DEVELOPMENT AND APPLICATION OF OPERATIONAL TECHNIQUES FOR THE INVENTORY AND MONITORING OF RESOURCES AND USES FOR THE TEXAS COASTAL ZONE

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October, 1977

TYPE III (FINAL REPORT)
April, 1975 through October, 1977

VOLUME II: APPENDICES

prepared for:

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

GENERAL LAND OFFICE OF TEXAS

BOB ARMSTRONG, COMMISSIONER

This investigation was funded by National Aeronautics and Space Administration, Goddard Space Flight Center and the State of Texas through cost sharing.

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APPENDICES

Appendix

APPENDIX A

LANDSAT DATA LIBRARY

APPENDIX A

LANDSAT COVERAGE OF THE TEST SITES 2, 3, 4, 5

FOR LANDSAT INVESTIGATION #23790

DATA AVAILABILITY	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 2:			
	<u>Summer</u>: June - Aug.			
2	1037 - 16251	08/29/72	20%	8888
	1343 - 16253	07/01/73	20%	8888
	1361 - 16252	07/19/73	20%	8888
2, 4	1703 - 16175	06/26/74	10%	8858
	<u>Fall</u>: Sept. - Nov.			
2	1073 - 16251	10/04/72	30%	8888
	<u>Winter</u>: Dec. - Feb.			
2	1217 - 16261	02/25/73	20%	8888
2	1505 - 16230	12/10/73	00%	2822
2	1901 - 16110	01/10/75	10%	8808
2, 4	2375 - 16112	02/01/76	00%	
2	1576 - 16152	02/19/74	00%	8888
	<u>Spring</u>: Mar. - May			
	1253 - 16262	04/02/73	20%	8888
2, 4	1289 - 16261	05/08/73	00%	8888
2	2051 - 16140	03/14/75	00%	8855
2	5027 - 16050	05/16/75	10%	5588

DATA AVAILABILITY	SCENE ID	DATE	CLOUD COVER	QUALITY
	Test Site 3:			
	Summer: June - Aug.			
	1343 - 16253	07/01/73	20%	8888
	1361 - 16252	07/19/73	20%	8888
	1038 - 16305	08/30/72	20%	8888
	1362 - 16305	08/30/72	20%	8888
2, 4	1703 - 16175	06/26/74	10%	8858
	Fall: Sept. - Nov.			
	1092 - 16312	10/23/72	20%	8888
	1110 - 16313	11/10/72	00%	8888
	1452 - 16291	10/18/73	00%	7828
	Winter: Dec. - Feb.			
2, 4	1146 - 16314	12/16/72	00%	8888
	1164 - 16312	01/03/73	10%	8888
	1182 - 16313	01/21/73	00%	8888
2, 4	2034 - 16200	02/25/75	00%	8888
	2016 - 16200	02/07/75	10%	5888
2	1578 - 16264	02/21/74	10%	8282
	Spring: Mar. - May			
	1253 - 16262	04/02/73	20%	8888
	1289 - 16261	05/08/73	00%	8888
	1236 - 16320	03/16/73	10%	8888

DATA AVAILABILITY	SCENE ID	DATE	CLOUD COVER	QUALITY
	1290 - 16315	05/09/73	00%	8888
	1308 - 16314	05/27/73	20%	8888
2, 4	1614 - 16261	03/29/74	10%	8888
	1974 - 16133	03/24/75	00%	8858
2	5028 - 16104	05/17/75	10%	8885
	Test Site 4:			
	Summer: June - Aug.			
2	1326 - 16315	06/14/73	10%	8888
5	1380 - 16311	08/07/73	30%	8883
5	1722 - 16232	07/15/74	30%	8858
5	2501 - 16081	06/06/76	20%	8885
2	1740 - 16225	08/02/74	20%	8888
5	1758 - 16221	08/20/74	20%	8888
2, 4	5082 - 16080	07/10/75	10%	8888
	Fall: Sept. - Nov.			
2, 5	1092 - 16314	10/23/72	10%	8888
5	1110 - 16320	11/10/72	10%	8888
	1452 - 16293	10/18/73	10%	8828
5	1776 - 16212	09/07/74	30%	5588
2	2268 - 16184	10/17/75	00%	5555
	Winter: Dec. - Feb.			
2, 4, 5*	1146 - 16320	12/16/72	20%	8888
5	1164 - 16315	01/03/73	20%	8888
2, 3**	1182 - 16315	01/21/73	00%	8888

DATA AVAILABILITY	SCENE ID	DATE	CLOUD COVER	QUALITY
5	2016 - 16202	02/07/75	00%	5885
2, 4	2034 - 16202	02/25/75	00%	8883
5	2375 - 16112	02/01/76	00%	8588
2, 4	2376 - 16172	02/02/76	00%	8888
	Spring: Mar. - May			
5	1236 - 16323	03/16/73	20%	8888
5	1254 - 16323	04/03/73	10%	8888
5	1290 - 16321	05/09/73	20%	8888
2	5334 - 15523	03/18/76	30%	8888
2	1308 - 16320	05/27/73	10%	8888
2	1974 - 16135	03/24/75	10%	8858
5	5028 - 16111	05/17/75	10%	5588
	Test Site 5:			
	Summer: June - Aug.			
	1362 - 16315	07/20/73	20%	8888
	1380 - 16314	08/07/73	20%	8888
	1722 - 16235	07/15/74	20%	8888
2, 4	1740 - 16231	08/02/74	10%	8888
2	1758 - 16223	08/20/74	10%	8888
	Fall: Sept. - Nov.			
2	1110 - 16322	11/10/72	10%	8888
2	1776 - 16215	09/07/74	20%	5855
	1452 - 16300	10/18/73	20%	8888

DATA AVAILABILITY	SCENE ID	DATE	CLOUD COVER	QUALITY
	Winter: Dec. - Feb.			
2, 4	1182 - 16322	01/21/73	00%	8888
	1506 - 16293	12/11/73	10%	8888
2, 4	2034 - 16205	02/25/75	00%	8888
	Spring: Mar. - May			
	1614 - 16270	03/29/74	20%	8888
	1974 - 16142	03/24/75	10%	8888
	2070 - 16203	04/02/75	20%	8588
2	1290 - 16324	05/09/73	20%	8888

* SPECIAL COLOR COMPOSITE (BANDS 4,5,6) REQUIRED DUE TO POOR BAND 7
** TAPE COULD NOT BE REPRODUCED BY EDC/GODDARD

DATA AVAILABILITY

1 Imagery on Order

2 Imagery on Hand

3 Tapes on Order

4 Tapes on Hand

5 Selected Products on Hand for Special Study

APPENDIX B

TEXAS PARKS AND WILDLIFE DEPARTMENT

VEGETATION SAMPLING METHOD AND FIELD INVESTIGATIONS SUMMARY

APPENDIX B

VEGETATION SAMPLING FOR LANDSAT DATA

prepared by Larry Lodwick
Texas Parks and Wildlife Department

Introduction

In an effort to obtain quantitative ground data on the plant communities as defined by Landsat Telemetry, a sampling system which will allow a quick, yet quantitative analysis of the communities needs to be developed. The procedure should be adaptable to the various communities present, from mud flats, with only sparse vegetation cover, to salt marshes being predominately grasses or grass-like plants, to woodlands.

The most efficient sampling system for large areas would be the point intercept measurement of cover. This has several advantages in that (1) it gives an indication of biomass (especially if height of the vegetation is known); (2) it can be used for all growth forms, from bryophytes to tree canopies; and (3) it can be adapted for the size of the community to be sampled (i.e., points farther apart for larger vegetation types). Although widely spaced points tend to reduce the precision of the measurements, it does serve as more rapid measurement than other sampling techniques (Mueller-Dombois and Ellenberg, 1974).

From the data obtained by the cover method, it is possible to designate plant associations which could be related to the various images interpreted by Landsat.

Materials and Methods

An advantage to sampling cover as opposed to other parameters is the small amount of equipment required for field sampling. The required materials consist of a tape measure with a minimum length of 25 meters (or

25 yards), a meter (or yard) stick, tally sheets (figure 1) for the sampling data and a plant press for collecting those plants which the investigator is unfamiliar with.

The method for data collection is as follows:

1. Prior to going into the field the sampling site should be located using the Landsat printout to determine the approximate center of the vegetation type to be sampled. This point should then be located on a topographic map (U.S.G.S.) or low-altitude photograph.
2. Using the topographic map or photograph, locate the sampling site on the ground, setting a stake at the center point. The tape measure should then be extended first to the north, then south, east, and west of the center point (preferably with the use of a compass) to a distance of 25 meters or yards (figure 2). The purpose of determining the location and direction of the transects prior to beginning of sampling is to reduce the bias of the investigator.
3. At 25 evenly spaced points in each of the four directions from the center point, preferably at 1 meter (or yard) intervals, all species directly above or below the points should be identified and their heights, measured with the meter (or yard) stick (which, in the case of trees, may be estimated), recorded on the tally sheet (figures 3 and 3a). Bare soil, without vegetation, should also be recorded and treated as a species. This will enable one to assess the bare ground (mud flats, dredge spoil, etc). Those plant species with which the investigator is unfamiliar should be collected, pressed, and sent in for identification. Preferably the

collection sample should consist of two or three individuals pressed separately with flowers (or fruits) and roots. These should be pressed. Information as to the sampling site, soil type, soil wetness (tidal marsh, dry uplands, standing water, etc.) should be recorded. The unknown plants should be numbered and the number listed on the tally sheet in place of the name. After the plant is identified, the number should be replaced by the correct name.

4. The information on the tally sheet should include the name of the investigator, the transect line number (as related to the map), the bearing of the line (north, south, east, or west), the date, and the amount of inundation at the time of the sampling (i.e., dry land, mud, standing water, etc.).
5. One copy of each field sheet should then be sent to Austin for evaluation and analysis of the plant associations.
6. After several sites have been investigated, any problems encountered need to be discussed to determine what changes in the procedures might be made to alleviate the problems.

Reference

Mueller-Dombois, Dieter, and Ellenberg, Heinz, 1974, Aims and Methods of Vegetation Ecology: John Wiley and Sons, New York, 547 p.

VEGETATION SURVEY

Investigator __________ Date __________ Line __________ Bearing __________

Level of Inundation ____________________

Sampling Points

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Figure 1. Sample tally sheet for recording ground cover.

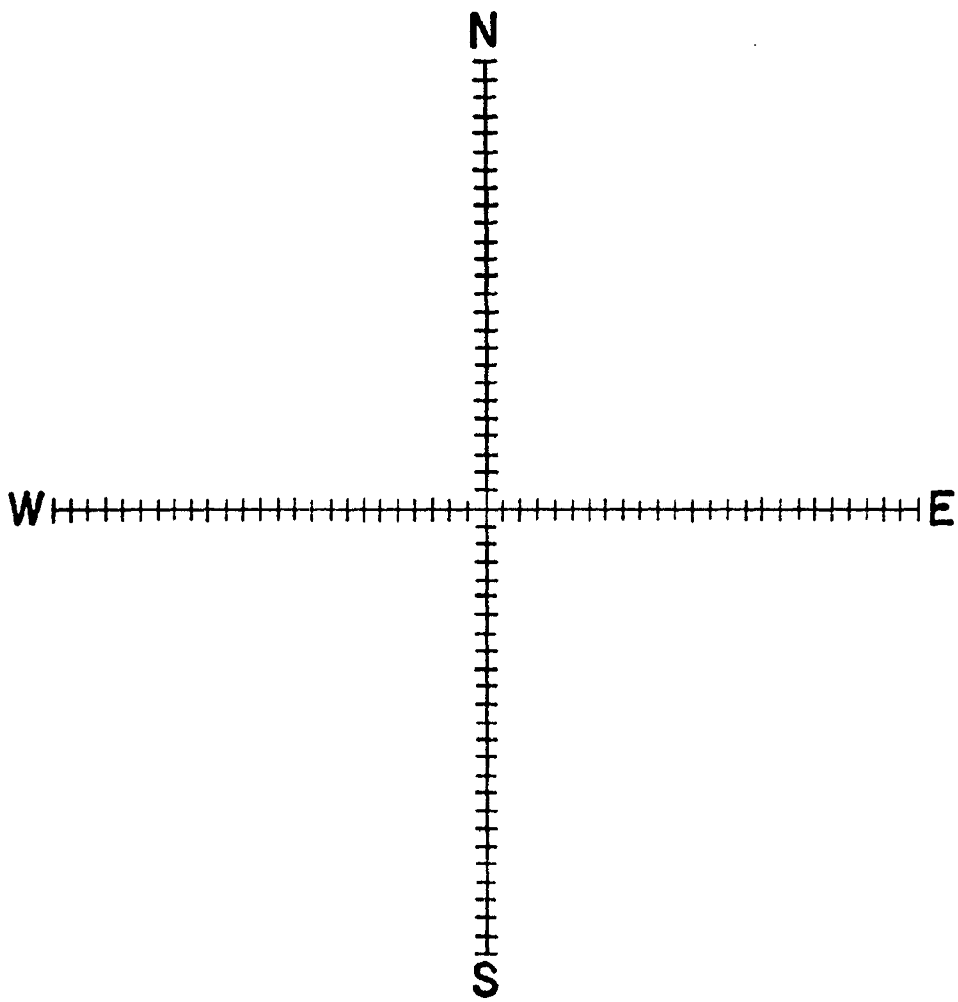

Figure 2. Sample area for the measure of the point intercept method. After reaching a predetermined sampling site, select the center point and with the use of a compass, record those species which occur at 25 regular intervals (preferably one-meter intervals) directly north, south, east, and west of the center point.

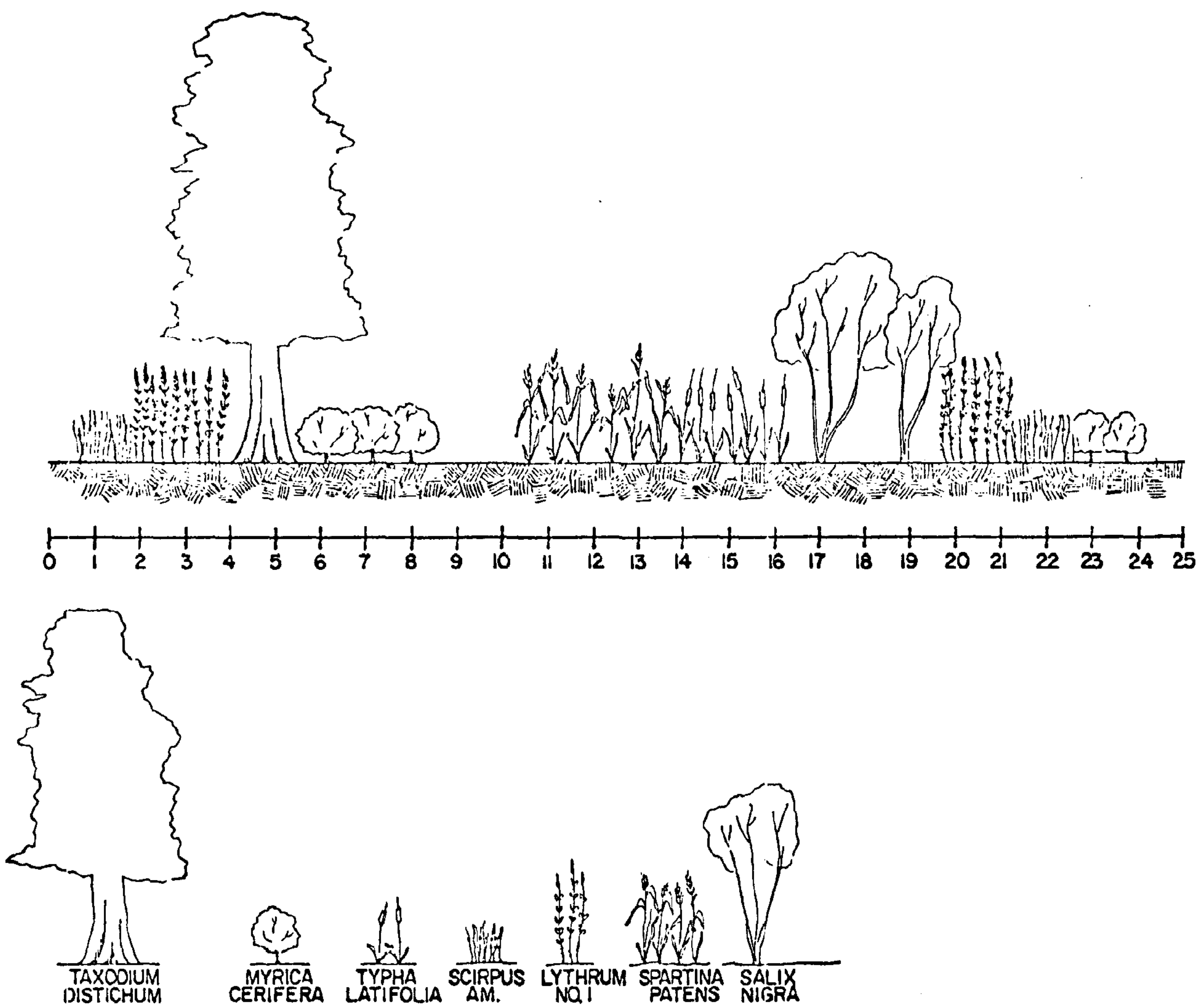

Figure 3. A schematic representation of a wetland vegetation type containing seven species.

VEGETATION SURVEY

Investigator L. Lodwick **Date** 14 Jan. 1976 **Line** 001 **Bearing** North

Level of Inundation Dry ground

Sampling Points

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	# of pts.
Scirpus americana	1m																					0.9m				2
Lythrum sp. #1		2m	2m																	2m	2m					4
Taxodium distichum			0.5m	0.5m	0.5m	0.5m																				4
Myrica cerifera						1.2m	1.2m	1.2m															1m	1m		5
Spartina patens											2m	2m	2m													3
Typha latifolia														2m	2m	2m										3
Salix nigra																4.5m	4.5m	4m	4m	4m						5
Exposed soil									X	X															X	3

Figure 3a. A tally sheet with the data for the association shown in Figure 3.

LANDSAT FIELD INVESTIGATION SUMMARY

prepared by George Clements
Texas Parks and Wildlife Department

Introduction

Biological field verification was conducted to assist in correlating ADP imagery data and to document vegetation represented in the ADP and image-interpretation marsh classes. Approximately 18 vegetation sampling sites were chosen within spectrally uniform areas, and image-interpretation results were verified for each of the four test sites.

The Texas Gulf Coast is an area characterized by many diverse vegetative ecosystems. These include large expanses of coastal prairie, salt marshes, fluvial timberlands and, farther south, resacas and and mesquital-chaparral brushlands. This diversity is attributed to the wide variance of climatic factors, substrates, and elevational differences of the coastal area.

This investigation was conducted with particular emphasis on those land areas immediately adjacent to the Gulf and estuarine waters, especially marshes. In the broadest sense, a marsh is a tract of soft, wet land usually characterized by monocotyledons such as grasses, rushes, and cattails. A more suitable definition applicable to the coastal regions of Texas is a tract of intertidal rooted vegetation which is alternately inundated and drained by the rise and fall of the tide. This tidal water can be saline, brackish, or fresh water, thus further delineating types of marsh. Differences in elevation affecting frequency of tidal inundation give rise to another set of marsh terminology: low and high marshes.
A marsh is, in reality, a series of communities which change gradually from the tidal creeks and pools to higher ground with the major varia-

tions in habitat steming from differences in elevation and the consequent effects on duration of tidal inundation and substrate differences (Odum, Copeland and McMahan, 1974).

Materials and Methods

The field approach used was the point intercept for some sites and detailed observations and estimations for sites where the vegetation was virtually homogeneous or when the site was impenetrable brushland.

The procedure for the point intercept transect method was as follows:

1. The site was located on a USGS topographic map by the image interpreter.
2. The site center point was located on the ground by the field investigator.
3. A 25-meter tape marked at one-meter intervals was stretched from the center point to the north, east, west and south for a total of 100 sampling points. At each of the points (1 m), the species of plant and the height were recorded on a field data sheet. If immediate identification could not be made, a sample specimen was taken for later identification.

Discussion

Low Marsh

The low brackish-to-saline marshes of the Texas coast, those which are tidally inundated almost daily, characteristically are vegetated with *Spartina alterniflora* as the dominant species. Often associated with it are *Batis maritima* and within its range, *Avicennia germinans*.

Generally, low marshes are more extensive on the upper coast in the Galveston-Freeport vicinity and gradually decrease in acreage southward down the coast. The low marsh in East Matagorda, West Matagorda, Espiritu Santo, and San Antonio bays are predominately situated on the bayward side of the barrier islands or peninsulas and, to lesser degrees, in other peripheral areas of the bays. Beginning in the Aransas-Redfish Bay system, acreage of low marsh diminishes giving way to tidal flats and extensive areas of shallow waters with submerged rooted vegetation.

In the Lower Laguna Madre area, the low Spartina alterniflora marsh is virtually nonexistent. However, low salinity areas well away from the bay shores were found which were not subject to tidal influences. Those areas supported typical halophytic vegetation. Site 1 of the Laguna Vista quadrangle was one example of this situation where Salicornia virginica, Batis maritima, Monanthochloe littoralis, Spartina spartinae and Borrichia frutescens were growing with Opuntia lindheimeri and Karwinskia humboldtiana. This tract was being utilized as rangeland for livestock.

High Marsh Flats

This topographical unit is difficult to define by speciation or delineate from other units. By definition, it is tidally affected by estuarine waters but only during those periods of highest neap tides or more often by wind tides. The difficulties in delineating the unit and assigning characteristic species arise from the frequency of its intergrading with other units, most often with both lower marsh and higher coastal prairie. Species most often found in the Unit I classified as high marsh are Distichlis spicata, Monanthochloe littoralis, Sporbolus virginicus and Borrichia frutescens. These species readily intergrade with lower ground species such as Batis maritima, Salicornia spp. and even Spartina alterniflora. Extensive patches of Spartina spartinae, the coastal prairie salt grass, are often found within the high marsh unit.

Generally, the acreage of high marsh is much less than low marsh on the Texas coast. One of the most well-delineated high marsh units, from a ground view, is a portion of the area known as Welder's Flats located southeast of Seadrift, Texas, and the largest tract is in the Aransas National Wildlife Refuge southwest of Seadrift.

Coastal Salt Grass Prairie

Thousands of acres of Gulf Coastal plain extending from the Sabine River to the Rio Grande are dominantly vegetated by *Spartina spartinae*. These coastal prairies are generally low, poorly drained, heavy clay and often saline soils. This ecosystem is most often closely associated with the lands immediately bordering the coastal estuaries and marsh systems and often intergrades with the high marshes. This unit is represented by transect and ground site observation data in all four of the test site areas where *Spartina spartinae* is the dominant vegetation. Residents of the lower Texas coast call this association "sacahuistal," while on the upper coast, it is called salt grass prairie. Many coastal ranchers burn these areas annually since fresh, new growth provides a more suitable range for cattle.

Barrier Islands

The Texas coast has the longest chain of barrier islands and peninsulas found anywhere in the world. They range in width from a few hundred yards to three or four miles (Andrews 1971). The generalized structure of these barriers is a gentle slope upward from the Gulf water line to the first set of dunes or foredunes. Height and development of the foredunes vary from low (six feet or less) on the upper Texas coast to the well-developed dunes of the lower coast which often attain heights of thirty feet or more. Continuing bayward, another set or two of dunes are found, usually not as high as the foredunes. These then give way to tracts of rolling, sandy substrate dotted with numerous depressions, swales, and hummocks, then grade into more level expanses until the bay shore is reached. At this point, the community may change to a barren tidal flat, high marsh, low marsh, or intergrades of the three depending on which bay system is being examined. The vegetation of the barrier islands varies more widely from the foredunes to the bayshore than from the upper coast to the lower coast. This vegetative community, on the whole, would have to be classified as grassland, as grasses constitute the dominant plants.

The species list of dune plants changes very little from the upper to lower coast. Most frequently encountered on the foredunes proper are Sesuvium portulacastrum, Ipomoea pes-caprae, I. littoralis, Heliotropium curassavicum, Philoxerus vermicularis and Uniola paniculata.

The dominant grass of the barrier flat along most of the coast is Spartina patens, with Spartina spartinae being second dominant on the upper coast and Schizachyrium scoparium second in the lower coastal barrier system. Other species frequently encountered during fieldwork in all areas included Cassia fasciculata, Helianthus spp., Ambrosia psilostachya, Andropogon glomeratus, Machaeranthera phyllocephala, and Croton spp. These species were usually more prevalent on higher ground and hummocks of the barrier flat. Low, wet or moist swales and depressions were encountered behind the dunes at all barrier flat ground investigation sites. In the Aransas area, these were vegetated with Typha sp., Scirpus spp. and Eleocharis spp., while in the Port Isabel area, Dichromena colorata and Scirpus supinus were dominant.

