REMOTE SENSING OF THE COASTAL APPLICATIONS TEST SITE--

TEST SITE 1: ECONOMIC AND ACCURACY EVALUATION OF MAPPING TECHNIQUES

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1.0 INTRODUCTION

1.1 Scope of study

This evaluation of mapping techniques was prepared as part of the Texas Applications System Verification and Transfer (ASVT) project, which is a joint effort of the Texas Natural Resources Information System (TNRIS) Task Force and the National Aeronautics and Space Administration (NASA). The goal of the ASVT project, as described by McCulloch and McKain (1978), is to develop a Texas Natural Resources Inventory and Monitoring System (TNRIMS). The TNRIMS is designed "to assist agencies of the State of Texas in carrying out their statutory responsibilities in the areas of natural resources and the environment" (Finley and Baumgardner, 1981b, p. 2). This study evaluates the use of one component of the TNRIMS, the Remote Sensing Information Subsystem (RSIS), in its developmental state between March and August 1981.

The project study area is part of the Coastal Applications Test Site (CATS) (fig. 1), one of five test sites in Texas included in the ASVT project. All test sites were selected to sample the wide variety of land cover/land use categories in the state. The coastal test site was chosen for this evaluation of the RSIS according to (1) state agency needs for information on coastal wetlands, (2) availability of personnel with experience in mapping coastal areas, (3) access to supplementary land cover/land use data, and (4) diversity of land cover/land use types in the area.

1.2 Objectives of study

As set forth in the research plan for this study, the "objective of this... analysis is to compare the cost and accuracy of map production using existing methods [of interpretation of aerial photographs] with map production [from digital Landsat data] using the Remote Sensing Information Subsystem (RSIS)" (Finley and Baumgardner, 1981a, p. 1). Interpretation of aerial photographs

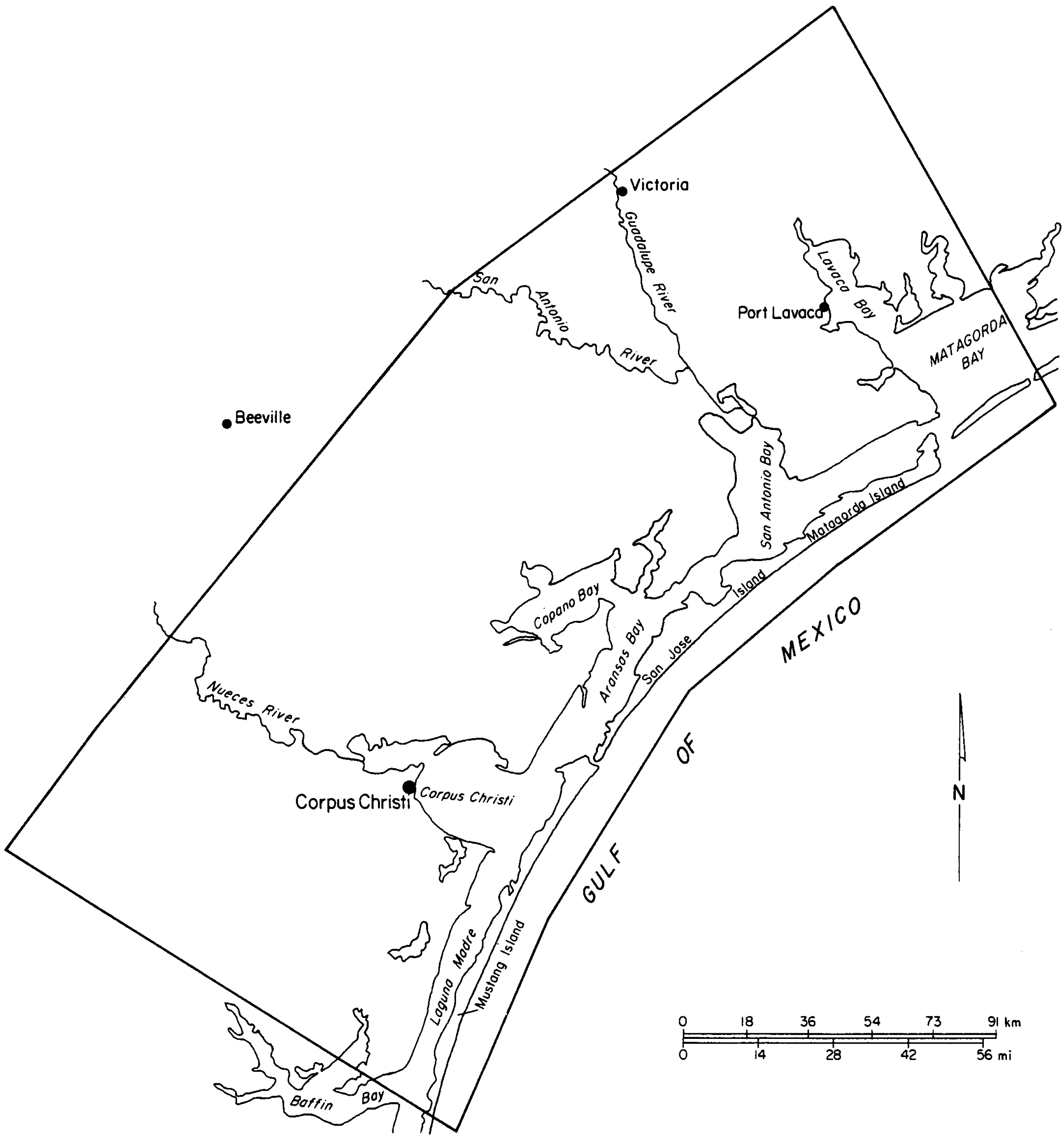

Figure 1. Coastal Applications Test Site boundaries (test site I).

included delineating map units on overlays of transparent, stable-base film. Each line-boundary map was scribed, and one full-size photographic copy was hand-colored. Digital Landsat data were interpreted with RSIS, a digital processing system that operates in a semi-interactive manner with the interpreter. Data were displayed on a cathode-ray-tube (CRT) screen, and photographic prints of the digital data display were produced with a Matrix 4007 color camera system.

A series of maps was generated from each data source at scales compatible with U.S. Geological Survey (USGS) topographic maps. Maps derived from aerial photographs were produced at scales of 1:250,000, 1:125,000, and 1:24,000. Maps based on digital Landsat data were produced at scales of 1:250,000, 1:125,000, and 1:48,000. Land cover/land use interpretation from both aerial photographs and digital Landsat data was based on the Anderson classification system (Anderson and others, 1976) modified for the Texas coast (table 1) (Finley, 1979a). The costs examined in this report include materials, labor, and equipment necessary to produce working copies of maps. Costs for producing multiple copies of maps are not included. Computer costs reflect the price that would be charged to another state agency by TNRIS. Some items, such as topographic maps, are available at no charge to state agencies and are not included in the cost analysis, although they are mentioned in the text. Accuracy of maps produced during the study was determined by comparison of independent interpretations of aerial photographs by several scientists. Specific final products were not field checked because personnel verifying the interpretations already had considerable field experience in the study area, and extensive field data were collected contemporaneously with Landsat overpasses. The computer-assisted analysis of digital Landsat data is detailed to familiarize the reader with the developmental techniques and the computer facilities of RSIS as of August 1981

Table 1. Land cover and land use classification system for the Texas Coastal Zone. Modified from Finley (1979a).

LEVEL I CATEGORIES	LEVEL II CATEGORIES	LEVEL III CATEGORIES
1 Urban or built-up land	11 Residential	131 Oil and gas fields
	12 Commercial and services	171 Made land
	13 Industrial	
	14 Transportation, communications and utilities	
	15 Industrial and commercial complexes	
	16 Mixed urban or built-up land	
	17 Other urban or built-up land	
2 Agricultural land	21 Cropland and pasture	241 Irrigated fields
	22 Orchards, groves, vineyards, nurseries, and ornamental	242 Non-irrigated fields
	23 Confined feeding operations	
	24 Other agricultural land	
3 Rangeland	31 Herbaceous rangeland	311 Vegetated dunes
	32 Shrub and brush rangeland	312 Vegetated barrier flat
	33 Mixed rangeland	
4 Forest land	41 Deciduous forest land	431 Oak woodland
	42 Evergreen forest land	
	43 Mixed forest land	
5 Water		
6 Wetland	61 Forested wetland	621 Topographically low marsh
	62 Nonforested wetland	622 Topographically high marsh
		623 Tidal flat
		624 Seagrasses and algal flats
		625 Vegetated dredge spoil
7 Barren land	71 Dry salt flats	731 Dunes
	72 Beaches	732 Dredge spoil (barren)
	73 Sandy areas other than beaches	
	74 Bare exposed rock	
	75 Strip mines, quarries, and gravel pits	
	76 Transitional areas	
	77 Mixed barren land	

as a means of comparison with conventional mapping methods from aerial photographs.

In addition to the primary objectives of cost and accuracy analysis, this study describes RSIS capabilities for analyzing digital data (in its present, developmental state) and serves as a basis for enhancing and improving that system in the future. Currently, RSIS can combine information from many sources, such as digital data bases, aerial photographs, and topographic maps. However, for this study, RSIS-derived products were generated from digital Landsat data only.

