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ERTS-A DATA USER INVESTIGATION

OF ERTS INFORMATION SYSTEM DEVELOPMENT

FOR POTOMAC RIVER BASIN

NATURAL RESOURCE MANAGEMENT

TYPE II REPORT #1

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PRINCIPAL INVESTIGATOR: N. H. MACLEOD

THE AMERICAN UNIVERSITY

WASHINGTON, D.C. 20016

F. Gordon
Code 902

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3.2.2.2 Preface:

The Potomac River Basin is one of the first watersheds to be used by colonial Americans for agriculture, mineral extractions, fisheries, transport and the siting of provincial and, now national, capitals. The variety of present use, influences from past use and pressures toward even more intense use in the future in combination with great geological, hydrologic and biological diversity make the Potomac Basin a challenging test site.

The objective of this ERTS-1 investigation is to develop a resource management information system which can store, retrieve, analyze, and produce desired resource status reports incorporating ERTS, aircraft and ground data. To this end, field work has been conducted in each of the five geologic provinces in the Basin to set out sub-test sites (quadrats in transects) for vegetation, soil and use analysis. The major work has been the development of computer programs to (1) read the ERTS CCT for MSS data input, (2) geographically locate MSS pixels, (3) 'correct' data values for sample deviations and for geographic location, (4) select geographic regions within frame to access multi-channel data for analysis, (5) analyze multiband data by feature discrimination, water quality assessment, plant community variations, cultural activity (strip mining).

This work is brought to the attention of federal agencies such as EPA, U.S. Park Service, USAID, U.S. Department of Interior, and interstate groups such as the Interstate Commission on the Potomac Basin, so they can evaluate the developing systems for their own needs. Some agencies are now working directly with this project incorporating the data products- maps, etc. into their current programs.

While substantial progress has been made in data analysis, there is still much to be done in completing the data system, particularly in correlating ground and aircraft data with the spacecraft imagery. A current cooperative program with the U.S. Park Service, EPA, the American University investigators, and some local groups interested in water quality has as its objective the intensive sampling of water quality in the Potomac estuary during ERTS passes. This will be continued. Much remains to be done in correlation of slope and plant ecotypes classifications with the analysed imagery.

Potomac Study:

3.2.3 Introduction

As the Potomac River Basin is studied and monitored by a number of federal, regional, state and local agencies, there exists a great deal of resource information concerning agriculture, forestry, hydrology, recreation, industry and urbanization. Numerous detailed studies in each of these disciplines exist. We saw the major problems as the need to quantitatively incorporate remotely-sensed data, including ERTS and aircraft data information, into a resource information base which included other existing data, the need to derive extracting resource information from this data, and the need to fashion a system to make the resource information base easily accessible to resource managers.

To reach these objectives, we have devised procedures for (1) field classification of relevant resource data including plant communities using Kuchler's physiognomic classification in pixel-sized quadrats and a water run-off classification, (2) analysing MSS-CCT data on the GSFC SESD 360/75 for various features including mineral and organic pollutants in water, strip mines, gravel pits and open (unvegetated) surfaces, and different plant communities, and (3) filing or archiving data on computer disc storage for retrieval in resource management studies.

Some field work has been carried out in each of the five physiographic regions of the Basin to obtain the plant community and run-off data though this work is by no means complete. Other field work has been suggested by analysis of the ERTS imagery. In particular we have been intrigued by the Wicomico River channel running to a drainage nexus (of other channels radiating from this junction) in the Cedarville Forest area of Maryland, as well as by the remarkable information on river pollution derived from computer analysis of the MSS data.

The objectives related to information processing and management were considered to be reasonable in terms of available software and the availability of the GSFC SESD computers for this investigation. In terms of producing specific analyses, we have been successful in reading CCT's, in geographic referencing (and corrections), and in analysis of plant communities. We still have much to do in making the data accessible in a systematic way. In part, this is because of the usual difficulties in bringing software components together in a compatible mode so that CCT tape reading produces data on which classification algorhithms can work, for example. In part, and perhaps more important, there is a lack of agreement and even understanding by resource managers of what a resource system should do and therefore, what one should be. In working with the Park Service or EPA. for instance, we find that they are also studying the question of what their information system should consist of, what purposes it should serve.

We have therefore paid more attention to the problems of analysing ERTS data, incorporating other data, including calibration data, into the data base and making the data base accessible. We will continue this work, making our results available to resource managers and working with them as their major information systems emerge (like the national land-use inventory of USDI, the EPA data base, the USDC census data).

Our cooperative work with other groups has grown with our ability to produce analysed ERTS data. Initially we did very little work with others, but we are now working with the U.S. Park Service, EPA, USDI, the Potomac Interstate Commission, and local conservation people. We are expanding this aspect of the project as our capacity to produce useful results increases.

New Technology:

New software has been developed under this task, reported as a system for feature classification and included in this type II report. We do not consider these programs to be new technology.

Several simple, inexpensive techniques are used for analog image analysis and enhancement-color compositing by multiple projection and use of diazo film using new assemblies of equipment. We do not consider these to be reportable new technology.

Therefore, we do not consider there is any new technology to report under this task.

APPENDIX

REPORTS

DRAFT

ERTS-ANALYSIS

A REMOTELY ACCESSED COMPUTER SYSTEM FOR ANALYSIS OF EARTH RESOURCES TECHNOLOGY SATELLITE DATA

PREPARED BY

DR. J. S. SCHUBERT AND DR. N. H. MACLEOD

DEPARTMENT OF BIOLOGY, THE AMERICAN UNIVERSITY

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DRAFT

JUNE 1973

A REMOTELY ACCESSED COMPUTER SYSTEM FOR ANALYSIS OF EARTH RESOURCES TECHNOLOGY SATELLITE DATA

INTRODUCTION

Earth Resources Technology Satellite (ERTS) multispectral-scanner (MSS) data is available as digital values of reflectance levels in four spectral bands on computer-compatible tape (CCT). The principal advantages of ERTS digital data over other ERTS products such as black and white or color images are two: first, the maximum spatial and grey-level resolution which can be obtained by the sensors is available to the user; second, the digital values can be manipulated either singly or in combinations, including spatial and multi-channel relationships, to extract information which would not be available from analog techniques. Thus, although each sensor is set to resolve up to 126 different reflectance levels, the maximum number of distinct levels of grey or an individual color which can be distinguished by the human eye is limited to approximately eight (1). The spatial resolution of the sensors is, likewise, much greater than that which can be resolved by the human eye. The actual spatial resolution of each sensor is the average reflectance level over an instantaneous field of view (IFOV) of 57 M x 80 M. But the maximum resolution which is obtained from standard NDPF photographic imager (2) is limited by film grain size to less than half of this. The apparent spatial resolution is even less when images are analyzed with the human eye because of the limitation in contrast or grey-level resolution. The principal disadvantages in the use of digital data arise from the computer processing time involved and from the difficulty in obtaining results from digital processing which are useful to the investigator or resource manager.

Often a combination of digital and analog techniques can be used of obtain more useful information from ERTS data than could be obtained by either technique alone. Thus the use of imagery to select areas of specific interest which are free of clouds, or for determining the analytical technique or algorithm to be used in computer analysis can greatly reduce computer processing time and increase the usefulness of the results obtained. The computer analysis system described here has been developed in an attempt to extract that information which best utilizes digital data, and to return the results of these analyses to an investigator or resource manager at a remote terminal in a form which can be readily interpreted by him.

