the CCT provided by NASA from which it was produced. Since the tape if from bulk processing, some geometrical errors exist and are carried over into the decision imagery. Also, the CCT data provided from the NASA bulk processing is not corrected for earth rotation; consequently, the decision imagery will not directly overlay a UTM map coordinate system.

A method of recording all computer classifications, each represented by a different color, onto a single image, was also evaluated. To accomplish this, three images, representing the three primary colors (red, green, and blue) and containing all target classes in shades of gray, are produced. Using an additive color process, a composite image, in which each target class is assigned a distinctive color, is created. An example of this process, showing a large portion (about 1.8×10^9 square meters or 700 square miles) of Muskingum County and the Ohio Power Company's operations in that area, is shown in Figure 3.

To produce data that will directly relate to a map, a method for correcting the decision CCT for earth rotation and other geometric errors was developed. A second CCT, with these geometric corrections applied in a format suitable for driving a Gerber plotter, was recorded. This tape, when played back on the computer, causes a geometrically-corrected map of each target category to be drawn on film at a scale specified to the computer by the investigator. The pen drawings were used to produce color-coded overlays for an AMS series map of the same scale.

Figures 4 through 7 are photographs of computer-produced transparent maps, from the Gerber plotter, that overlay a 1:250,000 scale AMS map. The two water classifications are shown in Figure 4, stripped earth is shown in Figure 5, partially reclaimed land in shown in Figure 6, and a composite of all the classifications is shown in Figure 7. The overlay technique was found to be particularly useful for updating base maps and, more importantly, for detecting and identifying changes; i.e., change detection between the base maps and ERTS-1 data.

At this time, analyses of the accuracy of classifications have been confined largely to analyses of classification tables generated from data from the training areas. To be truly objective in analyzing accuracy, the final output products must also be evaluated with other areas not used in the computer training process. This was accomplished by comparing classification results with available maps, ground-survey data, and aerial photographs.

Figure 8 is a mosiac of the Ohio Power Company's strip-mine operation, generated from photographs acquired by the NASA C-130 aircraft on 7 September 1973. By comparing Figures 7 and 8, it is evident that the target categories are classified correctly in nearly all cases. Especially noticeable is the accuracy with which small lakes, a product of the mining operation, were classified.

A direct comparison between aerial photography and the stripped earth decision image plot of a part of the mine is shown in Figure 9. This illustration shows, not only that there is close agreement between the two techniques, but also that there have been some significant changes in mining areas between 21 August 1972 and 7 September 1973.

Thus far, this investigation has demonstrated the feasibility of using ERTS-1 CCTs for mapping and monitoring strip mining. The technique is rapid, accurate, and very inexpensive when compared to standard methods using aerial photographs and ground teams.