1.3 Coastal Applications Test Site

The Coastal Applications Test Site (CATS) (fig. 1) covers the Texas coast from Matagorda Bay on the north to Baffin Bay on the south and extends inland from the coast about 160 km (100 mi). The maps of this area, which were derived from aerial photographs obtained as part of this study, are outlined in figure 2 and are listed in table 2. This test site was chosen because previous work in the area using Landsat imagery indicated that the diversity of land cover/land use types would provide a useful test of the RSIS mapping capabilities (Finley, 1979b). Additionally, environmental geologic mapping by the Bureau of Economic Geology (Brown and others, 1976; McGowen and others, 1976) and color and color-infrared aerial photographs acquired by NASA facilitated verification of interpretation of the Landsat data.

Map boundaries that were derived from digital Landsat data are shown in figures 3 and 4. These areas were chosen, in part, because the General Land Office of Texas requested that digital Landsat data be used to map coastal wetlands in these areas. Time constraints prevented us from using Landsat data to map the entire area previously mapped from aerial photographs (fig. 2). As a result, mapping based on Landsat data was limited to the areas shown in figures 3 and 4.

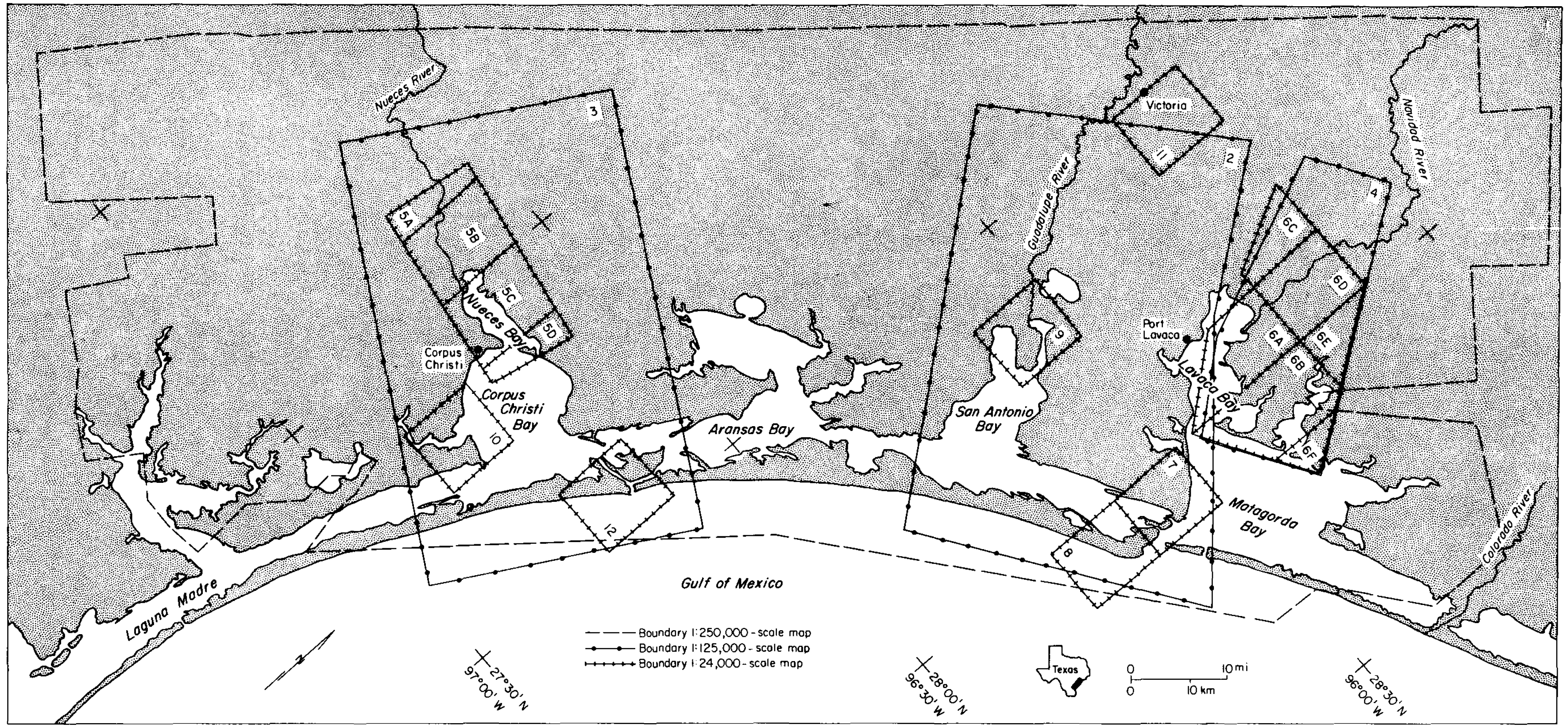

Figure 2. Study area, showing where maps were derived from aerial photographs. Numbers refer to table 2.

Table 2. Area of maps derived from aerial photographs.

Map mumber*		Land area (mi²)
	Scale 1:250,000	
1		6,398
	Scale 1:125,000	
2		**
3		998
4		307
	Total	1,305
	Scale 1:24,000	
5A		48.7
5B		75.4
5C		47.6
5D		11.3
6A		37.2
6B		48.9
6C		34.0
6D		63.5
6E		26.0
6F		6.6
7		31.2
8		13.4
9		42.3
10		32.6
11		**
12		***
	Total	518.7

* Map number refers to figure 2.
** Map not completed.
*** Practice map, time not recorded.

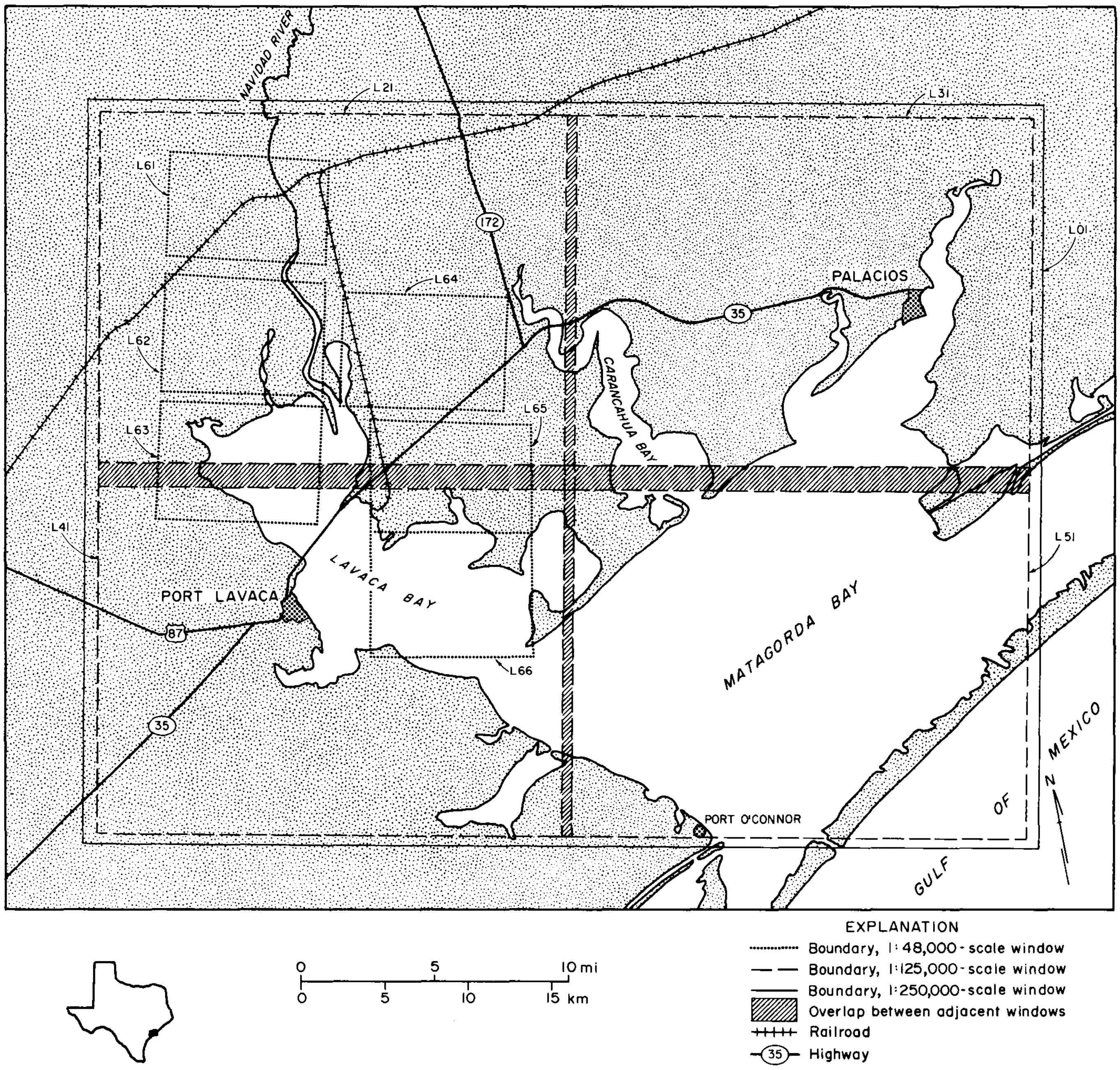

Figure 3. Lavaca Bay study area, showing where maps were derived from digital Landsat data. ISOCLS processing is done once for the entire 1:250,000-scale window, and the statistics are retained for classification of the smaller windows. Note that windows L51 and L66 are mostly water, which reduces sample size during accuracy checking.