Since the system has been designed to utilize the spatial resolution of the original data as well as the reflectance resolution, the analytical algorithms have been designed to operate on all the data contained within an area of interest selected by the user. The results from many of the analyses may be returned to the user at the remote terminal as maps at a scale of 1:20,000 in which the spatial resolution is retained by using one typewritten character to represent each 57 M x 80 M IFOV (or pixel). The results of some analyses are presented in the form of numerical tables.

ERTS-ANALYSIS SYSTEM

To operate the ERTS-ANALYSIS system a user at a remote terminal is connected by a dial-up system for remote entry of programs (CRBE) (3) to the Space and Earth Science Directorate (SESD) IBM360/75J-OS computer. The user selects the form of analysis most suited for his purposes from a library of programs, prepares some input data and specifies an ERTS CCT which has been previously cataloged at the SESD computer center, then submits the analysis to the computer for execution. The computer completes the analysis according to a priority determined by the estimated time for execution of the job. The user can then bring the results of the analysis to the remote terminal. The specific steps required to submit an analysis and retrieve the results are discussed in the next section.

ERTS-ANALYSIS Programs and Subroutines:

The ERTS-ANALYSIS system is written in PL/I for the IBM 360-75 OS operating environment. A complete analysis submitted through the system includes a main program, geographical referencing subroutines, a choice of several analytical routines, a printer or typewriter (remote terminal) mapping routine, job control language for execution of the analysis on the 360-75 system, and user input data. Descriptions of the analytical programs available are included in the next section.

Main Program:

The main program, referred to as MAIN, co-ordinates input from the user and from the ERTS CCT, establishes data flow through appropriate subroutines, and creates the necessary files for output. It includes geographical referencing subroutines that locate the line and column number on the ERTS data tape which correspond to geographical co-ordinates of any data value on an ERTS tape for which the co-ordinates are desired. The analytical algorithms perform the specified analysis on each pixel within the area specified by the user.

What is geographical resolution?

ALGORITHMS FOR COMPUTER ANALYSIS OF ERTS-1 MSS DIGITAL DATA

ALGALL

Function and Use: This algorithm produces a listing of the reflectance levels in each of the four MSS channels for each pixel within a specified area. No special user input data is required. The principal use of this table is in the development of new algorithms or for detailed pixel-by-pixel four-band analyses performed by the user.

Product: The results from this analysis are presented in a table with each i, j point within the specified area identified by row and column coordinates and latitude and longitude followed by the reflectance values for each of the four MSS bands (see Appendix A, Fig. 1).

User Input Data: No special user data is required.

Time: (001H01) for 100 columns x 100 rows.

ALGONE

Function and Use: This algorithm is used to produce a computer map of the reflectance values of a single band of MSS data selected by the user. The actual reflectance values of 0 to 126 may be requested with letters, numerals and other typewriter characters used to represent the values. Alternatively, a number of levels and specific characters for each level with the range of reflectance values included in each level may be specified. The default for the number of levels is 35 and the character defaults for the levels are numerals 1 through 9 and letters A through Z. Any or all defaults may be overridden by explicit specification in the user data submitted.

It is recommended that a preliminary analysis using the algorithm ALGHIST be submitted to determine the distribution of reflectance values for all channels over the area in question. The most useful levels for each band may then be selected.

Product: The results of the analysis are presented as a computer map at a scale of 1:20,000 with a user-selected character representing the reflectance value in a single MSS wavelength band for each pixel. The map is annotated to indicate the reflectance values or levels associated with each character as shown in Appendix A, Fig. 3.

User Input Data: In the standard data file shown ~~in Figure~~ 2, the number of the ERTS MSS channel, NO_CHAN, must be specified. A separate data file named ONEDATA must be submitted with this analysis. It is fetched and edited in the same manner as the standard data file (Figure 2), then saved as ONEDATA (see Figure 3). The number of levels (LEVS) for reflectance value slicing, and specific characters, CH(n) where n = 1 to 26, may be changed. Upper and lower reflectance value limits must be specified for each level; thus (LEVS + 1) numerical values must appear, beginning a separate line, as shown in Figure 3. The number of these values and the values themselves should be changed by the user for the specific area and ERTS band under analysis.

Time: (001002) for 228 columns x 250 rows. (001H01) for 228 columns x 50 rows.

ALGHIST (ALGHIS1)

Function and Use: This algorithm calculates the maximum, minimum and distribution of reflectance values for each channel over a specified area. This is normally a preliminary analysis used in establishing reflectance value levels for ALGONE and other density slicing algorithms. ALGHIS1 is used to establish mid-range and normal probability distribution classes for ALGWTR.

User Input Data: No special user data is required.

Product: The results of the analysis are printed in a table, with the selected geographical area, the maximum and minimum values and the distribution of values by tens within the selected area for each channel. (Appendix A, Fig. 2)

Time: (002001) for 228 columns x 200 rows.

ALGWTR

Function and Use: This algorithm is used in the analysis of sedimentation levels and organic pollutant levels in water. The user may use the previously established values for determination of the various levels of each type of pollutant or may wish to develop his own levels in conjunction with an analysis of the distribution of water values as discussed in ALGHIS1 (see also references 1, 3, 4).

Product: The results of this analysis are presented as a computer map at a scale of 1:20,000 of all water within the area specified. The water is classified by symbols as to the approximate degree of sediment or organic pollution present in each pixel. A typical map is shown in Appendix A, with an explanation of the significance of the characters.

User Input Data: In addition to the standard data file shown in Figure 2, a separate data file named WTRDATA must be submitted with this analysis. The symbols correspond to those shown in Appendix A, Figure 4. (The symbols, number of levels, and cut-off values may be changed by the user as described for ONEDATA (Figure 3). The file should be saved and submitted under the name MYWTR.

Time: (001H01) for 228 columns by 50 rows. (001002) for 228 columns by 250 rows.

ALGHIST

$\sqrt[4]{A \times B \times C \times D}$

ALGMIN

Function and Use: This algorithm calculates the relative reflectance in all four bands (the fourth root of the product of four bands) of each pixel. Subsequent level slicing, as with the single-band analysis (ALGONE), produces a printer-plot map that emphasizes features such as strip mines and sand and gravel pits (which are bright in all bands.) The standard values for relative reflectance level slicing given in the user input data are those which have been used effectively in the Potomac Basin region. The user may specify other relative reflectance levels which are more meaningful for the area of feature under investigation (see ALGHIST).

Product: The results are presented as a computer map at a scale of 1:20,000. If the slicing levels and characters shown in user input data are used, extracted areas (strip-mines, sand and gravel pits) will appear on the map as regions of '#'. (See Appendix A, Figure 5.) The only other feature identified will be water.

User Input Data: In addition to the standard data file shown in Figure 2, a separate data file named MINDATA must be submitted with this analysis. The symbols and levels in MINDATA correspond to those shown in Appendix A, Figure 5. (The number of slicing levels (LEVS) and the inclusive values for each level, or the character set for water and extracted areas, may be changed from the pre-selected values by the user as illustrated in Figure 3 for ONEDATA. The file should be saved and submitted under the name MYMIN).