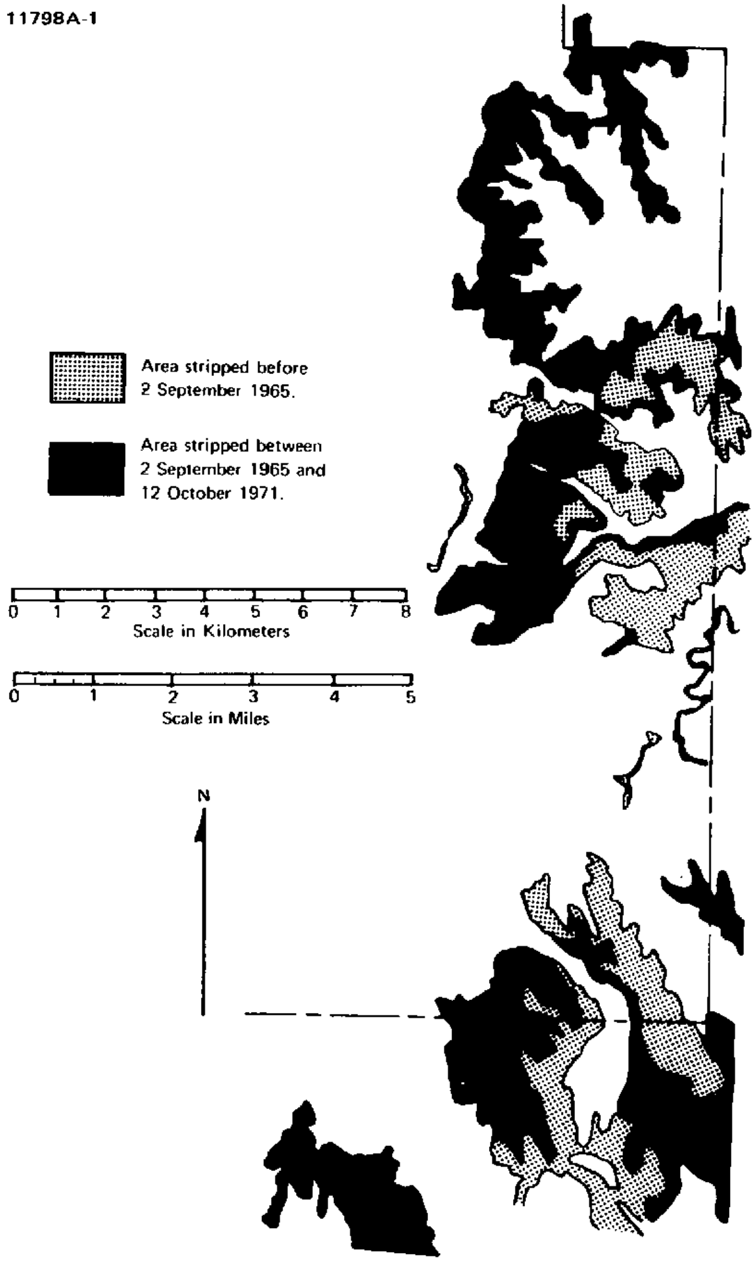
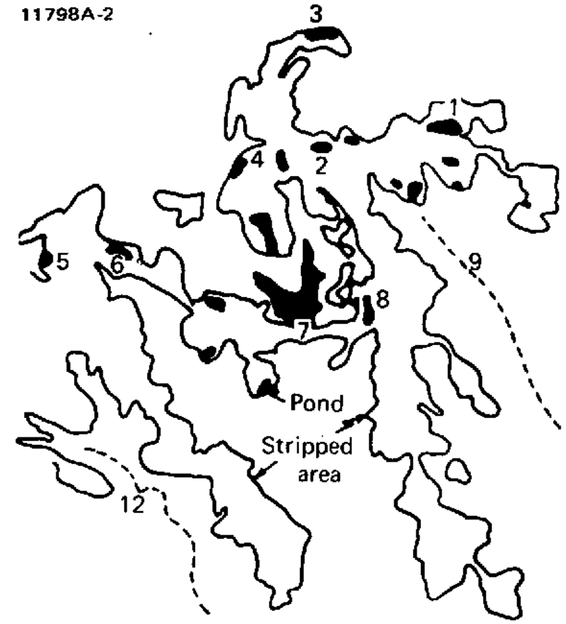