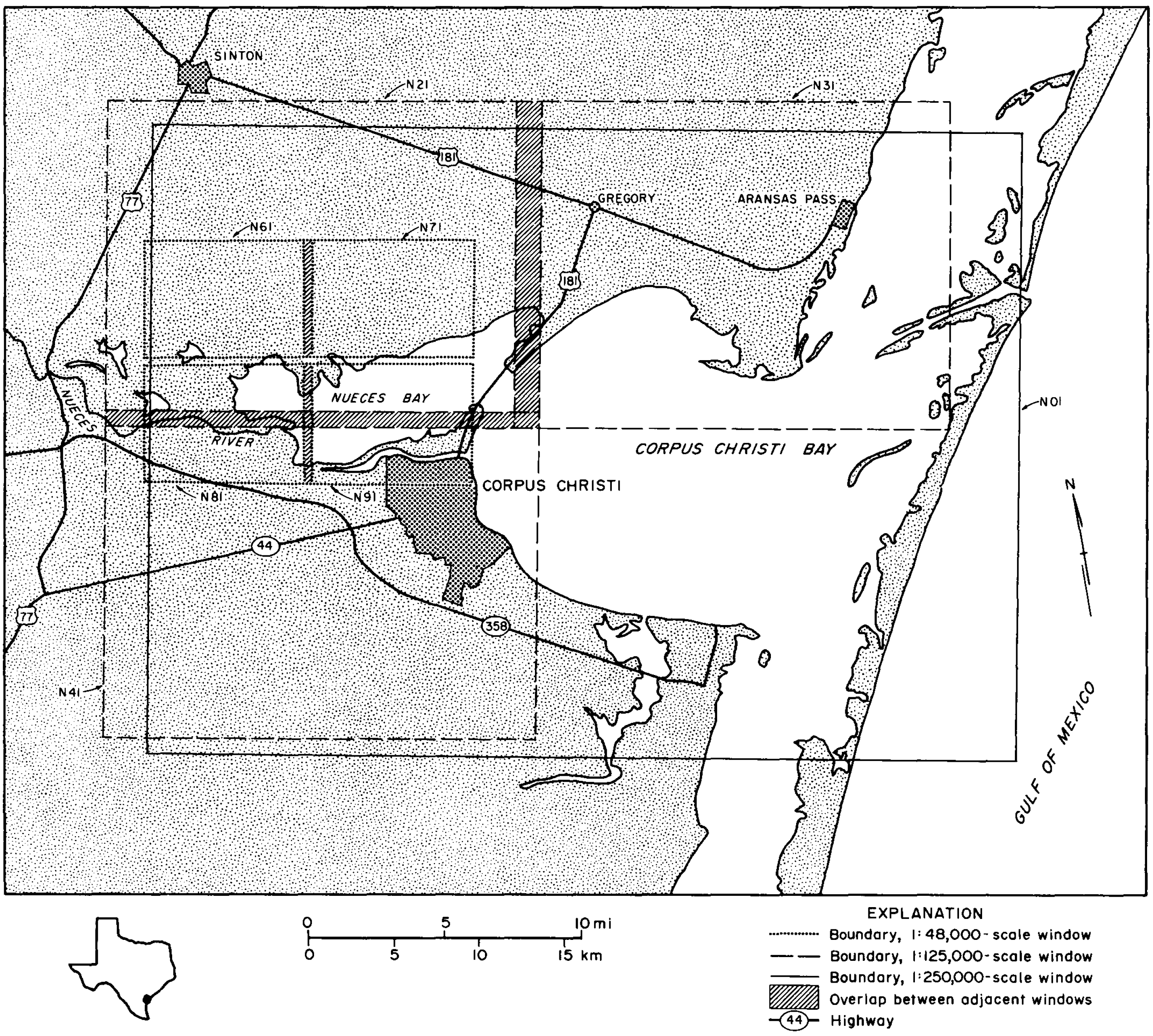

Figure 4. Nueces Bay study area, showing where maps were derived from digital Landsat data. No window south of N31 was examined because clouds covered much of the area in the Landsat data. Note that window N91 is mostly water. The land area for sampling during accuracy checking is thereby reduced.

1.4 Benefits of cost and accuracy analysis

The analyses in this report allow the reader to compare the cost and accuracy of land cover/land use maps generated by two methods: (1) conventional interpretation of aerial photographs, and (2) computer-assisted interpretation of digital Landsat data using RSIS as configured in August 1981. However, other methods of analyzing Landsat data, such as supervised rather than unsupervised classification of radiance data, may produce results different from those presented here, and capabilities of the RSIS may change and render the results in this report obsolete.

One goal of this study has been to determine the mapping method most appropriate to a particular need. The choice of a method depends on cost, desired accuracy of the product, time necessary to generate the product, availability of properly trained personnel, access to computers, and access to optical equipment, such as stereoscopes.

Product names are used in this report only for descriptive purposes. No endorsement of a product or company is implied or expressed by the use of these names.

2.0 MAPPING FROM AERIAL PHOTOGRAPHS

This section of the report describes the aerial photographs used, the equipment used for interpretation, and the costs of interpretation of aerial photographs. Following the presentation of mapping costs is a description of the methods used to assess the accuracy of the maps generated. The results of the accuracy analysis concludes this section.

2.1 Aerial photographs used

Color-infrared aerial photographs at a scale of 1:120,000 were interpreted to produce maps at scales of 1:250,000; 1:125,000; and 1:24,000. U.S. Geological Survey (USGS) topographic maps were used as map bases for extracting cultural and geographic features. Classification of land cover and land use followed the system by Anderson and others (1976) modified for use in the Texas coastal zone (table 1) (Finley, 1979a). The photographs were interpreted at Level I for the 1:250,000-scale maps, at Level II for the 1:125,000-scale maps, and at Level III for the 1:24,000-scale maps.

2.2 Equipment used

Optical equipment used for mapping from aerial photographs included: (1) Bausch and Lomb 515-95 Stereoscope mounted on a Richards MIM-1 light table, and (2) Bausch and Lomb Stereo Zoom Transfer Scope fitted with Richards reel brackets (one pair).

2.3 Equipment capabilities

2.3.1 Bausch and Lomb 515-95 Stereoscope

The Bausch and Lomb 515-95 Stereoscope was used for stereoscopic viewing of photographic transparencies or prints (9- by 9-inch [23- by 23-cm]). Two sets of oculars provide a 10X or up to a 20X stereo view of the photographs being studied. The stereoscope is mounted on a Richards MIM-1 light table.

2.3.2 Richards MIM-1 light table

The Richards light table has an illuminated viewing stage on which film is positioned for scanning and viewing. Attached to either end of the table are reel brackets that hold rolls of film transparencies, and film may be moved across the viewing field for easy access. The table may be used for individually cut frames that are placed on the table below the stereoscope and then manually maneuvered for stereo viewing. The 1:125,000-scale maps were the only ones to be made using this light table and stereoscope. The photographs (1:120,000 scale) sufficiently matched the scale of the base map (1:125,000 scale) so that they could be compared directly without enlargement. Therefore it was not necessary to use the Bausch and Lomb Stereo Zoom Transfer Scope.

2.3.3 Bausch and Lomb Stereo Zoom Transfer Scope

The Bausch and Lomb Stereo Zoom Transfer Scope (ZTS) enables an operator to view two materials, such as a map and a photograph, in superposition. The instrument can enlarge, stretch, and rotate a photograph to obtain a best fit with a map. The instrument consists of an illuminated viewing screen for photographic transparencies and a stereoscope for viewing a photograph and a map simultaneously. Lighting is controlled by foot pedals. The lights may be switched on and off to allow either the photo or the map or both to be viewed during interpretation and data transfer, thus leaving the analyst's hands free for drawing.

Film on rolls was used for this project. A pair of Richards reel brackets helped to roll the film across the field of view. Roll film (uncut) can only be viewed monoscopically on the ZTS because the distance between viewing areas is fixed and does not match the distance between frames on uncut rolls.

Maps scaled at 1:250,000 as well as 1:24,000 were interpreted using this equipment, utilizing the zoom (enlarging) adjustment to match the scales of the photographs (1:120,000) and the base maps (1:24,000 and 1:250,000).

2.4 Costs

Costs for interpretation of aerial photographs were separated into the following categories: (1) materials, (2) labor, (3) equipment use, and (4) other costs (tables 3 through 5). Costs were calculated on the basis of cost-per-square-mile of land (table 2). The time used to produce maps listed in table 2 was used to determine the map production rate (land area/time) at a given scale. Then the map production rate was used to determine a cost-per-unit-area for all component costs. These costs were used to calculate the expense of a standard map covering only land area (tables 3 through 5) at a scale compatible with USGS topographic maps. However, this study is based on a specific combination of staff, data, and equipment. Any generalization of these results of cost analysis to other situations must account for changes in these three variables.

Table 3. Cost analysis for generating a 1:250,000-scale map of 8,604 mi^2 (22,200 km^2) of land area (approximately one USGS 2-degree sheet) using aerial photographs.

