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INVESTIGATIONS USING DATA IN

ALABAMA FROM ERTS-A

Contract NAS5-21876
GSFC Proposal No. 271

Seventh Bi-Monthly Progress Report

Covering Period

October 7, 1973 - December 6, 1973

Acting Principal Investigator
Dr. George P. Whittle
GSFC ID UN604

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Submitted to

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland

by

Bureau of Engineering Research
The University of Alabama
University, Alabama

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INVESTIGATIONS USING DATA IN ALABAMA

FROM ERTS-A

Contract NAS5-21876

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The following items are those listed on page 2 of the contract document as the minimum contents of the bi-monthly progress reports.

a) Title of investigation with ERTS-A proposal number: "Investigations Using Data in Alabama from ERTS-A," Proposal No. 271.

b) GSFC identification number of the principal investigator: Dr. Harold R. Henry (Un604), Acting Principal Investigator, Dr. George P. Whittle.

c) A statement and explanation of any problems that are impeding the progress of the investigation: These are discussed in the contributions of each of the investigators.

d) A discussion of the accomplishments during the reporting period and those planned for the next reporting period: These are discussed in the contributions of each of the investigators.

e) A discussion of significant results: These are discussed in the contributions of each of the investigators.

f) Published articles and in-house reports: There have been no published articles or papers during this reporting period.

g) Recommendation concerning practical changes in opeartions: Improve quality of visual imagery and decrease time lag for receipt of data.

h) A list by date of any changes in standing order forms: None

i) ERTS Image Descriptor Forms: Those completed have been sent to ERTS User Services, Code 563, NASA GSFC, Greenbelt, Maryland 20771.

j) A listing by date of any Data Request Forms for retrospective data: August 15 - 20 + 18 = 38, August 31 - 12, September 4 - 20, September 7 - 16, September 14 - 14, October 1 - 40, October 4 - 19.

INVESTIGATIONS USING DATA IN ALABAMA

FROM ERTS-A

Contract NAS5-21876

Seventh Bi-Monthly Progress Report
Covering Period October 7, 1973-December 6, 1973

Page

APPENDIX I

LAND USE, MINERAL EXPLORATION, GEOLOGY

With contributions as follows:

Appendix I-A by Reynold Q. Shotts
Appendix I-B by Darry Ferguson
Appendix I-C by Lee S. Miller
Appendix I-C by Joseph Robinson
Appendix I-D by Linda Robinson

APPENDIX I-A

Seventh Bi-Monthly Progress Report

by Reynold Q. Shotts
Period Covering
October 7, 1973 - December 6, 1973

General

A fundamental land use classification study using ERTS, in part, simply provides an alternate method to the classification using SCS photography to reach the same objective. Use of high altitude airplane photography is a third alternative and composite sequential clustering methods for ERTS data constitute a fourth alternative. Thus, it does involve doing something that has been done before. Indeed, land use studies of large and small areas have been made for a long time, often on the ground, and all super-terra studies are merely alternate approaches. Some benefits that did not come with older methods of land use study may be discovered and thus be subjected to cost-benefit analysis but these appear to be more likely in the geology, minerals and ground water phases of the present study.

Illustrated by the discovery of hitherto unknown lineaments, circular and any other structural features, and their implications for mineralization and water supply, we have both new discoveries and possible new methods of doing things that have been done by other methods before. It seems unlikely that any minerals will be discovered by ERTS methods but they may provide us with some new, more probable places to look. Minerals and water have been searched for in many ways in the past but they have generally been "gnats eye" views and now remote sensing provides a "birds eye" view.

So far as being an alternative method to ground exploration, ERTS is susceptible to cost-effectiveness but as a new method, to cost-benefit analysis. Until discoveries are made, however, I see no way to calculating cost-benefits. Only experience that gives measurable successes from measureable efforts can serve as a basis for quantitative cost analysis.

Traditional land use studies involving maps, ground truth, etc., can be analyzed for cost-effectiveness. ERTS methods, even though they may not show exactly the same information or even as much of it, should be susceptible also. Only, however, if ERTS reveals facts important in land use that are not revealed at all, or as well, by the other methods, would cost-benefit analysis be used.

In the mineral-water part of our study, we can begin to list possible benefits that may accrue from ERTS photography but I see no way to make a quantitative cost benefit analysis until some benefits have actually arrived. It is all too problematical until that time.

Methods of Study of Mineral Resources

The study of the geology and mineral resources of the State of Alabama has been carried on for more than a century and a half by many people using many methods. In 1845, Sir Charles Lyell, the most famous of the early English geologists, visited The University of Alabama and the State and wrote much about his observations. In 1847, the State began geological investigations when Michael Toumey, Professor of Geology at The University of Alabama, was instructed to spend four months studying the geology of the State. The next year he was appointed the first State Geologist and began the first geological survey of the State. Until recent years, all geological study was conducted at or from the surface by foot, buggy or automobile reconnaissance, mapping, sample collecting, and study of underground mine works. Only in recent years were indirect methods of geophysical or geochemical traverses and aerial and satellite photographic studies, introduced.

At least four direct methods of study are now available for obtaining surface information on the geology and mineral (including groundwater) resources of the State. Allowing for some possible overlap or arbitrary distinctions, they are:

(1) Surface reconnaissance. To this method is easily added some drilling, sampling, inspection of accessible mine workings and geophysical or geochemical traverses.

(2) Low level photography. The altitude from which photographs are made usually are in the range 12,000-12,500 feet (3658 to 3810 meters). Photographs resulting from these flights are usually on a 1,000 to 2,000 feet per inch (305 to 610 km per inch) scale.

(3) High altitude (U-2) photography is usually done from altitudes of 60,000-65,000 feet (18,900-19,800 meters). Some of these photographs are on a scale of 1:60,000 or 5,000 feet (1524 meters) to the inch.

(4) Earth Resources Technology Satellite (ERTS) photographs from 560 miles out in space are repeated in any given area every 18 days. Photographs in four separate electromagnetic spectral ranges are made simultaneously. The 9" x 9" transparencies and photographs commonly furnished for study are on a scale of about 1:1,000,000 or about 15.73 miles (9.9 km) per inch.

It will be noted that these four methods of obtaining information, as listed, are progressively remote from the surface and therefore features shown on them are on a progressively smaller scale.

Each method also has its advantages and disadvantages. Method 1, for example, is readily and almost simultaneously augmented by useful auxiliary methods such as sampling for laboratory study, drilling and sampling of unexposed material and various geophysical and geochemical surveys. This is not possible with the three photographic methods. Because of its great surface resolution, observations such as the distribution of types of vegetation indicative of certain underlying conditions (i.e., cedar trees on limestone bedrock) or the exact dip angle of rock strata, are more difficult or impossible to get from photographs. A disadvantage is, however, that so much detail is seen that gross integrating features such as long, cross-country lineaments, may be missed entirely.

Another great disadvantage of surface work is a long time frame and great expense per unit of time or of area covered.

Photographic methods have the advantage of a birds-eye view rather than a gnats eye view or, in a more classical analogy, on the ground we see only the trees but above it we can see the woods. By using special ranges in the electromagnetic spectrum, photography can pick up things often more difficult to detect on the ground such as hot spots on coal refuse banks, otherwise undiscovered warm water flows, or even the "spectral signatures" of certain types or growth stages of vegetation for estimating probable productivity of field crops. Certain rock outcrops, lava flows, or aquifers may even prove to have "spectral signatures."

Gross geological features that are observed on the surface may show up well in superterra photographs. Low level photography of Alabama by the Soil Conservation Service, for example, shows by means of stream valley alignment, probable NW - SE fault in T6S R10, NE, Dekalb and Cherokee counties, Alabama. Much longer and more diffuse lineaments showed up in an Apollo 9 photograph of an area south of Jackson, Dekalb and Cherokee counties and are quite evident on ERTS photographs. One of the lineaments seems to extend more than 100 miles into Tennessee. Structural features such as lava flows, eroded astroblemes and domes may also be seen from remote distances.

When it comes to third dimensional features such as heights of hills, bluffs and stripmine highwalls, photographic methods are poor unless there is stereoscopic coverage.

Comparing the four methods and their costs is obviously somewhat like comparing the merits of apples, oranges and peaches as a fruit. Table 1 shows comparable cost figures obtained for certain projects of different magnitudes and with somewhat different objectives and cost factors. As they stand they are hardly comparable but will serve as a starting point.

The high and low altitude photography costs given are only for the flights and delivery of the photographs. To be useful in mineral evaluation work, someone must carefully study all photographs, along with other existing geological data and make interpretations. This cost will be mostly in salaries of personnel and will depend on the type and grade of personnel used. Such study certainly adds to the costs shown in Table 1.

TABLE I

Method	Gross Cost, $	Unit Cost, $		Adjusted Unit Cost
		mi^2	km^2	km^2
1. Making a reconnaissance geological map of an Ala. Co., including some drilling sampling and analysis[(1)]	25,000 per county	33.03	12.75	12.75
1A. Same for a larger or more geographically complex county[(2)]	40,000 per county	40.00	15.44	-
2. Low altitude photographs of a 75 mi^2 urban area[(3)]	1,500	20.00	7.72	11.04
3. Quotation for high altitude photograph for Alabama[(4)]	60,000	1.18	0.457	4.03
4. ERTS photography of Montgomery, Ala., area for land inventory[(5)]	130	0.00984	0.0038	0.38

Table Footnotes

[(1)] This is for an "average" Alabama county of 757 square miles (1960 km^2) area and an approximate median cost in a $15,000 to $40,000 range.

[(2)] A large county (1,000 mi^2) at maximum cost.

[(3)] City of Tuscaloosa photographed by a commercial aerial photographic company.

[(4)] Communication, Dr. George Whittle, ERTS Contract NAS5-21876.

[(5)] Mr. R. Paul Wilms, Fifth Bi-Monthly Project Report, June 7 - August 6, 1973, Contract NAS5-21876, page 9.

The ERTS costs shown are for a land use study of a 13-county area, including Montgomery, and was limited to manpower costs. For a mineral resource study, more time may be required and possibly at higher salaries for personnel. A tripling of the cost shown in Table 1 would bring the cost per square kilometer to only one cent.

The most striking feature of the table is the very evident reduction of unit cost per area covered with increase in distance from earth. The ratio of the distances, with the surface as unity, run about 1:12,500:65,000:3,000,000 while the ratio of costs are only about 33,550:2,030:120:1.

There are some large flaws in the figures of Table 1. It is seldom that a reconnaissance geological map must be made "from scratch." There is always a large body of available geological knowledge to study in any county or district and usually some regional or district maps are available. The assessment of the mineral potential of any county or region may require more study and correlation of old data than of new.