Summary

1. Low marsh is intertidal, rooted vegetation which is inundated on an almost daily basis. The characteristic species of this habitat on the Texas coast is *Spartina alterniflora*. Acreage of low marsh is more extensive on the upper Texas coast and diminishes to virtually nonexistent on the lower coast.
2. High marsh is that area which is tidally inundated only during highest neap tides or by wind tides. It is often difficult to delineate due to its intergrading with other units. I believe the key species of this system is *Distichilis spicata* and *Sporobolus virginicus*. Acreage of high marsh is much less than acreage of low marsh on the Texas coast.
3. Coastal salt grass prairie is probably the most abundant habitat or ecosystem on the Gulf Coastal plain. The key species in this habitat is *Spartina spartinae*.
4. The Texas coastline has the longest chain of barrier islands and peninsulas in the world. The dominant plants are the grasses *Spartina patens*, *S. spartinae* and *Schizachyrium scoparium*. Numerous microhabitats with their characteristic species are found within the strandplains.
5. Mesquital-chaparral is one of the more dominant associations on the arid lower Texas coast. This unit is found on the higher ground of the mainland areas. Characteristic species are *Prosopis glandulosa*, *Celtis spinosa*, and numerous other spiny trees and shrubs.

References

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APPENDIX C

WIND VELOCITY AND DIRECTION TIME-HISTORIES AT THE TIME OF EACH LANDSAT IMAGE ANALYZED

APPENDIX C

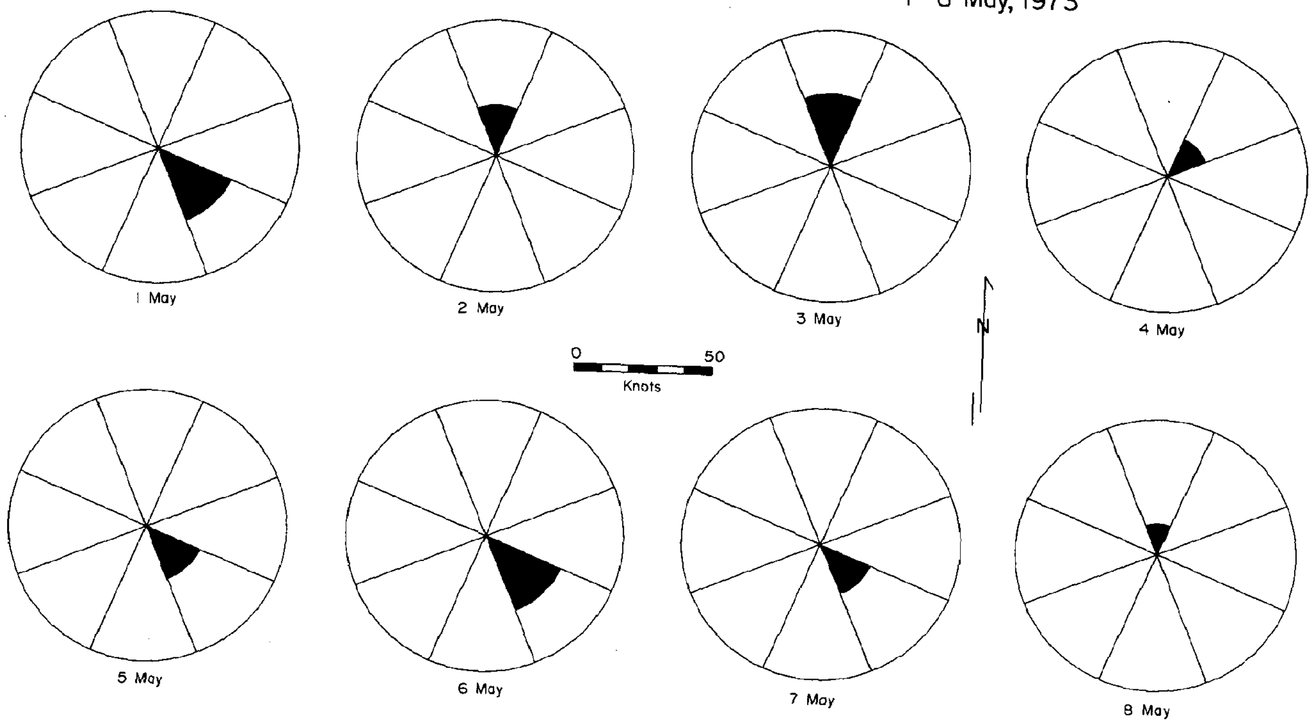
WIND VELOCITY AND DIRECTION TIME-
HISTORIES AT THE TIME OF EACH
LANDSAT IMAGE ANALYZED

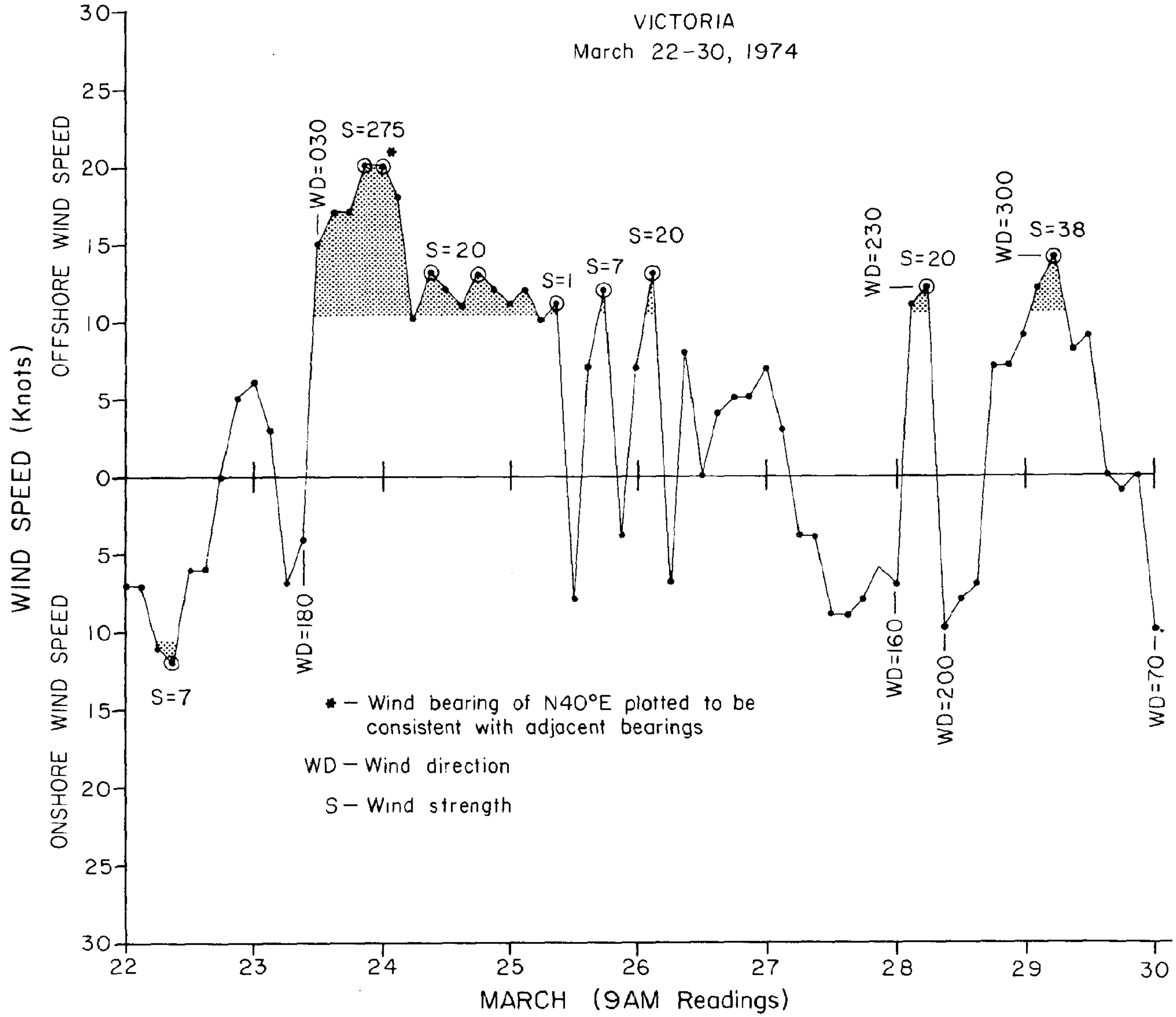
Effective winds are
those over 12 mph (10.4 knots).

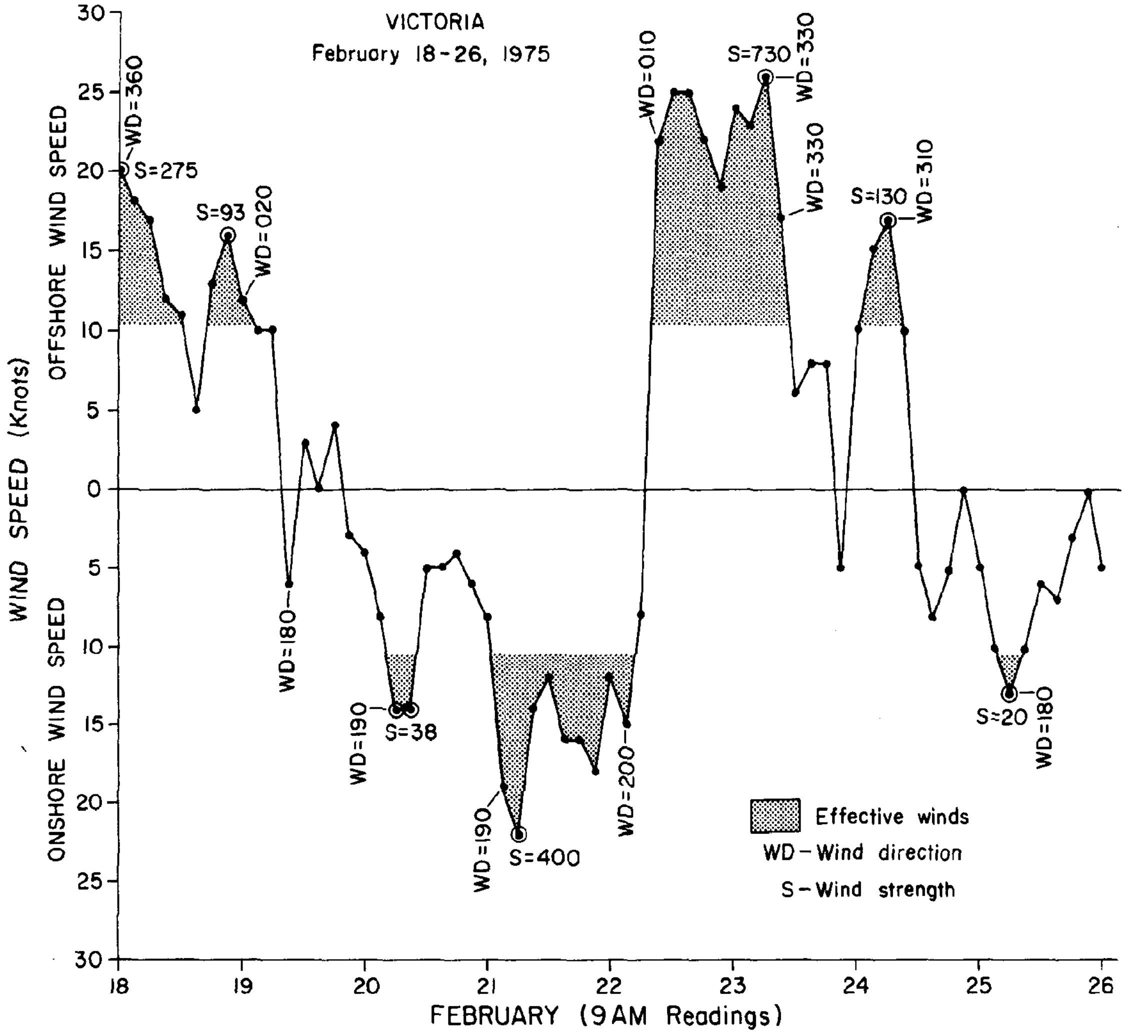
Wind strength is defined
by $S=(V-v)^2d$ where v
is observed velocity, v-12 mph,
d is duration in hours (Price, 1975).

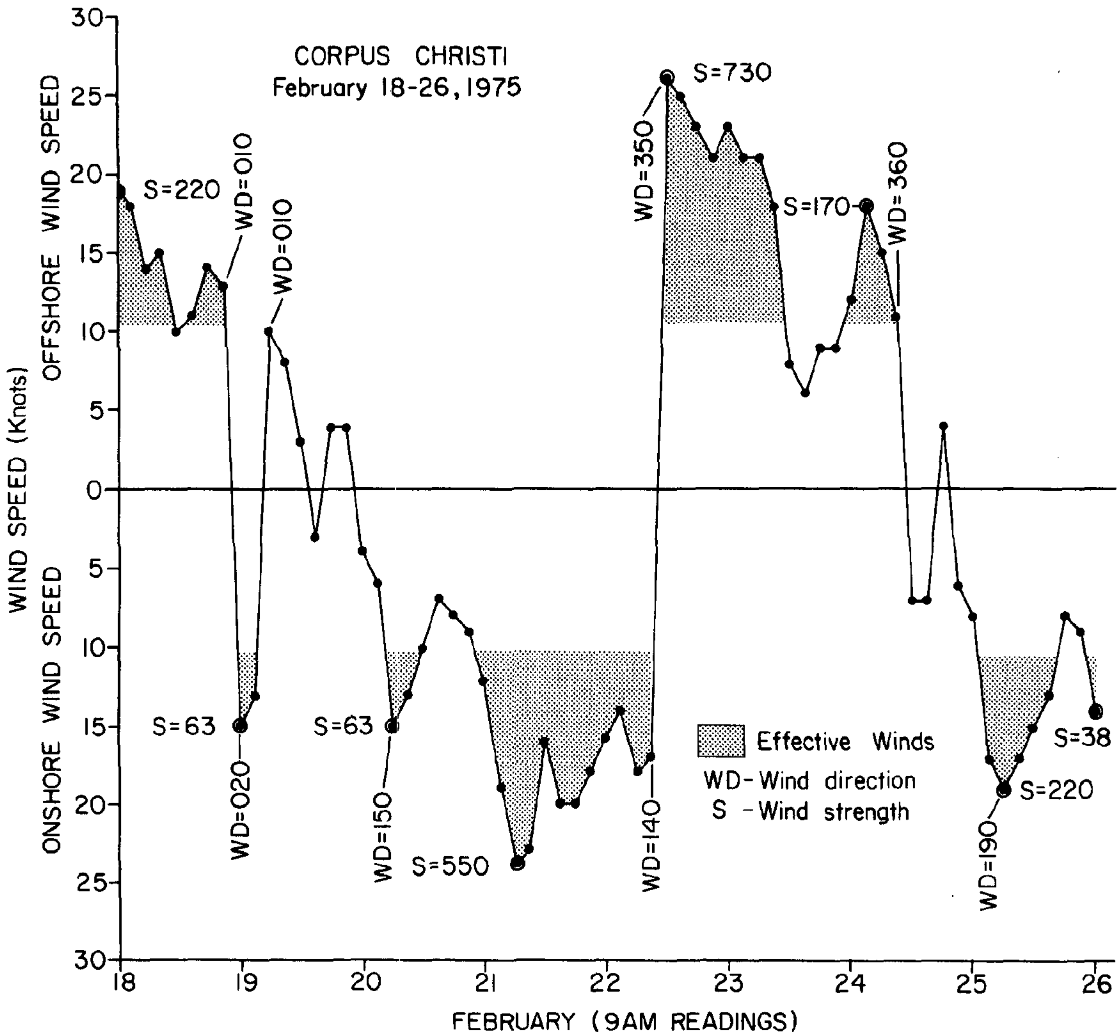
WIND SPEED (Knots)
Fastest mile, direction

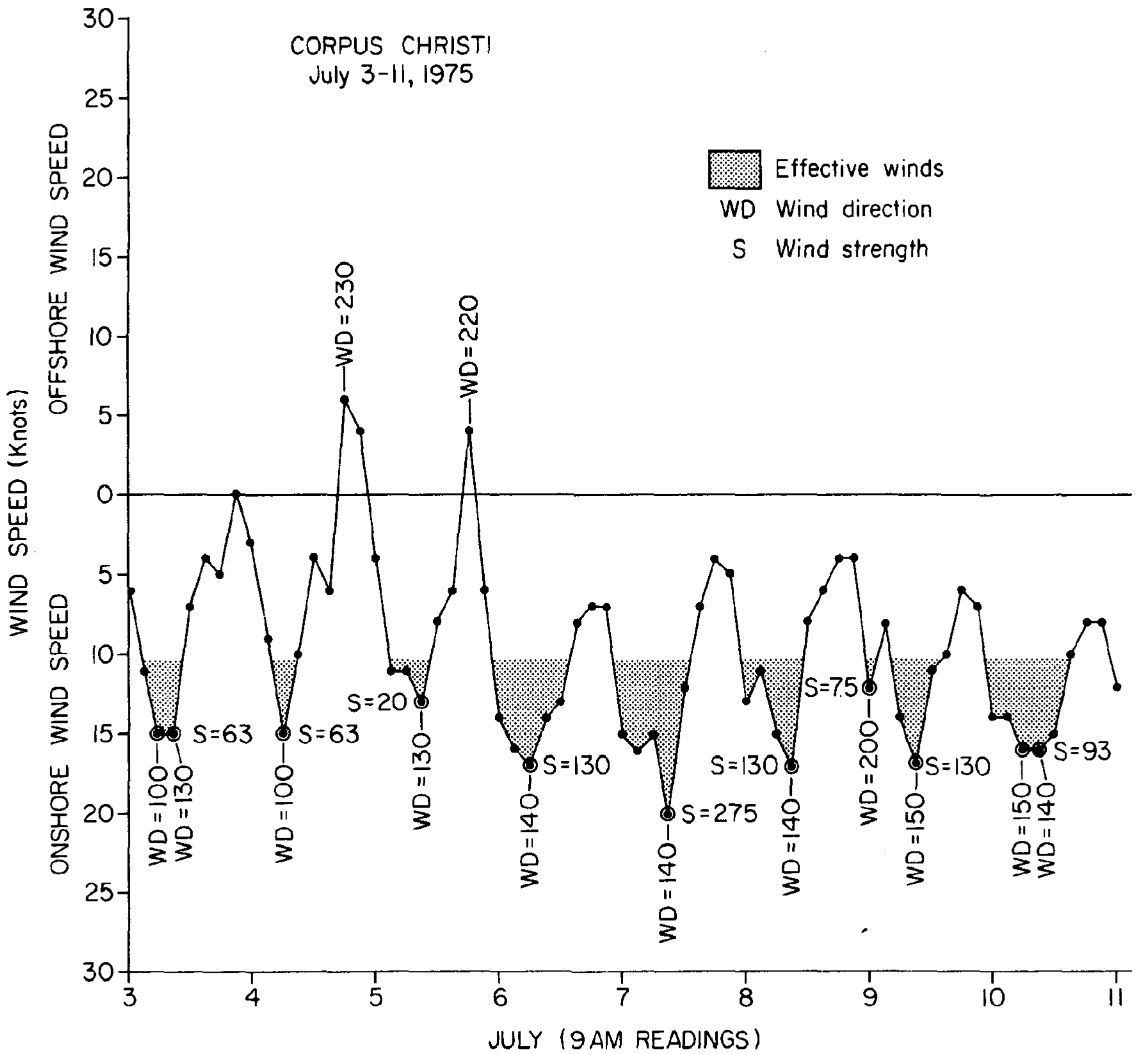
Galveston, Texas
1 - 8 May, 1973



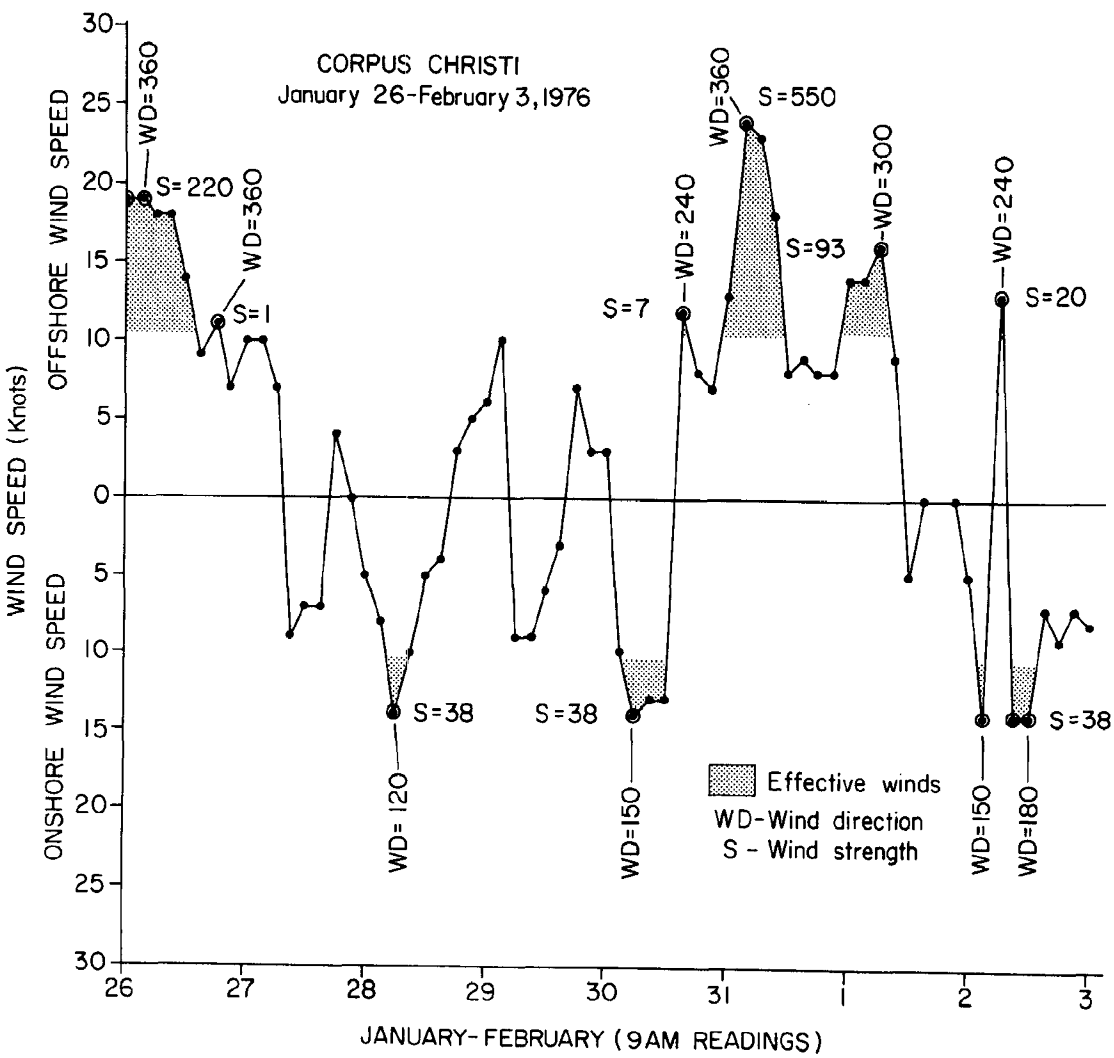

VICTORIA
March 22-30, 1974
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
30
25
20
15
10
5
0
5
10
15
20
25
30
22
23
24
25
26
27
28
29
30
MARCH (9AM Readings)
S=7
WD=180
WD=030
S=275
*
S=20
S=1
S=7
S=20
WD=230
S=20
WD=160
WD=200
WD=300
S=38
WD=70
* — Wind bearing of N40°E plotted to be consistent with adjacent bearings
WD — Wind direction
S — Wind strength