Time: (001H01) for 228 columns by 50 rows. (001002) for 228 columns by 250 rows.

ALGSIG

Function and Use: This algorithm compares the CCT reflectance values of bands 5 and 7 for each pixel with standard reflectance values (signatures) derived from field spectral measurements for 14 classes of vegetation and other features, such as water and bare soil. Numerical values from 1 to 14 are assigned to each pixel as a result of the classification. The signatures used to determine each class are shown in Table 1 with the standard set of characters. These characters may be changed by the user in his data input.

Product: The results of the analysis are presented as a computer map at a scale of 1:20,000. An identifying character based on the results of the signature analysis classification is printed for each pixel (Appendix A, Figure 6).

User Input Data: In addition to the standard data file shown in Figure 2, a separate data file named SIGDATA must be submitted with this analysis. This data may be fetched and the characters CH(n), n = 1 to 14 changed to any desired set of characters. The standard characters, as assigned in SIGDATA, are the characters shown in Table 1 and in Appendix A, Figure 6.

Time: (H01H01) for 228 columns by 50 rows, or for 76 columns by 250 rows.

Table 1. ERTS MSS SIGNATURE ANALYSIS FOR INTERNATIONAL BIOLOGICAL PROGRAMME VEGETATION CLASSES

·rected ;ital ›e Lues	No Vegetation	Sparse Vegetation (IBP* Class 3)	Open Vegetation (IBP Class 2)	Closed Vegetation (IBP Class 1)
S-7	MSS-5 >55	34 - 50	15 - 34	< 15
	Water (·)			
	Sand-flat in or near water (-)			Organic mud-flat (/)
				Seasonal short grass (orthophyll marsh) IBP-1M2-2 (M)
1	Bare soil or sand (_)	Scrub over sand IBP-3B (:)	Scrub IBP-2B (;)	Evergreen forest (narrow sclerophyll) IBP-1A1 (E)
5				Scrub IBP-1B (B)
2		Herbs, grasses over sand IBP-3C (+)	Steppe (herbs and grasses) IBP-2G (#)	Seasonal grasses IBP-1L2 and 1M2 (G)
7	White beach or desert sand (=)			Deciduous Forest IBP-1A2 (D)
6				

MAP:

The output returned to the user at a remote terminal by many of these algorithms is created by the subroutine MAP. This program creates a printer-plot map at a scale of approximately 1:20,000 with each 57 M x 80 M (63 x 86 yds.) data element or pixel represented by a single typewritten character. The map is limited in width to 228 characters (approximately 8 mi. or 13.5 km) and is subdivided into thirds, each of which fits a standard typewriter page. There is no maximum length for the data set, but 50 lines (approximately 2.5 mi. or 4 km) fits each typewriter page. An IBM-2741 typewriter terminal prints one page in approximately 5 minutes; therefore, to print a map 64 square miles in area requires approximately 45 minutes. An alternative program (MAP-75) exists which formats 360 x 400 pixels of output for the GSFC computer-printer rather than for return to the terminal. The actual analysis time for the GSFC SESD 360-75J computer to produce such a map with most of the analytical algorithms is less than 3 minutes (1.0 minutes CPU, 2.0 minutes IO).

ERTS-ANALYSIS Data Supplied by User:

All data is created by the user in a temporary active terminal file through use of the CRBE system as discussed in the next section. The format of the data supplied by the user is shown in Figure 2. The first value, which must be included, is the slot number assigned by the 360-75J computer user center for the specific ERTS tape under analysis. (VOL = SER + assigned no.). The data is specified in standard PL/I data format (4), and default values as shown in Figure 2 are provided so that only those values which the user desires to change need be specified since the system is designed to preserve maximum spatial resolution for selected small areas. Often, because of previous identification of a feature or area of interest on ERTS analog images, or as a result of pre-selection of specific ground test-sites of interest, the geographical co-ordinates of an area selected for computer analysis are known. These are then supplied as user data in the standard format (Figure 2 - TOP_DEG,TOP_MIN, and LEFT_DEG,LEFT_MIN, which correspond to the upper left corner co-ordinates for the area of interest. If the line and column number are known, these values may be entered (FSTLIN and LEFT). The size of the data set is specified by the values for NOROWS and NOCOLS. If the results are to be received in the form of a printer-plot map, NOCOLS should be less than 228 (or 354 for computer printer).

There are several possible correction values shown in Figure 2. These are used to correct for errors which exist in the apparent center location of some ERTS frames. Comparison of ERTS analog imagery with standard maps can be used to determine the necessity and the approximate magnitude of the corrections; CORR_LON and CORR_LAT are used when the error is known in minutes. Line LINE_CORR and COL_CORR are used when the error becomes apparent in a printer-plot map. Positive values move the apparent "image center" (and map) north and west, negative values move it south and east. CORR_ANGL is used to correct errors in the apparent satellite heading, usually arising from satellite yaw. Positive values rotate the apparent heading in a clock-wise direction. All other data in Figure 2 are used with specific analytical routines and are described with the specific routines.

Submitting Jobs and Retrieving Results from the ERTS-ANALYSIS System:

ERTS-ANALYSIS system uses the facilities of the GSFC IBM 360-75J Conversational Remote Batch Entry (CRBE) System (3). Access to the CRBE system is through a standard sign-on technique (Fig. 1). A special vocabulary permits the user to fetch ERTS-ANALYSIS programs and system information by name from a disc library into an active work area, to list and edit user data for preparation of any analysis job to be submitted to the computer, and to submit the completed job in standard format. The use of the CRBE vocabulary in preparing and submitting ERTS-ANALYSIS jobs is illustrated in Figs. 2, 3, and 4. The results of a completed analysis are brought into the active work area from the computer as illustrated in Figure 5.

1. USER dial CRBE terminal - 982-3113 (or from GSFC-33)

2. CRBE, when available, answers with a bell-like tone.
   The user places receiver in receiver cradle and proceeds to signon.

3. Signon procedure:

```
USER:   signon

CRBE:   CRBE SESD/75J - ENTER USRID,PASSWORD,SPONSOR CODE,TERMID ON LINE XX.
                ?
USER:             s0ert,erts,s0002,kj

CRBE:   SIGNON ACCEPTED    73.151 AT 15:38:09. ON LINE XX.
                /

 or     (USRID,PASSWORD,etc.)  INVALID
                ?
```

USER: (When invalid message is indicated should re-enter data after ?).