In the last column of the table are some adjusted costs to include reproduction and personnel. Assuming that the 25,000 low altitude photographs of an average Alabama County (757 mi^2 or 1960 km^2) would require the equivalent of one $18,000 per year geologist, working six months, $9,000 would be added to the cost. Making this $10,000 seems reasonable and would add $5.10/$km^2$ to the unit cost.

High altitude photography would require study, in the same area, of only about 1,000 photographs. The time would not be reduced quite proportionally because each photograph, covering a larger area, would require more time. Four months would be \$6,000 for salary. Using \$6,500, the cost per km^2 would be 3.32.

One county may be split between two ERTS photographs but as about 10 photographs cover the entire state, there are an average of 6.7 counties per photograph. Assuming about one-half month equivalent time, would give \$750 or \$0.38/km^2. The ratios of the adjusted costs in Table 1 are 33.6:29.1:10.6:1.

If all four methods of Table 1 yielded exactly the same quantity and quality of data, then the indicated adjusted costs should be comparable. As we have seen, this is not true. All the remote sensing methods must have added to their interpretations some subsurface and surface work before they can be verified in terms of actual mineral deposits. This is true, to a lesser extent, even of reconnaissance geological mapping.

The problem becomes one of assigning to each method the proper probilities for indicating the presence of mineral deposits. In the absence of any scheme of evaluation parameters, all methods probably will continue to be used with emphasis on what each apparently does best in the hope that a minimum cost combination will eventually be found.

About all that can be done now, toward cost-benefit analysis, is to list possible benefits. With regard to ERTS photography some of these may be:

(1) Because of its ability to pick up large geological features, some originating from large-scale tectonics or ancient extraterestrial events, ERTS photography may indicate new metallogenic provinces or probable extensions of known ones. Discovery of these possible

provinces would require much time and enormous expense by traditional methods.

(2) ERTS and other remotely sensed data that serve the search for mineral concentrations also serve many other human activities, thus, if new metallogenic provinces are found by traditional methods, virtually all the cost is chargeable to the minerals industry. Remotely sensed data are used for weather prediction, field crop evaluation, land use study, national security surveillance and many other activities that share the cost.

(3) Remote methods may detect structural features that indicate possible traps for water or petroleum fluids.

(4) Although not yet well developed, "spectral signatures" may be worked out for detecting certain rock outcrops, including moist strata; mine refuse and spoil banks, permafrost areas, etc. ERTS resolution does not appear to be sufficiently great for monitoring surface mining activity, as yet.

APPENDIX I-B

Seventh Bi-Monthly Progress Report

by Darry Ferguson
Period Covering
October 7, 1973 - December 6, 1973

The Use of ERTS-I Imagery to Survey and Monitor Stripping Reclamation in the Warrior Coal Basin

A study was conducted by the author to determine the feasibility of using ERTS-I imagery to survey and monitor stripmine reclamation by a) visual and graphical techniques and b) by the use of computer mapping. This report will be concerned only with the use of visual and graphical techniques to identify the various parameters sought in this investigation.

The study areas selected were three stripmines, two of which are inactive, each displaying a varying amount and time in the reclamation process. The study areas were first visually assessed by the author and recorded on photographs. Secondly, the same areas were carefully examined on U-2 65,000' infrared photography, using the same parameters and lastly ERTS-I imagery was examined for identification of the same parameters.

The summary of results has been tabulated in Table I. Each parameter was evaluated as good, fair, or poor as monitored through a particular system. A rating system was developed by the author for system evaluation. This system rates "good" as three points, "fair" as two points and "poor" as one point. By knowing the number of parameters a system may be rated by the following formula:

TABLE I

Summary of Results

Number of Parameters	Visual Parameter Surveyed	Monitored by 65000' Infrared Photography				Monitored by ERTS-I Imagery			
		G	F	P	U	G	F	P	U
1.	Area Topography	✓					✓		
2.	General Mine Topography	✓						✓	
3.	Highwall Condition		✓						✓
4.	Spoil Pile Dimensions		✓						✓
5.	General Vegetation		✓					✓	
6.	Tree Types		✓					✓	
7.	Grasses			✓				✓	
8.	Aga of Tree Growth		✓					✓	
9.	Soil Condition			✓					✓
10.	Water Quality		✓						✓
11.	Drainage Alterations	✓							✓
12.	Total Mined Area	✓						✓	
13.	Advancing Faces	✓						✓	
	QUALITATIVE POINTS PER COLUMN	3	2	1	0	3	2	1	0
	TOTAL EVALUATION POINTS PER COLUMN	15	6	2	0	0	2	7	0

G - Good

F - Fair

P - Poor

U - Undetermined (Generally insufficient definition in image to identify parameter).

$$\theta = \left[\frac{3G + 2F + P}{3N}\right] 100\% + \sigma$$

where, θ = System efficiency

G = Number of parameters rated "good"

F = Number of parameters rated "fair"

P = Number of parameters rated "poor"

N = Total number of parameters

σ = Enhancement factor

For the 65,000' U-2 infrared system,

$$\theta = \left[\frac{3G + 2F + P}{3N}\right] 100\% + \sigma$$

$$\theta = \left[\frac{3(5) + 2(6) + 2}{39}\right] 100\% + 15\%$$

$$\theta = 89.5\%$$

For the ERTS-I system,

$$\theta = \left[\frac{3G + 2F + P}{3N}\right] 100\% + \sigma$$

$$\theta = \left[\frac{3(0) + 2(1) + 7}{39}\right] 100\% + 15\% = 38\%$$

Cost Effective Analysis

A cost effective analysis was made for ground observation, U-2 high altitude data, and ERTS-I data. The three systems are explained in the following paragraphs.

The first system that was analyzed is the one that is currently used, although not all of the stripmined land is surveyed each year. Costs on foot were as follows: transportation, gas, vehicle costs, and personnel costs including inspection time, office and driving time. In addition, visual aid costs were estimated for general use.

The result was a cost of $0.575 per acre to visually look at each acre of stripmined land.

A high-altitude system was evaluated for a "per acre" cost. The general costs included: airplane rental, film development and processing, film costs, office equipment, engineer costs, office costs and miscellaneous. The total cost was $0.43 per acre. However, when we divide the cost per acre by the system efficiency we get,

$$\$0.43/0.895 = \$0.48 \text{ per acre for the cost for system equivalent.}$$

Lastly, an attempt was made to evaluate the cost to use ERTS-I imagery for monitoring stripmine reclamation. An estimation for engineering office time, support information, film cost with processing, visual aids and miscellaneous costs. The result was a cost of $0.91 per acre. Then, $0.91 divided by the system efficiency yields:

$$\$0.91/0.38 = \$2.40 \text{ per acre for system equivalent.}$$

In summary, the ERTS-I system is not as efficient as the high altitude photography as applied to surveying stripmine reclamation. In addition, the ERTS-I system is five times more expensive to operate for the same equivalent system performance as high altitude photography. It should be noted that all the calculations are based on a per acre of stripmined area in that year.

APPENDIX I-C

Summary of Research

By Lee S. Miller
Covering Period
October 7, 1973-December 6, 1973

A rigorious analysis of a computer technique for the manipulation of ERTS-I digital data has been completed. The technique used for the processing of ERTS data is the composite sequential clustering technique. This technique was developed by M. Y. Su[1] and is used for the unsupervised classification of multispectral scanner data. It was applied to ERTS MSS data of selected study areas in west-central Alabama.

The results are being compiled in a thesis which is to be submitted in partial fulfillment of the requirements for a master's degree. This document will also be submitted to NASA as a special report within the next few weeks.

[1]Su, M. Y., The Composite Sequential Clustering Technique for the Analysis of Multispectral Scanner Data, Report for NASA, Marshall Space Flight Center, Contract Number CR-128999, Northrop Services, Inc., Huntsville, Alabama, 1972.

APPENDIX I-D

Seventh Bi-Monthly Progress Report
by Joseph Robinson
Covering Period
October 7, 1973-December 6, 1973

Cost Effectiveness: Low Altitude Mapping vs. Reconnaissance Mapping

The concept of cost effectiveness may be applied to low altitude mapping and reconnaissance mapping of a city for development of a land use map for that city.

The technique most often used by cities for developing a land use map is the reconnaissance procedure which employs the use of aerial photographs coupled with visual ground truth inspection of the area. The reconnaissance procedure enables city planners to break the city up into different classifications such as single family residential, multi-family residential, light industrial, heavy industrial, commercial, parks, recreation, etc.

The low altitude procedure attempts to accomplish the same goals as the reconnaissance procedure, although using a different method. The methods that were used at the University of Alabama were as follows:

1. Tuscaloosa, Alabama was used as our study city. Universal Transverse Mercator Grids (UTM) were overlayed on a city map. Placing the UTM grid on the city map was relatively easy since we already had UTM grids on U. S. Department of Agriculture maps. The problem was reduced to just merely transferring UTM grids from the U. S. Department of Agriculture maps to the city map.

2. Determine the scale of the photographs. Once the scale of the photograph was determined a transparent grid was drawn which would overlay the photograph. For our purposes, each small grid square was

0.1 inch or 40 squares by 40 squares equaled 1 km^2. The scale of the photograph on the first pass of the airplane over Tuscaloosa was 1 in. - 0.1544 miles (altitude = 12,600 ft). At this scale, medium size houses completely filled the 0.1 by 0.1 inch grids. In determining the grid size be careful to choose a grid size that is small enough to adequately distinguish between different types of land use.

3. Orient the grid developed above to the photograph.

4. Once the grid has been oriented to the photograph, the classification of land began. The two digit classification scheme used is presented on the next page, (Figure 1). Since it would be hard to write two digits in a square only 0.1 in. by 0.1 in. an enlarged grid was drawn on which were written the classification digits.

5. The scale on every pass photographed by the low altitude aircraft should be checked. For better accuracy the scale should be checked for more than one photograph in every pass.

The following is a cost comparison of the low altitude and reconnaissance procedure for mapping a city.

<u>Low Altitude Mapping</u>	Time
1. Transferring UTM Grid to Tuscaloosa Map	6 hours
2. Orienting the grid to each photograph	25 hours
3. Classifing the land (Tuscaloosa) (approximately 1.5 hours per km^2)	150 hours
4. Verifying scale on every pass (5passes) and drawing appropriate grid	20 hours
	201 hours

At $4.20 per hour, the cost for preparation of the map would be $844.20.