Figure 1. Strip-Mined Area in Muskingum County

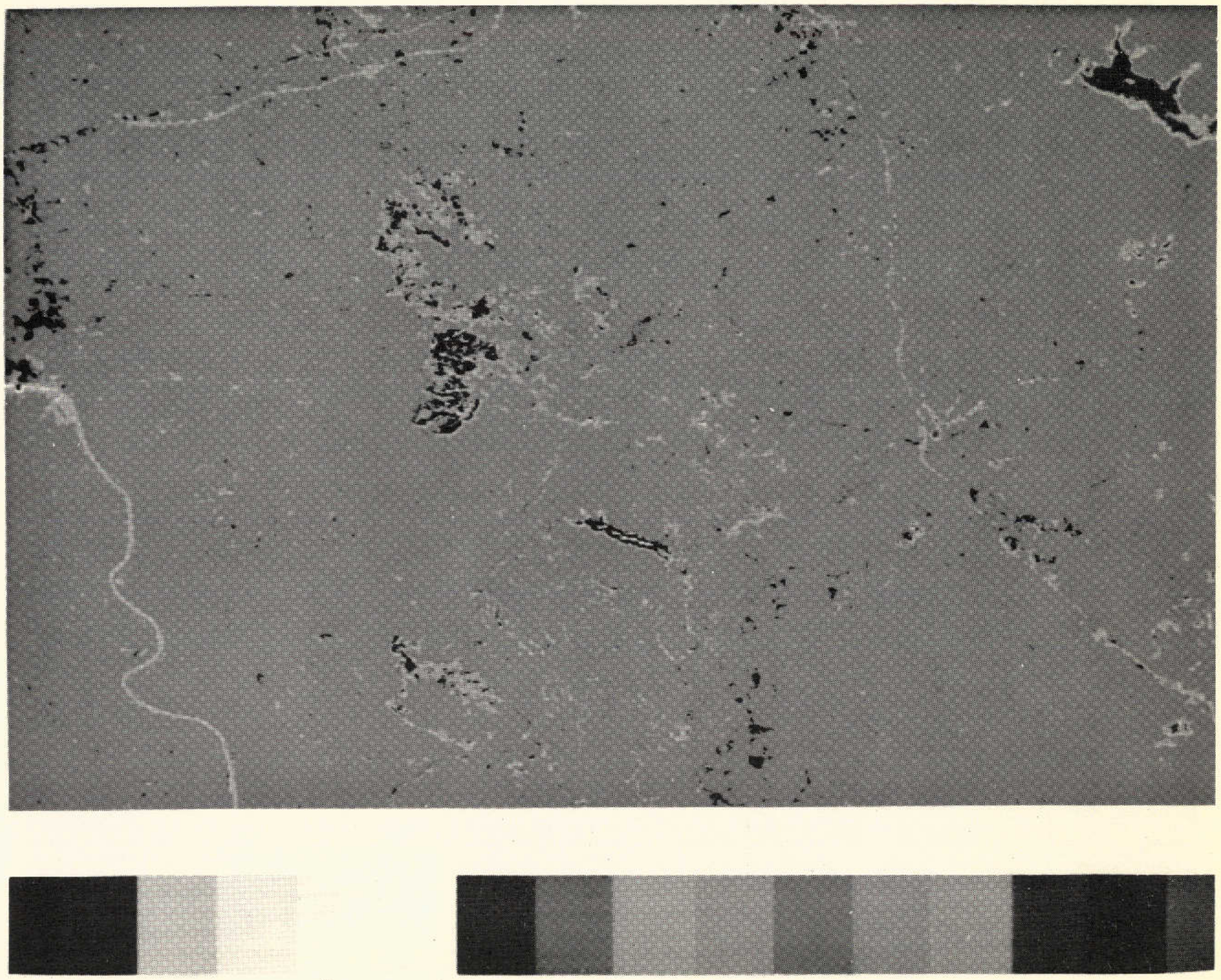


Site

1. Pond, nonexistent
2. Pond, pH-9.7, conductance-750
3. Lake, nonexistent
4. Lake, nonexistent
5. Lake, nonexistent
6. Pond, pH-9.3, conductance-580
7. Lake, pH-8.9, conductance-600
8. Pond, pH-3.1, conductance-1900
9. Stream, pH-8.2, conductance-775
12. Stream, pH-8.5, conductance-700

Base from May 9, 1972 air photograph
Field check on August 9, 1973

Figure 2. Water Quality and Reclamation Data in the Northeastern Part of the Ohio Power Company Mine



Classifications:

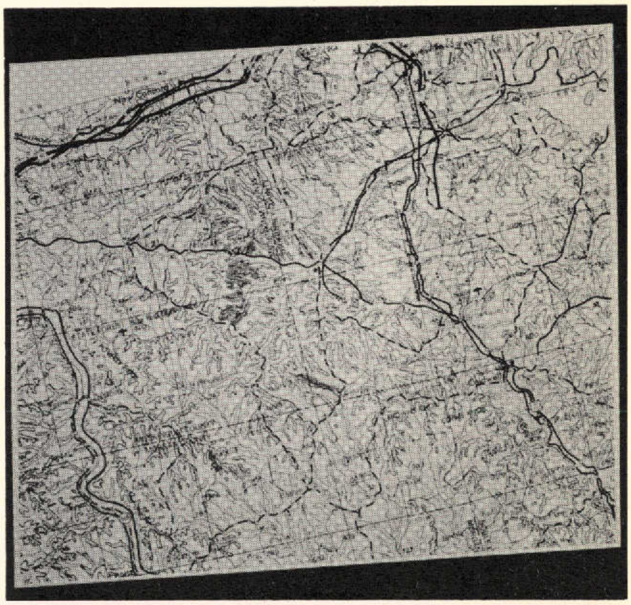
Red	- Stripped Earth and Major Sources of Erosion	Lt. Blue	- Shallow Water or Water with Sedimentation
Yellow	- Partially Heclaimed Earth and Minor Sources of Erosion	Blue	- Deep Water or Water without Sedimentation
Green	- Vegetation	Black	- Unclassified

11798A-3

Figure 3. Decision Imagery Representing a Large Part of the Study Area Based on the 21 August 1972 ERTS-1 CCT

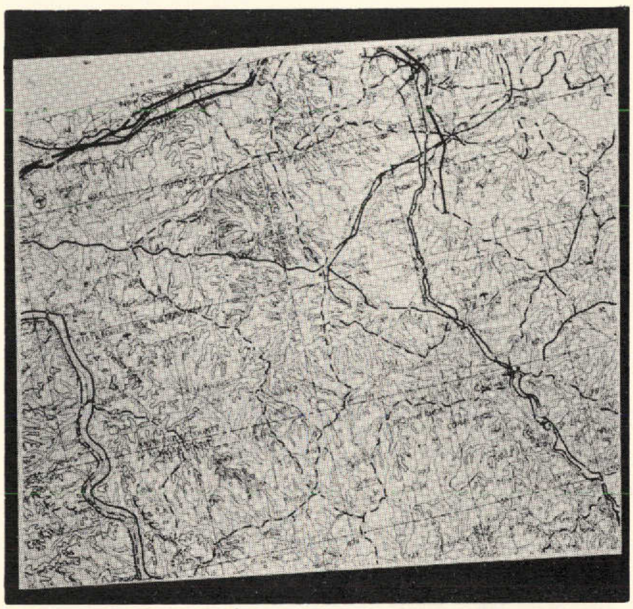
11798A-4

Figure 4. Overlay of Both Computer-Generated Water Categories on a 1:250,000 Scale Base Map