4. Signon is completed and CRBE is ready when ACCEPTED message is received.

Fig. 1. Signon procedure for ERTS-ANALYSIS SYSTEM.

```
CRBE:         /
USER:          fetch data
CRBE:         %
USER:          list
CRBE:      100 //  VOL=SER=Z1484
           200 //GO.SYSIN DD *
           300 FSTLIN=0000,LASTLIN=0000,LEFT=0000,RIGHT=0000,
           400 TOP_DEG=039,TOP_MIN=001,LEFT_DEG=077,LEFT_MIN=00,NOCOLS=0231,NOROWS=0050,
           500 CORR_LAT=-0.00,CORR_LON=00.00,LINE_CORR=+00,COL_CORR=+00,ANGL_CORR=+0.00,
           600 NO_CHAN=7;
              %
USER:          edit 100
CRBE:      100 //  VOL=SER=Z1484
USER:      100             (your catalog number)
CRBE:         %
USER:          edit 300
CRBE:      300 FSTLIN=0000,LASTLIN=0000,LEFT=0000,RIGHT=0000,
           300                                    |
USER:         %edit 400
CRBE:      400 TOP_DEG=039,TOP_MIN=001,LEFT_DEG=077,LEFT_MIN=00,NOCOLS=0231,NOROWS=0050,
           400                    55          8                    |76
              %
USER:            CONTINUE EDITING UNTIL ALL DATA IS SATISFACTORY.
                 AFTER COMPLETING EDITING LIST DATA WITH YOUR CHANGES.
USER:          list
CRBE:      100 //  VOL=SER=(YOUR CATALOG NUMBER)
           200 //GO.SYSIN DD *
           300 FSTLIN=0000,LASTLIN=0000,LEFT=0000,RIGHT= 000,
           400 TOP_DEG=039,TOP_MIN=055,LEFT_DEG=078,LEFT_MIN=00,NOCOLS=0 76,NOROWS=0050,
           500 CORR_LAT=-0.00,CORR_LON=00.00,LINE_CORR=+00,COL_CORR=+00,ANGL_CORR=+0.00,
           600 NO_CHAN=7;
              %
USER:            IF ALL DATA IS SATISFACTORY, SAVE IT IN LIBRARY UNDER NAME OF MYDATA.
USER:          save mydata,s,r
CRBE:         /
                 MYDATA MAY BE FETCHED AND EDIT AS WAS DONE FOR DATA, AS FOLLOWS:
USER:          fetch mydata
CRBE:         %
USER:            PROCEED TO EDIT AND LIST EXACTLY AS ABOVE.
                 WHEN FINISHED, SAVE IT IN LIBRARY UNDER NAME OF MYDATA, AS BEFORE.
USER:          save mydata,s,r
```

Fig. 2. How to create standard user-data for ERTS-ANALYSIS system.

```
RBE:          /
SER:           fetch onedata
RBE:          %
SER:           list
RBE:      100 LEVS=10,CH(1)='.',CH(2)='-',CH(3)='_',CH(4)='+',CH(5)='*',CH(6)='#',
          200 CH(7)='%';
          300  0, 40, 50, 55, 60, 65, 70, 75, 80, 90, 126, 32000,
              %
SER:           edit 100
RBE:      100 LEVS=10,CH(1)='.',CH(2)='-',CH(3)='_',CH(4)='+',CH(5)='*',CH(6)='#',
SER:      100      12
RBE:          %
SER:           edit 200
RBE:      200 CH(7)='%';
SER:      200           ,ch(8)='w';
RBE:          %
SER:           edit 300
RBE:      300  0, 40, 50, 55, 60, 65, 70, 75, 80, 90, 126,
SER:      300     1   2   30  4   50  60  70             00  110,||120,
RBE:          %                                                  (note use of strike-out, |)
SER:           list
RBE:      100 LEVS=12,CH(1)='.',CH(2)='-',CH(3)='_',CH(4)='+',CH(5)='*',CH(6)='#',
          200 CH(7)='%',CH(8)='W';
          300  0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110,  120,
              %
SER:           save myone,scratch,replace
RBE:          /
```

Fig. 3. How to create special user-data for use with the algorithm, ALGONE.

```
CRBE:                   /
USER:                    submit job(001h01)

                                 (job may be any three letter or number
                                  combination selected by user)

                                 (time(001h01,etc.) should be the estimated
                                  time given in the algorithm description)


CRBE:         ENTER INPUT (360/75).
                        ?
USER:                    =main
CRBE:                   ?
USER:                    =algone (or other selected algorithm)
CRBE:                   ?
USER:                    =map
CRBE:                   ?
USER:                    =jcl
CRBE:                   ?
USER:                    =mydata
CRBE:                   ?
USER:                    =onedata  (or other special user input data as
CRBE:                   ?            discussed with the individual algorithms)
USER:                    endinput  (note - no = sign to signal end of input)

CRBE:         JOB SOERTJOB SUBMITTED.
                        /
```

Fig. 4. Submitting an analysis with the ERTS-ANALYSIS system.

STEP 1. DETERMINING THE STATUS OF A USER JOB.

A message will be sent by CRBE when job is completed. If user has been away from terminal he may determine status of job by entering query as follows:

```
CRBE:          /
USER:           Msgr my
                  or
                status job (or other 3-letter id)
```

When job has been completed CRBE will reply, in addition to other messages, with the following:

```
CRBE:   WTR      158/1027:  JOB SOERTJOB READY (or other 3-letter id)
```

STEP 2. BRINGING THE MESSAGE TO LOCATE COMPLETED USER JOB RESULTS.

```
CRBE:          /
USER:           bring d=sysmsg.s0ertjob (or appropriate 3 letter id)
CRBE:          %
USER:           list 8000,11000

CRBE:    8000  CRB2371 WRITE         ON K3SCR4 NAMED CB.SOERTJOB.WRITE
         9000  CRB2371 WRT           ON K3SCR5 NAMED CB.SOERTJOB.WRT
        10000  CRB2371 WRT2          ON K3SCR3 NAMED CB.SOERTJOB.WRT2
                %
USER:            purge *
```

STEP 3. BRINGING THE COMPLETED USER JOB RESULTS

The data used in bringing the results in this step must correspond exactly to the name and location information given in the system message in Step 2.

```
CRBE:          /
USER:           bring d=cb.s0ertjob.write,v=k3scr4
                   (note that this is the data in line 8000 of Step 2.)
CRBE:          %
USER:           list all
```

CRBE will list all the data contained in the first data file, WRITE, without interruption, ending with %.

```
CRBE:          %
USER:           purge *
CRBE:          /
```

The user may repeat Step 3 for files WRT and WRT2, using the data in lines 9000 and 1000.

```
USER:          / bring d=cb.s0ertjob.wrt,v=k3scr5
and              bring d=cb.s0ertjob.wrt2,v=k3scr3
```

Fig. 5. Bringing the results from an ERTS-ANALYSIS system analysis to a remote terminal.

References:

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Spectral Signature Model for Water Quality Analysis
with ERTS - 1 Digital Data

Introduction

Reflected energy values detected by the ERTS - 1 multispectral scanner (MSS) in four wavelength bands between 0.5 and 1.1 micrometers are recorded as digital values on computer-compatible tapes (CCT's). The values represent the reflected energy measured in each of the four ERTS bands over an area 79 x 79 meters or instantaneous field of view (IFOV). There is a 14% overlap of IFOV's in the direction of scan-width so the reflected energy values on the CCT represent an average unique area or 'pixel' of 57 x 79 meters.

Water, because it absorbs energy in the infra-red region, reflects less energy than most other features on the surface of the earth in the wavelength region between 0.8 and 1.1 micrometers, which is the region in which reflected energy is measured by the MSS - 7 sensor. Surface water features are identified from the fact that the lowest digital values on the CCT for reflected energy in band 7 represent reflected energy over water-feature pixels. Water quality in these identified water-feature pixels is subsequently analyzed since digital values for reflected energy associated with water features in the three wavelength bands measured by the MSS - 4, 5 and 6 sensors (0.5 - 0.6; 0.6 - 0.7; 0.7 - 0.8 micrometers) vary with water quality.