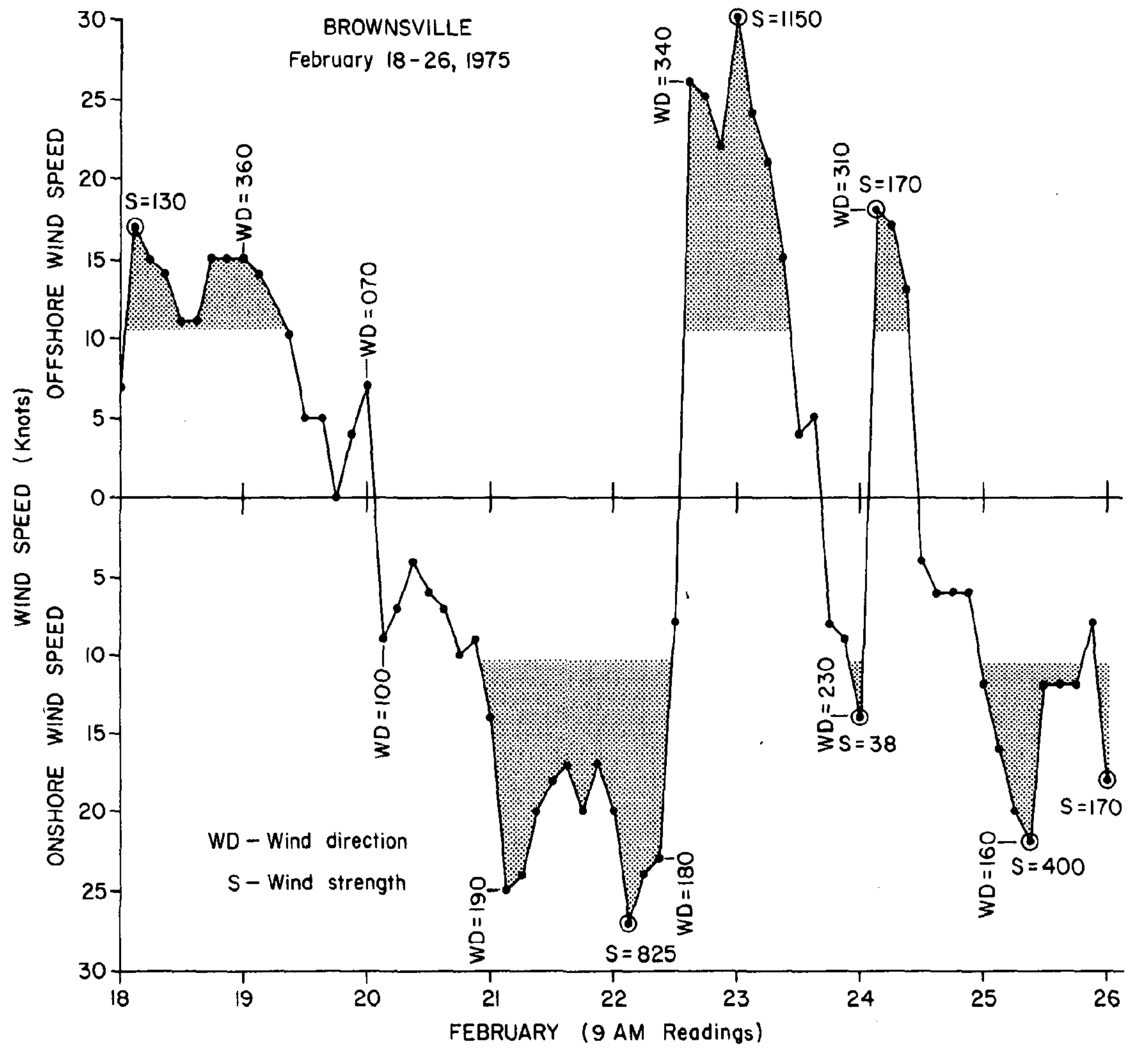

VICTORIA
February 18-26, 1975
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
30
25
20
15
10
5
0
5
10
15
20
25
30
WD=360
S=275
S=93
WD=020
WD=180
WD=190
S=38
WD=190
S=400
WD=200
WD=010
S=730
WD=330
WD=330
S=130
WD=310
S=20
WD=180
Effective winds
WD - Wind direction
S - Wind strength
18
19
20
21
22
23
24
25
26
FEBRUARY (9AM Readings)


CORPUS CHRISTI
February 18-26, 1975
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
30
25
20
15
10
5
0
5
10
15
20
25
30
S=220
WD=010
WD=010
S=730
WD=350
S=170
WD=360
S=63
WD=020
S=63
WD=150
S=550
WD=140
Effective Winds
WD-Wind direction
S -Wind strength
S=38
S=220
WD=190
18
19
20
21
22
23
24
25
26
FEBRUARY (9AM READINGS)



CORPUS CHRISTI
July 3-11, 1975
Effective winds
WD Wind direction
S Wind strength
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
WD=230
WD=220
S=63
S=63
S=20
S=130
S=275
S=130
S=75
S=130
S=93
WD=100
WD=130
WD=100
WD=130
WD=140
WD=140
WD=140
WD=200
WD=150
WD=150
WD=140
JULY (9AM READINGS)


CORPUS CHRISTI
January 26-February 3, 1976
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
30
25
20
15
10
5
0
5
10
15
20
25
30
WD=360
S=220
WD=360
S=1
S=38
WD=120
S=38
WD=150
S=7
WD=240
WD=360
S=550
S=93
WD=300
WD=240
S=20
S=38
WD=150
WD=180
Effective winds
WD-Wind direction
S - Wind strength
26
27
28
29
30
31
1
2
3
JANUARY-FEBRUARY (9AM READINGS)


BROWNSVILLE
February 18-26, 1975
WIND SPEED (Knots)
OFFSHORE WIND SPEED
ONSHORE WIND SPEED
S=130
WD=360
WD=070
WD=340
S=1150
WD=310
S=170
WD=100
WD=190
S=825
WD=180
WD=230
S=38
WD=160
S=400
S=170
WD - Wind direction
S - Wind strength
FEBRUARY (9 AM Readings)

APPENDIX D

SOFTWARE PROGRAMS AND MODIFICATIONS

APPENDIX D

SOFTWARE PROGRAMS AND MODIFICATIONS

As indicated in the text, much of the software utilized for this investigation was obtained from NASA. These programs were considered adequate for handling the basic classification tasks but were somewhat deficient in other areas. Consequently, during the course of the project, several programs were developed by the TNRIS staff to aid in the analysis effort. NASA also continued to develop capabilities in this area. Two such programs which were transferred to TNRIS are ELLTAB and HGROUP. Documentation and software for these and the other NASA programs used in the project can be obtained from the Computer Software Management and Information Center (COSMIC).

The information provided in this appendix regarding these programs developed by TNRIS staff describes the basic algorithm in each case. User manuals and related documentation can be obtained by contacting the Texas Natural Resources Information System, P.O. Box 13087, Austin, Texas 78711.

ELLTAB PROGRAM

```
C***PROGRAM NORMAL
C   THIS PROGRAM NORMALIZES A VECTOR ARRAY
C
C   NV = VECTOR DIMENSION
C   NS = NUMBER OF SAMPLES
C   KF = VARIABLE FORMAT FOR READING CLASS NAME AND DATA VECTOR
C
      DIMENSION KF(20),KC(50),D(50,50),VMAX(50)
C   READ PARAMETERS, FORMAT AND DATA ARRAY
      READ(5,100) NV,NS,KF
  100 FORMAT(2I5,/,20A4)
      DO 10 I=1,NS
   10 READ(5,KF) KC(I),(D(I,J),J=1,NV)
C   FIND MAXIMUM VALUE FOR EACH VARIABLE
      DO 20 J=1,NV
      DO 20 I=1,NS
   20 VMAX(J)=AMAX1(VMAX(J),D(I,J))
C   NORMALIZE THE VECTORS
      DO 30 J=1,NV
      DO 30 I=1,NS
   30 D(I,J)=D(I,J)/VMAX(J)
      DO 40 I=1,NS
   40 WRITE(1,KF) KC(I),(D(I,J),J=1,NV)
      WRITE(6,200)
  200 FORMAT(//,' NORMALIZATION COMPLETED',//)
      STOP
      END
```

DB0200*ELLTAB(1).S-F

```
      FUNCTION SUMF (X, KK, NN, ND)
C
C COMPUTES SUM X OR SUM X**2 FROM A VECTOR.
C X = ARRAY CONTAINING THE SCORES TO BE USED.
C KK = ROW OR COLUMN NUMBER IF X IS A MATRIX. SET = 1 IF X IS A VECTOR.
C    IF KK IS POSITIVE AND NOT 1, IT IS A COLUMN VECTOR.
C    IF KK IS NEGATIVE AND NOT 1, IT IS A ROW VECTOR.
C NN = NUMBER OF VALUES TO BE SUMMED. IF NEGATIVE, SUM X**2 COMPUTED.
C ND = NUMBER OF ROWS (OR ELEMENTS) DIMENSIONED FOR X IN THE
C    CALLING PROGRAM.
C
      DIMENSION X(54,1)
      SUMF = 0.0
      N = IABS(NN)
      K = IABS(KK)
      IF (NN) 5,55,10
    5 IF (KK) 15,55,25
   10 IF (KK) 35,55,45
   15 DO 20 I=1,N
   20 SUMF = SUMF + X(K,I)**2
      RETURN
   25 DO 30 I=1,N
```

```
   30 SUMF = SUMF + X(I,K)**2
      RETURN
   35 DO 40 I=1,N
   40 SUMF = SUMF + X(K,I)
      RETURN
   45 DO 50 I=1,N
   50 SUMF = SUMF + X(I,K)
   55 RETURN
      END
```

```
      SUBROUTINE CCDS (KF, KI, KJ, KK, KL, KM)
C
C READS AND PRINTS TITLE, PARAMETERS, AND FORMAT CONTROL CARDS.
C KF = VECTOR HOLDING VARIABLE FORMAT ON RETURN.
C KI, KJ, KL, KM = PARAMETER VALUES.
C KH = TEMPORARY STORAGE WITHIN THIS ROUTINE.
C BLANK TITLE CARD YIELDS STOP.
C
      DIMENSION KF(20), KH(20)
      READ (5,9) KH
    9 FORMAT (20A4)
      IF (KH(1) .EQ. KH(2)) STOP
      READ (5,10) KI, KJ, KK, KL, KM, KF
   10 FORMAT (5I5 / 20A4)
      WRITE (6,15) KH, KI, KJ, KK, KL, KM, KF
   150FORMAT (1H1, 20A4 // 11H PARAMETERS / 13H COL  1- 5 = , I5 /
     113H COL  6-10 = , I5 / 13H COL 11-15 = , I5 / 13H COL 16-20 = ,
     2I5 / 13H COL 21-25 = , I5 // 15H DATA FORMAT = , 20A4)
      RETURN
      END
```

HGROUP PROGRAM

```
      C     PROGRAM HGROUP
      C
      C  HIERARCHICAL PROFILE-GROUPING ANALYSIS.
      C  PARAMETER CONTROL-CARD FIELDS.
      C     COL 1-5. NUMBER OF VARIABLES (MAX = 54).
      C     COL 6-10. NUMBER OF SUBJECTS (MAX = 54).
      C     COL 11-15. LEVEL OF GROUPING TO BEGIN GROUP-MEMBERSHIP PRINTING.
      C     COL 20. 1 = STANDARDIZE DATA ON EACH VARIABLE BEFORE GROUPING.
      C     COL 25. 1 = TRANSPOSE DATA MATRIX IN ORDER TO GROUP VARIABLES.
      C  FORMAT MUST SPECIFY AN ALPHANUMERIC SUBJECT-CODE FIELD, FOLLOWED BY
      C     NV SCORE FIELDS. IF DATA MATRIX IS TRANSPOSED (COL 25 = 1),
      C     GROUP-MEMBERSHIP CODES WILL BE SERIAL NUMBERS OF VARIABLES.
      C  SUBPROGRAMS REQUIRED ARE SUMF AND CCDS.
      C
            DIMENSION D(54,54), KG(54), W(54), KF(20)
            REAL*8 LC(54), KC(54)
            ND = 54
          5 CALL CCDS (KF, NV, NS, KP, KS, KT)
            T = NS
      C READ ALL DATA CARDS AND STANDARDIZE COLUMNS (VARIABLES), IF
      C OPTIONED
            DO 10 I=1,NS
         10 READ KF, KC(I), (D(I,J), J=1,NV)
            IF (KS .EQ. 0) GO TO 20
            DO 15 J=1,NV
            A = SUMF(D, J, NS, ND) / T
            S = SQRT(SUMF(D, J, -NS, ND) / T - A * A)
            DO 15 I=1,NS
         15 D(I,J) = (D(I,J) - A) / S
         20 IF (KT .EQ. 0) GO TO 30
      C  TRANSPOSE DATA MATRIX, IF OPTIONED.
            N = MAX0(NS, NV)
            DO 25 I=1,N
            DO 25 J=1,N
            X = D(I,J)
            D(I,J) = D(J,I)
         25 D(J,I) = X
            NS = NV
            NV = T
      C  CONVERT DATA MATRIX TO INITIAL MATRIX OF ERROR POTENTIALS.
         30 DO 45 I=1,NS
            DO 35 J=1,NV
         35 W(J) = D(I,J)
            DO 45 J=I,NS
            D(I,J) = 0.0
            DO 40 K=1,NV
         40 D(I,J) = D(I,J) + (D(J,K) - W(K))**2
         45 D(I,J) = D(I,J) / 2.0
            DO 55 I=1,NS
            DO 55 J=I,NS
         55 D(J,I) = 0.0
```

```
      NG=NS
C  INITIALIZE GROUP-MEMBERSHIP AND GROUP-N VECTORS.
      DO 60 I=1,NS
      KG(I)=I
   60 W(I)=1.0
C  LOCATE OPTIMAL COMBINATION, IF MORE THAN 2 GROUPS REMAIN.
   65 NG=NG-1
      IF (NG .EQ. 1) GO TO 5
      X=10.0**10
      DO 75 I=1,NS
      IF (KG(I) .NE. I) GO TO 75
      DO 70 J=I,NS
      IF (I .EQ. J .OR. KG(J) .NE. J) GO TO 70
      DX = D(I,J) - D(I,I) - D(J,J)
      IF (DX .GE. X) GO TO 70
      X=DX
      L=I
      M=J
   70 CONTINUE
   75 CONTINUE
      NL = W(L)
      NM = W(M)
      WRITE (6,80) NG, L, NL, M, NM, X
   800FORMAT (/ I4, 25H GROUPS AFTER COMBINING G, I3,
     14H (N=, I3, 7H) AND G, I3, 4H (N=, I3, 10H), ERROR =,
     2 F16.6)
C  MODIFY GROUP-MEMBERSHIP AND GROUP-N VECTORS, AND ERROR
C  POTENIALS.
      WS = W(L) + W(M)
      X = D(L,M) * WS
      Y = D(L,L) * W(L) + D(M,M) * W(M)
      D(L,L) = D(L,M)
      DO 85 I=1,NS
      IF (KG(I) .EQ. M) KG(I) = L
   85 CONTINUE
      DO 95 I=1,NS
      IF (I .EQ. L .OR. KG(I) .NE. I) GO TO 95
      IF (I .GT. L) GO TO 90
     0D(I,L) = (D(I,L) * (W(I) + W(L)) + D(I,M) * (W(I) + W(M))
     1+ X - Y - D(I,I) * W(I)) / (W(I) + WS)
      GO TO 95
   900D(L,I) = (D(L,I) * (W(L) + W(I)) + (D(M,I) + D(I,M))
     1* (W(M) + W(I)) + X - Y - D(I,I) * W(I)) / (W(I) + WS)
   95 CONTINUE
      W(L) = WS
      IF (NG .GT. KP) GO TO 65
C  PRINT GROUP MEMBERSHIPS OF ALL OBJECTS, IF OPTIONED.
      DO 115 I=1,NS
      IF (KG(I) .NE. I) GO TO 115
      L=0
      DO 100 J=I,NS
      IF (KG(J) .NE. I) GO TO 100
```

HGROUP PROGRAM (Con't)

```
         L = L + 1
         LC(L) = KC(J)
         IF (KT .EQ. 1) LC(L) = J
     100 CONTINUE
         IF (KT .EQ. 0) GO TO 102
         IF (KT .EQ. 1) GO TO 104
     104 WRITE (6,105) I, L, (LC(J), J=1,L)
     105 FORMAT (2H G, I3, 4H (N=, I3, 2H) , 25I4 / (14X, 25I4))
     102 WRITE (6,110) I, L, (LC(J), J=1,L)
     110 FORMAT (2H G, I3, 4H (N=, I3, 2H) , 15A7 / (14X, 15A7))
     115 CONTINUE
         GO TO 65
         END
```

SCALE REGISTER PROGRAM

```
DB0200*-1).RDCLAS
            SUBROUTINE RDCLAS(ILDISK,ISDWLO,ISDWHI,NXWD,NSAM)
      C***THIS SUBROUTINE READS A LARSYS CLASSIFICATION FILE
      C***AND RETURNS CLASSIFICATION RESULTS FOR LINE ILDISK
            DIMENSION NXWD(4000),IDATA(1000),NPTS(4),LSTART(4),LEND(4),
           *ISTART(4),IEND(4)
            DATA JUMP/0/
            DEFINE XCCT(SDISK)=(SDISK+NSAM-1)/NSAM
            IF (JUMP.EQ.1) GO TO 10
            JUMP=1
            NCCTLO=MAX0(XCCT(ISDWLO-1),1)
            NCCTHI=MIN0(XCCT(ISDWHI+1),4)
      C***READ HEADER RECORDS FROM LARSYS FILES
            DO 5 NCCT=NCCTLO,NCCTHI
            NUNIT=24+NCCT
            READ(NUNIT,END=90,ERR=90) NXWD(1)
            READ(NUNIT,END=90,ERR=90) NXWD(1)
            READ(NUNIT,END=90,ERR=90) NXWD(1)
            READ(NUNIT,END=90,ERR=90) NXWD(1)
            READ(NUNIT,END=90,ERR=90) (NXWD(I),I=1,10)
      C***SAVE FIELD INFORMATION
            NPTS(NCCT)=NXWD(1)
            LSTART(NCCT)=NXWD(6)
            LEND(NCCT)=NXWD(7)
            ISTART(NCCT)=NXWD(9)
      5     IEND(NCCT)=NXWD(10)
      C***FILL LINE WITH 'NO DATA' FLAGS
      10    DO 20 I=1,4000
      20    NXWD(I)='000000'
      C***LOCATE REQUESTED DATA ON CLASSIFICATION FILES
            DO 50 NCCT=NCCTLO,NCCTHI
            NUNIT=24+NCCT
            IF (ILDISK.LT.LSTART(NCCT).OR.ILDISK.GT.LEND(NCCT)) GO TO 50
      C***READ A CLASSIFIED LINE
            J=NPTS(NCCT)
      30    READ(NUNIT,END=50,ERR=95) ILINE,(IDATA(I),I=1,J)
            IF (ILINE.LT.ILDISK) GO TO 30
      C***INSERT CLASSIFIED DATA INTO NXWD
            J=0
            KK=ISTART(NCCT)+NSAM*(NCCT-1)
            LL=IEND(NCCT)+NSAM*(NCCT-1)
            DO 40 I=KK,LL
            J=J+1
      40    NXWD(I)=IDATA(J)
      50    CONTINUE
            RETURN
      C***ERROR READING CLASSIFICATION FILE
         90 WRITE(6,100) NUNIT
        100 FORMAT(' ERROR READING HEADER ON CLASSIFICATION FILE--UNIT ',I2)
            STOP
```

```
   95 WRITE(6,200) NUNIT
  200 FORMAT(' ERROR READING CLASSIFICATION FILE--UNIT ',I2)
      STOP
C
C***REWIND FILES AND RESET JUMP FLAG
      ENTRY RESETJ
      JUMP=0
      DO 60 NCCT=NCCTLO,NCCTHI
      NUNIT=24+NCCT
60    REWIND NUNIT
      RETURN
      END
```

```
      SUBROUTINE MAPRNT(KT1PIX)
C     -----------------
C
C (E H SCHLOSSER)
C
C
C THIS SUBROUTINE REGISTERS ERTS MSS DATA FOR PRTCLASS
C
C
C EXTERNAL SUBROUTINES/FUNCTIONS CALLED
C ------------------------------------
C
C     NITHDG
C     SYMTAB
C     TICGEN
C     READ2N
C
C
      INCLUDE KOMXQT,LIST
      INCLUDE KOMNER,LIST
      INCLUDE KOMKLS,LIST
      INCLUDE KOMFIT,LIST
      INCLUDE WINDEF,LIST
      INCLUDE KOMDEN,LIST
      INCLUDE KOMOWW,LIST
      INCLUDE KOMALT,LIST
      INCLUDE KOMSYM,LIST
      INCLUDE KOMTIC,LIST
C
      DATA IOUT/8/  @ OUTPUT TAPE OF CLASSIFIED DATA
      DIMENSION NXWD(4000)
      DIMENSION IPBUF(1000)
      DIMENSION LINFMT(4)
      DATA LINFMT/'(1X,J4,1H:,NNNA1,1H:,J4)'/
      DATA KOLON/':'/
```

```
C
      INCLUDE TRFORM,LIST
      INCLUDE NITAB,LIST    @ DEFINE PROCEDURE TO COMPUTE ALT PRINT UNIT NUMBERS
      INCLUDE DIGITS,LIST     @ DEFINE PROCEDURES FOR DIGIT EXTRACTION
C
C
C INITIALIZE WINDOW
C
      NSAM=NERSAM/4
      IPLMIN=PPDOWW(WLIN,WMIN)
      IPLMAX=PPDOWW(WLIN,WMAX)
      IPCMIN=PPDOWW(WCOL,WMIN)
      IPCMAX=PPDOWW(WCOL,WMAX)
      NITMAX=1+(IPCMAX-IPCMIN)/(KPAGE-8)
      IF(NITMAX.LE.8) GO TO 110
      CALL MDWARN('WINDOW TOO WIDE')
      GO TO 900
  110 IF(KSYOWW(WORIG).EQ.'SCA') GO TO 130
      IF(KSYOWW(WORIG).EQ.'DEG') GO TO 140
      IF(KSYOWW(WORIG).EQ.'MIN') GO TO 140
      GO TO 160
  130 WRITE(6,135) NWNDOW,MSAOWW(WLIN,WORIG),MSAOWW(WSAM,WORIG)
  135 FORMAT(6X,'WINDOW #',I3,' (ORIGIN ',I4,' LINE, ',I4,' SAMPLE)')
      GO TO 170
  140 WRITE(6,145) NWNDOW,GEDOWW(WLAT,WORIG),GEDOWW(WLON,WORIG)
  145 FORMAT(6X,'WINDOW #',I3,' (ORIGIN ',F9.4,' LAT, ',F9.4,' LON)')
      GO TO 170
  160 WRITE(6,165) NWNDOW,UTMOWW(WEA,WORIG),UTMOWW(WNO,WORIG)
  165 FORMAT(6X,'WINDOW #',I3,' (ORIGIN ',-3P,F8.3,' KM E, ',F8.3,
     & ' KM N)')
  170 IPLTIC=99999
      IPCTIC=99999
      LVLTIC=1
C
C
C
C GENERATE TABULAR DATA
C
      NITLO=0
      NITHI=0
      INCLUDE NITROT,LIST
      NIT=0
      NUNIT=NTAB(NIT)
      CALL NITHDG(NUNIT)
      CALL SYMTAB(NUNIT)
      IF(KT1PIX.NE.1) WRITE(NUNIT,175) KT1PIX
  175 FORMAT('0(1 COUNT = 1/',I1,' PIXEL)'/)
      CALL GENTIC(NUNIT)
C
C
```

SCALE REGISTER PROGRAM (Con't)

```
C BREAK WINDOW INTO SECTIONS, EACH COMPOSED OF NOT MORE THAN MALTM PRINT UNITS
C
      IPCMOD=MOD((IPCMAX-IPCMIN),(KPAGE-8))+1
      FLD(30,6,LINFMT(2))=FLD(00,6,JHUNS(IPCMOD))
      FLD(00,6,LINFMT(3))=FLD(00,6,JTENS(IPCMOD))
      FLD(06,6,LINFMT(3))=FLD(00,6,JONES(IPCMOD))
      DO 800 NITLO=1,NITMAX,MALTM
      NITHI=MIN0((NITLO+MALTM-1),NITMAX)
      INCLUDE NITROT,LIST
      CORLIN=CORL4P(IPLMIN,0)
      MSALIN=CORLIN     @ FUTURE CORRECTION
      CORLIN=MSALIN     @ FUTURE CORRECTION -- TRUNCATE TO INTEGER
      IPLIN=PPDL4C(CORLIN,0)
      IPCLO=IPCMIN+(KPAGE-8)*(NITLO-1)
      IPCHI=MIN0((IPCMIN+(KPAGE-8)*NITHI-1),IPCMAX)
      NTICK=0
      CALL GETIC
C
C
C HEAD PRINT UNITS
C
      DO 180 NIT=NITLO,NITHI
      NUNIT=NTAB(NIT)
      CALL NITHDG(NUNIT)
  180 CONTINUE
      CORSAM=CORS4P(IPLIN,IPCLO)
      MSASLO=ADJS4C(CORLIN,CORSAM)
      CORSAM=CORS4P(IPLIN,IPCHI+1)
      MSASHI=ADJS4C(CORLIN,CORSAM)+1.0
      CALL SAMSCL
      CALL BORDER
C
C
C COMPUTE FIRST/LAST DENSITY SAMPLES
C
  200 CORSAM=CORS4P(IPLIN,IPCLO)
      MSASLO=ADJS4C(CORLIN,CORSAM)
      CORSAM=CORS4P(IPLIN,IPCHI+1)
      MSASHI=ADJS4C(CORLIN,CORSAM)+1.0
C
C
C READ DENSITY LINE
C
      CALL RDCLAS(MSALIN,MSASLO,MSASHI,NXWD,NSAM)
C
C
C LOCATE FIRST DENSITY PIXEL
C
      MSASAM=MSASLO
      NWDLO=MSASLO
```