Figure 1

A LAND USE CLASSIFICATION SCHEME FOR USE WITH REMOTE SENSOR DATA

Level I	Level II	Level I (Digit)	Level II (Digit)
Urban and Built-Up		01	
	Residential		01
	Commercial & Services		02
	Industrial		03
	Extractive		04
	Major Transport Routes & Areas		05
	Institutional		06
	Strip & Clustered Settlement		07
	Mixed		08
	Open & Other		09
Agricultural		02	
	Cropland & Pasture		01
	Orchards, Groves, Bush Fruits, Vineyards & Horticultural Areas		02
	Feeding Operations		03
	Other		04
Rangeland		03	
	Grass		01
	Savannas (Palmetto Prairies)		02
	Chaparral		03
	Desert Shrub		04
Forestland		04	
	Deciduous		01
	Evergreen (Coniferous & Other		02
	Mixed		03
Water		05	
	Streams & Waterways		01
	Lakes		02
	Reservoirs		03
	Bays & Estuaries		04
	Other		05
Nonforested Wetland		06	
	Vegetated		01
	Bare		02
Barren Land		07	
	Salt Flats		01
	Sand (other than beaches)		02
	Bare Exposed Rock		03
	Beaches		04
	Other		05
Tundra		08	
	Tundra		01
Permanent Snow & Ice Fields		09	
	Permanent Snow & Ice Fields		01

The cost of a low altitude photographic flight at 12,000 ft. is approximately $1500 for 75 square miles or $7.72 per square kilometer.

The cost of preparation of the map reduces to $4.35 per square kilometer.

Total cost is $\$7.72 + 4.35 = \$12.07/km^2$

(This cost does not include the cost of developing a finished product)

<u>Reconnaissance Mapping</u>

The actual cost to the city for contracting a firm to develop a city land use map by the reconnaissance procedure is variable. The cost is dependent upon how big the firm is, availability of aerial photographs and various other conditions. The cost used in this report is an estimate from the Soil Conservation Department but is considered reasonably accurate by the West Alabama Planning and Development Office. The cost of $12.75 per square kilometer includes all costs, from the initial step to the final product.

Since the costs are so close, another criteria must be the deciding factor. I believe the deciding criteria is the accuracy that is gained by using the reconnaissance method. Using low altitude photographs without any on-sight verification (as is done in the reconnaissance method) it is hard to tell whether the building you see on the photograph should be classified as residential or commercial. Similarly it is hard to distinguish between a field or a park or playground. Since the University of Alabama is located in Tuscaloosa, it is also hard to distinguish between motels and student apartment complexes.

Because of the need for accuracy and detail on a city land use map, I believe that the reconnaissance method is the better of the two methods. By inspecting the area by car or walking through the area, one can pick up much more detail than if he were flying over the area.

Seventh Bi-Monthly Progress Report

by Joseph Robinson
Period Covering
October 7, 1973 - December 6, 1973

A Comparison of ERTS-I and U-2 Photographs

Just how realiable are land use figures obtained from ERTS photographs? We are presently comparing ERTS photographs of an area with photographs taken from a U-2 airplane of the same area. The areas under study can be found on Figure 1.

The scale on the ERTS photographs was 1:1,000,000 and the scale on the U-2 photographs was approximately 1:136,000.

By the use of a computer program called CHGMAP which compares the dominant land use digits derived from ERTS and U-2 photographs, some results are now becoming available. The following results are for the City of Tuscaloosa. (Figures 2-5).

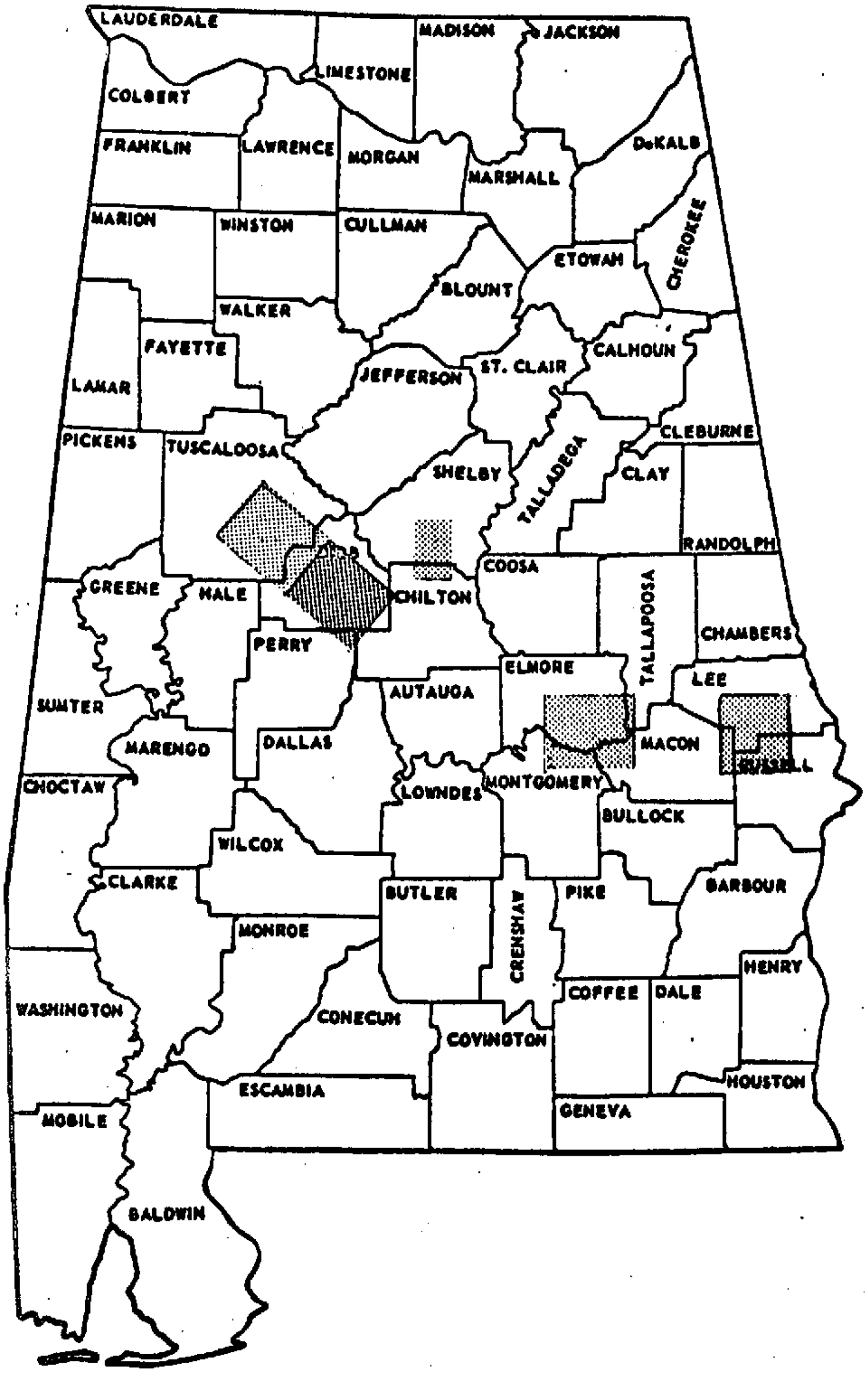


Figure I - "U-2-ERTS Comparison Study Area"

NUMBER OF CHANGES FOR COUNTY

ERTS DATA POSITION 2 * ERTSDATA POSITION 7 * CODE

TYPES	NOT PRESENT (..)	PRESENT (0)	IN FIRST ONLY (-)	IN SECOND ONLY (+)	TOTAL IN FIRST POS	TOTAL IN SECOND POS
URBAN	309	17	0	47	17	64
AGRICULTURE	294	24	32	23	56	47
FOREST	60	241	56	16	297	257
WATER	369	3	0	1	3	4
BARREN	372	0	0	1	0	1
WETLAND	373	0	0	0	0	0

POSITION TWO

POSITION ONE	URBAN	AGRICULTURE	FOREST	WATER	BARREN	WETLAND	CLOUD
URBAN	17	0	0	0	0	0	0
AGRICULTURE	16	24	16	0	0	0	0
FOREST	31	23	241	0	0	0	0
WATER	0	0	0	1	1	0	0
BARREN	0	0	0	3	0	0	0
WETLAND	0	0	0	0	0	0	0
CLOUD	0	0	0	0	0	0	0

Reading The Matrix

Position 2 corresponds to the land use digit obtained from U-2 airphotos. Position 1 corresponds to the land use digits obtained from ERTS. Reading down the Urban column, the interpreter of the U-2 photographs classified 17 cells as urban and the ERTS interpreter classified 17 cells as urban. However the U-2 interpreter also classified 16 cells as urban that were classified as agriculture by the ERTS interpreter. Finally the U-2 interpreter classified 31 more cells as urban that looked like forest to the ERTS interpreter. The cells that the ERTS interpreter classified as agriculture or forest when they were really urban, probably occurred in residential areas.

The accuracy obtained is the sum of the diagonal numbers divided by the total number of cells or $\frac{285}{373} = 76.4\%$.

FIGURE 2

```
680 +0+00.+.................../+
    |00.+..............++.+...|
    |-0+0.........0-.....+-...|
    |00+...-......-.....--....|
    |.-.-.--....+.......--....|
675 +.....-..............+....+
    |.00......................|
    |.....--..................|
    |..-..-....+....+.........|
    |.....-..-....+.+.........|
670 +...-...0........-+..+....+
    |...---.../...-0..000.....|
    |-......-....+.....--+...+|
    |0000+..-.-.0.............|
    |00+....+................/|
    *-+----+----+----+----+---*
```

MAP OF AGRICULTURE CHANGE

ERTS DATA POSITION 2 * ERTSDATA POSITION 7 * CODE

FIGURE 3

```
      450  455  460  465  470
    *-+----+----+----+----+---*
680 +........................./+
    I.........................I
    I+....+...................I
    I....+++..................I
    I+..+.++..................I
675 +0+....+..................+
    I0..0+++..................I
    I0000+++++................I
    I00++++++++...............I
    I000+.+++++...............I
670 +00+++++..................+
    I000++++..................I
    I+.+++....................I
    I........+................I
    I......................../I
    *-+----+----+----+----+---*
```

MAP OF URBAN CHANGE

ERTS DATA POSITION 2 * ERTSDATA POSITION 7 * CODE

FIGURE 4

```
     450  455  460  465  470
     *-+----+----+----+----+---*
680  +.-..0-0-000.000000000000/+
     |..0-00000.0.000000--0-000|
     |..-.0-0000000.+00000-+000|
     |..-0--.000000+00000++0000|
     |-+0.-..0000-0000000++0000|
675  +.-000+-0000000000000-0000+
     |....---000000000000000000|
     |....-..--0000000000000000|
     |...--.-----0000-000000000|
     |...-0.--.-000-0-000000000|
670  +..-.---.00000000+-00-0000+
     |......-000000+.00...00000|
     |.0---00+0000-00000++-000-|
     |....-00+-+0.0000000000000|
     |..-0000-0000000000000000/|
     *-+----+----+----+----+---*
```

MAP OF FOREST CHANGE

ERTS DATA POSITION 2 * ERTSDATA POSITION 7 * CODE

FIGURE 5

APPENDIX I-E

Seventh Bi-Monthly Progress Report
By-Linda Robinson
Covering Period
October 7, 1973-December 6, 1973

The organization of materials in the ERTS Library has been progressing smoothly. Detailed plans have already been carried out. The material in the library has been grouped by type of material for easier use until the card catalog is completed. A system for recording the receipt of materials, the materials now located in the library, and the material which can be located elsewhere, has been devised. Complete records of all materials received and sent out are being kept.