Organic materials absorb energy in all three of these bands, while most inorganic sediment particulates such as silt and sand are highly reflective. Thus, organically polluted water has lower digital reflected energy values for bands 4, 5, and 6 than normal water, while sediment or silt containing water has higher values than normal water. The analytical technique we have used for water quality analysis is based on differences in reflected energy, or 'signature', in bands 4, 5 and 6 for water feature pixels. The extent of deviations in reflected energy in all three of these bands, or the change in 'signature' from normal water, is an indication of the probability of the presence of pollution, and the direction of deviation or signature change to values above or below the normal values in each band is an indication of the type of pollutant present.

A statistical model is created for each ERTS pass-date to standardize the analysis and correct for variations in external factors, such as sun altitude and haze levels which cause day-to-day differences in reflected energy value measurements to occur. In this model a signature value for normal water, and various arbitrarily-defined ranges of deviations or signature changes for either organic or sediment pollution are defined. The computer is then used to compare the signature for each pixel defined as water in the scene with the signature ranges derived in the model. The results of these comparisons are printed in the proper geographical location of a digital map at a scale of 1:20,000 with one typewritten symbol representing one pixel.

Identification of Water-feature Pixels

Water-feature pixels are identified by their relatively low values for reflected energy in the wavelength region 0.8 to 1.1 micrometers, the region where reflected energy is measured by the MSS-7 sensor. In order for the computer to recognize digital values on the CCT for pixels which correspond to water features on a selected date, the range of values for MSS-7 on that date is determined. The lowest values falling below fourteen percent of this range have been found to correspond to water feature values.

The first step in the water-feature identification analysis is to (1) select a cloud-free test area on ERTS imagery of that date. The area corresponding to this test region is (2) accessed on the CCT of data for that date by the computer and the range of digital values in band 7 for all pixels for surface features in this region on that date is calculated (Table 1). The values falling below the lowest fourteen percent of these values are then defined as the values for water-feature pixels on that date.

Statistical Model of Water Quality

The range of digital values for reflected energy in MSS bands 4, 5 and 6 associated with water-feature pixels, as defined above, is determined for the ERTS frame by analysis of a standard subset of the frame. To insure that the full range of water-associated signatures are included in the statistical mode, including some which probably represent organic and sediment pollution, the subset selected covers an area with some variability in water quality. Thus, for the

Potomac Basin analysis, the standard subset includes portions of the Chesapeake Bay as well as of the Potomac River (Table 2). Using a probability model, a Gaussian distribution of values is calculated for each band from the ranges determined for each test-site. In this model it is assumed that a normal distribution of values exists around the mid-range of the values for each band, and that the maximum and minimum values seen on each date in the test-site area occurred at the four sigma probability levels, or, in normal water, at a frequency of less than once in 10,000 measurements. The values for reflected energy in each wavelength band corresponding to 0, $\pm$ 1, $\pm$2, $\pm$3 and $\pm$4 sigma probability levels are then calculated using probability tables or paper. From the values for each band a composite signature value is calculated for each sigma level. Digital values for the three wavelengths bands are combined by multiplication to give this composite value for each sigma level. The composite signature values are defined in the model as the signature ranges for 0, $\pm$ 1, $\pm$ 2, $\pm$ 3 and $\pm$ 4 sigma deviation units according to the sigma values for each single band in the calculation (Table 3). Water quality symbols are assigned to each composite signature range.

Signature Calculations and Analysis of Water Quality in ERTS Pixels

The last step in the water quality analysis includes computer scanning of the ERTS data on the CCT for the area actually selected for water quality analysis, identification of pixels in the analysis area which represent water features, calculation of a composite signature value for each identified water-feature pixel, comparison of these calculated signatures with model-defined signature ranges, for the appropriate date and assignment of a water quality symbol to each pixel based on the results of these comparisons. Pixels are identified as water-features by comparison with discriminator value for reflected energy in band 7 determined in the first step of the analysis. Thus, for each water-feature pixel, a composite signature value is calculated. This value is the product of the digital values for MSS bands 4, 5, and 6 for the pixel. The composite signature value is then compared with the values calculated in the model for the ranges associated with the various water quality symbols, and the proper symbol is assigned to the pixel. The symbols for the pixels are printed by the computer using a line printer-plot program in conjunction with a geographical referencing program to print each symbol in its proper geographical location on a map at a scale of 1:20,000.

Results and Discussion

For the results from the analysis of water quality in the Potomac Basin and Chesapeake Bay regions, we have selected the symbol N for pixels whose signatures in the 0.5 to 0.8 wavelength region fall in the range of the most probable signature value for water. The symbols P, L, O, and * were chosen to represent the probability ranges for signature values of more than one, two, three or four model-defined negative deviation units from the most probable signature value (normal water) in the range of signature values associated with organic pollution, while the symbols S, H and X were selected to represent values more than one, two or three unit positive deviations from normal in the range of signature values associated with inorganic or sediment pollution. Thus the symbol, *, represents a signature value for a water pixel which is most deviant from model values for normal water in terms of probable organic pollution, while X indicates a similar deviancy in the direction of probable sediment pollution.

Figure 1 shows the results from the water quality analysis of the Potomac River on two dates. Most of the sedimentation in the Potomac Estuary on the first date, September 23, 1972, was found either in the Anacostia River channel or down stream below the Occaquan Creek. Values in the region below Roosevelt Island are associated with local sewage outfalls. In fact, we seem to be able to identify most of the major sewage effluent source areas using this analysis. Very high values for sedimentation, on ther other hand, are found in the Anacostia River. These are associated with two ~~major sources of~~ sediment: a sand and gravel operation located at and run-off from open surfaces associated with extensive road and building construction.

On October 11, the pollution pattern exhibited by the ERTS-1 data is very different. Run-off from a heavy rainfall had carried sediment into the Potomac from as far west as West Virginia. The computer analysis developed from data obtained on this date shows a very different distribution of sediment from that existing in the September 23 date. The sediment load appears to be heavy throughout the Washington area, including the area around Roosevelt Island, an area known to have rather high levels of accumulated sludge and sewage waste most of the time. Thus, while signature ranges near the Roosevelt Island area are apparently modified by the presence of sewage effluent, so much sediment has been carried into the area that the outfall is obscured. In addition, the increased water flow will dilute the sewage waste and move it down stream more rapidly. The signature values corresponding to the highest deviation level of organic pollution are again found in the mudflats of the Blue Plains sewage plant near Wilson bridge, where the river flows into tidal waters and is generally restricted.

Figure 4 shows the results of the same water quality analysis used for oil-spill detection. The Baltimore harbor area was covered by an oil film on September 23, 1972. Apparently this film was the result of numerous small oil spills and bilge waste pumped into the harbor, coupled with low rainfall in the surrounding basin area, so that flushing of the harbor had not occurred for a period of several weeks. The oil film since it covers all or a large area of each pixel with material characterized by low reflectance values for the wavelength region 0.5 to 0.8 micrometers (MSS bands 4, 5, 6) causes the computer calculated signature values to fall much further outside the signature range calculated in the statistical model for normal water, than do other kinds of non-film organic pollutants. Oil film can thus be differentiated from sewage.