SCALE REGISTER PROGRAM (Con't)

```
          NWD=NWDLO
          NWDHI=MSASHI
          IF(MSASAM.LT.1) GO TO 350
C
C
C SCREEN PIXEL DENSITY
C
      310 IF(NXWD(NWD).EQ.'000000') GO TO 350
C
C
C REGISTER/COUNT SCREENED PIXELS
C
          CORSAM=CORS4A(MSALIN,MSASAM)
          IPCOL=PPDC4C(CORLIN,CORSAM)
          IPBUF(IPCOL-IPCMIN+3)=NXWD(NWD)
C
C
C SCAN DENSITY PIXELS
C
      320 MSASAM=MSASAM+1
          NWD=NWD+1
      325 IF(MSASAM.GT.MSASHI) GO TO 400
          GO TO 310
C
C
C REGISTER FIRST 'NO DATA' PIXEL
C
      350 CORSAM=CORS4A(MSALIN,MSASAM)
          IPC1=PPDC4C(CORLIN,CORSAM)
          IF(MSASAM.GT.0) GO TO 360
          MSASAM=1
          NWD=1
C
C
C SCAN 'NO DATA' PIXELS
C
      360 MSASAM=MSASAM+1
          NWD=NWD+1
      365 IF(MSASAM.GT.MSASHI) GO TO 380
          IF (NXWD(NWD).NE.'000000') GO TO 380
          GO TO 360
C
C
C REGISTER STRING OF 'NO DATA' PIXELS
C
      380 CORSAM=CORS4A(MSALIN,MSASAM-1)      @ LAST 'NO DATA' PIXEL
          IPC2=PPDC4C(CORLIN,CORSAM)
          DO 385 IPCOL=IPC1,IPC2
      385 IPBUF(IPCOL-IPCMIN+3)=+999999
          IF(MSASAM.GT.MSASHI) GO TO 400
          GO TO 310
```

```
C
C
C INCREMENT DISK LINE AND WRITE PRINT LINE
C
  400 MSALIN=MSALIN+1
      CORLIN=MSALIN     @FUTURE CORRECTION
      NLPRNT=PPDL4C(CORLIN,0)
      IF(NLPRNT.GT.IPLIN) CALL LINOUT
      IF(NLPRNT.GT.IPLMAX) GO TO 500
      GO TO 200
C
C
C FOOT PRINT UNITS
C
  500 CALL BORDER
      CALL SAMSCL
      DO 550 NIT=NITLO,NITHI
      NUNIT=NTAB(NIT)
      WRITE(NUNIT,525)
  525 FORMAT('0')
  550 CONTINUE
C
C
  800 CONTINUE
      WRITE(NUNIT,805)
  805 FORMAT('0'/6X,' **SEE UNIT 0 FOR LEGEND**'/)
      NWNDOW=NWNDOW+1
      ENDFILE IOUT
      CALL RESETJ
C
  900 RETURN
C
C
C
C
C
C
C
      SUBROUTINE GETIC
      NTICK=NTICK+1
      IPLTIC=LINTIC(NTICK)
      IPCTIC=COLTIC(NTICK)
      LVLTIC=LEVTIC(NTICK)
      RETURN
C
C
C
C
C
C
```

SCALE REGISTER PROGRAM (Con't)

```
      SUBROUTINE SAMSCL
   99 FORMAT(6X,124I1)
      IPCNLO=MSASLO
      DO 998 NIT=NITLO,NITHI
      NUNIT=NTAB(NIT)
      IPCNHI=MIN0((IPCNLO+KPAGE-9),MSASHI)
      DO 1000 I=IPCNLO,IPCNHI
 1000 IPBUF(I-IPCMIN+3)=I/1000
      WRITE(NUNIT,99) (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI)
      DO 100 I=IPCNLO,IPCNHI
  100 IPBUF(I-IPCMIN+3)=(I-1000*(I/1000))/100
      WRITE(NUNIT,99) (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI)
      DO 10 I=IPCNLO,IPCNHI
   10 IPBUF(I-IPCMIN+3)=(I-100*(I/100))/10
      WRITE(NUNIT,99) (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI)
      DO 1 I=IPCNLO,IPCNHI
    1 IPBUF(I-IPCMIN+3)=I-10*(I/10)
      WRITE(NUNIT,99) (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI)
  998 IPCNLO=IPCNHI+1
      RETURN
C
C
C
C
C
C
      SUBROUTINE BORDER
      DO 100 I=IPCLO,IPCHI
  100 IPBUF(I-IPCMIN+3)=':'
      IPCNLO=IPCLO
      DO 300 NIT=NITLO,NITHI
      NUNIT=NTAB(NIT)
      IPCNHI=MIN0((IPCNLO+KPAGE-9),IPCHI)
      WRITE(NUNIT,225) (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI)
  225 FORMAT(6X,124A1)
  300 IPCNLO=IPCNHI+1
      DO 800 I=IPCLO,IPCHI
  800 IPBUF(I-IPCMIN+3)=0       @ MUST ZERO PRINT BUFFER!!!
      RETURN
C
C
C
C
C
C
      SUBROUTINE LINOUT
      DIMENSION JSYTIC(2)
      DATA JSYTIC/'*','+'/
C
C LOOK UP SYMBOLS
C
```

```
      DO 150 I=IPCLO,IPCHI
      IPCCNT=MINO(IPBUF(I-IPCMIN+3),(KSYMSZ-1))
  150 IPBUF(I-IPCMIN+3)=KSYM(IPCCNT+1)
      GO TO 300
C
C
C FLAG PRINT LINE(S) WITHOUT SCAN LINE DATA DUE TO SCALING
C
  200 KSYBIT=-IABS(KSYBIT)      @ DISABLE OVERPRINT
      DO 250 I=IPCLO,IPCHI
      IF(IPBUF(I-IPCMIN+3).EQ.' ') GO TO 250
      IF(IPBUF(I-IPCMIN+3).EQ.'*') GO TO 230
      IF(IPBUF(I-IPCMIN+3).EQ.'+') GO TO 230
      IPBUF(I-IPCMIN+3)=':'
      GO TO 250
  230 IPBUF(I-IPCMIN+3)=' '
  250 CONTINUE
C
C
C INSERT TICK MARKS
C
  300 IF(IPLTIC.GT.IPLIN) GO TO 400      @ SAVE TICK FOR SUBSEQUENT LINE
      IF(LVLTIC.EQ.0) GO TO 330      @ ALWAYS INSERT PRIMARY TICKS
      IF(IPBUF(IPCTIC-IPCMIN+3).EQ.' ') GO TO 330
      IF(IPBUF(IPCTIC-IPCMIN+3).NE.':') GO TO 350
  330 IF(IPBUF(IPCTIC-IPCMIN+2).EQ.':')
     &   IPBUF(IPCTIC-IPCMIN+2)=' '      @ LEFT TICK HALO
         IPBUF(IPCTIC-IPCMIN+3)=JSYTIC(LVLTIC+1)      @ TICK
      IF(IPBUF(IPCTIC-IPCMIN+4).EQ.':')
     &   IPBUF(IPCTIC-IPCMIN+4)=' '      @ RIGHT TICK HALO
  350 CALL GETIC
      GO TO 300
  400 CONTINUE
C
C
C WRITE PRINT UNIT LINE
C
      IPCNLO=IPCLO
      DO 540 NIT=NITLO,NITHI
      NUNIT=NTAB(NIT)
      IPCNHI=MINO((IPCNLO+KPAGE-9),IPCHI)
      IF((NIT.EQ.NITMAX).AND.(IPCMOD.LT.122)) GO TO 530
      WRITE(NUNIT,520) MSALIN,
     & (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI),KOLON
  520 FORMAT(1X,J4,':',125A1)
      GO TO 540
  530 WRITE(NUNIT,LINFMT) MSALIN,
     & (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI),MSALIN
  540 IPCNLO=IPCNHI+1
      NPIX=IPCHI-IPCLO+1
      WRITE(IOUT) NPIX,(IPBUF(I-IPCMIN+3),I=IPCLO,IPCHI)
```

SCALE REGISTER PROGRAM (Con't)

```
      IF(KSYBIT.LT.6) GO TO 700
C
C
C OVERPRINT SYMBOLS
C
      DO 660 KBIT=06,KSYBIT,6
      DO 610 I=IPCLO,IPCHI
  610 FLD(30,6,IPBUF(I-IPCMIN+3))=FLD(KBIT,6,IPBUF(I-IPCMIN+3))
      IPCNLO=IPCLO
      DO 640 NIT=NITLO,NITHI
      NUNIT=NTAB(NIT)
      IPCNHI=MIN0((IPCNLO+KPAGE-9),IPCHI)
      WRITE(NUNIT,620)
     & (IPBUF(I-IPCMIN+3),I=IPCNLO,IPCNHI)
  620 FORMAT('+',5X,124R1)
  640 IPCNLO=IPCNHI+1
  660 CONTINUE
C
C
C INCREMENT PRINT LINE
C
  700 IPLIN=IPLIN+1
      IF(NLPRNT.GT.IPLIN) GO TO 200
C
C
C REINITIALIZE LINE
C
      KSYBIT=IABS(KSYBIT)      @ ENABLE OVERPRINT
      DO 750 I=IPCLO,IPCHI
  750 IPBUF(I-IPCMIN+3)=0
      RETURN
      END
```

<u>MR-CLEAN PROGRAM</u>

```
C***PROGRAM MR-CLEAN***
C
C***THIS PROGRAM WAS WRITTEN TO HOMOGENIZE LANDSAT CLASSIFICATION
C   RESULTS BY RECLASSIFYING A PIXEL TO REFLECT THAT OF ITS NEIGHBORS
C
C***READ IN CLASSES TO BE LEFT ALONE
      DIMENSION LINE(3300,3),ISCAN(3300),ISYM(30)
      DATA KNT/1/,IN,IOUT/10,11/
    5 READ(5,100,END=15,ERR=10) ISYM(KNT)
  100 FORMAT(A1)
      KNT=KNT+1
      GO TO 5
   10 WRITE(6,105)
  105 FORMAT(1H0,' ERROR READING SYMBOLS')
      STOP
C***READ FIRST THREE SCAN LINES
   15 KNT=KNT-1
      WRITE(31,333)
      WRITE(32,333)
      WRITE(33,333)
      WRITE(34,333)
      WRITE(35,333)
  333 FORMAT(1H1,T46,'TEXAS NATURAL RESOURSES INFORMATION SYSTEM',
     *//////)
      CALL MA6600('31          ')
      CALL MA6600('32          ')
      CALL MA6600('33          ')
      CALL MA6600('34          ')
      CALL MA6600('35          ')
      WRITE(6,106)
  106 FORMAT(1H1)
      READ(IN,END=98,ERR=99) NPIX,(LINE(I,1),I=1,NPIX)
      READ(IN,END=98,ERR=99) NPIX,(LINE(I,2),I=1,NPIX)
      READ(IN,END=98,ERR=99) NPIX,(LINE(I,3),I=1,NPIX)
C***DON'T PROCESS FIRST SCAN LINE OR FIRST OR LAST PIXELS
      WRITE(IOUT) NPIX,(LINE(J,1),J=1,NPIX)
      CALL MAP(LINE(1,1),NPIX)
   16 ISCAN(1)=LINE(1,2)
      ISCAN(NPIX)=LINE(NPIX,2)
      LAST=NPIX-1
C***PROCESS MIDDLE SCAN LINE, PIXEL BY PIXEL
      DO 90 I=2,LAST
      ISCAN(I)=LINE(I,2)
      IF (KNT.EQ.0) GO TO 25
      DO 20 J=1,KNT
      IF (LINE(I,2)-ISYM(J)) 20,90,20
   20 CONTINUE
   25 N1=0
      N2=0
      N3=0
      N4=0
```

MR-CLEAN PROGRAM (Con't)

```
C***COUNT NUMBER OF LIKE PIXELS FOR EACH NEIGHBOR
      DO 30 K=1,3
      DO 30 L=1,3
      IF (LINE(I+L-2,K).EQ.LINE(I-1,1)) N1=N1+1
      IF (LINE(I+L-2,K).EQ.LINE(I,1)) N2=N2+1
      IF (LINE(I+L-2,K).EQ.LINE(I+1,1)) N3=N3+1
   30 IF (LINE(I+L-2,K).EQ.LINE(I-1,2)) N4=N4+1
C***DOES ANY NEIGHBORING CLASS CONTAIN 5 PIXELS OR MORE?
      GO TO (40,40,40,40,45,45,45,45,45),N1
   40 GO TO (50,50,50,50,55,55,55,55,55),N2
   50 GO TO (60,60,60,60,65,65,65,65,65),N3
   60 GO TO (90,90,90,90,75,75,75,75,75),N4
C***CHANGE PIXEL CLASS
   45 ISCAN(I)=LINE(I-1,1)
      GO TO 90
   55 ISCAN(I)=LINE(I,1)
      GO TO 90
   65 ISCAN(I)=LINE(I+1,1)
      GO TO 90
   75 ISCAN(I)=LINE(I-1,2)
   90 CONTINUE
C***WRITE THE ALTERED SCAN LINE
      WRITE(IOUT) NPIX,(ISCAN(I),I=1,NPIX)
      CALL MAP(ISCAN(1),NPIX)
C***SHIFT SCAN LINES UP THE ARRAY
      DO 95 I=1,2
      DO 95 J=1,NPIX
   95 LINE(J,I)=LINE(J,I+1)
C***READ NEW SCAN LINE AND LOOP
      READ(IN,END=98,ERR=99) NPIX,(LINE(I,3),I=1,NPIX)
      GO TO 16
C***EOF, WRITE LAST SCAN LINE
   98 WRITE(IOUT) NPIX,(LINE(I,2),I=1,NPIX)
      CALL MAP(LINE(1,2),NPIX)
      ENDFILE IOUT
      WRITE(6,110)
  110 FORMAT(1H0,' END OF MR CLEAN')
  111 CALL MA6663('31          ')
      CALL MA6663('32          ')
      CALL MA6663('33          ')
      CALL MA6663('34          ')
      CALL MA6663('35          ')
      STOP
C***ERROR ON READ
   99 WRITE(6,115)
  115 FORMAT(1H0,' ERROR READING INPUT FILE')
      GO TO 111
      END
```

DETECT PROGRAM

```
C***PROGRAM DETECT
C
C***THIS PROGRAM COMPARES TWO REGISTERED CLASSIFICATION MAPS
C   OF THE SAME AREA AND NOTES CHANGE BETWEEN THE TWO.
C
C***INPUT FILES = UNIT 10 AND UNIT 11
C   UNFORMATTED FILES IN THE FORM: N,SYM1,SYM2,...,SYMN
C   WHERE N IS THE NUMBER OF SYMBOLS PER LINE AND IS
C   FOLLOWED BY THE N PRINT SYMBOLS TO BE USED
C***PARAMETER CARD(FREE FORMAT): LINE,SAMPLE,UNIT
C   WHERE LINE,SAMPLE ALLOW FOR OFFSETTING THE FILES
C   I.E., PIXEL M,N ON UNIT 10 IS MATCHED WITH PIXEL 1,1
C   ON UNIT 11 TO ADJUST FOR SLIGHT MISREGISTRATION
C   (MAXIMUM OF 5 LINES ALLOWED).
C   SPECIAL SYMBOLS (: * +) ARE EXCLUDED FROM TESTING SINCE
C   THESE ARE USED IN THE REGISTERED MAPS FOR TICK MARKS, ETC.
C   IF NO CHANGE OCCURS, THE OUTPUT PIXEL IS BLANKED OUT.
C   IF CHANGE OCCURS, THE SYMBOL ON UNIT 11 IS PRINTED UNLESS
C   'UNIT' ON THE PARAMETER CARD IS 10.  IN THIS CASE,
C   THE SYMBOL FROM UNIT 10 IS PRINTED.
C
      DIMENSION L10(1000),L11(1000),IPRNT(1000)
      DATA LINE,ISAMP/2*0/,IPRNT/1000*6H      /
      INTEGER COLON/':'/,ASTER/'*'/,PLUS/'+'/
C***WRITE THE HEADER ON THE ALTERNATE PRINT FILES
      WRITE(31,333)
      WRITE(32,333)
      WRITE(33,333)
      WRITE(34,333)
      WRITE(35,333)
  333 FORMAT(1H1,T46,'TEXAS NATURAL RESOURSES INFORMATION SYSTEM',
     *//////)
C***ELIMINATE MARGINS ON THE ALTERNATE PRINT FILES
      CALL MA6600('31           ')
      CALL MA6600('32           ')
      CALL MA6600('33           ')
      CALL MA6600('34           ')
      CALL MA6600('35           ')
      WRITE(6,666)
  666 FORMAT(1H1)
C***READ OFFSET DATA
      READ(5,100,END=20,ERR=90) LINE,ISAMP,IUNIT
  100 FORMAT()
      ISAM=ISAMP-1
      IF (LINE.EQ.0) GO TO 20
      IF (LINE-5) 10,10,5
    5 WRITE(6,66)
   66 FORMAT(' MAXIMUM OFFSET OF 5 LINES HAS BEEN EXCEEDED')
      GO TO 99
C***FIND STARTING LINE ON UNIT 10
   10 DO 15 I=1,LINE
   15 READ(10,END=86,ERR=90) N10,(L10(J),J=1,N10)
```

```
      GO TO 25
C***READ FILES AND LOOK FOR CHANGE
   20 READ(10,END=86,ERR=90) N10,(L10(I),I=1,N10)
   25 READ(11,END=87,ERR=95) N11,(L11(I),I=1,N11)
      NPIX=MIN0(N10,N11-ISAMP)
      DO 80 I=1,NPIX
C***EXCLUDE SPECIAL SYMBOLS FROM TESTING
      IF (L10(I)-COLON) 30,72,30
   30 IF (L10(I)-ASTER) 35,74,35
   35 IF (L10(I)-PLUS) 40,76,40
   40 IF (L11(I+ISAM)-COLON) 45,72,45
   45 IF (L11(I+ISAM)-ASTER) 50,74,50
   50 IF (L11(I+ISAM)-PLUS) 55,76,55
C***TEST FOR CHANGE AND SET PRINT SYMBOL
   55 IF (L10(I)-L11(I+ISAM)) 60,80,60
   60 IPRNT(I)=L11(I+ISAM)
      IF (IUNIT.EQ.11) IPRNT(I)=L10(I)
      GO TO 80
   72 IPRNT(I)=COLON
      GO TO 80
   74 IPRNT(I)=ASTER
      GO TO 80
   76 IPRNT(I)=PLUS
   80 CONTINUE
C***WRITE OUT CHANGE DETECTION LINE AND LOOP
      CALL MAP(IPRNT(1),NPIX)
      DO 85 I=1,1000
   85 IPRNT(I)=6H
      GO TO 20
C***EOF AND ERROR MESSAGES
   86 WRITE(6,300)
  300 FORMAT(///,' END OF FILE 10')
      GO TO 99
   87 WRITE(6,400)
  400 FORMAT(///,' END OF FILE 11')
      GO TO 99
   90 WRITE(6,500)
  500 FORMAT(///,' ERROR READING FILE 10')
C***RESET MARGINS ON ALTERNATE PRINT FILES
      GO TO 99
   95 WRITE(6,600)
  600 FORMAT(///,' ERROR READING FILE 11')
   99 CALL MA6663('31          ')
      CALL MA6663('32          ')
      CALL MA6663('33          ')
      CALL MA6663('34          ')
      CALL MA6663('35          ')
      STOP
      END
```

EXTRACT PROGRAM

```
C***PROGRAM EXTRACT
C
C   THIS PROGRAM EXTRACTS BOUNDARIES FROM LANDSAT CLASSIFICATION FILES
C   UNIT 8 = REGISTERED MAP USED AS INPUT
C   UNIT 15 = OUTPUT IGF BOUNDARY MAP
C***
      DIMENSION LINE1(4000),LINE2(4000),LPRT1(4000),LPRT2(4000)
      DATA IN,IOUT/8,15/,ID,NPTS,XINC/1,1,0.1/,ISAVE/0/
      YINC=-1./6.
      CALL SETADR(IOUT,1)
      WRITE(31,333)
      WRITE(32,333)
      WRITE(33,333)
      WRITE(34,333)
      WRITE(35,333)
  333 FORMAT(1H1,T46,'TEXAS NATURAL RESOURCES INFORMATION SYSTEM',
     */////)
      CALL MA6600('31         ')
      CALL MA6600('32         ')
      CALL MA6600('33         ')
      CALL MA6600('34         ')
      CALL MA6600('35         ')
C***READ IN CONTROL POINTS
    5 READ(5,500,END=6,ERR=85) NROW,NCOL
  500 FORMAT ()
      X1=(NCOL-1)*XINC + XINC/2.
      Y1=(NROW-1)*YINC + YINC/2.
      WRITE(IOUT) ID,NPTS,X1,Y1
      ID=ID+1
      GO TO 5
    6 NPTS=2
C***INITIALIZE ARRAYS
      DO 10 I=1,4000
      LPRT2(I)=6H
   10 LINE2(I)=6H
C***READ FIRST CLASSIFIED LINE INTO CORE
      READ(IN,END=99,ERR=86) NPIX,(LINE2(I),I=1,NPIX)
      NROW=1
      IEND=NPIX-1
C***LOCATE BOUNDARY POINTS IN THE FIRST LINE
      DO 20 I=1,IEND
      IF (LINE2(I)-LINE2(I+1)) 14,20,14
C***EXTRACT BOUNDARIES
   14 X1=I*XINC
      Y1=(NROW-1)*YINC
      X2=I*XINC
      Y2=NROW*YINC
      LPRT2(I)=LINE2(I)
      LPRT2(I+1)=LINE2(I+1)
      WRITE(IOUT) ID,NPTS,X1,Y1,X2,Y2
```

EXTRACT PROGRAM (Con't)

```
         ID=ID+1
   20 CONTINUE
C***SHIFT DATA, THEN PROCESS NEXT LINE
   30 DO 40 I=1,4000
         LPRT1(I)=LPRT2(I)
         LPRT2(I)=6H
         LINE1(I)=LINE2(I)
   40 LINE2(I)=6H
         READ(IN,END=99,ERR=86) NPIX,(LINE2(I),I=1,NPIX)
         NROW=NROW+1
C***LOCATE BOUNDARY POINTS
         DO 50 I=1,NPIX
         IF (I.EQ.NPIX) GO TO 46
         IF (LINE2(I)-LINE2(I+1)) 44,46,44
C***EXTRACT BOUNDARIES
   44 P1=I*XINC
         Q1=(NROW-1)*YINC
         P2=I*XINC
         Q2=NROW*YINC
         LPRT2(I)=LINE2(I)
         LPRT2(I+1)=LINE2(I+1)
         WRITE(IOUT) ID,NPTS,P1,Q1,P2,Q2
         ID=ID+1
C***CHECK FOR BOUNDARY POINTS WITH PREVIOUS LINE
   46 IF (LINE2(I)-LINE1(I)) 48,50,48
   48 LPRT1(I)=LINE1(I)
         LPRT2(I)=LINE2(I)
         IF (ISAVE.EQ.0) GO TO 150
C***SAVE NEW BOUNDARY LINE
         XX1=(I-1)*XINC
         YY1=(NROW-1)*YINC
         XX2=I*XINC
         YY2=(NROW-1)*YINC
C***IF THE END POINTS DON'T MATCH WRITE THE CHAIN
         IF (X2.EQ.XX1.AND.Y2.EQ.YY2) GO TO 145
         WRITE(IOUT) ID,NPTS,X1,Y1,X2,Y2
         ID=ID+1
         X1=XX1
         Y1=YY1
         X2=XX2
         Y2=YY2
         GO TO 50
C***TIE ADJACENT BOUNDARY CHAINS TOGETHER
  145 X2=XX2
         Y2=YY2
         GO TO 50
C***BEGIN A NEW CHAIN
  150 X1=(I-1)*XINC
         Y1=(NROW-1)*YINC
         X2=I*XINC
```

EXTRACT PROGRAM (Con't)

```
      Y2=(NROW-1)*YINC
      ISAVE=1
   50 CONTINUE
C***OUTPUT BOUNDARY ON LINE PRINTER, THEN GET NEXT LINE
      CALL MAP(LPRT1(1),NPIX)
      IF (ISAVE.EQ.0) GO TO 30
      WRITE(IOUT) ID,NPTS,X1,Y1,X2,Y2
      ID=ID+1
      ISAVE=0
      GO TO 30
C***ERROR READING CONTROL POINTS
   85 WRITE(6,101)
  101 FORMAT(' ERROR READING CONTROL POINTS')
      STOP
C***ERROR READING FILE
   86 WRITE(6,100)
  100 FORMAT(' ERROR READING CLASSIFICATION FILE')
      STOP
C***END OF FILE
   99 ENDFILE IOUT
      CALL MAP(LPRT1(1),NPIX)
      WRITE(6,199) ID
  199 FORMAT(///,I10,' CHAINS EXTRACTED')
      WRITE(6,200)
  200 FORMAT(/,' BOUNDARY EXTRACTION COMPLETED')
      CALL MA6663('31          ')
      CALL MA6663('32          ')
      CALL MA6663('33          ')
      CALL MA6663('34          ')
      CALL MA6663('35          ')
      STOP
      END
```

MERGE PROGRAM

```
C***THIS PROGRAM WILL MERGE SECTIONS OF TWO LANDSAT DATA TAPES
C***FILE ASSIGNMENTS
C***    UNIT 10--FIRST INPUT TAPE
C***    UNIT 11--SCRATCH FILE
C***    UNIT 13--OUTPUT TAPE
C***CARD INPUT:
C***   CARD 1:STARTING LINE, ENDING LINE, BEGINING SAMPLE
C***           NOTE:THE PROGRAM WILL ADJUST THE STARTING SAMPLE
C***           SO THAT IT WILL FALL ON A WORD BOUNDARY
C***   CARD 2:ID FOR SECOND TAPE
C***          NOTE:IF BOTH FILES ARE ON THE SAME TAPE,
C***          PUNCH 'SAME' IN COL 1-4
C***
      DIMENSION IBUF(733),JBUF(733)/733*0/,
     *CARD(5)/'@ASG,BOTH 10.,16N,        .     '/
C***COPY HEADER RECORD FROM FIRST TAPE
      CALL NTRAN(10,10,2,9,IBUF,ISTAT,22)
      CALL NTRAN(13,10,1,9,IBUF,ISTAT,22)
      CALL NTRAN(10,2,139,IBUF,ISTAT,22)
      CALL NTRAN(13,1,139,IBUF,ISTAT,22)
C***READ CONTROL CARD AND ESTABLISH LINE AND SAMPLE LIMITS
      READ(5,100) LINE1,LINE2,NSAM
100   FORMAT()
      MOVE=LINE1+1
      CALL NTRAN(10,10,7,MOVE,22)
      LAST=LINE2-LINE1+1
      ISTART=NSAM-MOD(NSAM-1,18)
      WRITE(6,200) ISTART
200   FORMAT(' THE FIRST SAMPLE NUMBER FROM TAPE 1 IS ',I4)
      ISTART=ISTART-(ISTART/18)*2
      NPIX=720-ISTART+1
C***COPY SECTION OF FIRST TAPE
      DO 20 I=1,LAST
      CALL NTRAN(10,2,733,IBUF,ISTAT,22)
      K=0
      DO 10 J=ISTART,720
      K=K+1
10    JBUF(K)=IBUF(J)
20    CALL NTRAN(11,1,NPIX,JBUF,ISTAT,22)
C***CHANGE TAPES
      CALL NTRAN(11,10,22)
      READ(5,300) TAPE
300   FORMAT(A6)
      IF (TAPE.NE.6HSAME  ) GO TO 25
      CALL NTRAN(10,10,22)
      CALL NTRAN(10,8,1,22)
      GO TO 26
25    CALL EQUIP('@FREE,S 10. . ')
```

MERGE PROGRAM (Con't)

```
      CARD(4)=TAPE
      CALL EQUIP(CARD)
26    CALL NTRAN(10,7,MOVE,22)
C***COPY SECTION OF SECOND TAPE
      DO 40 I=1,LAST
      CALL NTRAN(11,2,NPIX,JBUF,ISTAT,22)
      CALL NTRAN(10,2,733,IBUF,ISTAT,22)
      K=NPIX
      JJ=ISTART-1
      DO 30 J=1,JJ
      K=K+1
30    JBUF(K)=IBUF(J)
40    CALL NTRAN(13,1,733,JBUF,ISTAT,22)
      CALL NTRAN(13,9,22)
      STOP
      END
```

APPENDIX E

GLOSSARY

APPENDIX E

GLOSSARY

** Band - A group of wavelengths of light producing one color or convenient group of wavelengths, such as near-infrared.

* Change Detection - Change detection is the process by which two images may be compared, resolution cell by resolution cell, and an output generated whenever corresponding resolution cells have different enough gray shades or gray shade n-tuples.