		Percent
Materials		
EPA color-infrared photographs: 336 frames @ $15.00 ea	$5,040.00*	
mylar (24- by 36-inch [61- by 91.4-cm])	2.95	
scribe coat (24- by 42-inch [61- by 106.7-cm])	8.17	
matte print (24- by 36-inch [61- by 91.4-cm])	2.87	
supplies (map pencils, Rapidograph pen, tape, etc.)	+ 20.00	
	5,073.99	82
Labor (see table 7 for calculation of rates)		
Research Scientist Associate II @ $0.003/$mi^2$ x 8,604 mi^2	25.81	
Research Assistant I @ $0.09 /$mi^2$ x 8,604 mi^2	774.36	
Cartographic Technician II @ $0.03 /$mi^2$ x 8,604 mi^2	+ 258.12	
	1,058.29	17
Equipment use (see table 10 for calculation of rates)		
Bausch and Lomb Stereo Zoom Transfer Scope		
Richards reel brackets for 9-inch photo rolls (1 pair)		
hours of equipment use necessary for map: 8,604 mi^2 ÷ 88.5 mi^2/hr = 97.2 hr		
equipment cost to generate map: 97.2 hr @ $0.65/hr =	63.18	
	63.18	1
TOTAL	$6,195.46	100%

Total cost/mi^2 = $0.72/$mi^2$

*Acquisition of commercially available photographs would cost $2,577 if bought in complete rolls at $3 per frame. These complete rolls would contain 859 frames. Total materials cost would be reduced to $2,610.99, and the total cost per square mile would be reduced to $0.43/$mi^2$. The average price per frame for the 336 frames actually used would be $7.67. See Section 2.4.1 for further explanation.

Table 4. Cost analysis for generating a 1:125,000-scale map of 2,151 mi^2 (5,550 km^2) of land area using aerial photographs.

Materials		Percent
EPA color-infrared photographs: 75 frames @ $15.00 ea	$ 1,125.00*	
mylar (24- by 36-inch [61- by 91.4-cm])	2.95	
scribe coat (24- by 42-inch [61- by 106.7-cm])	8.17	
matte print (24- by 36-inch [61- by 91.4-cm])	2.87	
supplies (map pencils, Rapidograph pen, tape, etc.)	+ 20.00	
	1,158.99	46
Labor (see table 7 for calculation of rates)		
Research Scientist Associate II @ $0.07/$mi^2$ x 2,151 mi^2	150.57	
Research Assistant I @ $0.35/$mi^2$ x 2,151 mi^2	752.85	
Cartographic Technician II @ $0.20/$mi^2$ x 2,151 mi^2	+ 430.20	
	1,333.62	53
Equipment use (see table 10 for calculation of rates)		
Richards light table		
Bausch and Lomb Zoom 95 Stereoscope		
hours of equipment use necessary for map: 2,151 mi^2 ÷ 28.8 mi^2/hr = 74.7 hr		
equipment cost to generate map: 74.7 hr @ $0.47/hr =	35.11	
	35.11	1
TOTAL	$ 2,527.72	100%

Total cost/mi^2 = $1.17/$mi^2$

*It is not economical to purchase complete rolls of film for an area this size. The cost per frame of film used would then be higher than $15.00.

Table 5. Cost analysis for generating a 1:24,000-scale map of 61.7 mi^2 (159 km^2) of land area (approximately one USGS 7.5-minute quadrangle) using aerial photographs.

		Percent
Materials		
EPA color-infrared photographs: 3 frames @ $15.00 ea	$ 45.00*	
mylar (24- by 36-inch [61- by 91.4-cm])	2.95	
scribe coat (24- by 42-inch [61- by 106.7-cm])	8.17	
matte print (24- by 36-inch [61- by 91.4-cm])	2.87	
supplies (map pencils, Rapidograph pen, tape, etc.)	+ 20.00	
	78.99	13
Labor (see table 7 for calculation of rates)		
Research Scientist Associate II @ $1.02/$mi^2$ x 61.7 mi^2	62.93	
Research Assistant I @ $4.23/$mi^2$ x 61.7 mi^2	260.99	
Cartographic Technician II @ $3.06/$mi^2$ x 61.7 mi^2	+ 188.80	
	512.72	84
Equipment use (see table 10 for calculation of rates)		
Bausch and Lomb Stereo Zoom Transfer Scope		
Richards reel brackets for 9-inch photo rolls (1 pair)		
hours of equipment use necessary for map: 61.7 mi^2 ÷ 2.5 mi^2/hr = 24.7 hr		
equipment cost to generate map: 24.7 hr @ $0.65/hr	16.06	
	16.06	3
TOTAL	$ 607.77	100%

Total cost/mi^2 = $9.85/$mi^2$

*It is not economical to purchase complete rolls of film for an area this size. The cost per frame of film used would then be higher than $15.00.

Although the availability of remote sensing data changes from one area to another, in this study, the aerial photographs and the Landsat data were considered available for purchase at standard costs. In this way, cost comparisons were made with fewer assumptions regarding cost of data acquisition. If it were necessary to fund an aerial survey of an area, the costs of the aerial photographs would be higher than those used here (Harwood and others, 1977).

2.4.1 Materials

Material costs included aerial photographs used in interpretation, stable-base films used for mapping, scribe-coat and matte print used for photographic reproduction of original maps, and supplies (such as pens and pencils). Topographic maps used as base maps are available to state agencies at no cost.

Aerial photographs may be obtained from a number of suppliers through TNRIS Systems Central. Photo prices used in this study were obtained from an official USGS order form for aerial photographs (appendix 1). The cost of photographs depends on the source and the number of photographs purchased. If several complete rolls are purchased, the cost per frame is substantially reduced, even though more photographs may be bought than can be used. Color-infrared photographs used in a study of coastal wetlands currently underway at the Bureau of Economic Geology were purchased in complete rolls from the U.S. Environmental Protection Agency (EPA) for $3 per frame, rather than the standard $15 per frame (W. A. White, personal communication, October 2, 1981).

Prices of photographs used in this study are based on the standard $15 per frame for color photographs. Usually photographs are not commercially available at a scale of 1:120,000 (the scale of NASA-flown photographs used in this study); thus costs were calculated assuming photographs were purchased at a scale of 1:66,000. (This is the scale of the photographs currently being used to map wetlands on the Texas coast.)

Prices for cartographic materials (for example, mylar, scribe-coat, and matte print) were obtained from a local blueprint company (tables 3 through 5).

2.4.2 Labor

Labor costs calculated for this phase of the project included salaries for one Research Scientist Associate (RSA) II, one Research Assistant (RA) I, and one Cartographic Technician (CT) II. Basic requirements for the classification of a Research Scientist Associate II are a master's degree with major course work in the field of assignment or a bachelor's degree with two years' experience. For the classification of a Research Assistant I, the basic requirements are a bachelor's degree with major course work in the field of assignment. A Cartographic Technician II must have (1) completed high school with courses in mechanical drawing, (2) three to five years of cartographic drafting experience, and (3) knowledge of the use and care of cartographic and photogrammetric tools and equipment.

For accounting purposes, mapping from aerial photographs is divided into 8 tasks (table 6), described below. Weekly log sheets are kept by each worker to document time spent on each step of map development (appendix 2). Task 0, map base preparation, involves transferring significant cultural and topographic features from a USGS topographic map to the stable-base film for use as a base map by the photointerpreter. Task 1, the study of supporting materials, entails reviewing other maps and additional ancillary data of the area being mapped. Task 2, interpretation of photographs, involves delineating land cover/land use categories on the stable-base film. Task 3, checking interpretation, is done by someone other than the person who did task 2. Task 4, map cleanup and annotation, includes making the map legible for the cartographic technician. Task 5, scribing, includes the manual transfer of map data onto a mylar sheet by tracing. Task 6 is checking the scribe sheet. Task 7, preparing the final work

Table 6. Tasks involved in mapping from aerial photographs.

Task number	Task description
0	Map base preparation
1	Study of supporting materials
2	Interpretation of photographs
3	Checking interpretation
4	Map clean-up and annotation
5	Scribing
6	Checking scribe sheet
7	Preparing final work copy

copy, entails hand-coloring the map according to a color code that assigns a different color to each category in table 1. Tasks 0 through 2, 4, 6, and 7 are done by the Research Assistant I, task 3 is done by the Research Scientist Associate II, and task 5 is done by the Cartographic Technician II.

2.4.2.1 Salaries

Salaries were taken from the base pay scale for these positions at The University of Texas at Austin, February 1981. The hourly wages for these positions are:

Research Assistant I	$5.24
Research Scientist Associate II	9.50
Cartographic Technician II	7.26

2.4.2.2 Rates of map production

Rates of map production were calculated by individual task number (table 7). Cumulative rates were calculated (1) for all tasks performed by the same person on maps of the same scale, and (2) for all tasks on maps of a given scale. Data from more than one map are included in these calculations except for the map at 1:250,000-scale (table 2).

Table 7. Labor costs per square mile to map from aerial photographs. This is a composite of all maps generated from aerial photographs for this project. Only land areas are included in the area measurements. See table 6 for explanation of tasks.

Scale	Task	Area (mi^2)	Time (hr)	Rate for task (mi^2/hr)	Applicable salary for task*	Labor cost ($/$mi^2$)
1:250,000	0	6,398	8.75	731	1	.007
	1	6,398			1	Data unavailable
	2	6,398	70.25	91	1	.06
	3	6,398	2	3,199	2	.003+
	4	6,398	6.25	1,024	1	.005
	5	6,398	26.5	241	3	.03+
	6	6,398	1.25	5,118	1	.001
	7	6,398	18.75	341	1	.02
Cumulative	0, 1, 2, 4, 6, 7	6,398	105.25	61	1	.09+
	all tasks	6,398	133.75	48	-	.123**
1:125,000	0	1,305	8.5	154	1	.03
	1	1,305			1	Data unavailable
	2	1,305	35.75	37	1	.14
	3	1,305	9.5	137	2	.07+
	4	1,305	15.25	86	1	.06
	5	1,305	36	36	3	.20+
	6	1,305	1	1,305	1	.004
	7	1,305	25.25	52	1	.10
Cumulative	0, 1, 2, 4, 6, 7	1,305	85.75	15	1	.35+
	all tasks	1,305	131.25	10	-	.62**
1:24,000	0	519	33	15.7	1	.33
	1	519			1	Data unavailable
	2	519	152	3.4	1	1.54
	3	519	56	9.3	2	1.02+
	4	519	19	27.3	1	.19
	5	519	219	2.4	3	3.06+
	6	519	12	43.3	1	.12
	7	519	201	2.6	1	2.02
Cumulative	0, 1, 2, 4, 6, 7	519	417	1.24	1	4.23+
	all tasks	519	692	.75	-	8.28**

+ = Labor costs used in tables 3-5
** = Labor costs used in table 32

* 1 = Research Assistant I $5.24
  2 = Research Scientist Associate II $9.50
  3 = Cartographic Technician II $7.26

Map production rates (mi^2/hr) were calculated only for land areas (table 2). Water areas were not considered part of the mapped area because they were not separated into land cover/land use classes by the photointerpreters. Land area on each map was measured using a Keuffel and Esser Company Compensating Polar Planimeter. The rate of map production for a given task was computed by dividing the total land area by the time required for that task.