Conclusion

Generalized water quality analysis in a computer analytical technique using ERTS-1 MSS digital data; including detection of oil spills and differentiation of organic and sediment pollution levels can be performed. The technique includes the differentiation of water feature pixels from other earth surface features, the creation of a statistical model to correct for date-to-date differences in MSS acquired data and to establish signature values corresponding to different levels of organic or sediment pollution, and finally the analysis of water quality by comparison of the signature for each water feature pixel in the ERTS data with the signatures derived in the model. The results of the analyses are printed by the computer in map format at a scale of 1:20,000.

Ecological Analysis of the Potomac River Basin: A cooperative program involving The American University, Goddard Space Flight Center and National Park Service Project Lightship.

The American University and Goddard Space Flight Center (NASA) are participating in an experiment to determine the interactions of various components comprising the Potomac River and its watershed by the use of Earth Resources Technology Satellite data (ERTS contract UN443-NASA). The aim of the experiment is to develop a resource information system for the watershed which can be accessed by resource managers such as the U.S. Park Service, the various agencies responsible for water supply and sewage treatment, and other groups which require up-to-date information of the status of the river and its water such as the Environmental Protection Agency.

One major project currently under development is the use of the ERTS satellite to obtain information on the status of the river itself, particularly with regard to the presence of two major types of pollutant, silt and organic material, in the vicinity of Washington, D. C. The satellite obtains data every 18 days over the Washington area with an instrument known as the Multi-spectral Scanner, or MSS. This instrument measures the amount of reflection for a small area known as a "pixel" (57 meters by 80 meters) in four different spectral (color) bands simultaneously. As the MSS scans, or moves from one pixel to the next, the four reflectance values for each pixel are recorded. A picture composed of all the pixels may be produced by scanning the recorded reflectance values for each pixel and producing lighter or darker images on film according to the MSS values. The films may be combined in various ways to produce color pictures of the entire Washington area.

Alternatively, a computer can be used to determine a "signature" for each pixel by using the reflectance values in the four color bands. These signatures derived from the satellite data can then be compared with "signatures" for water and various kinds and amounts of pollutants in water and the results of the comparison for each pixel can be printed by the computer in map form. In order to develop a bank of known signatures for comparison with the signatures obtained by the satellite, "ground-truth" must be obtained by measuring actual levels of the various pollutants which correspond to the reflectance values or signatures measured by the satellite.

To obtain the ground-truth test-sites for measuring the levels of sediment and organic pollutants in the Potomac River have been established. Samples from these test-sites will be obtained by The American University and Park Service participants as the satellite passes overhead so that a direct relationship between the reflectance signatures as measured by the satellite and the levels of organic material and sediment in the river may be established.

The results of these experiments should make it possible to monitor the Potomac River for levels of sediment and organic materials on an 18-day cycle. This information, together with other existing information such as flow-rate and rain fall data, should make it possible to predict the effects on the river from various sewage-outfalls, from the removal of ground-cover, or from the addition of sewage-treatment plants at various locations.

DRAFT II

Field Trip Report
Friday, March 23, 1973
Cedarville State FØrest, Maryland
Anderson (GSFC), MacLeod (A.U.) and Schubert (A.U.)

OBJECTIVE; To study an apparent channel from the Wicomico River to Cedarville State Forest observed in ERTS-1 frames #1062-15193 (23 Sept. 73) amd #1080-15192 (11 Oct. 73).

BACKGROUND: In ERTS-1 imagery the channel appears as a former stream channel, approximately 30 miles to the north from the Wicomico River inlet to a complex of other channels which extend east-west from Chesapeake Bay to the Potomac River. This channel complex or intersection is located in the Cedarville State Park. The channels are observed to be approximately 2 mm or less wide at 1:1,000,000 scale (2 km on the ground) and filled with a uniform tone which appears dark red in color composites processed in a "false color" mode, i.e. the channels appear to be filled with rather uniform arborescent vegetation (trees).
HYPOTHESIS: The channel is a part of a former drainage basin pre-dating the present Potomac River Basin. Its drainage basin has been captured by the Potomac and its tributaries (the channel is as large as the adjacent Pautuxent River Channel). As it is still identifiable, (erosional processes on the Coastal Plain have not yet obliterated its remnant form), it is rather recent, perhaps belonging to the stage just previous to the formation of the present Potomac estuary.

PROCEDURE: Participants identified Zekiah Swamp on Hughsville USGS topo sheet AMS 5661-III SE Series V 833 and proceeded to the area in Cedarville Forest. After making our presence and purpose known to the duty Ranger, we prodeeded to a fishing pond parking lot (see map attached).

We then hiked into the area about two miles. On return to the parking lot we drove around the east forest border to a Route 5 bridge crossing of Zekiah Swamp. Plant, soil and photo observations were made.

OBSERVATIONS: Two well-developed terraces and a flood plain were observed wherever the channel is. The channel is an open stream bordered with the usual flood plain vegetation--gums, sycamores, elms, various maples in an approximately 50-year stand. The first terrace is covered with a beech, oak, holly and maple stand of similar age. The second terrace is covered with trees of mixed age and character--including significant amounts of Virginia pine, young hardwoods, vines, and shurbs (including young rhododendron). On the second terrace and on the coastal plain above there are open fields, some recently cultivated and some with old field vegatation (poverty grass dominant).

The site was located on the imagery. The channel is delineated by the bright reflectance of adjacent open fields, not by a change on tone of vegetated surfaces. The channel nexus at Cedarville State Forest may be real; but it is seen as such in the imagery primarily because of the lack of open fields within the forest.

Zekiah Swamp is not a swamp in the usual sense. The stream obviously floods occasionally, but little marsh vegetation was observed except where drainage was obstructed, for example by highway crossings. The swamp appears to be filled by lowland tree vegetation of surprisingly uniform age (undetermined). This indicates some event (siltation, farming) may have affected the swamp uniformly within the last century or two.

Reports from Short (GSFC) indicate that marsh vegetation does occur in a more southerly part of the channel, reenforcing the feeling that the plant communities in the channel are young. (Marshes fill in through accumulations of sediment and plant material--then develop into a mature forest community.)

CONCLUSION:

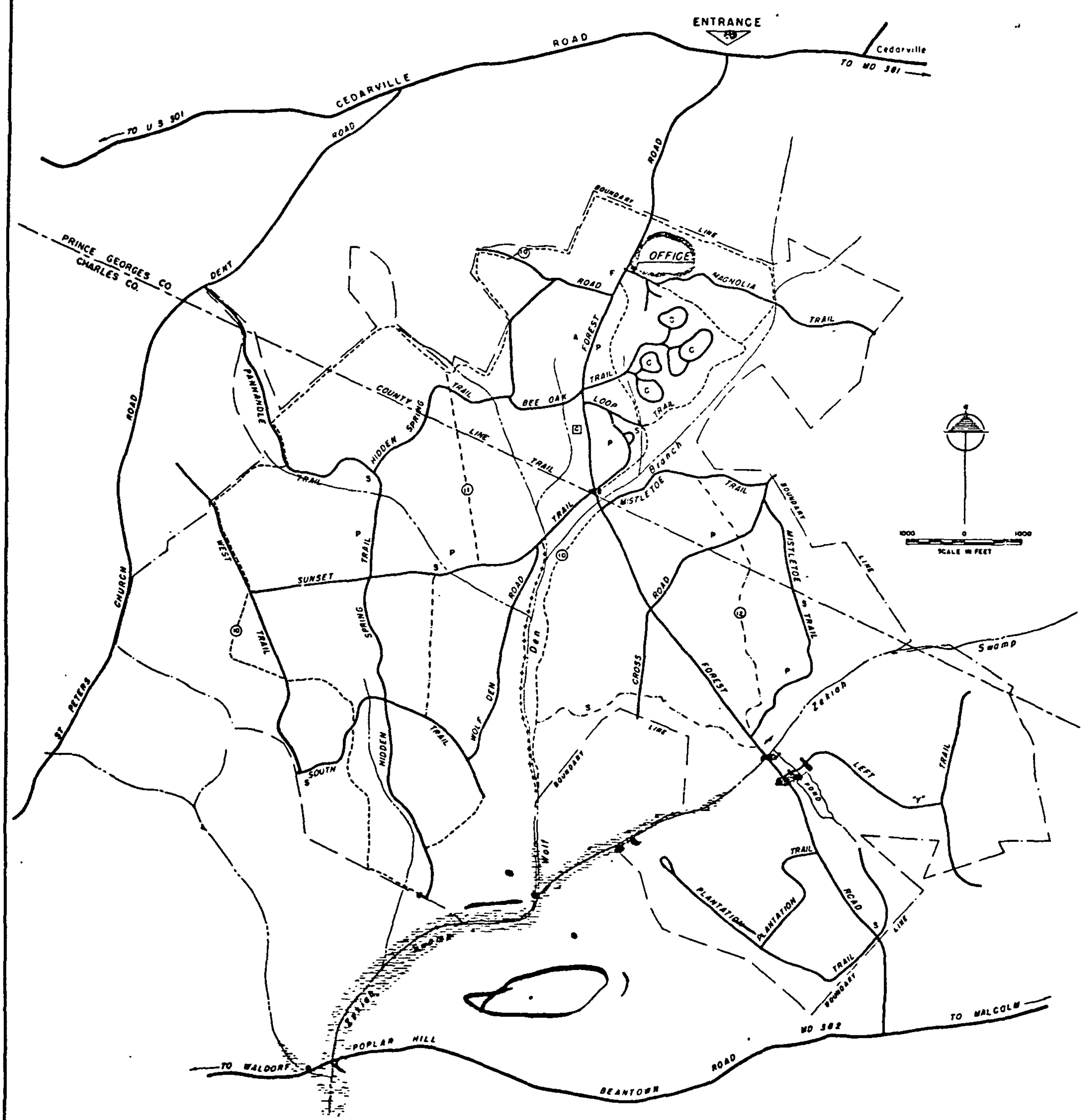
1. A substantial stream or river developed the observed valley or channel through three stages of flood plain development (two terraces plus the present flood plain).

2. There are indications of recent (since European colonization) changes in the stream valley as a whole, which are related to the observability of the channel (i.e., the abandonment of the flood plain for cropping, grazing, or forestry, the terraces for purposes other than some timber harvest and the use of the upland for occasional cropping).

3. Insufficient fieldwork has been done to establish the origin of the channel and its relationship to other adjacent stream valley development. While a genetic relationship seems to be apparent in the space imagery, it will be necessary to study more of the Southern Maryland area on the ground to sort our impressions into an evolutionary sequence.

CEDARVILLE

STATE FOREST AND PARK



LEGEND

FOOT TRAIL 10 MARKED - WHITE PAINT	▣ CHARCOAL KILN
FOOT TRAIL 11 MARKED - YELLOW PAINT	C CAMPING AREA
FOOT TRAIL 12 MARKED - RED PAINT	F FENCE POST TESTING AREA
WOLF DEN TRAIL	A PLAY AREA
COUNTY LINE FOOT TRAIL MARKED-WHITE PAINT	S SPRING
	P PICNIC AREA

PERMITS ARE NECESSARY TO USE PICNIC OR CAMPING AREAS
HUNTING IS PROHIBITED IN OR NEAR RECREATION OR OTHER RESTRICTED AREAS
FOR PERMITS AND PERMIT FEES CONTACT SUPERINTENDANT, CEDARVILLE STATE PARK, BRANDYWINE, MARYLAND 20613

THE AMERICAN UNIVERSITY
Department of Biology

ERTS Image Analysis: Preliminary Report #1
January 1973

ID # 1062-15190
Date of Acquisition, 22 Sept. 1972

A simple feature discriminator for sedimentation levels in rivers and shoal estuarine waters has been applied by Dr. J. S. Schubert to the 23 September 1972 Washington Image (ID # 1062-15190). Figure 1 shows the results at the confluence of the Potomac and Anacostia Rivers. Hain's Point and the Washington Channel are also visible.

Procedure: Data values for CCT MMS7 are geographically located by GEOG_LOC, and then scanned for low values. Geographic coordinates in Channels 4, 5, and 6 are then multiplied thus: 4 x 5 x 6 = __. Previously selected product ranges are matched with each pixel product. The matching range is associated with a type symbol and printed, using ERTS_MAP. Procedure references are to ERTS_TAPE, a PL/1 program reported January 1973. The procedure is straight-forward, does not require large core and appears to result in better sedimentation discrimination than photoanalysis.