** Channel - The same as "band" when used in computer work.

** Clustering - Mathematical procedure for organizing multispectral data into spectrally homogeneous groups. Clusters require identification and interpretation in a post-processing analysis. ISOCLS is a spectral clustering program.

**Color Composite - Color composite of three channels of ERTS-1 multispectral scanner digital data. The composites are third-or fourth-generation images, compared to first-generation composites produced from computer-compatible tapes using film recorder.

**Computer-Compatible Tapes - Tapes containing digital ERTS-1 data. These tapes are standard 19-cm (7-1/2-in.) wide magnetic tapes in 9-track or 7-track format. Four tapes are required for the four-band multispectral digital data corresponding to one ERTS-1 scene.

*Digital Image - A digital image, or digitized image, or digital picture function of an image, is an image in digital format and is obtained by partitioning the area of the image into a finite two-dimensional array of small uniformly shaped mutually exclusive regions, called resolution cells, and assigning a "representative" gray shade to each such spatial region. A digital image may be abstractly thought of as a function whose domain is the finite two-dimensional set of resolution cells and whose range is the set of gray shades.

**ERTS-1 Scene - Collection of the image data of one nominal framing area (185 km^2) of the Earth's surface. The scene includes all data from each spectral band of each sensor.

*Feature Selection - Feature selection is the process by which the features to be used in the pattern recognition problem are determined. Sometimes feature selection is called property selection.

**Gray Scale - A scale of gray tones between white and black with an arbitrary number of segments. The ERTS-1 images have a 15-step gray scale exposed on every frame of imagery. The scale gives the relationship between gray level on the image and the electron beam density used to expose the original image.

*Image - An image is a spatial representation of an object, scene, or another image. It can be real or virtual as in optics. In pattern recognition, image usually means a recorded image such as a photograph, map, or picture. It may be abstractly thought of as a continuous function I of two variables defined on some bounded region of a plane. When the image is a photograph, the range of the function I is the set of gray shades usually considered to be normalized to the interval 0,1 . The gray shade is located at spatial coordinate (x,y). A recorded image may be in photographic, video signal, or digital format.

*Image Enhancement - Image enhancement is any of a group of operations which improve the detectability of the targets or categories. These operations include, but are not limited to, contrast improvement, edge enhancement, preprocessing, quantization, spatial filtering, noise suppression, image smoothing, and image sharpening.

**ISOCLS - Iterative Self-Organizing Clustering System, a computer program developed at JSC using a clustering algorithm to group homogeneous spectral data. Controlling inputs allow investigators to control the size and number of clusters. Because the system produces a classification-type clustering map in which clusters require post-processing identification and interpretation, the system is frequently called a nonsupervised classification system.

**LARSYS - The set of classification programs for aircraft data handling and analysis developed at the Laboratory for the Applications of Remote Sensing, Purdue University.

**Maximum Likelihood Ratio - Maximum likelihood ratio in remote sensing is a probability decision rule for classifying a target from multispectral data. Two types of errors are feasible: failure to classify the target correctly and misclassification of background as the target. In its simplest form, the likelihood ratio is P_t/P_b. This expression compares the probability (P) of an unknown spectral measurement being classified as target (t) to the probability of an unknown spectral measurement being classified as background (b). When $P_t/P_b \geq 1$, the formula decides t; and when $P_t/P_b < 1$, it decides b. Probability density functions are computed from spectral samples, often called training samples. As the number of training samples increases, the mathematical computations of the maximum likelihood ratio increase in complexity. As a result, digital computer analysis is required. The analysis is called automatic data processing of multispectral remotely sensed data or automatic spectral pattern recognition of multispectral remotely sensed data.

**MSS - Multispectral scanner system, sometimes called the multispectral scanner. The MSS usually refers to the ERTS-1 operational scanning system.

**Nonsupervised Classification - A procedure grouping spectral data into homogeneous clusters. Identification and interpretation are done in a postprocessing analysis.

*Pattern Recognition - Pattern recognition is concerned with, but not limited to, problems of: (1) pattern discrimination, (2) pattern classification, (3) feature selection, (4) pattern identification, (5) cluster identification, (6) feature extraction, (7) preprocessing, (8) filtering, (9) enhancement, (10) pattern segmentation, or (11) screening.

**Pixel - Picture resolution element, or one instantaneous field of view recorded by the multispectral scanning system. An ERTS-1 pixel is about 0.44 hectare (1.09 acres). One ERTS-1 frame contains about 7.36×10^6 pixels, each described by four radiance values.

*Preprocessing - Preprocessing is an operation applied before pattern identification is performed. Preprocessing produces, for the categories of interest, pattern features which tend to be invariant under changes such as translation, rotation, scale, illumination levels, and noise. In essence, preprocessing converts the measurements patterns to a form which allows a simplification in the decision rule. Preprocessing can bring into registration, bring into congruence, remove noise, enhance images, segment target patterns, detect, center, and normalize targets of interest.

**Radiance - Measure of the radiant energy emitted by a radiator in a given direction.

**Reflectance - Ratio of the radiance of the energy reflected from a body to that incident upon it. Reflectance is usually measured in percent.

*Registering - Registering is the translation-rotation alignment process by which two images of like geometries and of the same set of objects are positioned coincident with respect to one another so that corresponding elements of the same ground area appear in the same place on the registered images. In this manner, the corresponding gray shades of the two images at any (x,y) coordinate or resolution cell will represent the sensor output for the same object over the full image frame being registered.

*Resolution - Resolution is a generic term which describes how well a system, process, component or material, or image can reproduce an isolated object or separate closely spaced objects or lines. The limiting resolution, resolution limit, or spatial resolution is described in terms of the smallest dimension of the target or object that can just be discriminated or observed. Resolution may be functions of object contrast or spatial position as well as element shape (single point, number of points in a cluster, continuum, or line, etc.).

**Signature - A set of spectral, tonal, or spatial characteristics of a classification serving to identify a feature by remote sensing.

**Spectral Response - Spectral radiance of an object sensed at the satellite and recorded by the multispectral scanner.

**Supervised Classification - Classification procedure in which data of known classes are used to establish the decision logic from which unknown data are assigned to the classes. The automatic data processing supervised classification procedure used at JSC during the ERTS-1 project used a Gaussian maximum likelihood decision rule.

**Training Field - The spatial sample of digital data of a known ground feature selected by the investigator. From the sample the spectral characteristics are computed for supervised multispectral classification of remotely sensed data. The statistics associated with training fields form the input to the maximum likelihood ratio computations and train the computer to discriminate between samples.

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*Extracted from Interpretation Systems Inc., 1976.

**NASA Tech Memorandum, 1974.

APPENDIX F

DEVELOPMENT AND TESTING OF EXPERIMENTAL COMPUTER-ASSISTED ANALYTICAL TECHNIQUES

DEVELOPMENT AND TESTING OF EXPERIMENTAL COMPUTER-ASSISTED ANALYTICAL TECHNIQUES

Introduction

The development and testing of computer-assisted techniques for analysis of Landsat digital data was an evolutionary process throughout the course of the investigation. The basic software for accomplishing classifications of spectral data was obtained from NASA's Johnson Space Center and adapted to the UNIVAC 1100/41 System used by the Texas Natural Resources Information System (TNRIS) staff. Additional software was developed by the TNRIS staff during the project to enhance the basic capability. Three of the four designated test areas, test sites 2, 3, and 5, were used to experiment with the various software routines and to develop a set of procedures for application of the software and related techniques to classification of land cover and land use within the test area. Test site 4 was reserved for a test and evaluation of the developed procedures and software.

The following paragraphs will provide some of the details regarding the analysis effort on each test site, primarily to document the difficulties encountered during the development effort and to record the parameters used for the analysis. The test sites are discussed in the same order in which they were addressed during the investigation. Two Landsat scenes were used on test site 3 and one each on sites 2 and 5. The control networks established for many of the Landsat scenes are contained in appendix D for future reference if these same scenes need to be analyzed. The test site 4 analysis results are described in the main body of the report.

Test Site 3

Early computer-assisted classification efforts were aimed primarily at establishing unsupervised analysis procedures and evaluating available software for classifying Landsat Multispectral Scanner (MSS) data.

Test site 3, consisting of the Austwell, Welder Flats, and adjoining Pass Cavallo/Port O'Connor USGS 7 1/2-minute Quadrangles, was the first test site classified. Two Landsat scenes containing test site 3 were evaluated:

Scene	Date
1614-16261	29 MAR 74
2034-16200	25 FEB 74

The first of two areas examined in site 3 (Scene 1614-16261) was the Austwell quadrangle area.

ISOCLS clustering was performed on the entire Austwell quad area by sampling every third line and every other column of MSS data. Resulting statistics were used by the CLASSIFY and DISPLAY processors to produce a five-class computer map of the Austwell area. When visually compared to the Environmental Geologic Atlas of the Texas Coastal Zone - Port Lavaca Area (McGowen et al., in print), the five classes correspond to pasture lands, agricultural land, one class of marsh, and two classes of water. Further clustering in the marsh area separated the marsh into two distinct types. Unclassified areas were also reexamined and yielded three more classes: an industrial area and two industrial holding tanks. The final classification resulted in nine classes which compared favorably with the broad categories on the BEG Biological Assemblages and Land Use Maps.

Using procedures similar to those previously described, a classification map was produced for the Pass Cavallo/Port O'Conner quad areas. A procedural change in the clustering process was tried in producing this classification. Using ISOCLS to cluster entire quad-sheet-size areas consumes large amounts of computer time. A less expensive method was adopted: a grayscale map was examined, along with available photography, to select numerous small areas throughout the scene in order to cover the observed spectral variation. Training class statistics were derived from clustering every other line and column of data within these small areas. Classification of the Pass Cavallo/Port O'Conner area yielded thirteen classes. When compared to photography and the maps of the Port Lavaca area, four to six classes corresponded to water of various depths and turbidity. The remaining classes delineated the barren land (beaches, dunes, and spoil areas) and separated the low vegetated wetland areas from the higher and drier vegetated areas.

The second computer-assisted classification of test site 3 was made using Landsat scene 2034-16201 MSS data.

Clustering was performed on all test site 3 areas with line and column sampling intervals identical to the previous analysis. New ISOCLS parameter values were introduced to correct shortcomings found in the previous classification results.

ISOCLS parameter values for both the first and second evaluation of site 3 are noted in the table below.

TEST SITE # ISOCLS PARAMETER VALUES

Scene 1614-16261		Scene 2034-16200	
Channels	2,3,4	Channels	1,2,3,4
ISTOP	20	ISTOP	10
NMIN	100	NMIN	20
DLMIN	3.2	DLMIN	2.0
STDMAX	4.5	STDMAX	3.0
MAXCLS	30	MAXCLS	30
KRN	2	KRN	2

The classification results contained 17 classes for the Austwell area and 26 classes for both the Welder Flats and Pass Cavallo/ Port O'Conner areas.

It should be noted that ELLTAB, a fast new "look-up" type of classifier, was introduced at this time. The new classifier produced results identical to the LARSYS Classifier and was 17 times faster. SCALE/ REGISTER was also substituted for the LARSYS DISPLAY processor to produce a more usable map-like product (scaled and registered to the USGS quad maps).

Correlation between the computer-assisted analysis results and BEG photo-interpretation results helped determine which classes were common to both techniques. Common classes again included water of various degrees of turbidity, high and low marsh environments, and barren areas such as beaches, dunes, and spoil areas. The computer-assisted procedures and techniques proved adequate for producing favorable classification results. A formalized set of steps for computer-assisted analysis was established as a result of the work on test site 3. This was changed several times during the investigation. The final set of procedures used for the site 4 analysis are contained in the main body of the report.

Test Site 2

The computer-assisted analysis of test site 2 (scene 1289-16261/8 May 1973) followed the procedures established at the end of test site 3. Considerable experimentation was done regarding the classification parameters in an attempt to attain smaller standard deviations. The results of this work established the parameters which were used during the remainder of the project. Because of the size and shape of the test area (seven quadrangle sheets arranged stepwise along the coast), each of the steps required four runs to complete all seven maps. The quad sheets included in test site 2 were: Jones Creek, Freeport, Oyster Creek, Christmas Point, Hoskins Mound, Sea Isle, and San Luis Pass.

The Landsat scene contained an exceptionally wide range of spectral levels, including particularly high reflectance areas (urban/industrial), compared to those scenes previously studied. To allow for this wider range of reflectances and improve upon the initial classification obtained using previously established parameters, the sample size for acquiring the ISOCLS statistics was increased in some areas. Between 40 and 50 clusters were generated which had to be reduced to 40 subclasses for use of the ELLTAB programs. Because of Table limits, the 40 subclasses had to be displayed in two sets and consolidated manually by overlaying the two printouts for comparison with ground truth and subsequent refinement.

The classification results compared favorably with similar results from the image-interpretation approach.

Test Site 5

The environmental make-up of test site 5 (scene 2034-16205) was somewhat more complex than sites 2 or 3. The presence of (1) subaqueous grass flats, (2) algal mats, (3) undifferentiated barren areas, (4) croplands, and (5) urban areas, contributed to the site's complexity.

Test site 5 consisted of an area represented by five 7 1/2-minute USGS Quadrangles: Hawk Island, Laguna Atascosa, La Leona, La Coma, and Three Islands. By grouping adjoining quadrangle areas, the analysis was handled as three separate runs. Classification and display procedures were similar to those used in the site 3 analysis with the exception of an additional program: HGROUP was introduced to the classification scheme.

The establishment of a DAM control network for test site 5 required slightly more time than previous test sites. This was due to a lack of adequate control points in key locations and approximately 40 percent of the scene contained coverage over Mexico.

ISOCLS clustering was performed on two selected areas in site 5 with sampling intervals consisting of every other line and column of data. Previously established parameter values were used with the exception of MAXCLS. The maximum number of clusters to be generated was changed from 30 to 50 in order to deal with the somewhat larger and more complex test site.

The computer-assisted classification and display results compared favorably with the broad categories of the BEG land use and land cover classification scheme. Similar categories were: (1) water, (2) urban/built-up land, (3) grasslands, (4) wetlands, and (5) barren areas.

Classified results contained 25 classes of which 17 were displayed. HGROUP was utilized for determining the 17 classes.

After the site 5 analysis, a convenient method for combining spectrally similar classes was introduced (HGROUP) and the computer-assisted classification procedures were further modified for better efficiency.

APPENDIX G

CONTROL NETWORK DATA SUMMARY

APPENDIX G

CONTROL NETWORK DATA SUMMARY

Test Site 5 Control Network

Scene Id 2034-16205

Attitude

Pitch = +.18
Roll = -.35

Control/Check Points (DAM-405)

CCT	POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
3	1	665	746	26.2424	97.4070
3	2	703	765	26.2135	97.4043
3	3	705	788	26.2108	97.3920
3	4	718	792	26.2009	97.3915
3	5	768	718	26.1730	97.4433
3	6	786	711	26.1605	97.4507
4	7	517	20	26.3371	97.3305
4	8	583	86	26.2860	97.3042
4	9	610	45	26.2701	97.3335
4	10	608	94	26.2675	97.3050
4	CHK-11	619	88	26.2590	97.3113
4	12	695	135	26.2037	97.2977

RMS = 60 meters

Test Site 2 Control Network

Scene Id 1289-16261

Attitude

Pitch = +0.00
Roll = -0.72

Control Check Points (DAM-405)

CCT	POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
1	CHK-2	492	92	29.52410	96.66320
1	CHK-4	797	392	29.28210	96.54950
1	CHK-5	544	637	29.43840	96.35930
1	8	1841	188	28.56630	96.86740
2	26	1612	218	28.65200	96.34080
3	CHK-9	868	652	29.05820	95.47530
3	CHK-13	1501	19	28.67300	95.96600
3	17	267	423	29.50280	95.48730
3	18	390	454	29.41330	95.49350
4	19	1069	70	28.89600	95.38400
4	21	987	176	28.94320	95.30730
4	CHK-22	470	450	29.28000	95.04690
4	23	563	417	29.21800	95.08370
4	25	594	199	29.21700	95.21440
4	CHK-29	782	154	29.08910	95.27960
4	CHK-35	937	207	28.97510	95.27990
4	CHK-37	1066	52	28.89900	95.39520

RMS = 57 meters

Scene 1, Test Site 4

Scene Id 2034-16202

Attitude

Pitch = +.05
Roll = -.43

Control/Check Points (DAM-405)

CCT	POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
1	1	57	408	28.2707	98.0213
3	2	369	435	27.9064	97.1350
2	3	539	625	27.8433	97.5250
2	4	536	585	27.8492	97.5477
2	5	1050	771	27.4733	97.5390
1	6	1598	787	27.1579	98.0950
3	7	1936	156	26.8336	97.5913

RMS = 60 meters

Scene 2, Test Site 4

Scene Id 2376-16172

Attitude

Pitch = -.06
Roll = -.41

Control/Check Points (DAM-7605)

POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
1	68	920	28.0860	97.8903
2	150	2250	27.9064	97.1360
3	318	1593	27.8493	97.5477

Scene 2, Test Site 4 (continued)

POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
4	506	770	27.7917	98.0594
5	836	1781	27.4713	97.5396
6	1387	997	27.1600	98.0973
7	2194	1616	26.5427	97.8931

RMS = 111 meters

Scene 3, Test Site 4

Scene Id 5082-16080

Attitude

Pitch = +.28

Roll = -.46

Control/Check Points (DAM-7605)

POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
1	726	1618	27.8493	97.5477
2	728	1660	27.8432	94.5251
3	1235	1803	27.1600	97.5390
4	1788	1005	26.8249	98.0973
5	2129	1989	28.2630	97.6060
6	268	651	28.0825	98.0136
7	486	941	28.0825	97.8903
8	155	2440	28.1698	96.9684
9	143	2495	28.1725	96.9337

RMS = 95 meters

Scene 4, Test Site 4

Scene Id 1146-16320

Attitude

Pitch = +.26
Roll = -.57

Control/Check Points (DAM-405)

CCT	POINT	LINE	SAMPLE	LATITUDE	LONGITUDE
1	1	129	752	28.0873	97.8903
3	2	224	474	27.8989	97.1361
2	3	383	624	27.8493	97.5477
2	4	1125	697	27.3267	97.6545
2	5	1449	36	27.1600	98.0973
3	7	2136	647	26.5572	97.4254
2	8	2284	629	26.5275	97.9236

RMS = 82 meters

APPENDIX H

ANNOTATED BIBLIOGRAPHY ON THE APPLICATION OF AERIAL PHOTOGRAPHY AND LANDSAT IMAGERY TO THE STUDY OF COASTAL REGIONS

APPENDIX H

ANNOTATED BIBLIOGRAPHY ON THE APPLICATION OF AERIAL PHOTOGRAPHY AND LANDSAT IMAGERY TO THE STUDY OF COASTAL REGIONS

Two references which appear repeatedly are:

1. Symposium, Significant Results obtained from ERTS-1, referring to:

   Freden, S.C., Mercanti, E.P., and Becker, M.A., eds., 1973a, Symposium on significant results obtained from the Earth Resources Technology Satellite-1, Vol.I, Technical presentations. Sections A and B: Washington, D.C., Goddard Space Flight Center, NASA SP-327, March 5-9, 1973, 1730 p.

2. 3rd ERTS-1 Symposium, referring to:

   Freden, S.C., Mercanti, E.P., and Becker, M.A., eds., 1973b, Third Earth Resources Technology Satellite-1 Symposium, Vol.I, Technical presentations, Sections A and B: Washington, D.C., Goddard Space Flight Center, NASA SP-351, December 10-14, 1973, 1974 p.

Alexander, R.H., 1973, ERTS regional-scale overview linking land use and environmental processes in CARETS: Symposium, Significant Results Obtained from ERTS-1, p. 931-937.

The pattern of tones and textures of ERTS-1 images was found to most closely correspond to land use maps when compared with preexisting maps of various types for the same area.

Anderson, D.M., Gatto, L.W., McKim, H.L., and Petrone, A., 1973, Sediment distribution and coastal processes in Cook Inlet, Alaska: Symposium, Significant Results Obtained from ERTS-1, p. 1323-1339.

Bands 6 and 7 allowed determination of the coastline of Cook Inlet, while bands 4 and 5 showed the suspended sediment and current patterns in the estuary. Circulation was seen to be primarily counterclockwise. Previously unmapped tidal flats and certain cultural features were identified.

Anderson, R.R., Alsid, L., and Carter, V., 1975, Applicability of Skylab orbital photography to coastal wetland mapping: Proc. Am. Soc. Photogrammetry, 41st Ann. Mtg., March 9-14, 1975, p. 371-377.

Skylab S190A color IR photographs were enlarged to a scale of 1:125,000, allowing transparent overlays to be used in mapping wetland features directly from the imagery. The study area was divided into five mappable units: (1) fresh estuarine river marsh, (2) brackish estuarine river marsh, (3) fresh estuarine bay marsh, (4) brackish estuarine bay marsh, and (5) near saline marsh.

Anderson, R.R., Carter, V., and McGinness, J., 1973, Applications of ERTS data to coastal wetland ecology with special reference to plant community mapping and typing and impact of man: 3rd ERTS-1 Symposium, p. 1225-1242.

ERTS-1 imagery is shown to be useful in wetland studies for test areas in North Carolina and Georgia. The authors explain why different data enhancement techniques were used and how each type aided the program.

Anderson, R.R., Carter, V., and McGinness, J., 1973, Mapping Atlantic coastal marshlands, Maryland, Georgia, using ERTS-1 imagery: Symposium, Significant Results Obtained from ERTS-1, p. 603-608.

ERTS-1 data were used as an inexpensive source of information for mapping the extensive coastal marshes of the Eastern United States. This paper is a report on the feasibility of this approach. The study found that the following information could be derived from LANDSAT: (1) upper wetland boundary, (2) drainage pattern in wetland, (3) plant communities, (4) ditching activities associated with agriculture, and (5) lagooning for water-side housing developments.

Anderson, R.R., and Wobber, F.J., 1973, Wetlands mapping in New Jersey: Photogramm. Eng., v. 39, p. 353-358.

Color and color IR aerial photographs were shown to be a practical way to map or inventory wetlands. Determinable features include the mean high-water mark, the upper wetland boundary, and species associations in the area.

Barrell, E.C., and Curtis, L.F., eds., 1974, Coastal vegetation surveys, _in_ Environmental remote sensing: Applications and achievements: Edward Arnold, publisher, p. 127-143.

Ecological zones in the coastal region have distinct vegetation coverage which is discernible on aerial photographs. The vegetation assemblages in six zones are discussed; these are intertidal, mudflat, salt marsh, shingle beach, sand dunes, and cliffs. The examples given are for the English coast.

Bartlett, D., Klemas, V., and Rogers, R., 1975, Investigations of coastal land use and vegetation with ERTS-1 and SKYLAB-EREP: Proc. Am. Soc. Photogrammetry, 41st Ann. Mtg., March 9-14, 1975, p. 378-389.