The cumulative mapping rate (mi^2/hr) decreased 79 percent (from 48 to 10 mi^2/hr) from the 1:250,000-scale map to the 1:125,000-scale maps (table 7). This was primarily a result of an 80 percent decrease in the amount of land area mapped, because the time required to produce the map decreased 2.5 hours (table 8).

However, the mapping rate decreased 92 percent (from 10 to 0.75 mi^2/hr) from the 1:125,000-scale maps to the 1:24,000-scale maps primarily because of the large increase in time required to produce the maps. Mapping time increased 427 percent while the mapped land area decreased only 60 percent. Tasks 2, 5 and 7 account for 475 hours of the 560.75-hour increase in map production time (table 8). Task 2 (photointerpretation) required more time at Level III than at Level II because of the increased detail required for interpretation. The time required to do tasks 5 and 7, scribing and hand-coloring the maps, required time proportional to the amount of detailed interpretation done in task 2.

These relations do not apply to the 1:250,000-scale and 1:125,000-scale maps. On the 1:125,000-scale map, time spent on task 2 decreased by 34.5 hours, while time spent on tasks 5 and 7 increased by 9.5 and 6.5 hours, respectively (table 8). The decrease in time spent on photointerpretation may be caused by two factors: (1) a more experienced photointerpreter produced the

Table 8. Changes in time (ΔT) spent on individual tasks in mapping from aerial photographs. See table 6 for list of tasks.

	Scale: 1:250,000		1:125,000			1:24,000		
Task	T_1(hr)	%	T_2(hr)	%	ΔT*(hr)	T_3(hr)	%	ΔT**(hr)
0	8.75	6.5	8.5	6.5	-0.25	33.0	4.8	+24.5
2	70.25	52.5	35.75	27.3	-34.5	152.0	22.0	+116.25
3†	2.0	1.5	9.5	7.2	+7.5	56.0	8.1	+46.5
4	6.25	4.7	15.25	11.6	+9.0	19.0	2.8	+3.75
5††	26.5	19.8	36.0	27.4	+9.5	219.0*	31.6	+183.0
6	1.25	1.0	1.0	0.8	-0.25	12.0	1.7	+11.0
7	18.75	14.0	25.25	19.2	+6.5	201.0	29.0	+175.75
0,1,2,4,6,7•	105.25	78.7	85.75	65.3	-19.5	417.0	60.3	+331.25
Total	133.75	100.0	131.25	100.0	-2.5	692.0	100.0	+560.75

†Performed by the Research Scientist Associate II
††Performed by the Cartographic Technician II
•Performed by Research Assistant I
*Relative to 1:250,000-scale map (Level I)
**Relative to 1:125,000-scale map (Level II)

Table 9. Typical rates of map production using aerial photographs for areas that include at least 30-percent water.

Quadrangle name	Map number*	Land area (mi^2)	Water area (mi^2)	% Water	Mapping hours**	Map production rate (mi^2/hr)
Oso Creek	10	32.59	30.91	48.7	53.75	1.18
Austwell	9	42.27	21.23	33.4	39.25	1.62
Pass Cavallo SW	8	13.44	50.06	78.8	22.75	2.79
Port O'Connor	7	31.22	32.28	50.8	32.75	1.94

*Refers to figure 2
**Does not include scribing (task 5)

1:125,000-scale maps, and (2) map and photo scales are almost the same for the 1:125,000-scale maps.

2.4.2.3 Map production in areas with large amounts of surface water

Because water may cover a sizeable part of an area to be mapped in some regions, the following calculations were made. Four 1:24,000-scale quadrangle maps containing significant areas of water were mapped (fig. 2, maps 7, 8, 9, 10). Land and water areas were measured, and table 9 lists typical rates of map production that can be expected for areas that include at least 30-percent water. Calculations for rates of map production in table 9 were based on the total area (land and water) of map.

Map production rates for areas with at least 30-percent water area (table 9) are 1.6 to 3.7 times higher than for maps at the same scale (1:24,000) with no water (table 7). This increase in the square mile per hour ratio results from the increase in mapped area that occurs when water is included and classified only at Level I.

Map production rates for the Oso Creek and Port O'Connor USGS 7.5-minute quadrangle maps differ considerably even though both have similar percentages of area covered by water (48.7 percent and 50.8 percent) (table 9). The Oso Creek area included a highly urbanized zone and was more difficult to classify. Thus, mapping time was greater owing to the analyst's longer decision-making process, and a lower mapping rate resulted from a more complex map area. Mapping rates for any area are subject to variation, because interpreters work at different speeds, and there are often varying numbers and types of land cover/land use categories.

2.4.2.4 Labor cost per square mile

Labor cost per square mile was calculated for each task involved in mapping from aerial photographs at each map scale (table 7). Labor cost (dollars/mi^2) was computed by dividing the salary of the individual performing the task by the map production rate described in Section 2.4.2.2. Cumulative costs were derived for (1) all tasks performed by the same person on maps of the same scale and (2) all tasks on maps at the same scale. These figures were used to compute labor costs (tables 3 through 5) and to compare with cumulative labor costs of Landsat-based mapping.

Labor cost per square mile was highest at all scales for the Research Assistant I. This person's work (tasks 0, 1, 2, 4, 6, 7) constituted between 60 and 78.7 percent of total time spent on map production from aerial photographs (table 8). Labor cost per square mile was least for the Research Scientist Associate II. This person's work amounted to only 1.5 to 8 percent of total time spent on mapping from aerial photographs.

The cumulative labor cost per square mile increased proportionally with map scale (table 7), resulting from the decrease in the cumulative mapping rate (Section 2.4.2.2). The increase in labor cost per square mile from the scale of 1:250,000 ($0.12) to the scale of 1:125,000 ($0.62) resulted from the sizable decrease in map area. However, the increase in labor cost per square mile from the scale of 1:125,000 ($0.62) to the scale of 1:24,000 ($8.28) resulted more from a fivefold increase in the cumulative time required to produce the maps at that scale than from a 60-percent decrease in map area (table 7).

Records were not kept for time spent studying supporting materials (task 1) for any of the various scale maps; therefore data were unavailable for any calculation of rates for this task. It seems likely that the time required for task 1 would be similar whether using aerial photographs or Landsat imagery.

2.4.3 Equipment expense

Equipment expense is the most difficult cost to assess in this project (table 10). Equipment used for mapping from aerial photographs must be purchased; it is not available for lease. However, one can rent a computer or buy time on a computer system, so the equipment cost can be far less for computer-assisted data analysis than for mapping from aerial photographs. Because of this, any comparison between equipment costs for mapping from aerial photographs and for computer-assisted mapping is somewhat misleading. On the other hand, if the equipment necessary for mapping from aerial photographs is already on hand, then the costs calculated in table 10 cannot be entirely attributed to one project. The costs for the purchase of optical equipment might be offset by their resale at the end of the study, but the market for such a transaction is unknown and therefore not figured into this comparison.

The costs of equipment used for photointerpretation were computed by dividing the purchase price of the equipment by the lifetime of the equipment

Table 10. Costs and usage rates for equipment used to map from aerial photographs. See table 6 for list of tasks.

Scale	Area viewed (mi^2)	Total time spent (hr), tasks 2 and 3	Usage rate (mi^2/hr)	Equipment used
1:250,000	6,398	72.3	88.5	+A
1:125,000	1,305	45.3	28.8	+B
1:24,000	519	207.2	2.5	+A

Equipment used	Total cost (Jan. 1981)	Lifetime (yrs)	Equipment cost/yr	Annual equipment use (work hr/yr)*	Cost/hr of use
+A	$12,980.00	10	$1,298.00	2,000	$.65
+B	9,475.00	10	947.50	2,000	.47

*50 work wk/yr x 40 hr/work wk = 2,000 hr/yr

+A = Bausch and Lomb Stereo Zoom Transfer Scope @ $12,800.00
Richards reel brackets for 9-in photo rolls (1 pair) @ 180.00
$12,980.00

+B = Richards light table Model No. MIM-2-231100 @ $6,875.00
Bausch and Lomb Zoom 95 Stereoscope @ 2,600.00
$9,475.00

(assumed to be 10 years) (table 10). The prorated annual equipment cost was then divided by the number of work-hours in a year to yield a cost per hour of use. This cost per hour of use was then used to determine the cost of equipment use for each scale of map based on aerial photographs (tables 3 through 5).

2.4.4 Other costs

Other costs incurred in interpretation of aerial photographs may include field checking and report production.

2.4.4.1 Field checking

Because field checking would cost essentially the same for either the photointerpretation or computer-assisted interpretation of digital data, this expense was not figured into the comparison.