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19000' '23SEP72' '                SUN EL44 AZ143 '
30'DEG'      56 'MIN IS IN  ROW'        1029
15'DEG'      59 'MIN IS IN COLUMN NUMBER'        350
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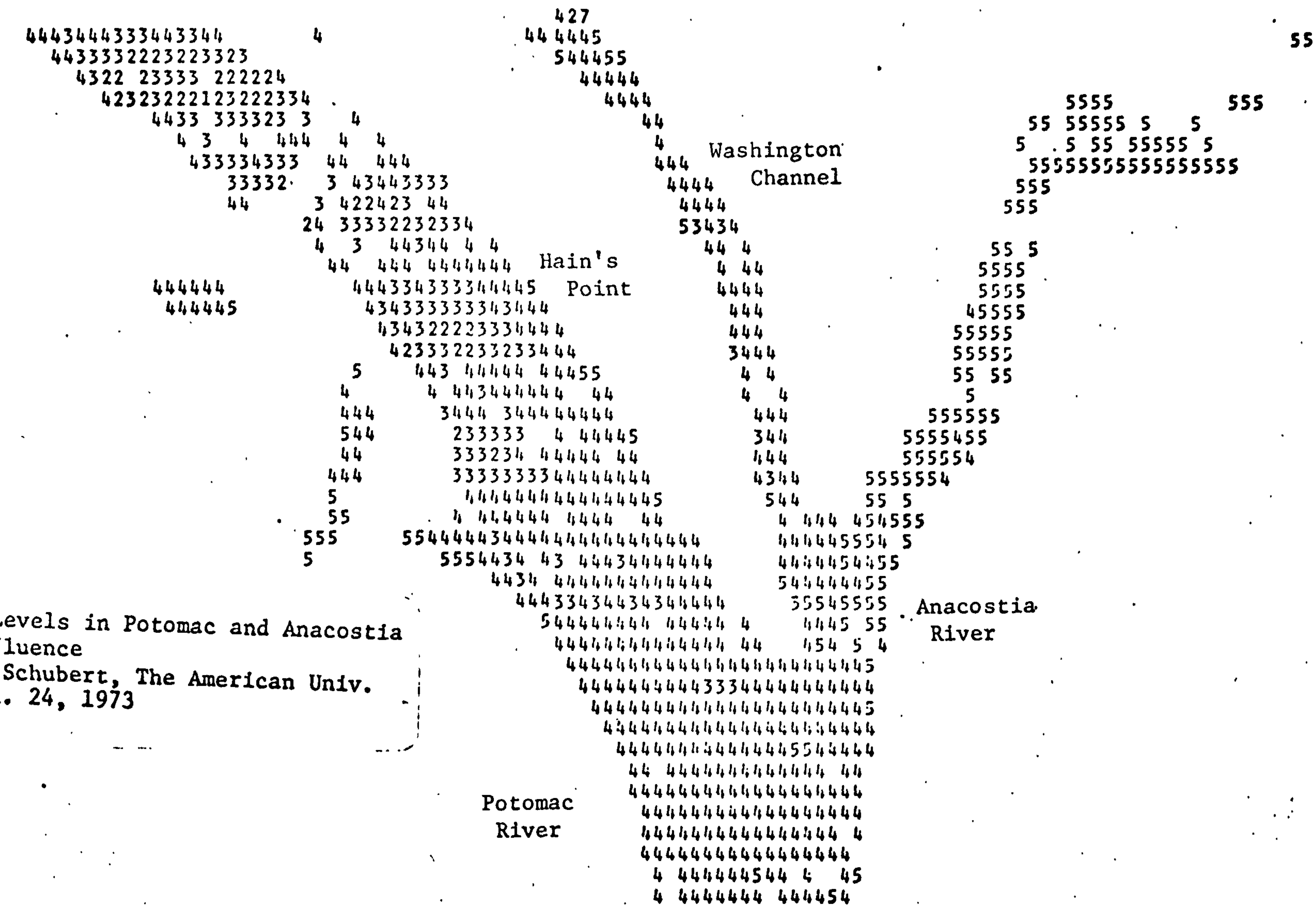
'1' '	IS'	51 'TO'	2000
'2' '	IS'	2001 'TO'	2500
'3' '	IS'	2501 'TO'	3000
'4' '	IS'	3001 'TO'	5000
'5' '	IS'	5001 'TO'	30000



Sediment Levels in Potomac and Anacostia River Confluence
Dr. J. S. Schubert, The American Univ.
UN441, Jan. 24, 1973

Introduction:

Increased interest in land use application and environmental harmony, has made it necessary that resource management administrators be familiar with an ever-increasing volume of inter-related data, and to be able to evaluate these data on a timely basis. To facilitate these requirements, a computer-based resource management system can be designed which will integrate field and remotely sensed data to provide timely regional resource data. The requirements for such a computer resource management information system can be divided into three basic elements. These are: (1) the incorporation of input data into the system, (2) the processing or analysis of that data, and (3) the production of useable output information for resource managers. The design of such a system is, therefore, strongly dependent on the definition of the information required by resource managers in the context of available relevant input data. The analysis and/or processing of input data, and the extraction of information is dependent not only on the requirements of resource managers but also on the properties of the input data selected for incorporation into the system, and on the available analytic techniques for information extraction and analysis of the data. This is especially important in the case of remotely-sensed input data.

In designing a resource management information system specifically for use with ERTS digital data, three specific design constraints must first be defined:

1. Data and information input should be so stored that they can be available at their original resolutions.

2. Output information should be available at more than one scale and resolution. This permits varied requirements to be met as they are established for specific application areas.

3. The size of data cell used in the processing system, including any analytical routines, should be determined by the resolution of the output information; in addition, it must be possible to vary the data-cell size in the processing system in order to adapt to the needs of specific user requirements.

In constructing general resource bases incorporating satellite-derived data the processing system will generally receive input data of different types at different resolutions (or data-cell unit sizes). These may include for example, ERTS-1 data at a data-cell unit size of 57 x 80 meters, ground-truth data at a second unit size, and digital information from existing soils, geology and vegetation maps at yet different unit cell-sizes. Interface routines are thus required to convert the various input data-cell unit sizes to the gridded data-cells established for the processing system. In addition, geographical referencing of each data-cell unit in the input data sets is also necessary if the input data sets are at different scales or at variable locations with regard to some standard set of co-ordinates, as is generally the case with ERTS-1 and other remotely-sensed data. This referencing may be implicit, as is the case of ERTS-1 CCT digital data in which the referencing must be obtained by calculation from header record data, or it may be explicit and associated with each data-cell unit; the latter should be the case with ground-truth data. Interface routines for referencing of the input data relative to the processing and output system matrices are required for proper overlay of the input and processing data cells. Therefore, special routines for averaging, interpolation and gridding are also required.

In addition to the development of ERTS data flow through the management information system, a number of analytical techniques have been developed and programmed as algorithms within the ERTS-ANALYSIS SYSTEM. The results of these analyses and ERTS-ANALYSIS in the form of printer-lot maps generated by the algorithms and mapping programs of the system, have been presented to numberous federal agencies and other groups involved in resource management in the Potomac Basin region.

A Prototype Resource Management Information System

Data Storage and Referencing:

A. Two possible approaches considered

   1. Constant data-set size with pre-set amount of information within each cell, each cell referenced.

   2. Variable data-set size, with lowest resolution element size set as cell for each data-set.

B. Advantages and disadvantages of each

   1. a. large amount of data storage must be set aside, or alternatively, storage area must be updated at frequent intervals to add new data.

      b. optimum cell size (sizes) are set initially without regard for variability in resolution of data or for subsequent desired resolution of information products.

      c. disc storage and manipulation of disc data is the only practical method of access or up-date with approach 1

      d. languages of choice for disc management systems are assembler languages, PL/1 and COBOL. The first two are machine specific and might limit transfer of prototype; the last is not widely used by scientific programmers and is limited in interface with information processing systems which might be used with the data.

      e. regularity of data makes standard, existing data management systems of practical consideration for data manipulations.

      f. indexing may be done by standard key techniques.

2. a. variable format could lead to excessive manipulation of data for interchange and comparison or information extraction from different sized data-sets.

   b. space for both index description and indices would be required for each data set: more pre-manipulation required.

   c. maximum resolution of data would be retained and products at different resolutions according to the needs of the user could be attained. (ie. compatibility between 2,000 ft. grid-system of the State of Maryland product requirement, digitized map data at 1 hectare or 1 km^2, analyzed ERTS data at 5,000 m^2 all stored at original resolution.

   d. FORTRAN language and grid system can be created and accessed with lesser amounts of data in core or active storage area by selection of data on applicability rather than on its presence at a specific location.

   e. Disc or tape storage may be used. New types of data or additional data or old data at a new resolution may be added

Information Manipulations:

A. Programs in ERTS-ANALYSIS SYSTEM written for extraction of information from ERTS data. Interface program exists to access JPL-VICAR system via intermediate tape generation. This is for use of ERTS data only.

B. Purpose of and possible nature of other types of information extraction techniques require further discussion.

Presentation of Results from Data and Information Analyses

A. Digital map techniques have been developed. These may be used to produce digital maps at remote terminals.

B. ERTS data may be presented as GPCP contoured maps.

C: Tables for further studies on such effects as sun-angle can be produced.

D. The nature of the products which are of use to resource managers requires further discussion.