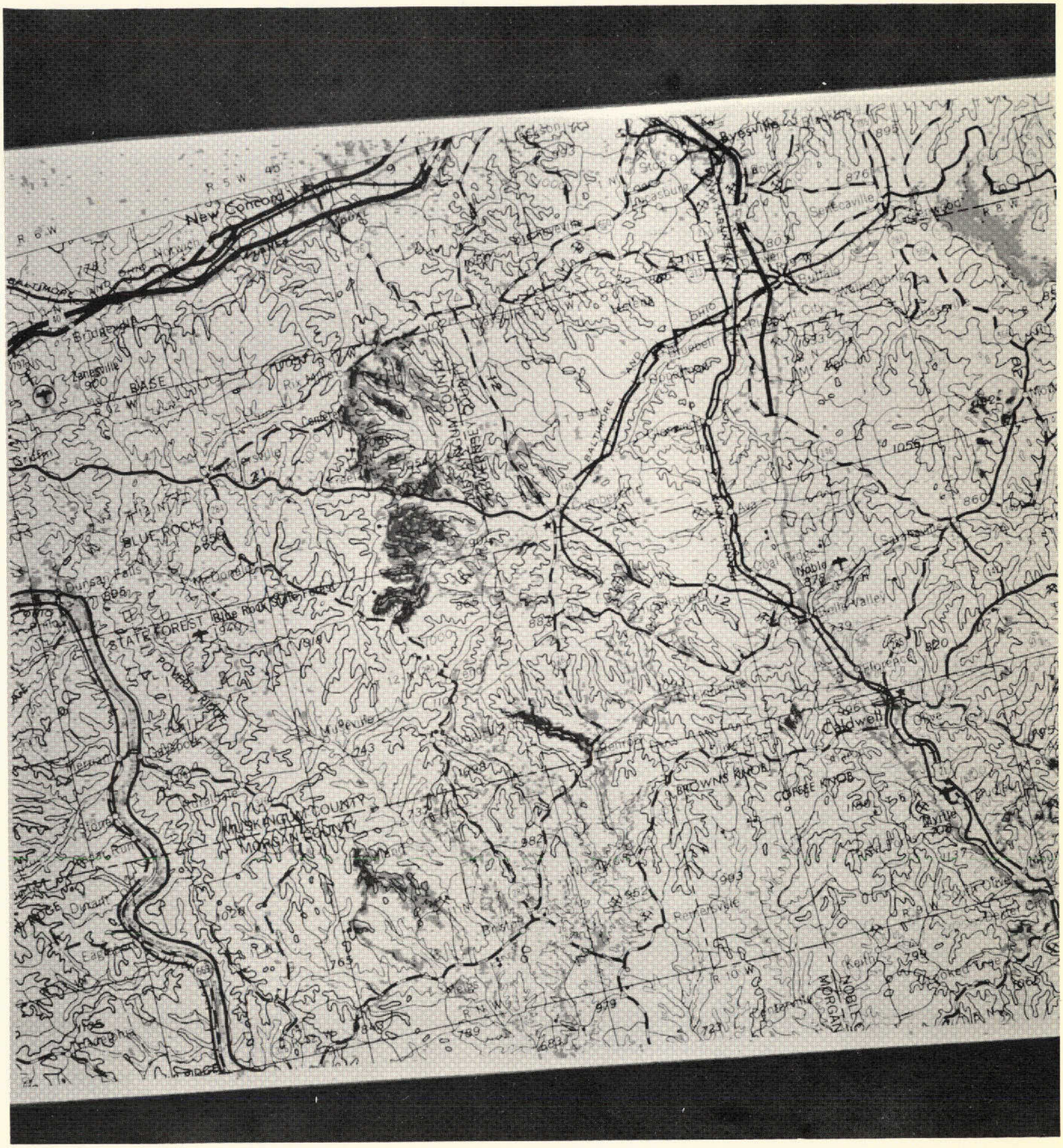
11798A-5

Figure 5. Overlay of Computer-Generated Stripped Earth Category on a 1:250,000 Scale Base Map



11798A-6

Figure 6. Overlay of Computer-Generated Partially Reclaimed Category on a 1:250,000 Scale Base Map



11798A-7

Figure 7 Color-Coded Overlays Generated by Computer from ERTS Data Acquired 21 August 1972
Red: Stripped Earth; Yellow: Partially Reclaimed Earth
Dark Blue: Water without Sedimentation; Light Blue: Water with Sedimentation (1:250, 000 Scale Base Map)

11798A-8

Figure 8. Aerial Photo-Mosaic of Southeastern Muskingum County, Ohio, and the Ohio Power Company Strip Mine

11798A-9

Figure 9 Stripped Earth Category (Red) Generated from
21 August 1972 ERTS Tape Overlaying
Aerial Photograph Acquired on
7 September 1973