2.4.4.2 Report production

Report production costs can be separated into (1) reproduction cost for map inserts and (2) printing and labor costs for texts. Because labor and printing costs for the text of a report about either interpretation method would be generally the same, depending upon the length and style of the manuscript, these costs were not considered in the cost comparison.

Reproduction expenses for map inserts depend entirely on the size of the map. For example, color separation for a 10- by 12-inch (25.4- by 30.5-cm) map costs $270 and for a 23- by 24-inch (58.4- by 73.7-cm) map costs $1,000. Because the map sizes produced from the two processes described are so different, it is impossible to compare the costs of map production without distorting the cost per square mile of the maps. For this reason, cost comparisons do not include report production expenses.

2.5 Accuracy check of mapping from aerial photographs

2.5.1 Random dot method

Interpretation of aerial photographs was verified in the following manner: A grid was made containing red and black dots randomly oriented on graph paper with 10 lines per inch (2.5 cm). Dot coordinates were derived from a random number table, and dot density was two dots per square inch (0.31 dots per cm^2).

An independent checker randomly placed the grid over the map being examined and noted the classification of each area beneath a dot. A tally was kept for each dot examined (appendix 3). When the checker disagreed with an interpretation, the map was corrected, and the corrected category number was placed in the original category column at which the area was originally mapped. When checking was complete, each category column was tabulated, and a ratio between number of wrong interpretations and total number of interpretations per category was noted. Then the ratio of the total number of wrong interpretations and the total number of points examined was used to calculate the percentage error. Only the accuracy of land classifications was calculated for each map. No water classifications were checked (table 11).

2.5.2 Fitzpatrick-Lins method

In addition to calculating the accuracy of interpretation, the level of confidence in that accuracy was also determined. The following is an explanation of the method used in this study excerpted from Fitzpatrick-Lins (1980).

> Once the sample was selected, the points were examined for correctness of interpretation. The ratio, p (expressed as percent), of the number of points correct, r, to the total number of points, n, was the accuracy value for the map. As this value is the test value for comparison to the minimum standard of 85-percent accuracy, a one-tailed test is appropriate. The 95-percent one-tailed lower confidence limit for a binomial distribution is obtained from the equation (derived from Snedecor and Cochran, 1967, p. 211):
>
> $$p = \hat{p} - \left\{1.645\sqrt{\hat{p}\hat{q}/n} + 50/n\right\},$$

Table 11. Accuracy values for interpretation of aerial photographs using the random dot method. See figure 2 for location of map.

Map*	Scale	Accuracy (% correct)
1	1:250,000	76.5
3	1:125,000	97.3
4	1:125,000	75.6
5A	1:24,000	87.8
5B	1:24,000	85.1
5C	1:24,000	91.6
5D	1:24,000	96.0
6A	1:24,000	97.8
6B	1:24,000	80.1
6C	1:24,000	95.7
6D	1:24,000	88.0
6E	1:24,000	91.0
6F	1:24,000	74.3
7	1:24,000	90.3
8	1:24,000	96.3
9	1:24,000	95.3
10	1:24,000	89.3
	Average accuracy =	88.7%

*Maps 2, 11, and 12 were not checked because they were considered low priority areas for this project and thus were never completed.

where p = the accuracy of the map expressed as a percent;
$\hat{p}$ = the sample value of p or r/n expressed as a percent;
$\hat{q}$ = 100 - $\hat{p}$; and
n = the sample size.

If the p value exceeds the 85-percent criterion at the lower confidence limit, we may accept with 95-percent confidence that the maps meet or exceed the accuracy standards.

This is not to say that those maps that fall short of 85-percent accuracy at the lower confidence limit do not meet the accuracy standards, but that we have less confidence that they do. In fact, there is still a possibility that they exceed it.

Seventeen maps derived from aerial photographs were analyzed for interpretation accuracy of land areas only. Of the 17 maps, 5 were below the level of 95-percent assurance of an 85-percent accuracy (table 12). No correlation exists between map scale and accuracy of interpretation. The highest and lowest p values are from maps at a scale of 1:24,000. Neither is there any correlation between accuracy and the number of points sampled (n).

Anderson (1971) favored a minimum level of interpretation accuracy of 85 percent. He asserted that for interpretation at Levels I and II, 85- to 90-percent correct interpretation is satisfactory for land cover/land use mapping (Anderson and others, 1976). He also concluded that for regulation of land use activities or for tax assessment, greater accuracy would be required.

Twelve of the 17 maps in our study derived from aerial photographs meet or exceed this standard. Only 6 of these 17 maps have an accuracy (p) greater than 90 percent.

2.5.3 Discussion

Because three scientists examined three different interpreters' results, it may be questioned whether the maps with p values less than 85 (table 12) are uniformly below the 85-percent accuracy standard or whether the checkers' interpretation and consistency also contributed to the low accuracy value.

Table 12. Accuracy values using the Fitzpatrick-Lins (1980) method for interpreting aerial photographs (land area only).

Scale	Map number	p	p̂	n
1:250,000	1	*71.1	76.5	187
1:125,000	3	95.3	97.3	219
	4	79.8	86.4	88
Mean		87.6	91.9	154
1:24,000	5A	*84.8	87.8	358
	5B	*82.5	85.1	504
	5C	89.2	91.6	355
	5D	91.6	96.0	74
	6A	96.2	97.8	227
	6B	*76.4	80.1	342
	6C	93.3	95.7	231
	6D	85.2	88.0	400
	6E	87.2	91.0	178
	6F	*65.3	74.3	74
	7	86.8	90.3	217
	8	92.3	96.3	82
	9	92.9	95.3	256
	10	85.4	89.3	197
Mean		86.4	89.9	250
Mean of all maps		85.6	89.3	235

p = the accuracy of the map expressed as a percent

p̂ = the sample value of p or number of points correct/total number of points

n = the sample size

*Accuracy is below the level of 95-percent assurance of an 85-percent accuracy.

Conversely, because there were different checkers, there is no way to show adequately that the maps with p values greater than 85 (table 12) actually have an accuracy as high as they appear to have. Perhaps a better way to judge the accuracy of map interpretation in future projects would be to have all maps subject to two independent accuracy checks. A comparison could then be made of checking leniency (and consistency) versus mapping consistency. However, the interpreters checking maps for this project were well trained and had prior mapping experience; one individual had nearly three years of mapping experience along the Texas coast. Because of this experience, we concluded that the five maps in table 12 with p values below 85.0 are below the 85-percent accuracy standard rather than concluding that the checkers' interpretation and possible variation in consistency contributed to the low accuracy value.

3.0 COMPUTER-ASSISTED MAPPING FROM LANDSAT DATA

This section of the report describes the RSIS-based analysis of digital Landsat data. The Landsat data used, the equipment used for interpretation, the procedures used during the data interpretation, and the costs of interpretation of digital Landsat data are all examined. Following the presentation of mapping costs is a discussion of the accuracy of land cover/land use maps derived from digital Landsat data. However, the procedures described here are subject to change as the RSIS changes.

3.1 Landsat data used

Landsat computer compatible tapes (CCT's) were analyzed using the computer facilities of the TNRIS. In addition to the CCT's, a 7.3-inch (18.5-cm) false-color composite (FCC) transparency covering each study area was used to locate windows and to assist interpretation by computer analysis of the CCT. Maps were generated at scales of 1:250,000; 1:125,000; and 1:48,000 directly from the Matrix 4007 color camera system. It was impossible to generate photographic prints with the Matrix camera system at a scale of 1:24,000. However, maps at these three smaller scales have detail comparable to the maps generated from aerial photographs. Nevertheless, they cover less area because of the size of the photographic print (8- by 10-inch) produced by the Matrix camera system (tables 2 and 13).

3.2 Equipment used

Within RSIS four major pieces of equipment are required for the analysis of Landsat or other digital imagery data. These are the Univac 1100/41 computer, the Interdata 7/32 minicomputer, the Ramtek 9050 color graphic display system, and the Matrix 4007 color camera system.

3.3 Equipment capabilities

3.3.1 Univac 1100/41 computer

The Univac 1100/41 configuration with a 1004 subsystem is a general purpose, large scale, digital computer system intended for scientific data processing. The central processor has a 524,000-word (36-bit) core memory, and a 300-nanosecond instruction time. The system is operated by the Texas Department of Water Resources Computation Center and was used for most of the digital processing of Landsat data.

3.3.2 Interdata 7/32 minicomputer

The Interdata Model 7/32 minicomputer was used to drive the semi-interactive digital image analysis station. This machine is a 32-bit micro-programmed minicomputer capable of directly addressing one million bytes of memory. The graphics software for this machine was used to drive the Ramtek display system and to allow the analyst to adjust the digital display on the Ramtek system.

3.3.3 Ramtek 9050 color graphic display system

The Ramtek 9050 color graphic display system is a microprocessor-based system that displays digital image data on a color video monitor. The data

Table 13. Area of maps derived from digital Landsat data.

Window*		Land area (mi^2)
	Scale 1:250,000	
L01		586
N01		505
	Total	1,091
	Scale 1:125,000	
L21		208
L31		170
L41		172
L51		27
N21		163
N31		114
N41		205
	Total	1,059
	Scale 1:48,000	
L61		28.4
L62		32.7
L63		14.9
L64		33.0
L65		30.2
L66		4.0
N61		33.3
N71		30.3
N81		30.7
N91		17.3
	Total	254.8

*Window numbers refer to figures 3 and 4.

cover an area on the screen 512 pixels wide by 512 pixels high. The system includes a joystick that allows the analyst to move a cursor on the cathode-ray-tube (CRT) display and to aid in finding coordinates and selecting colors. The color graphic display interfaces with a keyboard for executing commands and manipulating the data displayed on the Ramtek screen.