The ERTS photos have been cataloged, and records are kept of the location of these photos at all times. The high-altitude photos are in the process of being cataloged and labeled; the self-adhesive labels, which are placed between frames on each roll, designate the most obvious feature on the frame and facilitate determining the geographic location of the frame. After the high-altitude photos are finished, I will catalog the low-altitude reels, the maps, and the printed material, in that order. As the cataloging of each type of material is completed, location symbols will be assigned to each item in the group. The same symbol will appear on the catalog cards for the item, so that a person looking in the card catalog will know, from the symbol, in what group of material, and what number within the group, he will find the item that he wants.

I am also in the process of writing two manuals for the ERTS library. One, a User's Manual, will give complete, explicit instructions about the location of materials in the library, how to use the card catalog, how to check out materials and what types of materials are available. The other, a Technical Manual, will explain, in minute detail, the processing of materials, particularly ERTS photos, from their receipt to the time when they are filed and their catalog cards are interfiled in the card catalog. This manual will cover all aspects of handling materials and will be a guide for the person who will be in charge of the library after January 1, 1974.

This is the status of the library at present and a general overview of the plans which have been made for the completion of its organization.

APPENDIX II

ENVIRONMENTAL, HYDROLOGY, WATER RESOURCES

With Contributions as follows:

Appendix II-A by G. P. Whittle
Appendix II-B by Lamar Larrimore

APPENDIX II-A

Seventh Bi-Monthly Progress Report

Water Resource Management

by G. P. Whittle
Covering Period
October 7, 1973 - December 6, 1973

A major effort has been initiated to utilize the data collected from the five DCPs installed in the Warrior River in a water quality mathematical model.

DCP Monitoring

The water quality data received from the DCPs have been stored in a computer and include the parameters of dissolved oxygen (DO), temperature, pH, and conductivity. Computer programs have been written and applied to extract the collected data and present it in a graphical form. The computer programs have considerable flexibility permitting graphing of each data point, or orbital, daily, weekly, or monthly averages.

As a first step, orbital averages for each parameter for a given DCP have been plotted and the dissolved oxygen plots for DCP No. 6060 for the month of August, 1973 are shown in Figures 1, 2, and 3. The detail presented in these graphs is noteworthy. The date and time for each orbital overpass when data were collected are shown. For reference, the critical DO concentrations of 5.0 and 4.0 ppm are noted on the graphs by the "A" and "B" symbols, respectively. In addition, data collected during the daylight hours may be plotted separately from data collected during the nightime hours, as shown in Figures 2 and 3, respectively. Such a comparison will yield information on the degree and effect of photosynthetic activity within the waterway.

DCP NO. 6060

DISSOLVED OXYGEN (PPM)
(ORBIT AVERAGES)
Day and Night Averages

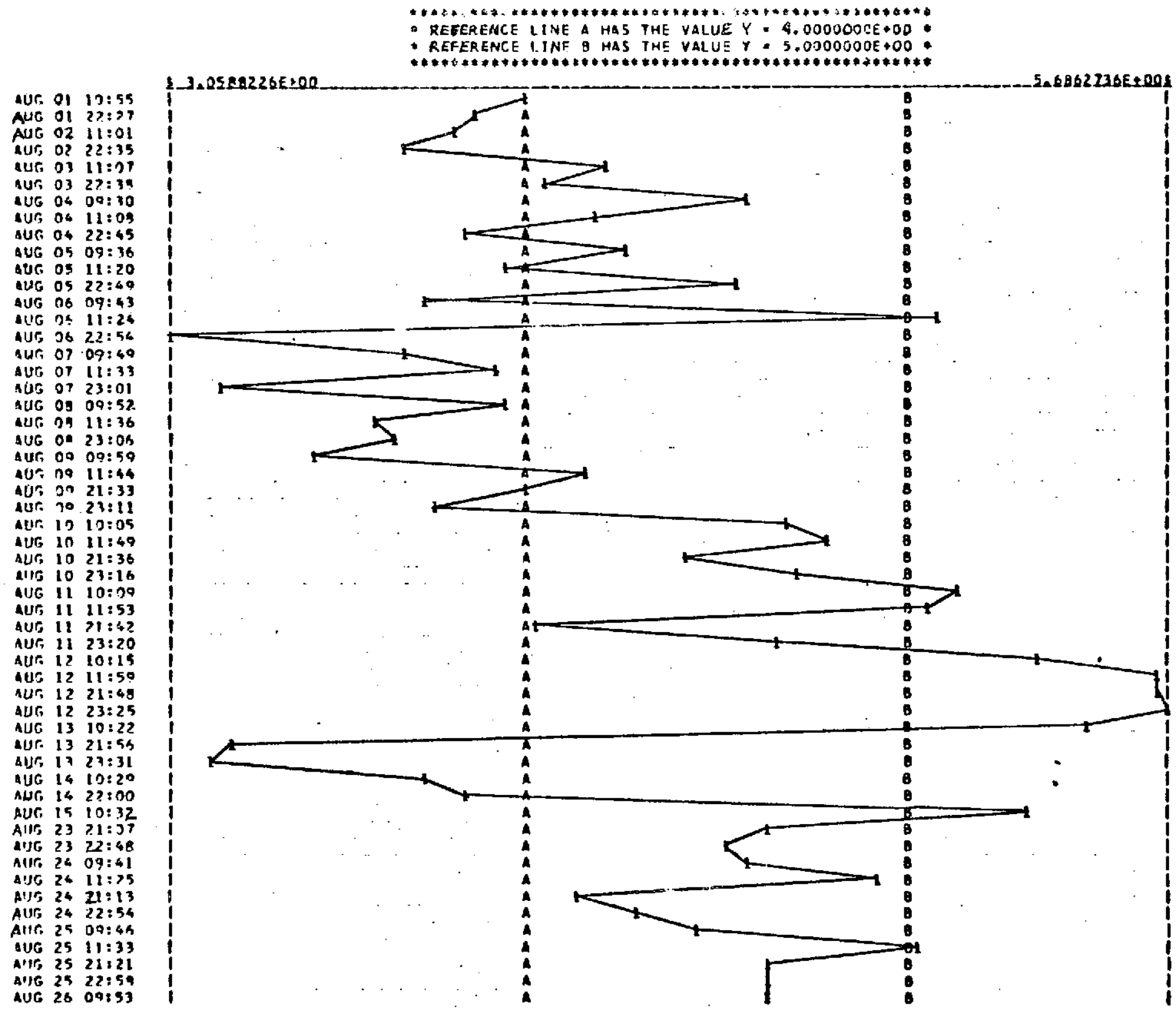
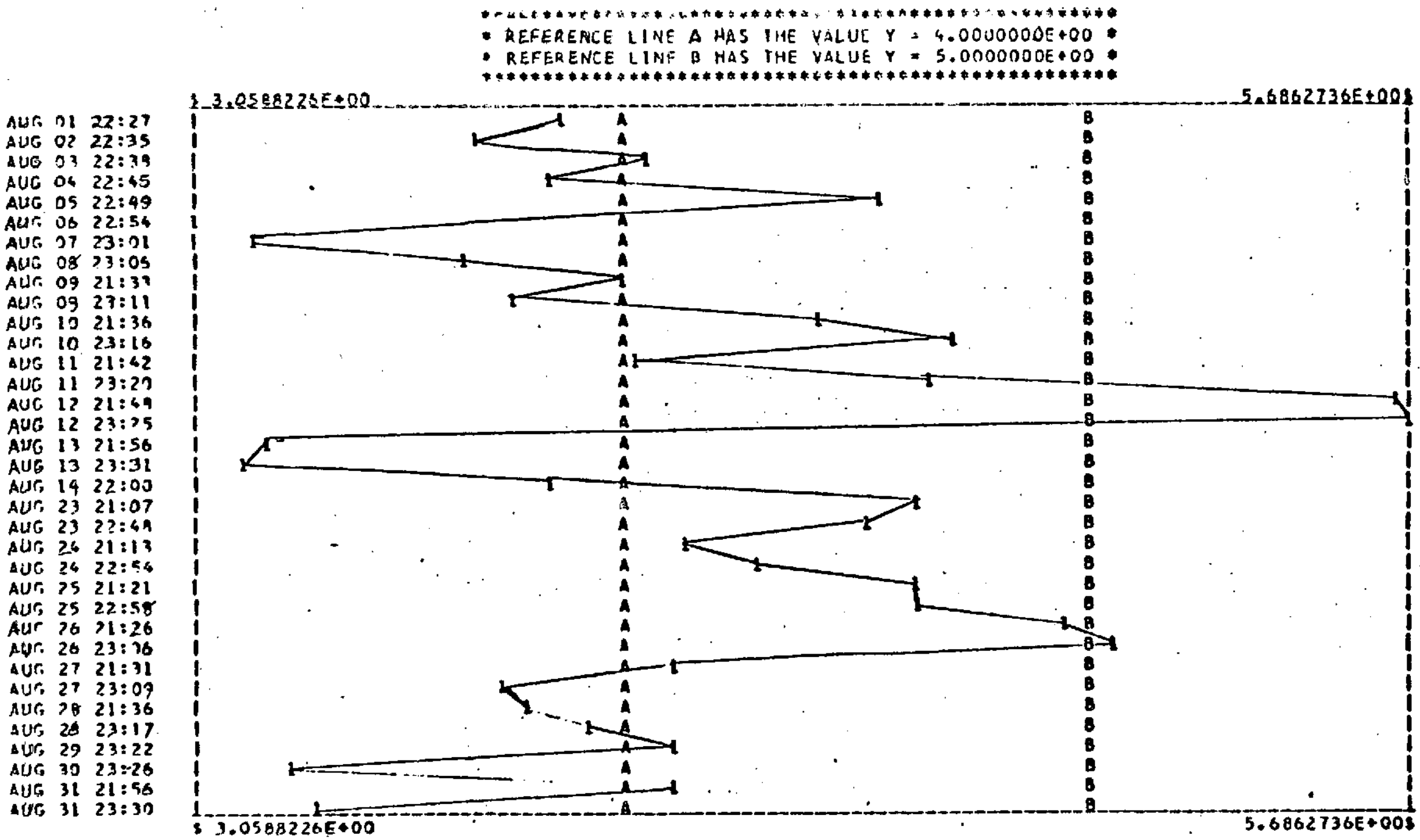