Machine-assisted analysis of ERTS-1 MSS scanner data was compared to manual interpretation of Skylab-EREP S190B photographs to determine their usefulness in wetlands management. Skylab-EREP S190B was found to be superior in resolution but had the disadvantage of limited coverage. The authors conclude that either type of data is useful for the inventory of land cover types on a regional basis.

Bowker, D.E., and others, 1973, Correlation of ERTS multispectral imagery with suspended matter and chlorophyll in lower Chesapeake Bay: Symposium, Significant Results Obtained from ERTS-1, p. 1291-1297.

ERTS data were shown to be useful in monitoring estuarine waters for the assessment of siltation, productivity, and water type. Major areas of suspensate concentrations have been determined for Chesapeake Bay.

Carter, V., and Schubert, J., 1974, Coastal wetlands analysis from ERTS MSS digital data and field spectral measurements: Ann Arbor, Michigan, Proc. 9th Internat. Symposium, Remote Sensing of Environment, p. 1241-1260.

In utilizing vegetation distribution in the coastal area to map wetlands, signature analysis of vegetation types and physical features found in the zone has been tabulated. Also, seasonal variation and its effects are discussed. The system utilized computer analysis of the digital data.

Clark, D.K., Zaitzeff, J.B., Strees, L.V., and Glidden, W.S., 1974, Computer derived coastal water classifications via spectral signatures: Ann Arbor, Michigan, Proc. 9th Internat. Symposium, Remote Sensing of Environment, p. 1213-1239.

ERTS-1MSS data were shown to be highly effective in the detection, classification, and delineation of water masses. Technical details of the processing of the color and black-and-white photographs are given, along with good definitions of terms. The enhancement and color slicing techniques used in the study are explained.

DeBlieux, C., 1962, Photogeology in Louisiana coastal marsh and swamp: Gulf Coast Assoc. Geol. Soc., Trans., 12th Ann. Mtg., Oct.-Nov. 1962, p. 231-241.

Aerial photographs of the Louisiana coastal zone show several structural features which exhibit surface expressions. This method may be useful in the search for stratigraphic and structural traps for oil and gas.

Denathieu, P.G., and Verger, F.H., 1973, The utilization of ERTS-1 data for the study of the French Atlantic Littoral: 3rd ERTS-1 Symposium, p. 1447-1450.

By utilizing ERTS-1 data, it was possible to accurately determine the direction of transport of sediments from rivers emptying into the Atlantic Ocean along the southwest coast of France. Ocean currents and a turbidity front at a depth of about 50 meters were observed.

Dolan, R., and Vincent, L., 1973. Coastal processes: Photogramm. Eng., v. 39, p. 255-260.

High-altitude aircraft photographs were used in conjunction with ground truth to study the crescentric forms seen on long, sandy coasts. These features indicate where overwash may occur during storms.

Dolan, R., and Vincent, L., 1973, Evaluation of land use mapping from ERTS in the shore zone of CARETS: Symposium, Significant Results Obtained from ERTS-1, p. 939-948.

ERTS-1 data provided a basis for land cover and land use mapping within the shore zone. MSS bands 4, 5, 6, and 7 are compared for their respective utility in delineating various features. Problems in mapping are discussed for: urban and built-up areas, forest areas, water, nonforested wetland, and barren land.

El-ashry, M.R., and Wanless, H.R., 1967, Shoreline features and their changes: Photogramm. Eng., v. 33, p. 184-189.

Sequential aerial photographs are shown to be essential in understanding long-term changes in shoreline geomorphology. Through the use of sequential photographs, net changes and the rate of change can be determined.

Estes, J.E., Thaman, R.R., and Senger, L.W., 1973, Applications of ERTS-1 satellite imagery for land use mapping and resource inventories in the central coastal region of Claifornia: 3rd ERTS-1 Symposium, p. 457-490.

ERTS-1 data were used to construct land use, landform, drainage, and vegetation maps of central California. Kelp distribution offshore was also mapped. The appendix lists the various categories mapped from the ERTS data.

Feinberg, E.B., Yunghans, R.S., Stitt, J., and Mairs, R.L., 1973, Impact of ERTS-1 images on management of New Jersey's coastal zone. 3rd ERTS-1 Symposium, p. 497-503.

The New Jersey Department of Environmental Protection utilized ERTS data to monitor and manage that state's coastal zone. Primary uses of ERTS are to: (1) detect land use changes, (2) monitor offshore waste disposal, (3) pick sites for outfalls of sewage treatment plants, and (4) allocate funds for shore protection.

Fezer, F., 1971, Photo interpretation applied to geomorphology--A review: Photogrammetria, v. 27, n. 1, p. 1-50.

The majority of the previous literature on the utilization of aerial photographs in geomorphology is reviewed. Most examples (and literature subjects) are for regions outside the United States. The paper includes a section on coastal landforms (p. 21-22) and a small section on deltas (p. 20).

Flores, L.M., Reeves, C.A., Hixon, S.B., and Paris, J.F., 1973, Unsupervised classification and areal measurement of land and water coastal features on the Texas Coast: Symposium, Significant Results Obtained from ERTS-1, p. 1675-1681.

By using two classification algorithms with digital ERTS data, it was possible to determine from 17 to 30 different classes representing mixtures of water, land, and vegetation. The two areas studied were the Trinity River delta and the Galveston area.

Fontanel, A., Guillenot, J., and Guy, M., 1973, First ERTS-1 results in Southeastern France: Geology, sedimentology, pollution at sea: Symposium, Significant Results Obtained from ERTS-1, p. 1483-1511.

There are four parts to this paper: (1) Linear Trends Observed in the Western French Alps; (2) Some Results from the Study of the Dynamic Behavior of Coastal Sedimentation in the Gulf of Lions; (3) Study of Pollution at Sea in the Western Mediterranean; and (4) Processing of ERTS Imagery.

Part 2.—p. 1492-1499. ERTS-1 data clearly showed past shorelines of the Rhone River delta and allowed them to be accurately mapped. Many of these shorelines had not been known prior to ERTS data usage. Fault control is also indicated in the area of ERTS data coverage.

Gallagher, J.L., Reimult, R.J., and Thompson, D.E., 1972, a comparison of four remote sensing media for assessing salt marsh primary productivity: Ann Arbor, Michigan, Proc. 8th Internat. Symposium, Remote Sensing of Environment, 2-6 Oct. 1972, p. 1287-1296.

Four types of imagery from fixed wing aircraft were compared: Kodak Aerochrome Infrared, Ektachrome MS Aerographic, Kodak Infrared Aerographic, and imagery from a Bendix thermal mapper. Imagery interpretation was done with and without enhancement, and ground truth was used to evaluate results.

Grimes, B.H., and Hubbard, J.C.E., 1971, A comparison of film type and the importance of season for interpretation of coastal marshland vegetation: Photogramm. Rec., v. 7, p. 213-222.

Color aerial photographs were found to be the best film type to use in England for the determination of coastal marshland vegetation. October was found to be the best time of the year for determination of vegetation while February was best for mapping topographic features. Mudflats were best seen on false color imagery.

Guss, P., 1972, Tidelands management mapping for the coastal plains region: Washington, D.C., Am. Soc. Photogrammetry, Proc. Coastal Mapping Symposium, June 5-8 1972, p. 243-262.

The author describes a pilot project conducted for the State of South Carolina to determine the feasibility of using aerial photographs to produce multipurpose maps for tidelands management. Requirements of the project are discussed as well as limitations of the data.

Heath, G.R., and Parker, H.D., 1973, Forest and range mapping in the Houston area with ERTS-1 data: Symposium, Significant Results Obtained from ERTS-1, p. 167-172.

The paper discusses procedures and results for two types of investigations using ERTS-1 data: forestry studies in which species content and condition of timber stands were determined, and a range investigation concerned with vegetation mapping in the Gulf coast marsh. Species of _Spartina_ could be differentiated with or without computer-aided analytical techniques. The boundary between _S. patens_ and _S. spartinae_ in the area closely coincides with the wetlands inner boundary.

Hunter, R.E., 1973, Distribution and movement of suspended sediment in the Gulf of Mexico off the Texas coast: Symposium, Significant Results Obtained from ERTS-1, p. 1341-1348.

Sediment plumes observed on ERTS imagery differ very slightly in amount of suspended sediment. Data along the Texas coast show the extent and form of these plumes, some of which extend for many kilometers parallel to the shoreline. These plumes permit interpretation of nearshore currents.

Kevlin, R.T., 1973, Recognition of beach and nearshore depositional features of Chesapeake Bay: Symposium, Significant Results Obtained from ERTS-1, p. 1269-1274.

ERTS-1 support aircraft imagery was used to map such nearshore features as longshore bars in Chesapeake Bay. Also mapped were welded beach ridges and recurved spits.

Klemas, V., Bartlett, D., Philpot, W., Rogers, R., and Reed, L., 1974, Coastal and estuarine studies with ERTS-1 and Skylab: Remote Sensing of Environment, v. 3, p. 153-174.

The repetitive nature of the ERTS and Skylab imagery covering Delaware Bay allowed detection of changing conditions in and around the bay. Coastal vegetation, land use, current circulation, water turbidity, and ocean waste dispersion were studied. Ground truth allowed correlation of sediment concentration with reflectance on the images. The method used to determine currents from ERTS-1 data is discussed.

Klemas, V., Bartlett, D., Rogers, R., and Reed, L., 1974. Inventories of Delaware's coastal vegetation and land-use utilizing digital processing of ERTS-1 imagery: Ann Arbor, Michigan, Proc. 9th Internat. Symposium, Remote Sensing of Environment, p. 1399-1410.

Computer analysis of digital ERTS-1 data produced maps of various vegetative types with accuracies of 83-90 percent when compared with previous, conventional vegetation maps. The investigators plan to update and refine the system until higher accuracies are attained.

Klemas, V., Daiber, F., and Bartlett, D., 1973, Identification of marsh vegetation and coastal land use in ERTS-1 imagery: Symposium, Significant Results Obtained from ERTS-1, p. 615-627.

ERTS-1 data were used in combination with high- and low-altitude aircraft coverage and ground truth to determine the accuracy of using ERTS-1 data alone to distinguish stands of vegetation. Plant communities can be discriminated, but problems were encountered owing to the limited resolution of the satellite data. U-2 and RB-57 coverage were used to map small vegetation communities and the larger stands more accurately.

Klemas, V., Ouley, C.W., and Rogers, R., 1973, Monitoring coastal water properties and current circulation with ERTS-1: 3rd ERTS-1 Symposium, p. 1387-1411.

Currents in Delaware Bay detectable from ERTS-1 data coincided with predicted and measured currents in the bay. Convergent boundaries between different water masses were detected; some exhibited convergent shear. Waste disposal distribution was mapped. Results from the ERTS study are being used to predict potential oil slick movement and to estimate sediment transport.

Klemas, V., Srna, R., Treasure, W., and Otley, M., 1973, Applicability of ERTS-1 imagery to the study of suspended sediment and aquatic fronts: Symposium, Significant Results Obtained from ERTS-1, p. 1275-1290.

ERTS images of Delaware Bay were studied and compared with ground truth and aircraft coverage. Suspended sediment patterns and several types of aquatic interfaces, or fronts, were observed.

Klemas, V., and others, 1974, Correlation of coastal water turbidity and current circulation with ERTS-1 and Skylab imagery: Ann Arbor, Michigan, Proc. 9th Internat. Symposium, Remote Sensing of Environment, p. 1289-1317.

Imagery and digital tapes of ERTS-1 data, along with extensive ground truth as to the exact amount of suspended sediment in the water, gave an indication of reflectance signatures for various sediment concentrations. The study of sediment distribution has also allowed determination of circulation patterns in Delaware Bay.

Klemas, V., and others, 1974, Inventory of Delaware's wetlands: Photogramm. Eng., v. 40, no. 4, p. 433-439.

Enhanced RB-57 color IR imagery was used to map five categories in the wetlands of Delaware: (1) salt marsh cord grass, (2) salt marsh hay and spike grass, (3) reed grass, (4) high tide bush and sea myrtle, and (5) freshwater species in impounded areas.

These units were characterized by:

#1 - Spartina alterniflora

#2 - Spartina patens and Distichlis spicata

#3 - Phragmites communis

#4 - Iva frutescens and Baccharis halimifolia

Magoon, O.T., Berg, D.W., and Hallermeier, R.J., 1973, Application of ERTS-1 imagery in coastal studies: Symposium, Significant Results Obtained from ERTS-1, p. 1697-1698.

Use of MSS ERTS images has permitted more accurate determination of tidal inlet configuration (as well as information on long-shore transport), updating of navigation charts in uninhabited, remote areas, and the near-shore water movement patterns. No enhancement techniques were used.

Mairs, R.L., Wobber, F.J., Garefalo, D., and Yunghans, R., 1973, Application of ERTS-1 data to the protection and management of New Jersey's coastal environment: Symposium, Significant Results Obtained from ERTS-1, p. 629-633.

Using MSS bands 4 and 5, it was possible to detect the extent, drift, and dispersion of waste disposed in coastal waters.

Moore, G.K., and North, G.W., 1974, Flood inundation in the southeastern United States from aircraft and satellite imagery: Ann Arbor, Michigan, Proc. 9th Internat. Symposium, Remote Sensing of Environment, p. 607-620.

ERTS-1 data are useful in flood mapping if satellite passage coincides with the exact time of flooding. Otherwise, color-infrared photography is the most useful for determining the extent of flooding in forested areas during winter months.

Orr, D.G., and Quick, J.R., 1971, Construction materials in delta areas: Photogramm. Eng., v. 37, no. 4, p. 337-351.

Black-and-white, color, and color-infrared aerial photographs were used to locate depositional features on the Mississippi River delta. This method is shown to be a practical way of locating new sand, gravel, and clay deposits in this area.

Pestrong, R., 1969, Multiband photos for a tidal marsh: Photogramm. Eng., v. 35, p. 453-470.

The author compares various wavelength-sensitive films used in aerial photography to determine their usefulness in delineating vegetation zones within tidal marshes. Ektachrome IR was superior for vegetation type determination, while Ektachrome color transparencies were the most useful for general interpretation.

Pirie, D.M., and Stellar, D.D., 1973, California coastal processes study: 3rd ERTS-1 Symposium, p. 1413-1446.

ERTS-1 data were used to analyze nearshore currents, sediment transport, and river discharge along the California coast. Seasonal patterns in sediment transport were found to be related to current systems and coastal morphology. Sediment plumes at times extended much farther offshore than previously thought. Sediment distribution was determined by using computer enhancement of the data.

Polcyn, F.C., and Lyzenga, D.R., 1973, Updating coastal and navigational charts using ERTS-1 data: 3rd ERTS-1 Symposium, p. 1333-1346.

Fairly accurate water depth data, up to 30 feet in the Bahamas and up to 200 meters in Lake Michigan, were obtained from ERTS-1 data. Processing of original ERTS data for depth information costs approximately $1.50 per square mile. Details of the process were not given.

Reimold, R.J., Gallagher, J.L., and Thompson, D.E., 1972, Coastal mapping with remote sensors: Washington, D.C., Am. Soc. Photogrammetry, Proc. Coastal Mapping Symposium, p. 99-112.

Slaughter, T.H., 1973, Seasonal changes of littoral transport and beach width and resulting effect on protective structures: Symposium, Significant Results Obtained from ERTS-1, p. 1259-1267.

The direction of littoral transport and resulting beach width along Maryland's shoreline changes seasonally. This change makes erosion rates difficult to determine. Ground truth combined with ERTS-1 coverage points out the need for a year-long study to see a complete seasonal cycle. This would aid in protective structure design along waterfront properties, since the full potential for erosion would be shown.

Sonu, C.J., 1964, Study of shore processes with aid of aerial photogrammetry: Photogramm. Eng., v. 30, p. 932-941.

Ways in which aerial photographs may be used to better understand coastal environments are discussed. A large bibliography lists the majority of papers printed on the subject prior to this paper.

Stafford, D.B., and Langfelder, J., 1971, Air photo study of coastal erosion: Photogramm. Eng., v. 37, no. 6, p. 565-575.

Aerial photographs taken in successive years permit accurate determination of erosion in coastal areas. Only horizontal distances can be measured, making volumetric measurements of erosion difficult. These data are shown to be necessary for development of urban areas or industry in coastal regions.

Steller, D., Lewis, L.V., and Phillips, D.M., 1972, Southern California coastal processes as analyzed from multisensor data: Ann Arbor, Michigan, Proc. 8th Internat. Symposium, Remote Sensing of Environment, p. 983-998.

Airborne imagery was used to detect and measure suspended sediment and tracer dyes in the nearshore zone off southern California. The methods discussed were developed to study sediment transport and coastal effluent distribution in the area.

Steller, D.D., and Pirie, D.M., 1974, California nearshore processes: Ann Arbor, Michigan, Proc. 9th Internat. Symposium, Remote Sensing of Environment, p. 1261-1278.

The suspended sediment present in turbulent nearshore waters, along with the repetition of ERTS-1 data over a year-long period, have allowed the oceanic circulation patterns near the California coast to be determined.

Tuyahov, A.J., and Holz, R.K., 1973, Remote sensing of a barrier island: Photogramm. Eng., v. 39, 177-188.

Three types of imagery are compared for their effectiveness in determining the environments of Padre Island, Texas. Color, color-infrared, and thermal infrared are compared in delineating vegetation stands, vegetated vs. nonvegetated dunes, tidal flats, and hurricane washover channels.

Williams, R.S., Jr., 1973, Coastal and submarine features on MSS imagery of southeastern Massachusetts: Comparison with conventional maps: Symposium, Significant Results Obtained from ERTS-1, p. 1413-1422.

ERTS-1 data provided the necessary geologic and hydrographic information to update conventional maps of coastal areas where conditions vary rapidly. The data obtained through ERTS are both accurate and relatively inexpensive and provide a constant update.

Williamson, A.N., and Grabau, W.E., 1973, Sediment concentration mapping in tidal estuaries: 3rd ERTS-1 Symposium, p. 1347.

Methods are discussed for the determination of the amount of suspended sediment in water and of ways ERTS data may be used to exactly locate and delineate surface-water turbidity.

Wobber, F.J., and Anderson, R.R., 1973, Simulated ERTS data for coastal management: Photogramm. Eng., v. 39, p. 593-598.

ERTS data are shown to be potentially very useful in mapping wetland boundaries, monitoring land use changes in wetlands, studying offshore currents, and in planning dredge spoil disposal.

Wright, F.F., Sharma, G.D., and Burbank, D.C., 1973, ERTS-1 observations of sea surface circulation and sediment transport, Cook Inlet, Alaska: Symposium, Significant Results Obtained from ERTS-1, p. 1315-1322.

Suspended sediment, visible on MSS 4 and 5, allowed the determination of sediment and pollutant trajectories, areas of probable commercial fish concentration, and the circulation regime.

Yost, E., Hollman, R., Alexander, J., and Nuzzi, R., 1973, An interdisciplinary study of the estuarine and coastal oceanography of Block Island and adjacent New York coastal waters: 3rd ERTS-1 Symposium, p. 1607.

Water samples were taken to correspond with the timing of ERTS-1 coverage. This procedure allowed reflectance to be "quantified" in terms of the amount of suspended sediment present in the water.

APPENDIX I

ACCURACY EVALUATION FOR EACH SCENE MAPPED, BY LAND COVER AND LAND USE CATEGORY

APPENDIX I

Accuracy Evaluation For Each Scene Mapped, by Land Cover and Land Use Category

The percent correct value for each category is based on the assumption that one-half of the questionable points would ultimately be considered correct if additional data became available.

Analysis of Test Site 2

Landsat Scene 1289-16261, 8 May 1973

Classification	Correct	Incorrect	Questionable	Total	Percent Correct
	Number of Points Checked				
U	3	0	0	3	100
Ui	1	0	0	1	100
Ut	4	0	0	4	100
Ue	--	--	--	--	--
A	0	1	0	1	0
G	42	10	3	55	80.0
Gd	--	--	--	--	--
Gb	8	0	0	8	100
Gbr	1	0	0	1	100
WO	4	0	3	7	85.7
Wlm	21	2	0	23	91.3
Whm	14	1	0	15	93.3
Wtf	1	0	0	1	100
Wga	--	--	--	--	--
Ws	3	0	0	3	100
B	1	0	0	1	100
Bd	--	--	--	--	--
Bds	--	--	--	--	--
Bu	--	--	--	--	--
Total	103	14	6	123	86.2

Percent correct assuming one-half of questionables are correct 86.2%

Percent correct assuming all of questionables are correct 88.6%

Percent correct assuming all of questionables are incorrect 83.7%

Analysis of Test Site 3

Landsat Scene 1614-16261, 29 Mar. 1974

	Number of Points Checked				
Classification	Correct	Incorrect	Questionable	Total	Percent Correct
U	--	--	--	--	--
Ui	1	0	0	1	100
Ut	--	--	--	--	--
Ue	--	--	--	--	--
A	36	0	0	36	100
G	81	6	0	87	93.1
Gd	2	0	0	2	100
Gb	--	--	--	--	--
Gbr	--	--	--	--	--
WO	0	0	1	1	100
Wlm	11	0	0	11	100
Whm	4	2	0	6	66.7
Wtf	--	--	--	--	--
Wga	--	--	--	--	--
Ws	2	0	0	2	100
B	2	0	0	2	100
Bd	--	--	--	--	--
Bds	3	0	0	3	100
Bu	--	--	--	--	--
Total	142	8	1	151	94.7%

Percent correct of total assuming one-half of questionables are correct . . 94.7%

Percent correct of total assuming all of questionables are correct 94.7%

Percent correct of total assuming all of questionables are incorrect . . . 94.0%

Analysis of Test Site 3

Landsat Scene 2034-16200, 25 Feb. 1975

Classification	Correct	Incorrect	Questionable	Total	Percent Correct
	Number of Points Checked				
U	--	--	--	--	--
Ui	1	0	0	1	100
Ut	1	0	0	1	100
Ue	--	--	--	--	--
A	32	1	--	33	97.0
G	88	5	--	93	94.6
Gd	--	--	--	--	--
Gb	--	--	--	--	--
Gbr	--	--	--	--	--
WO	--	--	--	--	--
Wlm	7	4	0	11	63.6
Whm	5	2	0	7	71.4
Wtf	2	0	0	2	100
Wga	--	--	--	--	--
Ws	1	0	0	1	100
B	1	0	0	1	100
Bd	--	--	--	--	--
Bds	--	--	--	--	--
Bu	1	1	0	2	50.0
Total	139	13	0	152	91.5%

Percent correct of total assuming one-half of questionables are correct . . 91.5%

Percent correct of total assuming all of questionables are correct 91.5%

Percent correct of total assuming all of questionables are incorrect . . . 91.5%

Analysis of Test Site 4

Landsat Scene 2034-16202, 25 Feb. 1975

Classification	Correct	Incorrect	Questionable	Total	Percent Correct
	Number of Points Checked				
U	4	2	1	7	71.4
Ui	3	0	1	4	100
Ut	6	0	0	6	100
Ue	--	--	--	--	--
A	3	0	0	3	100
G	14	0	0	14	100
Gd	--	--	--	--	--
Gb	4	0	0	4	100
Gbr	--	--	--	--	--
WO	12	0	2	14	92.9
Wlm	3	0	1	4	100
Whm	0	0	1	1	100
Wtf	8	3	2	13	69.2
Wga	13	0	0	13	100
Ws	--	--	--	--	--
B	1	0	0	1	100
Bd	--	--	--	--	--
Bds	2	1	1	4	75.0
Bu	1	2	2	5	40.0
Total	74	8	11	93	86.0%

Percent correct of total assuming one-half of questionables are correct . . 86.0%
Percent correct of total assuming all of questionables are correct 91.4%
Percent correct of total assuming all of questionables are incorrect . . . 79.6%

Analysis of Test Site 4

Landsat Scene 5082-16080, 10 July 1975

Classification	Correct	Incorrect	Questionable	Total	Percent Correct
	Number of Points Checked				
U	5	0	1	6	100
Ui	2	0	0	2	100
Ut	3	0	0	3	100
Ue	--	--	--	--	--
A	4	3	0	7	57.1
G	8	1	0	9	88.9
Gd	--	--	--	--	--
Gb	4	2	0	6	66.7
Gbr	2	0	2	4	75.0
WO	13	1	2	16	87.5
Wlm	2	1	0	3	66.7
Whm	--	--	--	--	--
Wtf	3	0	0	3	100
Wga	16	1	1	18	94.4
Ws	1	0	0	1	100
B	1	0	1	2	100
Bd	--	--	--	--	--
Bds	3	0	0	3	100
Bu	2	1	0	3	66.7
Total	69	10	7	86	84.9%

Percent correct of total assuming one-half of questionables are correct . . 84.9%
Percent correct of total assuming all of questionables are correct 88.4%
Percent correct of total assuming all of questionables are incorrect . . . 80.2%

Analysis of Test Site 4

Landsat Scene 2376-16172, 2 Feb. 1976

Number of Points Checked

Classification	Correct	Incorrect	Questionable	Total	Percent Correct
U	3	0	1	4	100
Ui	2	1	0	3	66.7
Ut	5	0	0	5	100
Ue	--	--	--	--	--
A	4	1	0	5	80.0
G	12	0	0	12	100
Gd	1	0	0	1	100
Gb	5	0	0	5	100
Gbr	--	--	--	--	--
WO	8	1	1	10	90
Wlm	0	0	1	1	100
Whm	--	--	--	--	--
Wtf	5	5	6	16	50.0
Wga	8	0	0	8	100
Ws	--	--	--	--	--
B	1	0	1	2	100
Bd	--	--	--	--	--
Bds	4	0	0	4	100
Bu	1	1	0	2	50.0
Total	59	9	10	78	82.1%

Percent correct of total assuming one-half of questionables are correct . . 82.1%

Percent correct of total assuming all of questionables are correct 88.5%

Percent correct of total assuming all of questionables are incorrect . . . 75.6%

Analysis of Test Site 5

Landsat Scene 2034-16205, 25 Feb. 1975

Number of Points Checked

Classification	Correct	Incorrect	Questionable	Total	Percent Correct
U	--	--	--	--	--
Ui	--	--	--	--	--
Ut	1	0	0	1	100
Ue	--	--	--	--	--
A	16	1	0	17	94.1
G	42	1	0	43	97.6
Gd	1	0	0	1	100
Gb	--	--	--	--	--
Gor	--	--	--	--	--
WO	--	--	--	--	--
Wlm	--	--	--	--	--
Whm	--	--	--	--	--
Wtf	15	1	0	16	93.8
Wga	13	0	0	13	100
Ws	--	--	--	--	--
B	4	2	0	6	66.7
Bd	--	--	--	--	--
Bds	1	0	0	1	100
Bu	18	7	0	25	72.0
Total	111	12	0	123	90.2%

Percent correct of total assuming one-half of questionables are correct . . 90.2%
Percent correct of total assuming all of questionables are correct 90.2%
Percent correct of total assuming all of questionables are incorrect . . . 90.2%

APPENDIX J

DATA TABLES FOR ACCURACY OF COMPUTER CLASSIFICATION IN THE HARBOR ISLAND TEST SITE

Table 2

COMPUTER AND IMAGE-INTERPRETATION CLASSIFICATION ACCURACY COMPARISON
10 JULY 1975

	U	A	G	WO	W	B
U	2	0	0	0	0	0
A	0	1	0	0	0	0
G	0	0	1	0	0	0
WO	6	4	8	19	0	1
W	2	0	2	0	22	0
B	0	0	0	0	0	6

51 ÷ 74 = 69%

Table 3

COMPUTER AND IMAGE-INTERPRETATION ACCURACY COMPARISON
WITH CLASS ADJUSTMENTS
10 JULY 1975

	U	Up	W	B	WA
U	1	0	0	0	0
Up	6	33	0	1	0
W	2	2	22	0	0
B	0	0	0	6	0
WA	0	0	0	0	1

63 ÷ 74 = 85%

Appendix J

DATA TABLES FOR ACCURACY OF COMPUTER CLASSIFICATION IN THE HARBOR ISLAND TEST SITE

Table 1.