3.3.4 Matrix 4007 camera and processor

The Matrix 4007 color graphic camera system is an instrument that produces photographs from the output of a raster scan terminal. Film media available for this system include 8- by 10-inch (20.3- by 25.4-cm) Polaroid print film, 8- by 10-inch Ektachrome transparency film, and 35-mm film. This camera was used to record images from the Ramtek display system. Because the Matrix camera uses its own flat-screen video monitor, no geometric distortion was introduced in the photographic process.

3.4 Map production procedure

In this report, production of a land cover/land use map from digital Landsat data included all the steps from obtaining and reviewing imagery to producing the Matrix camera print (table 14). Accuracy checking, task 13 of table 14, is considered separately in Section 3.6. The procedures described in Sections 3.4.1 through 3.4.10 are not the only techniques available through RSIS for analysis of digital Landsat data. Other methods are available or are currently being developed. The techniques used in this study, and described in the sections that follow, were used because the participants had experience with these techniques. Because this study was designed as a test of existing capabilities of the RSIS in an operational sense, no untried methods were used, even though they might possibly have yielded better classification results.

3.4.1 Select and review imagery

The initial stages of map production using the RSIS-based, computer-assisted analysis of Landsat data were not very different from those of mapping

Table 14. Tasks involved in mapping from digital Landsat data.

0 - Obtain, review imagery*

1 - Select scene

2 - Produce control net†

3 - Select window (coordinates)*, scale

4 - Select ISOCLS parameters

5 - Run ISOCLS†

6 - Evaluate ISOCLS statistics

7 - Assign colors

8 - Run CRLCLASS†

9 - Display on Ramtek†

10 - Analysis (color changes, etc.)†

11 - Terminate analysis, produce Matrix print*†

12 - Other, specify

13 - Accuracy checking

*Involves materials cost

†Involves computer cost

from aerial photographs. The user must review the Landsat imagery (black-and-white and false-color composite transparencies) to determine its utility, select a study area, and choose the scale of map to be generated.

Users can determine which Landsat imagery is more useful to them by consulting the Texas Natural Resources Information System (TNRIS). The user specifies the location of the study area, the time period during which Landsat overpasses occurred, the minimum quality of acceptable imagery, and the maximum percentage of cloud cover that is acceptable. A computer-generated list of all Landsat imagery that meets these specifications is given to the user, who then selects the pertinent imagery.

In this study the initial standards used were image quality 8 (the highest) in all 4 bands, and 0-percent cloud cover. Because the available imagery lacked this quality, the October 1, 1978, image (ID No. 21348-16030), which has 20-percent cloud cover and image quality 8 in all bands except 5, was used for the Nueces Bay test site (fig. 4). Vertical and oblique aerial photographs and ground-truth data were collected in conjunction with the October 1, 1978 Landsat overpass. Clouds obscured much of Corpus Christi Bay and prevented analysis of the southeast quadrant of that test site. The October 1, 1978 image for the Lavaca Bay test site (ID No. 21348-16023) (fig. 3) has 10-percent cloud cover, which did not affect image analysis. All bands have data of image quality 8.

3.4.2 Produce control network

After a Landsat scene was selected, a control network was produced to remove geometric distortion from the Landsat data. These geometric distortions, which vary with each scene, are removed by fitting the data to a network of ground control points. The control network was generated once for an entire Landsat scene. A transformation matrix was used to resample the data into a map coordinate system. Data for calculating this matrix were obtained by collecting ground control points within the scene; for each point, the exact scanner coordinates (line, sample) and earth coordinates (either latitude and longitude or easting and northing, measured from USGS 7.5-minute topographic maps) are recorded. Approximately 6 to 20 control points were used on each scene. The coordinates were fed into the CONTROL program, which generated the transformation matrix (fig. 5).

Because the control network is produced once for an entire Landsat scene, its cost per map decreases as the number of maps produced from a given scene increases. In the cost analysis of this study (Section 3.5), the cost of producing the control network was applied to each map, or group of maps, at a given scale made from each Landsat scene. Where more than one map was prepared at a given scale, the cost was equally divided between maps at that scale.

3.4.3 Select window

In this study, a "window" is that part of a Landsat scene that has been selected for study and display on the Ramtek CRT. The windows (figs. 3 and 4) over Lavaca and Nueces Bays were selected in this study to cover parts of the same areas covered by the mapping done from aerial photographs (fig. 2) and to fulfill data requirements regarding coastal wetlands.

3.4.3.1 Centerpoint coordinates

To select a window from the Landsat scene the analyst specified its centerpoint in terms of horizontal line and vertical sample numbers (fig. 6). The 7.5-inch (19-cm) Landsat transparencies (band 7 or false-color composite) were used with two overlays made for locating centerpoints and determining map scales of the selected windows. The line/sample overlay superimposes line and sample grids on the image with every fiftieth line and sample shown (fig. 6). The window overlay (fig. 7) has rectangles of various sizes that enclose the area covered by windows displayed at different scales on the Ramtek CRT screen. The

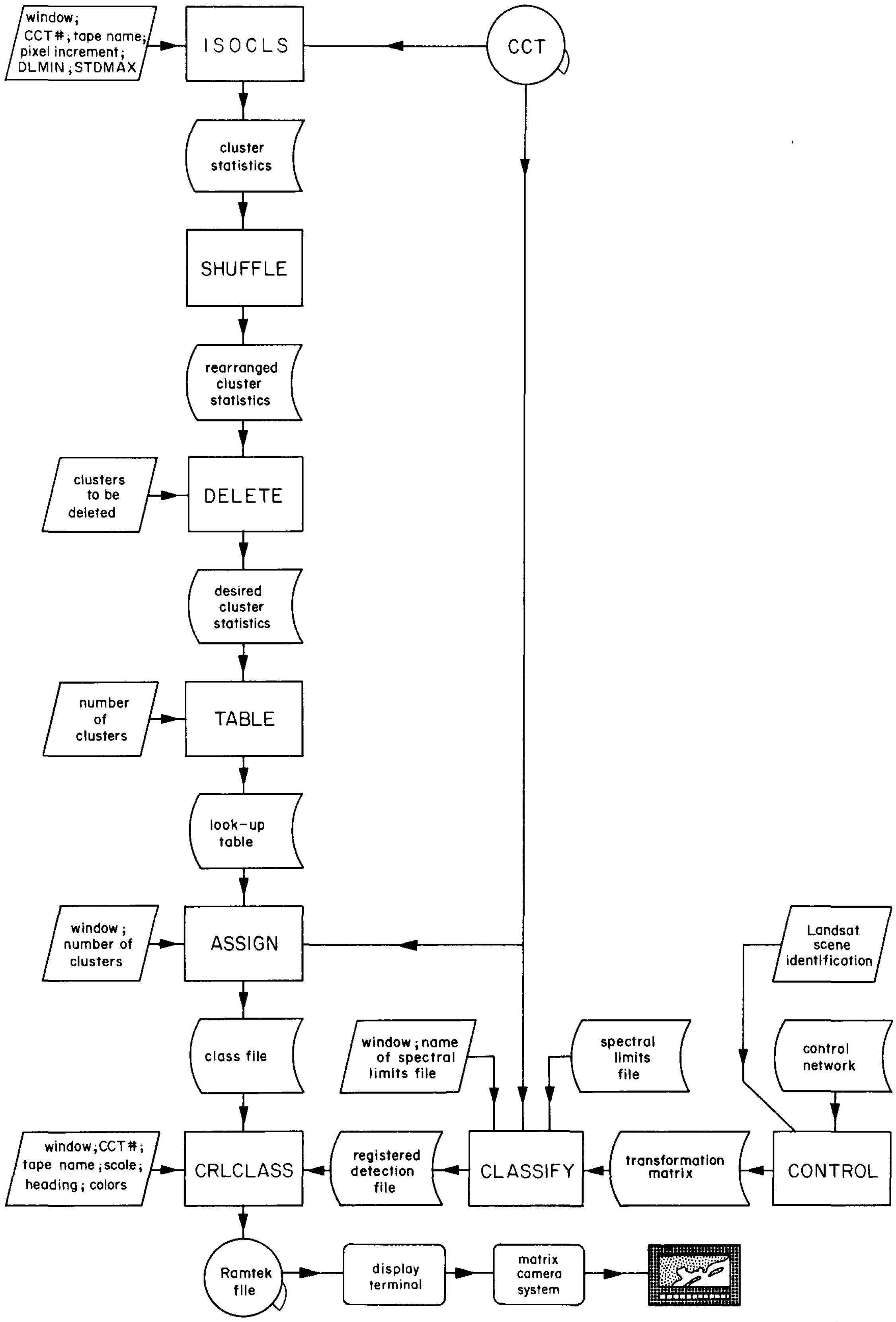

Figure 5. Flow diagram of digital Landsat data from computer compatible tape (CCT) through classification programs to output on the Ramtek CRT. Processing is usually interrupted after ISOCLS to examine cluster statistics and assign colors to clusters.