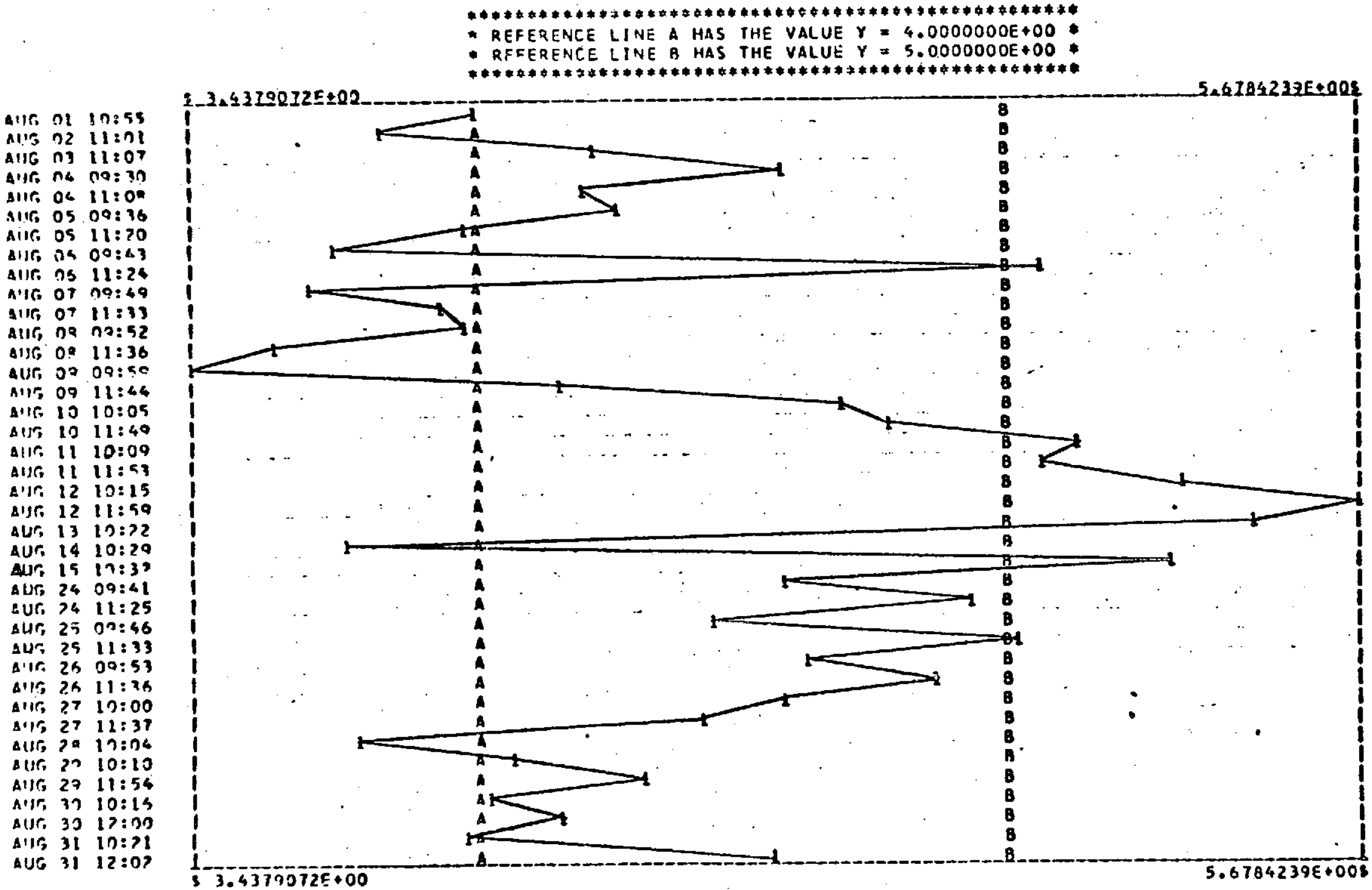
Figure 1. Averaged Orbital Dissolved Oxygen Values Collected by DCP No. 6060 for the Month of August, 1973.



DCP NO. 6060

DISSOLVED OXYGEN (PPM)
(ORBIT AVERAGES)
Night Only

Figure 2. Averaged Orbital Dissolved Oxygen Values for Daylight Hours
Collected by DCP No. 6060 for the Month of August, 1973.



DCP NO. 6060

DISSOLVED OXYGEN (PPM)
(ORBIT AVERAGES)

Day Only

Figure 3. Averaged Orbital Dissolved Oxygen Values for Nightime Hours Collected by DCP No. 6060 for the Month of August, 1973.

industry, the AWIC, and The University of Alabama through the ERTS-A Contract, to develop a total system of water resource management. The DCPs will play a central role in model verification studies as well as in routine monitoring after waste discharges have been allocated to assure that established water quality standards will be met.

Cost Analysis of ERTS-DCP Water Quality Data Collection System

The concept of cost/effectiveness may be applied to the DCP monitoring system since it is possible to remotely-sense water quality data by conventional monitoring stations. Also, as will be discussed, a cost-benefit approach may be applied.

Actually, two comparisons may be made: 1) The DCP system vs conventional sampling from a boat; 2) the DCP system vs on-shore conventional monitoring stations capable of transmitting the data by radio to a central receiving station.

During the summer of 1973, four DCPs were placed at strategic points in the Warrior River beginning at river mile (R.M.) 385.0 and proceeding downstream to R.M. 338.3. This length of 46.7 miles exemplifies a wide variety of water resource uses ranging from agricultural runoff to drainage from strip mine to receiving industrial waste waters. Concurrent with the DCP program, a conventional boat sampling survey was conducted in a cooperative effort involving the University and five major industries on the river. The river is sampled at eight sampling stations on one to three days per week. The cost of this survey, not including the purchase of the sampling boat, was approximately $4,200 for a four-month period. This cost, however, is not realistic since student salaries were utilized in

A second example of graphed data is shown in Figure 4 where orbital averages of pH values are presented.

Mathematical Modeling

The graphed data presented in this bi-monthly progress report are but examples of the capability being developed. The mathematical model developed by Lamar Larrimore* will be utilized to predict the water quality as a function of waste loadings and river flows. Verification of the model will be attempted by comparison of the predicted values with those observed in the DCP system.

The use of the remotely sensed data in modeling verification will offer unique advantages in water resource management. The state water pollution regulatory agency, the Alabama Water Improvement Commission (AWIC), has been apprised of our efforts and expressed considerable interest in this approach. In this regard, the AWIC has recently awarded a contract to the Department of Civil and Mineral Engineering, The University of Alabama, to model selected stream segments, including the reach of the Warrior Rvier where the DCPs are presently installed. The AWIC intends to use the developed models to allocate waste loadings and issue discharge permits to the waste contributers within each segment. Five major industries located on the Warrior River have indicated their interest in our DCP concept and efforts are underway to secure an industry sponsored project for a conventional sampling water quality survey to compliment the remotely sensed survey. A joint cooperative venture is being pursued involving

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*Third Bi-Monthly Progress Report, Alabama ERTS-A, Special Report, "An Investigation to Determine the Optimum Monitoring Sites for Placing ERTS Data Collection Platforms in a River Basin."

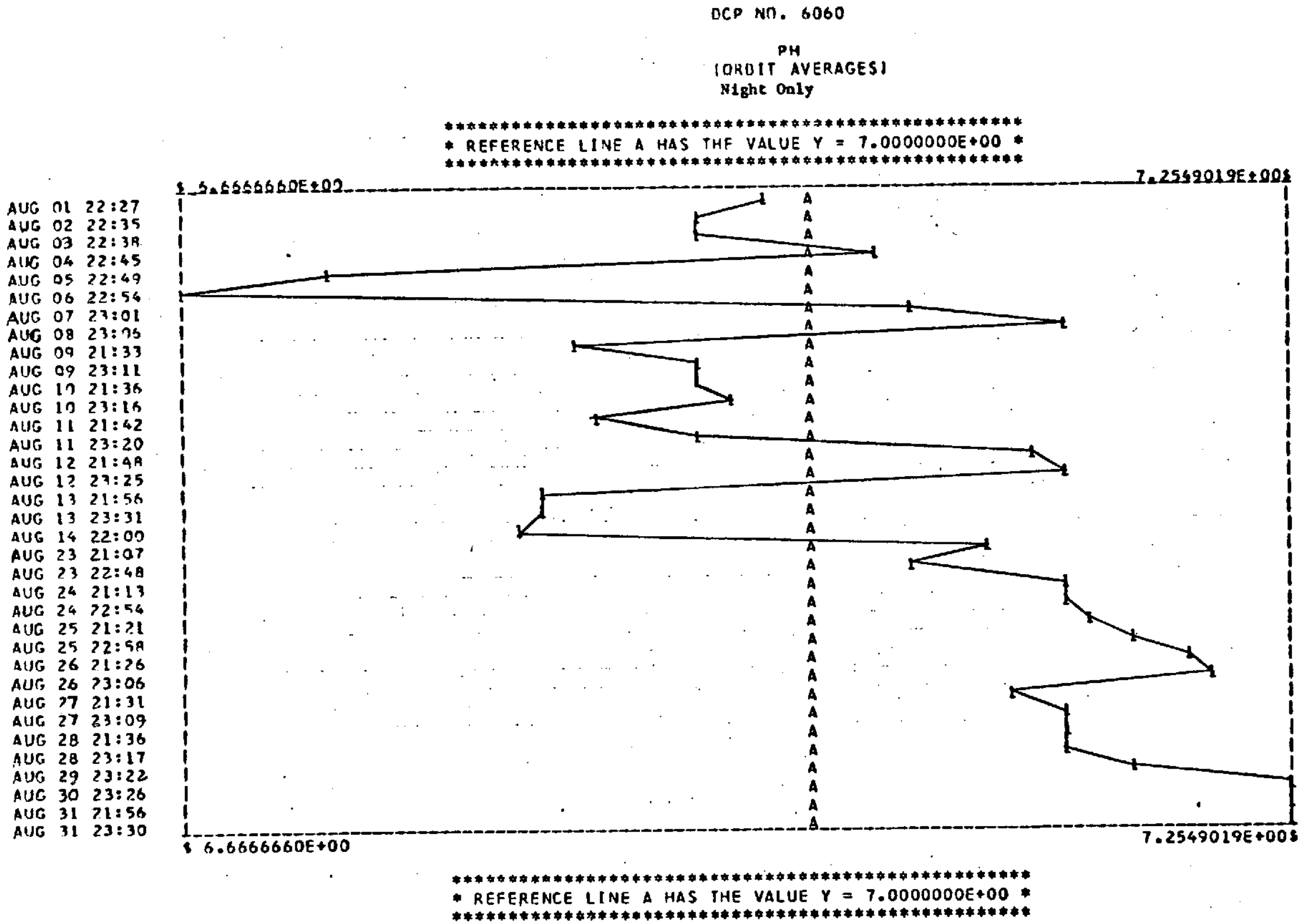

Figure 4. Averaged Orbital pH Values Collected by DCP No. 6060 for the Month of August, 1973.

calculating the funds required. A comparison may be made based on man-hours expended on the conventional and DCP programs as related to the quantity of data collected.