COMPUTER AND IMAGE-INTERPRETATION CLASS CORRELATION MATRIX
10 JULY 1975

	U	A	G	WO	W	B
'	0	0	0	0	0	21
/	12	10	16	19	0	0
⊐	7	8	5	3	1	2
Δ	1	0	0	0	63	0
&	0	0	10	25	0	4
%	4	0	8	0	15	1
#	5	2	9	22	1	0
=	2	0	0	0	4	0
G	0	0	0	0	0	0
Z	8	0	0	0	2	0
>	0	0	0	3	2	4

Table 4

COMPUTER AND IMAGE-INTERPRETATION CLASS CORRELATION MATRIX
2 FEB. 1976

	U	A	G	WO	W	B
'	2	0	0	0	2	23
/	11	1	47	15	12	4
	13	4	7	9	0	0
Δ	0	4	0	0	14	0
&	2	0	7	16	1	0
%	6	1	2	0	29	4
#	2	10	1	0	13	1
=	0	0	0	0	0	0
G	4	0	0	0	8	0
Z	3	0	0	0	17	0
A	0	0	0	0	1	0

Table 5

COMPUTER AND IMAGE-INTERPRETATION CLASSIFICATION
ACCURACY COMPARISON
2 FEB. 1976

	U	A	G	WO	W	B
U	3	1	2	2	0	0
A	0	0	0	0	0	0
G	4	0	12	4	2	2
WO	0	0	2	4	0	0
W	3	4	0	0	22	1
B	1	0	0	0	0	5

46 ÷ 74 = 62%

Table 6

COMPUTER AND IMAGE-INTERPRETATION ACCURACY COMPARISON
WITH CLASS ADJUSTMENTS
2 FEB. 1976

	U	A	Up	Wa	W	B
U	3	1	4	0	0	0
A	0	0	0	0	0	0
Up	4	0	22	0	2	2
Wa	0	0	0	8	0	0
W	0	4	0	0	17	1
B	1	0	0	0	0	5

55 ÷ 74 = 74%

Table 7

COMPUTER AND IMAGE-INTERPRETATION CLASS CORRELATION,
USING AN INTENSIFIED SAMPLE
10 JULY 1975

	U	A	G	WO	W	B	WA
'	0	0	1	0	1	18	0
/	4	7	16	21	5	1	1
⊐	10	3	2	5	2	2	1
Δ	4	0	0	0	41	1	3
&	0	3	3	24	2	0	0
%	1	4	5	0	13	1	0
#	0	10	3	16	2	1	0
=	2	0	0	0	1	0	10
Z	8	0	0	0	2	0	56
A	1	0	0	0	2	0	50
>	1	0	0	2	1	1	0

Table 8

COMPUTER AND IMAGE-INTERPRETATION CLASSIFICATION ACCURACY COMPARISON
USING AN INTENSIFIED SAMPLE
10 JULY 1975

	U	A	G	WO	W	B	WA
U	10	3	2	5	2	2	1
A	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0
WO	5	20	22	61	10	3	1
W	5	4	5	2	54	2	3
B	0	0	1	0	1	18	0
WA	11	0	0	0	5	0	116

259 ÷ 374 = 69%

Table 9

COMPUTER AND IMAGE-INTERPRETATION CLASSIFICATION ACCURACY COMPARISON
WITH CLASS ADJUSTMENTS (COMBINING ALL VEGETATION CLASSES-A, G, WO),
USING AN INTENSIFIED SAMPLE
10 JULY 1975

	U	Up	W	B	WA
U	10	10	2	2	1
Up	5	103	10	3	1
W	5	11	54	2	3
B	0	1	1	18	0
WA	11	0	5	0	116

301 ÷ 374 = 80%

Table 10

COMPUTER AND IMAGE-INTERPRETATION CLASS CORRELATION,
USING AN INTENSIFIED SAMPLE
2 FEB. 1976

	U	A	G	WO	W	B	WA
'	2	0	0	0	1	20	2
/	8	3	52	8	8	4	2
	16	1	7	3	0	2	1
Δ	0	2	0	0	7	0	0
&	2	0	4	27	3	1	0
%	3	6	1	0	25	2	4
#	5	8	1	0	10	0	0
=	0	0	0	0	0	0	0
G	3	0	0	0	9	1	56
Z	1	0	0	0	10	0	6
A	4	0	0	0	0	0	10

Table 11

COMPUTER AND IMAGE-INTERPRETATION CLASSIFICATION ACCURACY COMPARISON
USING AN INTENSIFIED SAMPLE
2 FEB. 1976

	U	A	G	WO	W	B	WA
U	16	1	7	3	0	2	1
A	0	0	0	0	0	0	0
G	8	3	52	8	8	4	2
WO	2	0	4	27	3	1	0
W	9	16	2	0	52	2	10
B	2	0	0	0	1	20	2
WA	7	0	0	0	9	1	66

233 ÷ 351 = 66%

Table 12

COMPUTER AND IMAGE-INTERPRETATION CLASSIFICATION ACCURACY COMPARISON
WITH CLASS ADJUSTMENTS, USING AN INTENSIFIED SAMPLE
2 FEB. 1976

	U	A	Up	W	B	WA
U	16	1	10	0	2	2
A	0	0	0	0	0	0
Up	10	3	91	11	5	2
W	9	16	2	52	2	10
B	2	0	0	1	20	2
WA	7	0	0	9	1	66

245 ÷ 351 = 70%

APPENDIX K

COST RECORDING FOR THE LANDSAT PROJECT

APPENDIX K

COST RECORDING FOR THE LANDSAT PROJECT

prepared by Ed Deakin III
August 7, 1975

I. Objectives

Cost records are to be maintained for product development at each of the test sites. The purpose of maintaining these records will be to assist in the evaluation of cost effectiveness of satellite data-gathering methods.

II. Types of Records

There are two types of records that are to be kept by individual project participants. These are:

1. time allocation records, and
2. equipment usage records.

Data from these records will be accumulated by a project accountant. The records which the project accountant will use are:

1. staff cost accumulation sheets, and
2. equipment cost accumulation sheets.

Each of these types of records and their use is described below.

III. Time Allocation Records

Staff members are to maintain an account of the time spent on each task at each site, and for time spent on each step according to the Project Evaluation Review Schedule (PERS). The Time Allocation Record (Exhibit I) is designed to facilitate this record-keeping.

EXHIBIT I

LANDSAT PROJECT
TIME ALLOCATION RECORD

AGENCY ______________________

NAME: ______________________ Week Ending: ______________________

STAFF LEVEL: ______________________ PERS Draft Date: ______________________

MONDAY				TUESDAY				WEDNESDAY				THURSDAY				FRIDAY			
Task	Site Code	Step	Hours	Task	Site Code	Step	Hours	Task	Site Code	Step	Hours	Task	Site Code	Step	Hours	Task	Site Code	Step	Hours
Other: ________				Other: ________				Other: ________				Other: ________				Other: ________			
TOTAL HOURS				TOTAL HOURS				TOTAL HOURS				TOTAL HOURS				TOTAL HOURS			

The staff member should fill in a new Time Allocation Record each day; as work is performed, a notation is made on the record. There are two task codes:

E for Examining ADP Software, and

B for Building a Regional Base.

If a staff member is working on examining ADP software for test site 3, and is indexing tapes from EROS (Step 4), the person would enter an E in the Task column, a 3 in the Site Code column, and a 4 in the Step column. Exhibit Ia shows a Time Allocation Record that has been filled in for John Doe, who performed that task on Tuesday of the week ending September 5, 1975.

Exhibit Ia also shows sample entries for Monday, a holiday, and for other days of the week. Note that on Friday, this person performed several tasks. The second task, which is labeled B 4 7 2 in the four columns of the form indicates that this person spent two hours on Friday building a regional base at Harbor Island, and during that time the person was involved in "ground truth" interpretation.

Time should be kept to within 1/4 of an hour. (Smaller divisions of time are generally more costly than the benefit of increased accuracy obtained).

IV. Equipment Usage Records

Use of specialized equipment and use of the computer should be recorded on Equipment Usage Records (Exhibit II). The recording of computer use will be handled by the computer accounting system; thus use of these records by the staff will concentrate on the use of specialized equipment. An Equipment Usage Record form should be kept

AGENCY ____________

LANDSAT PROJECT
TIME ALLOCATION RECORD

EXHIBIT 13

NAME: John Doe

STAFF LEVEL: Geologist I

Week Ending: September 5, 1975

PERS Draft Date: July 7, 1975

MONDAY				TUESDAY				WEDNESDAY				THURSDAY				FRIDAY			
Task	Site Code	Step	Hours	Task	Site Code	Step	Hours	Task	Site Code	Step	Hours	Task	Site Code	Step	Hours	Task	Site Code	Step	Hours
				E	3	4	7	E	3	4	2	E	3	8	2	E	4	6	2
				E	3	5	1	E	3	6	1 3/4	E	3	10	1	B	4	7	2
								E	3	7	4 1/4	E	3	11	4	E	3	17	1/2
																E	4	1	3 1/2
Other: Holiday			8	Other:				Other:				Other: IDLE: Equipment breakdown			1	Other:			
TOTAL HOURS			8	TOTAL HOURS			8	TOTAL HOURS			8	TOTAL HOURS			8	TOTAL HOURS			8

EXHIBIT II

LANDSAT PROJECT
EQUIPMENT USAGE RECORD

AGENCY ______________________

TYPE OF EQUIPMENT:

____

____

Week Ending: ______________________

PERS Draft Date: ______________________

MONDAY				TUESDAY				WEDNESDAY				THURSDAY				FRIDAY			
Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.
TOTAL USAGE				TOTAL USAGE				TOTAL USAGE				TOTAL USAGE				TOTAL USAGE			

near each piece of equipment. When the equipment is used, the user should record the task, site code, step, and time of use in the appropriate columns on the Equipment Usage Record (EUR). In many cases, equipment use is limited to a few of the steps for each task. The project accountant should be able to compare the times spent on tasks with the equipment usage record to help verify the data contained on the EUR.

An example of an EUR for a Richards Light Table is shown in Exhibit IIa. This type of equipment is used to perform Steps 7 and 8 in Task B only. Thus, usage for the equipment should conform fairly closely to the time spent on those tasks. From the example, one can see that the equipment was used on Tuesday and Friday only. Tasks performed on those days were as noted.

V. Staff Cost Accumulation Sheets

Data from the time allocation records must be transferred to cost records which accumulate costs by task, site, and step. The project accountant will use the cost accumulation forms in order to transfer data from the time allocation records. An example of a Staff Cost Accumulation Sheet is shown in Exhibit III.

An example of a filled-in Staff Cost Accumulation Sheet is presented in Exhibit IIIa. The first line shows that a Geologist I spent one hour during the week on Step 1 of Task E at Site 3. The standard rate for a Geologist I is $10.00. This rate is multiplied by the hours

EXHIBIT IIa

LANDSAT PROJECT
EQUIPMENT USAGE RECORD

AGENCY ______________________

TYPE OF EQUIPMENT: Richards' Light Table

Week Ending: ______________________

PERS Draft Date: ______________________

MONDAY				TUESDAY				WEDNESDAY				THURSDAY				FRIDAY			
Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.	Task	Site Code	Step	Hrs.
				B	3	7	1½									B	3	7	
				B	3	8	½									B	3	8	
				B	3	7	2												
Holiday																			
TOTAL USAGE			0	TOTAL USAGE			4	TOTAL USAGE			0	TOTAL USAGE			0	TOTAL USAGE			

EXHIBIT III

LANDSAT PROJECT

COST ACCUMULATION SHEET

STAFF

TASK: ______________________

SITE: ______________________

CUMULATIVE /_/ WEEKLY /_/

WEEK ENDING: ______________________

Step	Staff Level	Hrs.	Std. Hrs.	Total	Staff Level	Hrs.	Std. Hrs.	Total	Staff Level	Hrs.	Std. Hrs.	Total	Total For This Step

LANDSAT PROJECT
COST ACCUMULATION SHEET
STAFF

EXHIBIT IIIa

TASK: E

SITE: 3

CUMULATIVE ☐ WEEKLY ☒

WEEK ENDING: September 5, 1975

	Step	Staff Level	Hrs.	Std. Hrs.	Total	Staff Level	Hrs.	Std. Hrs.	Total	Staff Level	Hrs.	Std. Hrs.	Total	Total For This Step
	1	G1	1	10.00	10.00									$10.00
	2	G1	3	10.00	30.00	G2	2	8.00	16.00					46.00
	3													-00-
→	4	G1	5	10.00	50.00	G2	9	8.00	72.00	53	2	5.20	10.40	132.40
→	5	G2	1	8.00	8.00									8.00
→	6	G1	2	10.00	20.00	G2	1 3/4	8.00	14.00					34.00
→	7	G2	4 1/4	8.00	34.00									34.00
→	8	G1	4	10.00	40.00	G2	2	8.00	16.00	52	2	6.50	13.00	
		53	1	5.20	5.20									74.20
	9													-00-
→	10	G2	1	8.00	8.00									8.00
→	11	G2	4	8.00	32.00									32.00

worked to obtain the total cost for that staff level during the week. The totals are added across the line, and a total cost for each step is entered in the last column.

In Step 4, there are three staff levels which were engaged in performing this particular step this week. The hours for each and the standard rates for each are used to determine the totals. The three total costs are added together to arrive at a total cost for Step 4 for this week. (Notice that the Geologist II hours can be tied back to Exhibit Ia. The arrow indicates the steps where this can be done.)

Step 8 required more than three staff levels. To indicate the continuation onto the next line, a diagonal line was placed in the "Total for This Step" column, and the additional data were entered in the next line.

If a particular task requires more than one Staff Cost Accumulation Sheet, additional sheets can be added, with the notation "Continuation" made at the top.

Weekly accumulations should be made in order to facilitate reporting. At the time that reports are due, the weekly cost accumulation sheets can be used as a basis for preparing cumulative cost accumulation sheets. The cumulative box would be checked, and the accumulated hours for each of the staff levels would be entered under the appropriate steps. At the end of each task for each site, the cumulative cost accumulation sheet will have the total times spent on each of the steps in that task as well as the total standard costs for that step.

The standard costs to be used for each staff level should be the costs that are expected to occur if the project is operational. These costs would include the employee's hourly rate plus a provision for employee benefits, and other costs related to that employee's time.

The staff levels are abbreviated in the cost accumulation forms. The project director should prepare a key to indicate the staff levels associated with each of the abbreviations, as well as the standard rate for each level.

VI. Equipment Cost Accumulation Sheets

The costs associated with the use of each piece of specialized equipment and with the computer should be accumulated on Equipment Cost Accumulation Sheets (Exhibit IV). The process of transferring the data from individual Equipment Usage Records to these sheets is identical to the process for transferring staff time records.

The standard rates for equipment use should be determined based on the expected life of equipment. This can be approximated by taking the expected life of the equipment in years and multiplying it by the expected annual usage in hours. This "productive hours" life of the equipment is then divided into the equipment cost to arrive at an hourly cost for use of the equipment. For example, if a machine will last for two years, and is used an average of 520 hours per year (or 10 hours per week), it has a productive-hours life of 1040 hours (2 years x 520 hours per year). If the equipment costs $18,560 and can be sold for $4,000 at the end of the second year, then the net equipment cost is $14,560 ($18,560 - $4,000). The hourly rate

EXHIBIT IV

LANDSAT PROJECT
COST ACCUMULATION SHEET
EQUIPMENT

TASK: ______________________ SITE: ______________________

CUMULATIVE /_/ WEEKLY /_/ WEEK ENDING: ______________________

Step	Equip Type	Hrs.	Std Rate	Total	Equip Type	Hrs.	Std Rate	Total	Equip Type	Hrs.	Std Rate	Total	Total For This Step

would be this $14,560 divided by 1,040 hours, or $14.00 per hour.

Computer costs should be assigned to each step based on the records maintained by the computer center. Each job submitted to the center should be coded to indicate the task, site, and step to which the job applies. Standard computer use costs should be based on the computer costs expected to occur under operational conditions.

VII. Other Cost Records

Certain other costs will be incurred under the project. The most significant of these is likely to be travel costs. The basic document for these costs will be the travel voucher. These vouchers should be coded with the task, site,and step codes so that the travel costs can be associated with the final cost reports.

Other costs,such as supplies, should be estimated. In general, these costs will be too small to require detailed record-keeping. Estimates of supplies use should be reported by breaking down the total use for the project to individual steps on an appropriate basis.

VIII. Reporting Costs Incurred

A report of costs incurred for each step should be prepared to indicate the costs likely to occur in an operational setting. Such a report should list costs for each of the three major step categories:

Data Acquisition,
Information Extraction, and
Display.

Under each of these steps, costs should be shown with the following categories:

Cost	Source of Information
Staff	Staff Cost Accumulation Sheets--Cumulative
Equipment	Equipment Cost Accumulation Sheets--Cumulative
Travel	Travel Vouchers--according to codes
Other	As Estimated

The estimates for Other Costs should be documented to provide a means of tracing these costs.

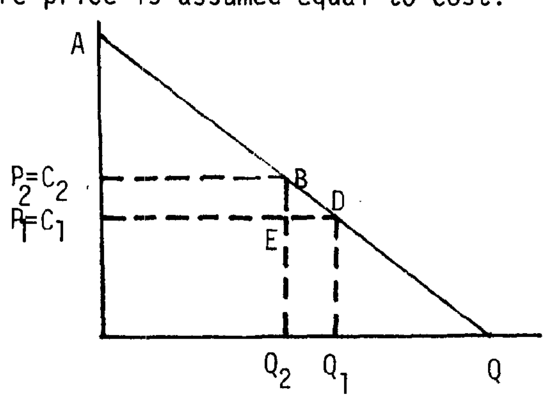
APPENDIX L

THE COST-SAVING ANALYSIS IN AN ECONOMIC CONTEXT

APPENDIX L. THE COST-SAVING ANALYSIS IN AN ECONOMIC CONTEXT

In general, the cost-benefit method of analysis provides a framework by which alternative government investments can be evaluated. Any expenditure of monies involves both benefits and costs, the gain from the action and the expense of undertaking it. In a decision-making context, it is not only the direct benefits and costs of an action which should be weighed, but also the benefits and costs of alternatives. It is then the net gain over the alternative or the opportunity cost of a selected course of action which should count. The key to a cost-benefit study, then, is opportunity cost, or the value foregone in deciding to undertake a particular action rather than an alternative. Cost-benefit, then, is examination of choices among the most promising alternatives. Selection is forced upon society because of limited means or, in the context of government, on government agencies because of budget constraints.

A cost-saving study is a form of cost-benefit. Any investment of monies which has the objective of reducing costs for a product or service focuses on the costs only. If the benefits and costs of one action are B and C, and the benefits and costs of the closest cost alternative are B_2 and C_2, since $B_1 = B_2$, then $C_1 - C_2$ is equal to the cost-savings.[1] This is shown in the diagram below, where price is assumed equal to cost:



[1] See E.J. Mishan, Cost-Benefit Analysis: Praeger Publishers, Washington, D.C., 1971, p. 34.

B_1 or total benefits of Action 1 is $OABQ_2$ and C_1 or total costs is OC_1EQ_2. For alternative 2, total benefits (B_2) are $OABQ_2$ and total costs are OC_2BQ_2. Since for Q_2 amount of the good, B_1=B_2, then cost-savings reduces to C_2-C_1 or C_1C_2BE. This approach assumes that demand, AQ, is the same for all products.

In the context of this study, a cost-savings approach assumes decision-makers are indifferent to the type of map they use. Each map supplies him with the information he needs, regardless of the differences in number of classes, mapping technique, etc. The question of choice among maps is dictated by the least-cost method of mapping whether it is by computer-assisted processing of digital tapes, image interpretation of Landsat imagery, or conventional mapping using aerial photos.

This approach contrasts with one which considers the demand for each map as being slightly different. The demand for a map would depend upon the information content of each map and its impact on the decision-making process. If decision-makers have a desire to make the best decision for the State of Texas, then their demand for a map will be dictated by how they see each map influencing this decision. The benefit-cost equation would be slightly more complicated than that for the cost-saving approach.

From the diagram illustrating cost-saving, it can be deduced that this study has several major faults. One is that no account is made for user needs (demands). Table 8 in the text shows the various costs per square mile of information assuming various volumes of users, but these volumes of demand are hypothetical only. The comparison of Landsat maps with conventional methods does not establish the demand for either. A survey of potential users would assess each user's current source of information, and the cost of such information, and compare that cost to Landsat products. The cost-savings for a Landsat map would be the sum of the savings in cost for each user where each individual savings in cost would be computed as the cost of Landsat maps minus the costs of present information sources. Another fault in the study is that the mapping results from computer and image analysis techniques are based on small areas. One inherent advantage of the computer approach is that once the mapping parameters are established, large areas can be mapped quickly, albeit with possibly different features being mapped than by image-interpretation methods. An additional weakness in comparing the products from the three mapping approaches is that the maps contain different levels of information and different accuracies. Also, the computer methods still can be improved upon, whereas the methods based on more conventional techniques are essentially stable with regard to significant improvements.

These faults in the cost-savings study are, of course, due to difficulties and incompatibilities in the sources of information rather than in the cost-savings approach itself. The study compared Landsat-derived maps to conventional mapping by way of illustration; the cost-savings study is an example only. Several other points should be made about the Landsat study.

Costs shown would be costs to the state if it should invest. This is not the relevant criterion for a cost-benefit study, however. The costs which should count are costs to the nation. In this study, purchase costs of Landsat imagery and tapes are counted as the only costs, yet such costs do not count placing a satellite into orbit. The remaining cost which is not calculated here amounts to a positive transfer or subsidy to the state from the federal government.[2]

[2]See E.J. Mishan, Cost-Benefit Analysis: Praeger Publishers, Washington, D.C., 1971, p. 34.

A cost not treated in Landsat mapping is that of administrative overhead. Some other indirect costs may have been omitted. For the environmental geology map, no calculation was made of office overhead or labor costs other than interpretation.

Quality criteria such as accuracy and consistency of classification or timeliness in delivery of products were not compared to costs.

Finally, it is assumed that the areas mapped by these various approaches will be completed within the period of a year so that all costs are current costs as much as possible. The present value of money, and therefore discounting, was not considered in the computations.

APPENDIX M

RAW DATA COSTS FOR LANDSAT MAPS DERIVED FROM IMAGE INTERPRETATION AND COMPUTER-ASSISTED ANALYSIS, WITH ONE TABLE ON LABOR COSTS FOR THE ENVIRONMENTAL-GEOLOGY MAP

APPENDIX M.

RAW DATA COSTS FOR LANDSAT MAPS DERIVED FROM IMAGE INTERPRETATION AND COMPUTER-ASSISTED ANALYSIS, WITH ONE TABLE ON LABOR COSTS FOR THE ENVIRONMENTAL-GEOLOGY MAP.