The man-hour/data collected analysis is presented below:

Program	Man-Hours Per Week	Data Bits Collected/Week	Man-Hours Per Data Bit
Conventional	40	80	0.50
DCP	40	448	0.09

The above comparison shows a cost ratio of approxiamtely 5.5 to one in favor of the DCP system based on data bits collected.

The costs of the DCPs manufactured in mass quantities are not known since the ones presently employed were developed in a research effort. Similarly, the cost of the satellite, launching, ground receiving stations, and support personnel cannot be utilized in the present system since these costs would be prorated over the entire future users of the DCP concept.

At this time the cost of remote-sensing conventional stations is not known but these figures will be obtained for the final cost comparisons.

At cost/benefit approach is also applicable to the DCP system as certain benefits are obtained which normally are absent from conventional systems. These include: 1) The ability to monitor continuously day and night, summer and winter, under adverse environmental conditions; 2) portability and quick transport features of DCPs compared to the lack of these features in on-shore facilities; 3) elimination of need for conventional power sources, air-conditioning, and submerged piping structures required for on-shore installation;

4) ease of access for servicing and calibration deemed better than for conventional methods. The benefits of these features are not easily priced but should be considered in comparative study.

APPENDIX II-B

Progress Report Concerning Environmental Studies

by Lamar Larrimore
Covering Period
October 7, 1973-December 6, 1973

As stated in the previous progress report, all data collection platforms (DCPs) have been installed and are transmitting data to the satellite.

We are presently working with people in the data processing group to convert DCP data to a form such that it can be used together with conventionally acquired data in verification studies using the water quality prediction model previously developed by our group. This involves converting the raw data to averages over various time intervals. We are also having the conventionally-acquired data and the DCP data (averaged over each orbit) plotted versus time in order to keep a check on the accuracy of data received from the data collection platforms.

Based on back-up measurements taken by conventional means at each DCP site (during servicing), all sensors seem to be performing acceptably with the possible exception of the pH sensor. It seems that during calibration procedures both the pH sensor on the DCP and our own portable pH meter read pH 4 and pH 7 buffer solutions correctly but five different readings when placed in a sample of river water. This could be an indication of nonlinear response in the supposedly linear range of measurement on one or both of the instruments. As a means of verfying this initial diagnosis, both instruments will be checked with a series of intermediate pH buffer solutions.

We have also experienced some difficulties with the band clamps which keep the CDP watertight, as they will become twisted to such an extent that the necessary torque can't be applied. This situation has been remedied by switching from spot welds to seam welds as a means of strengthening the clamps.

One other problem encountered was that the section of pipe supporting the antenna on one of the DCPs had broken loose from the float and toppled over. Since it had ripped loose from the aluminum float, there was no way to keep it upright with only the support of the guy wires. As a means of solving the problem without either bringing the entire float and DCP unit in to the shop or requiring any welding to be done at the DCP site, it was decided to place a strip of thick aluminum across the float diagonally, with openings cut out for the antenna support and the eyes to which the guy wires are attached. Once the guy wires were put back in place there was no way for the aluminum strip to shift or come loose. Should the problem occur again, this solution will provide a quick and simple method of repairing the damage with only minimal "down time" time for the DCP.

These and other minor problems encountered during the set-up and initial operational stages of the DCP network have hopefully been eliminated such that we can now turn our efforts toward fully utilizing the capabilities of the DCPs as a water quality management tool.

APPENDIX III

DATA PROCESSING AND DATA MANAGEMENT

With contributions as follows:

Appendix III-A by E. T. Miller and
Sam Schillaci

APPENDIX III-A

Data Management and Data Processing

by
Dr. E. T. Miller
and
Sam Schillaci

Covering Period October 7, 1973-December 6, 1973

As of November 1, 1973, The University of Alabama's IBM 360/50 system was replaced by an RCA Spectra 70/6. The new system is an interim system until the Univac 1110 Computer arrives and is installed sometime next summer. The Spectra 70 Computer was installed so that we would not lose our IBM software and so that conversion could take place smoothly. Many of our programs and software were programmed in PL/1, a language developed first by IBM, which Univac currently does not support.

The interim computer is intended to run in an emulator mode so that no changes in programs or job control language were needed. No 7-track tape drives are installed on the Spectra 70 which was unfortunate because all data sent from Huntsville are on 7-track tapes. When the Spectra 70 was installed, many things that did work on the 360 were found to have problems on the Spectra 70. Indexed sequential file structure, of which our base file is constructed, many of the utilities, and GIS failed to work properly. These problems were finally corrected, although strange problems still occur once in a while, causing delays in processing on the project.

In spite of these problems, the data processing section did make notable progress. One, a Water Quality Information System was produced using GIS (Generalized Information System). The data used in this project was the water quality data from the Warrior River. A file called WATER was created using GIS to be used mainly by this data base language.

With this language, such tasks as listings, reports, and graphs would be a lot easier to perform, compared to standard language such as FORTRAN or PL/1.

The file created by GIS is a generation data group consisting of two entries for ease of updating and changing records. This type of file is sequential in organization making it faster to access than on Index Sequential Type file. The two entries give you two copies of the data, the -1 generation and the 0 generation. An update would be the +1 generation. The -1 copy would have the oldest data, i.e. last month's, the 0 copy, the current month, and the -1 is used to add the future months.

The ease in accessing is shown by the following procedure. Suppose an industry added some new water pollution equipment to their discharge water which is located around DCP #6060. A manager of the plant may want to know how effective the new equipment was to the surrounding water in raising the DO of the water since it was installed on September 1. An average of the DO is needed before and after this date; thus the following GIS procedure could be used:

```
QUERY WATER (0)
LOCATE RECORD
WHEN PLATID EQ 6060
IF MONTH LT 9
AND YEAR LE 73
AVERAGEI DO
ELSE
AVERAGE2 DO
IN ANY CASE
EXHAUST RECORD
LIST 'AVERAGE DO BEFORE SEP 12=',AVERAGE1
LIST 'AVERAGE DO AFTER SEP 12=',AVERAGE2
```

GIS eliminates the data and record description of the other languages in accessing the file by putting the descriptions in a DDT library (Data Description Table).

Also completed in the past two months is a general plot routine for the DCP data. This program developed by Gary Darby is capable of producing a plot of any or all of the sensors by month and/or DCP number and a specific type, either orbital, night time, day time, or monthly averages. The routine is very versatile in input to the type of graphs needed.

These two factors will help in one of the objectives of the water quality system, to compare historic data to that collected by ERTS and DCP's and also to help validate the river model proposed by Lamar Larrimore in his thesis. Work is now taking place to collect historic data to feed into his model.

On the land use side, work has been done in terms of validation also. For instance, the data collected from the U-2 photographs have been keypunched and placed into the base file. With this data a comparison program was run to check the visual classification techniques of ERTS photographs against the U-2 prints. Some of the initial output has been analyzed and sometimes around 75% of the scene is classified in the same way.

The next validation process consists of comparing the sequential clustering technique developed at Huntsville versus the ground truth data. This process is discussed in full in Lee Miller's thesis.

One of the future prospects to be looked at is the actual sequential clustering algorithm. The algorithm is considered to be a very good one, but the cost of processing a scene is very high. Other techniques will be studied to determine if this cost can be decreased while also keeping or improving the classification ability.

APPENDIX IV

ECONOMIC CONSIDERATION AND USER LIAISON

With contributions as follows:

Appendix IV-A by J. F. Vallery and
L. Davis

M E M O R A N D U M

TO: Dr. George Whittle, Acting Director, ERTS Project

FROM: Ted Vallery and D. Larry Davis, Economists

SUBJECT: Bi-monthly Progress Report (October 7-December 6)

DATE: December 5, 1973

Our activities over the last two months can be categorized into two areas:

1. Continued efforts to improve the analysis of ERTS's investigators so that a cost-effectiveness and cost-benefit analysis may evolve; and,

2. Continued consulting support to interface users and investigators information flows.

In order to accomplish the first set of activities, four specific tasks were completed. First, the interim report for evaluating ERTS information was discussed at length during two sessions with all ERTS investigators. The conceptual framework and required inputs were explained. However, since some terms and concepts were unfamiliar to many of the investigators, a second task was to prepare a handout on benefit/cost analysis. This handout explained, in some depth, the basic terminology of benefit/cost analysis, including relevant constraints, various theoretical and methodological issues of the objective function, alternative objectives, measurement of prices, value of forgone opportunities, and various other related topics of benefit/cost analysis. The third task designed to improve ERTS's investigators' understanding of B/C analysis was to critique the cost analysis that we had received from various ERTS investigators. This was especially fruitful for the cost-analysis of ERTS-DCP Water Quality Data Collection Systems. (Prepared by Dr. George P. Whittle.) This feedback response technique provided other ERTS investigators with a realistic example of cost-effective analysis. Finally, our fourth task in this category was to brief two associate scientists from the Earth

Satellite Corporation (EARTHSAT), Drs. Alexander J. Tuyahov and Dave Stroal, on the current status of the cost analysis of ERTS information. Dr. Tuyahov appeared to be impressed with the accomplishments here in the areas of land-use and water quality (DCP's).

In the second category, we continued to be available as consultants for ERTS users and investigators during weekly meetings and anytime by phone or appointment. We are still acting as a clearing house for all cost information; but maintain that cost analysis for particular projects should be included in the individual investigator's report. We feel that this format provides the most meaningful input to the ERTS project.

APPENDIX V

MARINE SCIENCE STUDIES

With contributions as follows:

APPENDIX V-A

MARINE SCIENCE STUDIES

The progress report for the period October 7, 1973 - December 6, 1973 will be submitted in the Eighth Bi-Monthly Progress Report due February 6, 1974.

APPENDIX VI

MARSHALL SPACE FLIGHT CENTER CONTRIBUTIONS

APPENDIX VI

MARSHALL SPACE FLIGHT CENTER CONTRIBUTIONS

The progress report for the period October 7, 1973 - December 6, 1973 will be submitted in the Eighth Bi-Monthly Progress Report due February 6, 1974.

APPENDIX VII

GEOLOGICAL SURVEY OF ALABAMA CONTRIBUTIONS

With contributions as follows:

Appendix I-A by J. A. Drahovzal

APPENDIX VII-A

by J. A. Drahovzal
Covering Period October 7, 1973-December 6, 1973

USER ORIENTED WORK

The manuscript entitled "Remote Sensing of Earth Resources in Alabama: A New Environmental Perspective" authored by the members of the Remote Sensing Section has been submitted to the in-house editors (GSA). Moreover copies for review and approval have been sent to NASA-MSFC and EROS-MTF. Thus far, a very favorable response has been voiced by personnel at NASA-MSFC.

PHYSIOGRAPHIC MAPPING

As part of the geological activities, the Survey is presently investigating the feasibility of delineating from ERTS-1 data. The many physiographic region lying within the state of Alabama (fig. 1). Thus far a few regions have identified and outlined in the northern part of the state. The scale utilized in this project is 1:250,000. In one instance ERTS data has been helpful in obtaining the boundary between Little Mountain and Moulton Valley. This delineation was not discernible on the 1:250,000 topographic map. Some problems are presently being encountered in the Coastal Plain-Appalachian Plateau and Coastal Plain-Piedmont regions where topographic definition is not very apparent.

DETECTION OF SHORELINE CHANGES FROM ERTS-1 DATA

A paper which was delivered at the Southeastern Division of the Association of American Geographers on November 19, 1973, is presently under review for publication in the Southeastern Geographer. The Abstract has been published.

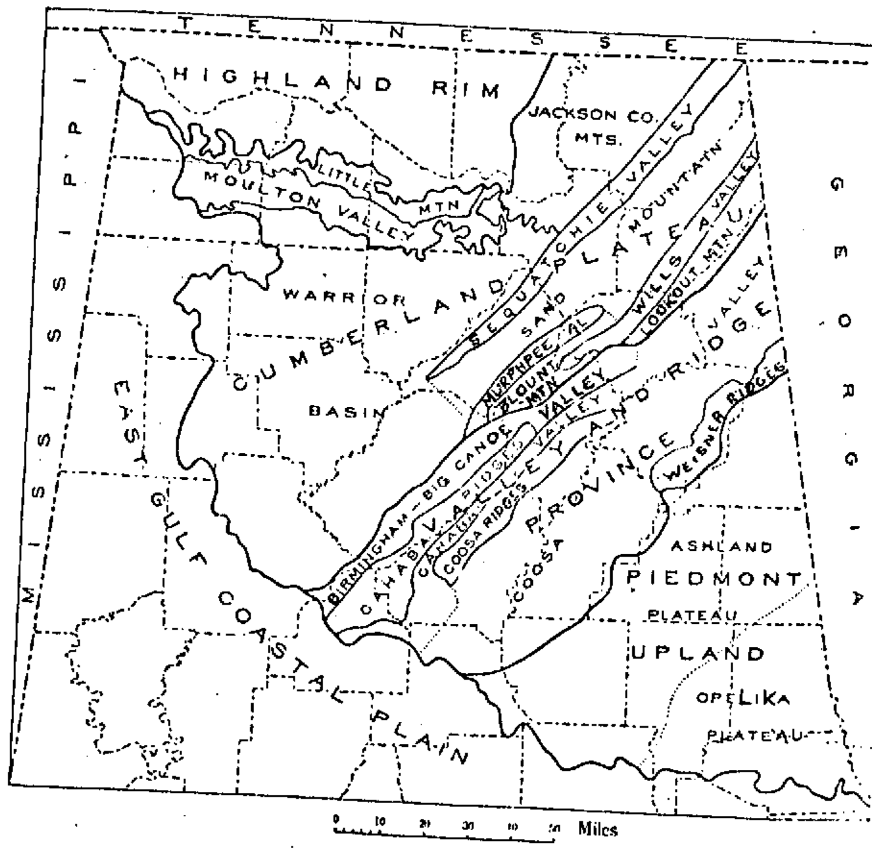

Figure 1. Physical divisions of Northern Alabama.

As a follow-up from this paper, studies of changes in the shoreline are now being continued along the Mississippi Sound area west of Mobile Bay (fig. 2). Investigations of this type east and west of Mobile Bay will provide a better understanding of the dynamic processes of the whole Gulf Coast and also of Mobile Bay itself.

ALABAMA SALT MARSH INVENTORY FROM ERTS DATA

Along with changes in the shoreline studies concerning salt marsh, inventories have also been undertaken by the Environmental Geology Division.

Alabama's coastal marshes are amoung the most productive seafood nursery grounds on the Gulf Coast. It is important that these areas be mapped for management and protection (fig. 3).

Salt marshes were delineated from ERTS MSS band 7 image 1158-15564. The marshlands appear as dark-gray areas because of their high moisture content. Mapping was done at a scale of 1:250,000. U-2 infrared photographs of the Mobile Bay area were used as support data.

The usefulness of ERTS imagery in gross mapping and inventorying is evident from this project. The map produced will be used in a report being prepared by the Environmental Geology Division of the Alabama Geological Survey dealing with offshore drilling and superport construction in Alabama waters.

The marsh areas delineated were measured with a planimeter and an estimate of total acreage was calculated. A total of 30,200 acres of salt marsh were measured. This compares with a published figure of 34,614 acres which was derived from topographic maps. Known areas were also measured from the ERTS data and comparison produced an error of approximately 2 percent. The difference in marsh areas is thought to be a result of marshland draining especially along the eastern margin of Mobile Bay.

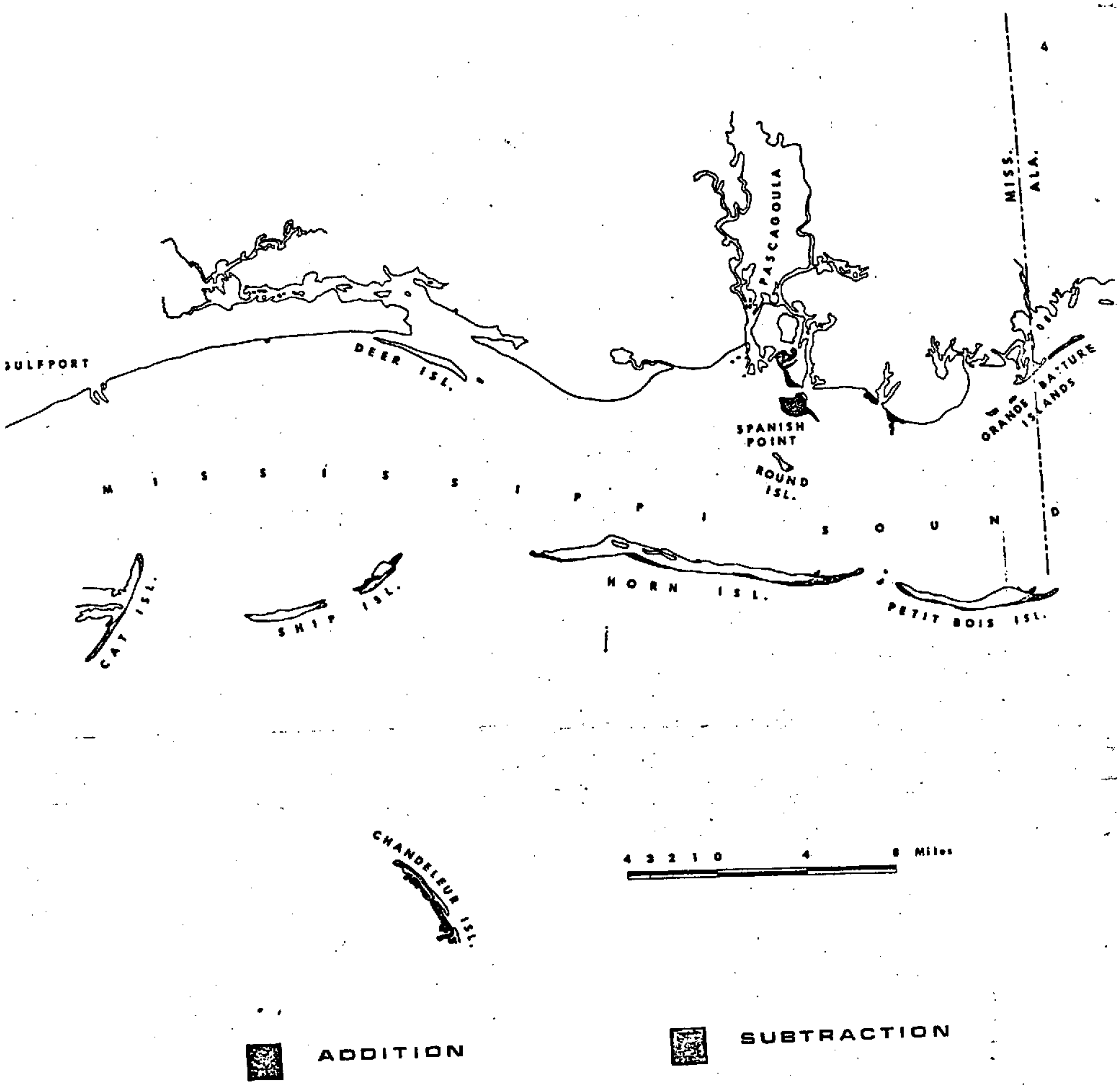

FIGURE 2

CHANGE DETECTION FROM ERTS-1 DATA ALONG THE MISSISSIPPI

The major problem encountered was the differentiation of marsh and upland vegetation in inherently wet areas such as the floodplain of the Mobile River. U-2 photography had to be employed in these areas to map the marshlands. The accuracy of the mapping is also a problem but the intended usage of this map warrants a sacrifice of accuracy.

Future projects of this type are possible. However, more data in the form of color composite and inhanced images is needed.

LINEAMENTS

The study of lineaments from ERTS-1 data has been consistently described in bi-monthly reports from the beginning of the project. This section updates progress which has been accomplished with lineaments in the last two months.