These tables contain the cost data: labor costs, equipment costs, office overhead, and miscellaneous costs. Frequently they contain additional data not actually used in the computations in the text. This data is not extraneous, though, for it permits additional computations for parties who are interested in tabulating their own costs. A list of tables is shown below.

Table 1. Labor Costs of Image Interpretation: Staff Salary and Fringe Benefits by Staff Level, Per Hour (1976-77).

JOB CLASSIFICATION	RANGE PER MONTH	AVERAGE PER MONTH	SALARY FOR YEAR	HOURLY RATE	FRINGE BENEFITS PER HOUR	TOTAL REMUNERATION
Research Scientist Associate IV	$1465-1852	$1659	$19,908	$9.58	$1.13	$10.71
Research Scientist Assistant II	804-1014	909	10,908	5.25	.73	5.98
Research Scientist Assistant I	680-888	784	9,408	4.53	.64	5.27
Technical Staff Assistant III	538-727	633	7,596	3.65	.54	4.19
Secretary	595-804	661	7,932	3.82	.56	4.38

Explanation of Positions:

Research Scientist Associate IV is the Senior Image Interpretor.

Research Scientist Assistant (I or II) is an assistant who mainly performs steps 5 and 7.

Technical Staff Assistant III is a draftsman.

Fringe Benefits

OASI (Social Security) = 5.85% of first $ 15,300.
UCI (Unemployment Compensation) = .2% of first $ 4,200.
WCI (Workmen's Compensation) = .35% of total salary.
Premium Sharing = $ 15 per month for full-time employees, only half-time to full-time employees are eligible and the $ 15 per month is prorated on hours of work.
Matching Retirement = 6.0% of the first $ 25,000 and only those working half-time or more are eligible.

[1] The hourly rate is figured as 173.2 hours per month.

Source: Gary Otting, Univ. of Texas Personnel.

Table 2. Labor Costs of Computer-Assisted Analysis: Staff Salary and Fringe Benefits by Staff Level, Per Hour.

Job Classification	Range Per Month	Average Per Month	Salary For Year	Hourly Rate[1]	Fringe Benefits Per Hour	Total R Per Hour
System Analyst I, Group 16	\$1302-1639	\$1470.50	\$17,646	\$ 8.49	\$ 1.19	\$ 9.68
Engineering Technician IV, Group 14	1141-1437	1289.00	15,468	7.44	1.11	8.55
Clerk Typist II, Group 4	590-743	666.50	7,998	3.85	.62	4.47

Explanation of positions: A system analyst served to adapt programs to LANDSAT needs during the investigation. Actual analysis by computer was carried on by an engineering technician.

Fringe Benefits: OASI (Social Security) = 5.85% of first \$15,300.
UCI (Unemployment Compensation) = .2% of first \$4,200.[2]
WCI (Workman's Compensation) = .35% of total salary.[2]
Premium sharing for health insurance = \$15 maximum per month
Matching Retirement = 7.5% of gross salary.

[1] The hourly rate is figured as 173.2 hours per month.

[2] The state pays both unemployment and workman's compensation from general funds. In order to obtain a comparable opportunity cost, the rate for the university system (paid by employers) was used. These rates are computed on experience for professionals and therefore should be comparable to professionals in state government.

Source: Phyllis Snyder, Office of Personnel, General Land Office and Bill Monks, Texas Employment Commission.

Table 3. Labor Costs for Bureau of Economic Geology South Texas Mapping Project: Staff Salary and Fringe Benefits by Staff Level, Per Hour (1976-77).

Job Classification	Range Per Month	Average Per Month	Salary For Year	Hourly Rate[1]	Fringe Benefits Per Hour	Total Remuneration Per Hour
Research Scientist Associate III	$1370-1675	$1523	$18,276	$8.79	$1.08	$ 9.87
Research Scientist Associate IV	1465-1852	1659	19,908	9.58	1.13	10.71
Senior Cartographer	1281-1620	1451	17,412	8.38	1.05	9.43
Research Scientist Assistant I	680-888	784	9,408	4,53	.64	5.27

Fringe Benefits:

OASI (Social Security) = 5.85% of first $15,300.
UCI (Unemployment Compensation) = .2% of first $4,200.
WCI (Workmans Compensation) = .35% of total salary.
Premium Sharing = $15 per month for full-time employees, only half-time to full-time employees are eligible and the $15 is prorated on hours of work.
Matching Retirement = 6.0% of the first $25,000 and only those working half-time or more are eligible.

[1]Hourly rate figured on average hours per month of 173.2.

Source: Gary Otting, University of Texas Personnel.

Table 4. Labor Costs of Image Interpretation: Data Interpretation, Staff Time By Steps in Interpretation, Representative Time for a Scene in Site Four.

Step	Description	Hours of Time for Research Scientist Associate IV				Hours of Time for Research Scientist Assistant 1				Representative, Total Time In Hours, Associate IV and Assistant 1
		Scene 1	Scene 2	Scene 3	Representative	Scene 1	Scene 2	Scene 3	Representative	
1	Review aerial photography, Coastal Atlas Maps, and published tide and weather data for test site and image data	7 1/4	5 1/4	6	6 1/4[A]					6 1/4
2	Take a preliminary field trip to become generally acquainted with test site	4	4	4	8[A]	4	4	4	8[A]	16
3	Complete line boundary map of test site area	13 3/4	12 3/4	12	12 3/4[A]	1/2			0	12 3/4
4	Classify features according to the *modified Anderson system*	15 1/2	3 3/4	6 1/4	6 1/2					6 1/2
5	Study supportive data in detail, review results, field check and correlate with biological data									
6	Document results for scene, especially problems and unique aspects of imagery									
7	Produced corrected image interpretation at 1:125,000 and overlays at 1:24,000									
8	Qualitative analysis of classification products to evaluate accuracy									
9	Evaluate format and content of result*ing map*	1	1	1/2	3/4[A]	5 1/2	5	7	5 3/4	6 1/2
10	Evaluate image interpretation of scene in conjunction with other scenes						3		1[A]	1
	Total				50				81 1/2	131 1/2

Footnotes: Average time, taken as representative time, is denoted by an "A". All other representative times were adjusted.
Scene 4 of site 4 was not completed.

Source: Robert Finley and Robert Baumgardner, Bureau of Economic Geology.

Table 5. Other Labor Costs of Image Interpretation: Data Interpretation, Staff Time by Activities Other Than Interpretation.

Description of Activity	Hours of Time: Research Scientist Associate IV	Research Scientist Assistant I	Grand Total
(1) Meetings	18 3/4		18 3/4
(2) Research (Literature and Design)	18 3/4		18 3/4
(3) Quarterly Report	18 1/4		18 1/4
(4) Other	20 1/4		20 1/4
Total, Labor Cost other than Interpretation	76		76
(5) Turbidity Study	53 3/4	24	77 3/4
(6) Change Detection in Spoil Area Study	2 1/2	4	6 1/2
Total, Special Studies	56 1/4	28	84 1/4

Table 6. Labor Costs Of Computer-Assisted Analysis: Data Interpretation, Staff Time By Steps, Representative Time For A Scene In Site Four[1].

Step	Description With Computer Program Package In Parentheses	Representative Hours For Four Scenes	Average For Scenes 3 & 4
1	Select LANDSAT scene and determine data tapes ID number (ERTSIDC)	1.5	.5
2	Examine available imagery	1.0[A]	.5
3	Merge data tapes or duplicate tapes if necessary (MERGE)[2]	3.0	1.0
4	Estimate scan line and sample numbers for the area of interest	2.5[A]	2.5
5	Generate grayscale maps of the area (GRAYMAP/PICOUT)	7.0[A]	9.0
6	Obtain meteorological data[3]	.5	.5
7	Participate in orientation field trip[4]	8.0	8.0
8	Establish control network (COEF)	13.0[A]	12.0
9	Classify water (DAM)	8.0	6.0
10	Cluster all training areas within the scene (ISOCLS)	5.0[A]	4.5
11	Examine class statistics[2]	3.0	4.0
12	Refine a training class if indicated by step 10[5]	-	-
13	Use class statistics to build the look-up table (ELLTAB Table)	5.0[A]	3.0
14	Combine classes for display purposes (HGROUP)	7.0	4.0
15	Classify the area (ELLTAB CLASSIFY)	9.0[A]	8.0
16	Register and display the classified results (REGISTER)	19.0[A]	14.0
17	Outline or color code homogeneous areas	1.0	1.0[N]

Table 6. Labor Costs of Computer-Assisted Analysis (Con't)

Step	Description With Computer Program Package In Parentheses	Representative Hours For Four Scenes	Average For Scenes 3 & 4
18	Examine the classification map and field check	24.0	24.0[N]
19	Stop if satisfied with results		
20	Retrain on unclassified or poorly separated areas (ISOCLS)	2.0	2.0
	other programs, computer name		
18	Correlation	7.0	3.5
	Mr. Clean	3.0[A]	2.5
	Change Detection	1.0	1.0
	Total	130.5	111.5

[A]Average used for all four scenes to the nearest half hour.

[N]In step 18, 8 hours was used as typical analysis time and 16 hours for a field trip. In step 17, each map would normally be color coded.

[1]Staff is an Engineering Technician IV, Group 14.

[2]Scene four was contained on one computer compatible tape. In certain cases, it is a non-representative scene and therefore the times on the first three scenes prove more representative.

[3]Thirty minutes is the maximum time for all four scenes.

[4]An orientation field trip is necessary for at least one scene. The twenty-four hours could be taken as a figure for one scene or, alternatively, as sufficient for all four scenes.

[5]Step 12 proved to be a bogus case, for more than one class had to be refined in every case.

Source: Bill Hupp, Texas Natural Resources Information System, The Interpreter for Site Four.

Table 7. Labor Costs Of Data Acquisition: Staff Time By Agency.

Step No.[1]	Responsible Agency		Estimated Time (Hours)
1	TWDB		1.0
2	BEG		2.0
3	TWDB		0.5
4	GLO		0.5
5	TWDB		1.0
6	TWDB		2.0
7	TWDB		0.5
8	TWDB		0.5
		TOTAL	8.5

[1] Steps are described in the LANDSAT Quarterly Report of December, 1975. These steps could be expected for data acquisition for any site, given four scenes as a data acquisition package for the site.

Table 8. Equipment Costs: Special Equipment in Image Interpretation.

Name	Description or Other	Model No.	Producing Company	Costs as of July 1, 1976[1]	Life
Richards Light Table with Zoom Transfer Scope:					
--Zoom Transfer Scope™	Wide Base	2T4	Bausch and Lomb Scientific Optical Instruments Rochester, N.Y. 14602	$4,975.00	
--Richards Light Table		MM-231100	Richards 1545 Spring Hill Rd. McLean, Va. 22101	$4,950.00	
TOTAL				$9,925.00	5
Richards Light Table with Zoom Transfer Scope:[2]					
--Richards Table	Table Only	MM 475100	Richards (See Above)	$8,785.00	
--Light Source	2500 Ft. L-3500 K			$ 50.00	
--Reel Bracket	Motorized 1000 Ft.			$1,490.00	
--200M 240 Stereoscope		240R/ 15AE	Bausch and Lomb	$4,770.00	
TOTAL				$15,095.00	5

[1] All costs are retail.

[2] This system is comparable to an FMA (Photointerpreters Station) used in the LANDSAT Project owned by the Bureau of Economic Geology and obtained from the U.S. Air Force, Ogden, Utah.
Source: Neil P. Yingling, Bausch and Lomb Salesman, Dayton, Ohio.

Table 9. Equipment Costs: Special Equipment in Computer-Assisted Analysis.

Name	Model No.	Company	Costs	Life
Keyboard Printer Terminal	AJ832-30	Anderson Jacobson, Inc. 1065 Morse Ave. Sunnyville, Calif.	$4,490.00	5
Teleterm Printer	COI1132	Computer Devices, Inc. 9 Ray Ave. Burlington, Mass.	$3,900.00	5
Film Viewing Table, Photographic Interpretation	GFL3040	Richards Corp., Inc. 1545 Springhill Rd. McLean, Va.	$2,755.00	5
Microfiche Reader	"Realist 3335," Vanguard Series	Realist, Inc. N. 93, W. 16288 Regal Dr. Menomonee, Wis.	$ 466.00	5
Motorized Reader/Printer	400M	3M Business Products Sales 1948 S. Interregional Austin, Texas 78104	$2,582.21	5

[1]Retail equipment costs as of July, 1976 include transportation.

Source: O.T. Greer, Texas Water Development Board.

Table 10. Equipment Costs: Data Acquisition, Special Equipment In Ordering Imagery.

Name	Description or Other	Catalogue No.	Company	Retail Cost[1]	Life
Recordak Unit: Total	Access Files to LANDSAT Photography		Eastman Kodak, Co. 610 Gray St. Houston, Texas 77702	$9,434.20	5
1. Recordak Microstar Reader	With Printer Adapter	150 1683	"	2,565.65	5
2. Lens 21-28x Lens Kit		103 0477	"	121.25	5
3. Recordak Microstar Zoom Kit		103 0535	"	266.75	5
4. Recordak Image Control Board, Interface		130 7362	"	4,462.00	5
5. Recordak Printer		141 3343	"	1,421.05	5
6. Recordak 11 inch Print Platen		141 1776	"	130.90	5
7. Recordak Retrieval					
Station Console		150 1444	"	252.20	5
Side Shelf		150 1469	"	63.05	5
Front Shelf		150 1485	"	63.05	5
8. Recordak Access Files					
Module	Type 16-60	150 1527	"	36.90	5
Base and Top		150 1568	"	51.40	5

Table 11. Equipment Costs: Image Interpretation, Total Hours of Use of Special Equipment for a Representative Scene in Site Four.

Equipment	Hours	Steps
Zoom Transfer Scope	19 1/4	Total time of associate on steps 3 and 4
Richards Light Table (MIM-231100)	6 3/4	1/4 of total time for assistant on step 5
Richards Light Table (MIM-475100)	1	Total time of assistant on step 9

Table 12. Equipment Costs: Computer-Assisted Analysis, Total Hours Of Use Of Special Equipment For Scene 3 of Site Four.

Remote Computer Terminal:

	Step	Hours	Date
	8	7	August 8
	8	7	August 10
Total	8	14	

The remote computer terminal can be treated as either of two pieces of equipment, the keyboard printer terminal or the teleterm printer. See the table on special equipment in computer-assisted analysis.

Table 13. Equipments Costs: Computer-Assisted, Total Minutes of Computer Time by Program, Representative Operational Run and Estimates for Supplemental and Error Runs.

OPERATING RUN:

PROGRAM	STEP	COMPUTER TIME IN MINUTES
ERTSIDC	1	1.15
MERGE	3	1.21
GRAYMAP	5	3.16[A]
PICOUT	5	11.30[A]
COEF	8	NIL
DAM	9	8.62[A]
ISOCLS	10	7.00
ELLTAB TABLE	13	8.66[A]
HGROUP	14	.15[A]
ELLTAB CLASSIFY	15	8.86[A]
SCALE REGISTER	16	39.30[A]
MR. CLEAN	N.A.	2.88
CHANGE DETECTION	N.A.	2.28
	TOTAL OPERATING	94.57
	SUPPLEMENTAL	30.00
	ERROR	15.00
	GRAND TOTAL	139.57

[A] Average for scenes 3 and 4.

Source: Bill Hupp, Texas Natural Resources Information System.

Table 14. Equipment Costs: Data Acquisition, Total Hours of Use of Special Equipment in Ordering Imagery.

Step In Data Acquisition	Description of Step[1]	Hours Of Use	Equipment[2]	Percent Use Attributable to LANDSAT Project[3]	Life In Years
1	Obtain current LANDSAT Accessions List From EROS Data Center	.5	Keyboard Printer Terminal	100.0	5
2	Select LANDSAT Imagery According to Criteria For Cloud Cover and Quality	.5	Recordak Unit	10.00	5
6	Receive and Index LANDSAT Data	.5	Richards Light Table (Model GFL 3040)	100.0	5

[1]A full list of steps can be found in the December, 1975 Quarterly Report.

[2]See tables on equipment for cost and model information.

[3]The Recordak Unit is used by other agencies working through the Texas Natural Resources Information System Library.

Source: Sam McCulloch, Texas Natural Resources Information System.

Table 14. Equipment Costs: Special Equipment in Ordering Image (Con't)

Name	Description	Cost Per Cassette	Number of Cassette	Cost[2]	Source
9. Master EROS File	Black and White Cassette	$15.00	142	$2,130.00	EROS Data Center Sioux Falls, S.D.
	Color Cassette	40.00	96	3,840.00	"
10. Duplicate File	Black and White Cassette	6.60	142	937.20	"
	Color Cassette	26.00	96	2,496.00	"

[1] Cost of Recordak equipment from July 1, 1976 to June 30, 1977.

[2] Purchase cost of microfilm files to TWDB.

Source: Recordak Unit, O.T. Greer, Texas Water Development Board; microfilm cassettes, Sam McCulloch, Texas Natural Resources Information System.

Table 15. Costs of Office Equipment In Image Interpretation, Site Four[1]

Room, 15 Ft. by 20 Ft., Housing Senior Interpreter and Assistant:

Description of Furniture	Cost Per Item	No. of Items	Total
Metal Executive Desk	$200.00	1	$200.00
Metal Executive Chair	60.00	1	60.00
Work Tables (30 inches by 50 inches)	100.00	1	100.00
Tracing Table (24 inches by 36 inches)	150.00	1	150.00
Drafting Stool	65.00	1	65.00
Chalk Board (4 Ft. by 6 Ft.)	150.00	1	150.00
Bulletin Board (4 Ft. by 6 Ft.)	75.00	2	150.00
Guest Arm Chairs	60.00	2	120.00
TOTAL			$995.00

Room, 10 Ft. By 12 Ft., Housing Secretary

Description of Furniture	Cost Per Item	No. of Items	Total
Secretarial Desk (Metal)	$220.00	1	$220.00
Secretarial Chair (Metal)	60.00	1	60.00
Five Drawer File Cabinet	125.00	1	125.00
Typewriter	694.00	1	694.00
TOTAL			$1,099.00

[1]This list of equipment approximates current costs (August, 1976) of replacing equipment used by personnel at the Bureau of Economic Geology during the Landsat Project, excluding drafting personnel. The room, housing the senior interpreter and assistant (Research Scientist Associate IV and Research Scientist Assistant), is approximate size for the area of a room shared with personnel working on other BEG projects. A standard room size was used for all secretaries working on the project.

Source: Ruth King, Planning Program, General Land Office.

Table 16. Office Overhead: Computer-Assisted Analysis, Costs of Office Equipment.

Room, 15 Ft. by 20 Ft., Housing Two Engineering Technicians, the Computer Operator and Supervisor

Description of Furniture	Cost Per Item	No. of Items	Total
Metal Executive Desk	$200.00	2	$400.00
Metal Executive Chairs	50.00	2	100.00
Five Drawer Map File (with Bases and Caps)	350.00	2	700.00
Metal Work Table	100.00	2	200.00
Guest Arm Chair	60.00	2	120.00
Metal Bookcase (Five-Shelf)	125.00	1	125.00
Five-Drawer File Cabinet	125.00	1	125.00
Film Cannister Rack (Wood, Sixty Bin)	150.00	1	150.00
Wood Bookcase (36 inches by 84 inches)	135.00	1	135.00
TOTAL			$2055.00

Room, 8 Ft. by 10 Ft., Housing System Analyst

Description	Cost Per Item	No. of Items	Total
Metal Executive Desk	$200.00	1	$200.00
Metal Executive Chair	50.00	1	50.00
Wood Bookcase (36 in. by 84 in.)	135.00	1	135.00
Five-Drawer File Cabinet	125.00	1	125.00
TOTAL			$510.00

Table 16. Office Overhead: Computer-Assisted Analysis, Costs of Office Equipment[1].

Room, 10 Ft. by 12 Ft., Housing Secretary:

Description of Furniture	Cost Per Item	No. of Items	Total
Secretarial Desk (Metal)	$220.00	1	$220.00
Secretarial Chair (Metal)	60.00	1	60.00
Five-Drawer File Cabinet	125.00	1	125.00
Typewriter	694.00	1	694.00
TOTAL			$1099.00

[1]This list of equipment approximates current costs (August, 1976) of replacing equipment used by personnel at the Texas Natural Resources Information System during the Landsat Project. It excludes housing of the computer and computer support staff and housing of the recordak equipment. The room size approximates true size with the exception of the room housing the secretary. A standard room size was used for all secretaries working on the project.

Source: Ruth King, Planning Program, General Land Office.

Table 17. Office Overhead: Image Interpretation and Computer-Assisted Analysis, Costs of Office Space and Materials.

Office Space: Rental at $ .31 per month per square foot.

Office Supplies: Initial cost @ $90.00 per office
Monthly cost @ $25.00 per office

$90.00 ÷ 2078.4 (hours in a year) =	$	.043/hour
$25.00 ÷ 173.2 (hours in a month) =		.144/hour
	$	.187/hour

Source: Ruth King, Planning Program, General Land Office.

Table 18. Miscellaneous Costs: Data Acquisition, LANDSAT Imagery and Digital Tapes for One Site.

Cost of Imagery for Image Interpretation

	Item	Scale	Band	Cost
1)	Color Transparency	1:1,000,000	Composite	$12.00
2)	Black and White Print	1:250,000	5	15.00
3)	Black and White Positive Transparency	1:1,000,000	4	5.00
			5	5.00
			6	5.00
			7	5.00
4)	Black and White Negative Transparency	1:1,000,000	5	6.00
			7	6.00
			TOTAL	$74.00
5)	Color Master			50.00
		Total Cost Per Scene		$124.00
		Times Four Scenes For Site[1] =	TOTAL	$496.00

Cost of Digital Tapes for Computer-Assisted Analysis Interpretation

	Item		Cost
1)	Black and White Positive Transparency, with Scale 1:1,000,000 and Band 7		$ 5.00
2)	Nine Track Tape Set, BPI = 1600		200.00
			$205.00
	Times Four Scenes Per Site[1] =	TOTAL	$820.00

Table 18. Miscellaneous Costs (Con't)

[1]A typical order for one site is four scenes. The primary scenes are the latest imagery on winter scenes. Two are chosen, a year apart. A summer scene is then chosen between the two winter scenes. A final scene is one some years back, giving historical perspective. For example, for site 4, the four scene dates were: February 25, 1975; February 2, 1976; July 10, 1975; December 16, 1972.

Source: Order form for site four, with purchase costs dated March 6, 1976.

Table 19. Travel Costs For One Site.[1]

Preliminary Field Trip:

Computer-Assisted Analysis Interpretation (Step 7)

Technician and assistant @ 2 1/2 days @ per diem of $22.00 = $110.00

Image Interpretation (Step 2)

Senior Interpreter and Assistant @ 2 1/2 days @ per diem of $22.00 = $110.00

Field Check:

Computer-Assisted Analysis Interpretation (Step 18)

Technician and Assistant @ 2 1/2 days @ per diem of $22.00 = $110.00

Image Interpretation (Step 5)

Senior Interpreter and Assistant @ 2 1/2 days @ per diem of $22.00 = $110.00

[1] The travel time could cover a larger area than the 200 square miles representing one site. The degree of homogeneity of the area would influence the amount of traveling necessary.

Table 20. Miscellaneous Cost: Scene and Scribe Coat Enlargement In Image Interpretation.[1]

Enlarge portion of LANDSAT scene to scale of 1:125,000 from scale of 1:1,000,000		$2.80/Scene
Enlarge scribe coat sheet to scale of 1:24,000 from scale of 1:125,000		$23.00/Scene
	Total	$25,80/Scene

[1]This work is done by the Automation Division (D-19), Texas Department of Public Highways and Transportation.

Source: Bill Hupp, Texas Natural Resources Information System.

Table 21. Miscellaneous Costs: Image Interpretation, Drafting Costs for One Scene.

Step	Labor	Materials	Print	Total
3	$56.58	$6.00		$62.58
7	9.43		$6.00	15.43
				$78.01

Table 22. Miscellaneous Costs: Data Display, Commercial Costs of Hard Copy, Color Display for Computer-Assisted Analysis and Image Interpretation Maps.

		Number of Classes Identified	Approximate Area In Square Mile	Scale	Approximate Map Size	Number of Copies	Cost
Computer-Assisted Analysis Map	(1)	23	200	1:125,000	10"x10"	1	$ 560.00
	(2)	23	200	1:125,000	10"x10"	100	682.00
	(3)	23	200	1:125,000	10"x10"	2,400	1,248.00
	(4)	23	4,000	1:125,000	42"x41"	1	1,750.00
	(5)	23	4,000	1:125,000	42"x41"	100	3,113.00
	(6)	23	4,000	1:125,000	42"x41"	3,500	3,859.00
Image Interpretation Map	(1)	23	200	1:125,000	10"x10"	1	208.00
	(2)	23	200	1:125,000	10"x10"	100	330.00
	(3)	23	200	1:125,000	10"x10"	2,400	896.00
	(4)	23	4,000	1:125,000	38"x42"	1	1,772.00
	(5)	23	4,000	1:125,000	38"x42"	100	3,135.00
	(6)	23	4,000	1:125,000	38"x42"	2,500	3,981.00

Source: Seiscom Delta, Inc., Houston, Texas.