Thus far, lineaments show possible correlation with many of the known hydrothermal mineral deposits of the Valley and Ridge and Piedmont provinces. Investigations have shown the relationship of fluorite-barite prospects with the two major lineaments (the Anniston and Harpersville). About half of these prospects fall on one or the other of the two major lineament complexes. As a result of this apparent correlation, geochemical surveys were conducted. A series of soil sampling traverses were made across some of the lineaments. Results to date have been mixed, but some traverses show an apparent direct relationship to the lineament. In one traverse, chromium highs are located on two lineaments associated with the Anniston lineament. In another, farther to the south, highs in lead, zinc, and chromium correlate with the trace of the Anniston lineament. Further studies are planned in other parts of the state and especially near lineament intersections where samples will be collected on a grid pattern. This

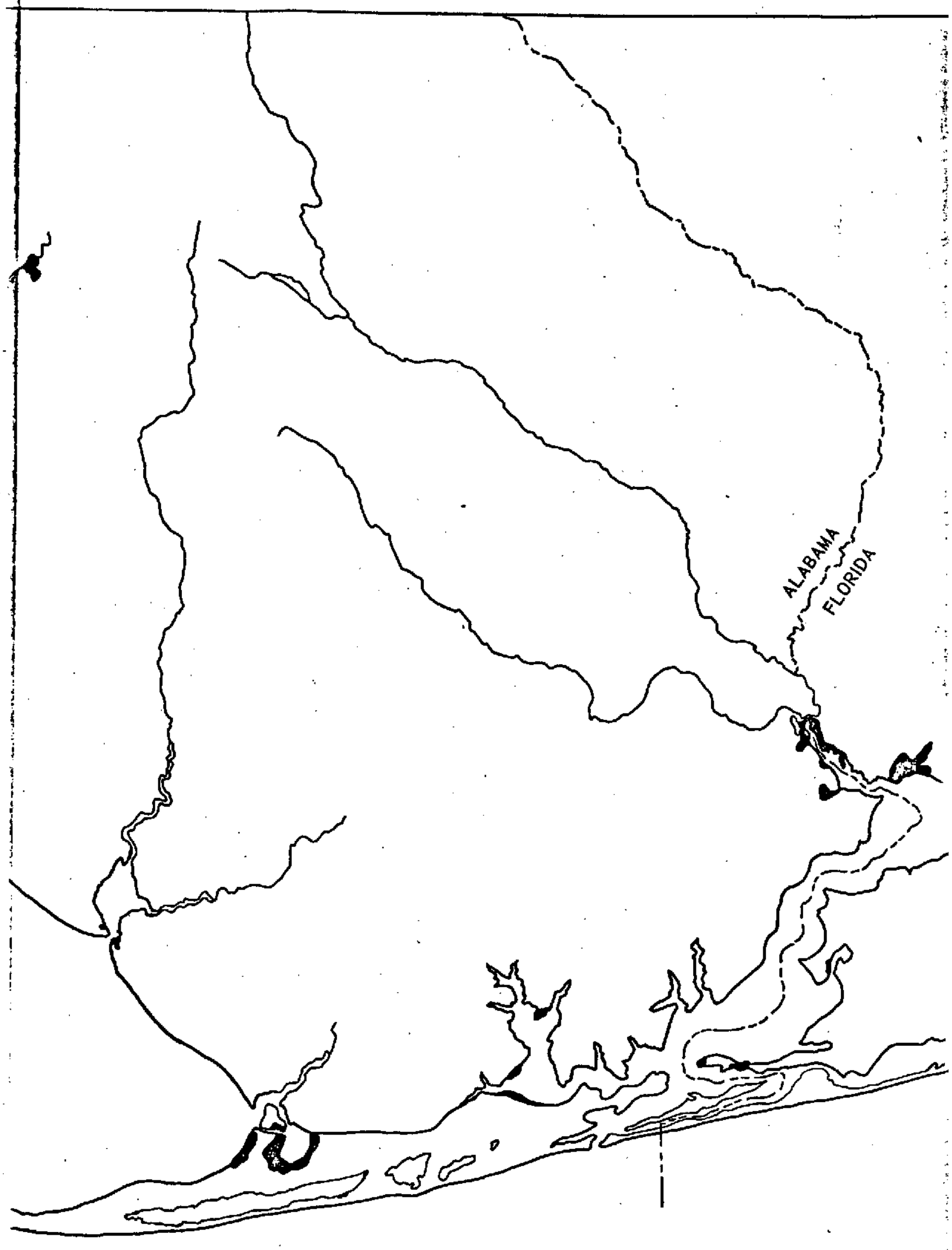

FIGURE 3

Distribution of Alabama Salt Marshes

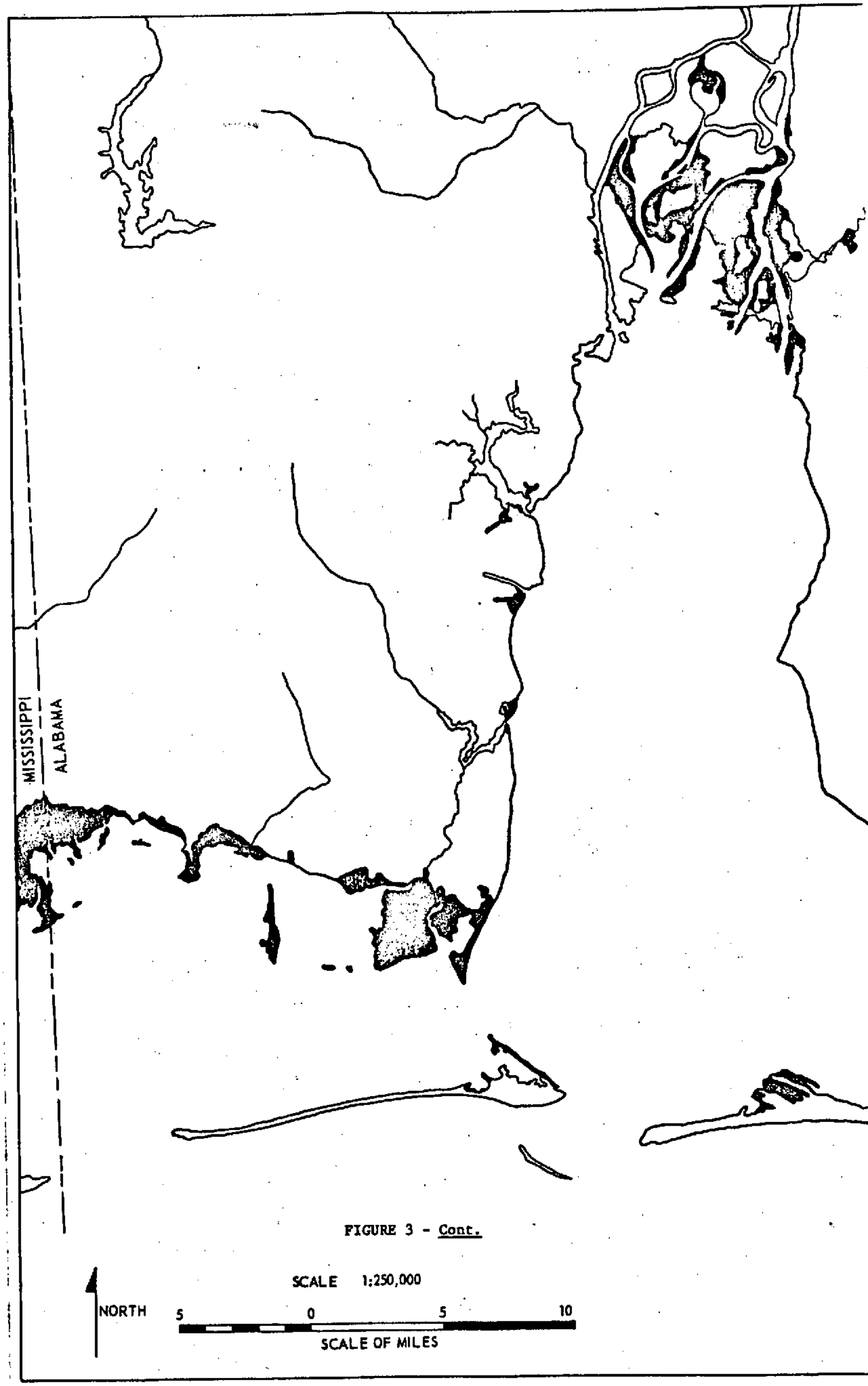

FIGURE 3 - Cont.

method of mineral exploration is becoming a standard operational procedure in searching for mineral resources in the state.

Several detailed gravity surveys have been run across the Anniston lineament. The survey conducted lies between a gravity maximum centered about 50 kilometers to the southwest and a minimum centered 20 kilometers to the northeast. A profile was made over Lower Mississippian carbonates of the Interior Low Plateaus province. The profile shows a small, but marked negative gravity anomaly at the point that the Anniston lineament passes through the area. The sharpness of the anomaly suggest that it represents a fault downthrown to the southwest. Applying the "half maximum" rule, the anomaly could originate as much as 1,500 meters below the surface. The depth to basement in the area is unknown but is estimated to be between 1,500 and 1,900 meters below the surface. The anomaly could represent offset in the basement or possibly the Cambrian Copper Ridge Dolomite. This structure contour map of the top of the Chattanooga Shale shows a trend that may be either a flexure or a fault. There the lineament is shown in red. A second profile was run 64 kilometers to the southeast across the Anniston lineament. Here the lineament crosses the Pennsylvanian Pottsville Formation of the Cumberland Plateau. A similar, but smaller, negative gravity anomaly is encountered where the lineament is traversed by the profile.

The gravity results to date suggest that faulting is associated with the Anniston lineament at least along part of its trace. Magnetic surveys are planned, but to date, magnetic interference has prevented these studies.

Another feature of the two major lineaments which may be of significance is their apparent seismicity. Since 1886, 15 earthquake epicenters have been recorded in Alabama. Nine of them are shown on this map and six have occurred directly on one or the other of the two major lineaments. Coincidence of epicenters with lineament traces not only indicates that the lineament-causing features are still active, but also implies that they are related to basement structure.

In addition to the work carried out on the two large lineament complexes, some fairly detailed information has been collected on two shorter lineaments that are significant to site selection studies. Many of the smaller lineaments run in echelon, intersecting the longer major lineaments at low angles. Most of these features have now been transfered on 1:250,000 scale maps. Lineaments which were detected on SLAR imagery have now been confirmed on ERTS data and vice-versa. However, the concentration of the Survey's efforts are oriented more toward a close analysis of major lineaments where field investigations have been and will continue to be intensive.