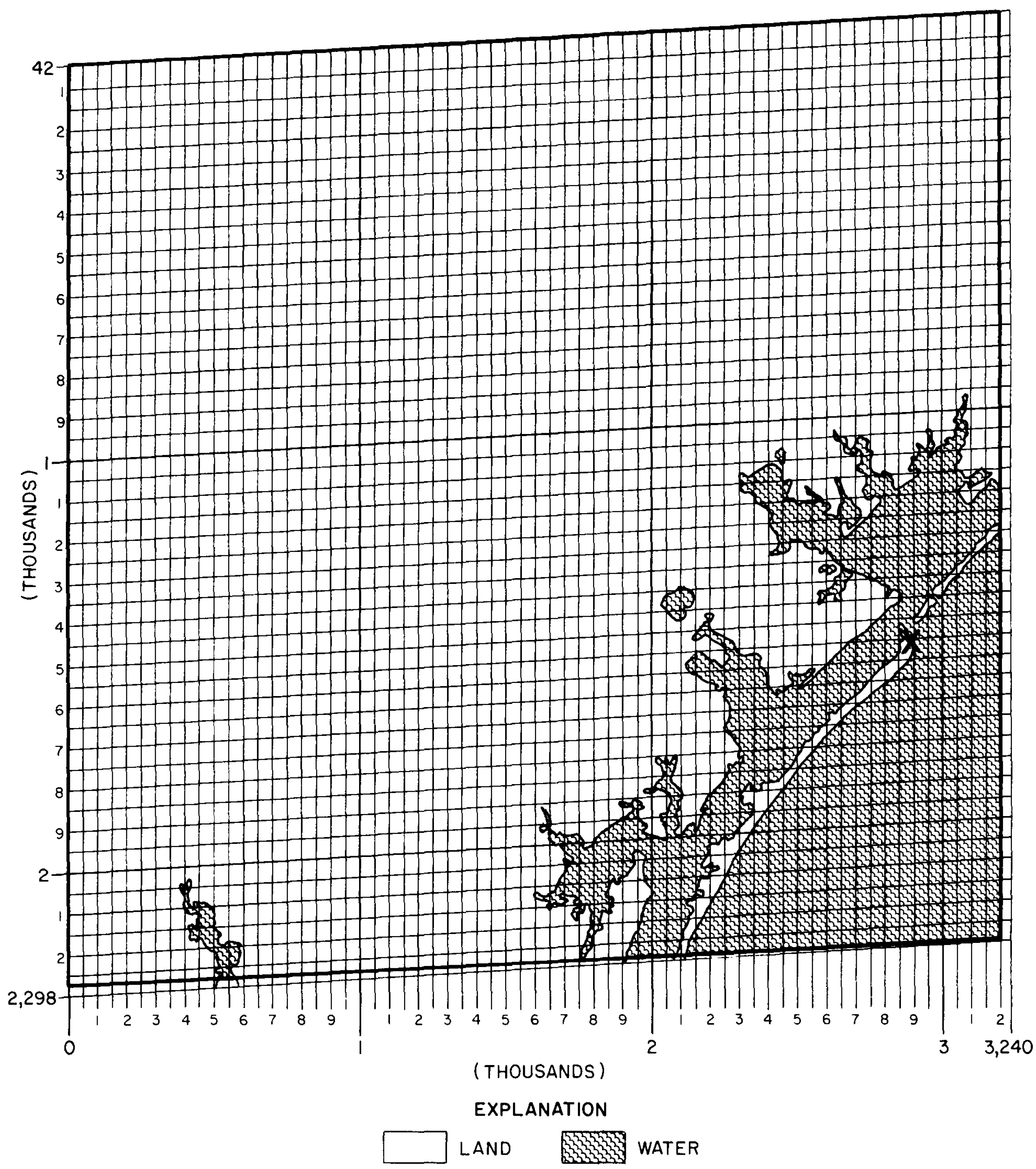

Figure 6. Schematic representation of line/sample grid overlain on 7.5-inch (19-cm) (scale 1:1,000,000) Landsat transparency. Line numbers (vertical axis) begin with 42 and end with 2,298. Sample numbers (horizontal axis) begin with 0 and end with 3,240. At the X (lower right), line/sample coordinates are about 1,560/2,880. This overlay is used in conjunction with the window overlay (fig. 7) to specify windows on Landsat scenes.

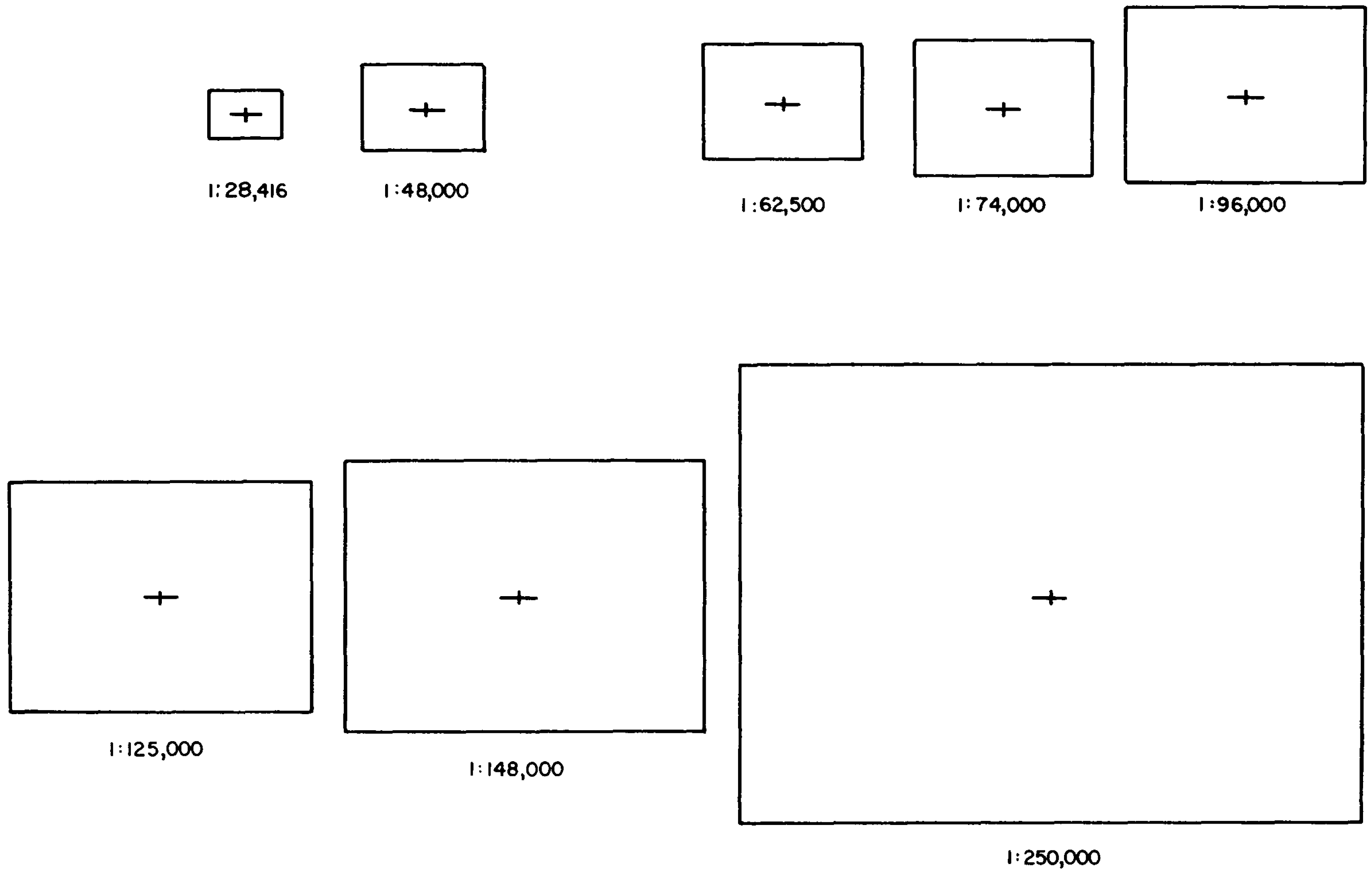

Figure 7. Window overlays used with 7.5-inch (19-cm) (scale 1:1,000,000) Landsat transparencies for assigning window centerpoints and scales. The scale below each window is the scale of the image on the Ramtek CRT.

centerpoint of each rectangle on the window grid is shown on the window overlay, and when used in conjunction with the line/sample overlay, the line and sample coordinates of the centerpoint of the window can be determined and used to specify the window to be analyzed.

3.4.3.2 Scale

The scale of the window must also be specified (fig. 7). The scale of an image on the Ramtek CRT screen is 1.69 times larger than the scale of the 8- by 10-inch photographic print produced by the Matrix camera. For example, an image at a scale of 1:148,000 on the Ramtek CRT screen is reproduced at a scale of 1:250,000 (148,000 x 1.69 ≅ 250,000). In this study, the first image produced for each study area (L01 and N01) was at a photographic print scale of 1:250,000 (figs. 3 and 4). Subsequent prints were made at scales of 1:125,000 and 1:48,000.

No prints were generated at a scale of 1:24,000 because the Matrix camera could not make a print at that scale directly from Landsat data at the time of this study. In addition, limited resolution of the original Landsat data reduces precision of large-scale prints. Consequently, no land cover/land use map derived from Landsat data was available at a scale of 1:24,000. This was a significant disadvantage of the RSIS configuration.

3.4.4 Select parameters, run ISOCLS program

In this study the ISOCLS program was used to classify radiance data of the Landsat scenes. The ISOCLS program is an unsupervised classification routine that organizes radiance data into a set of clusters (fig. 5). The following description only briefly explains the use of the program; details of the operation of the ISOCLS program are available elsewhere (Finley and Baumgardner, 1980).

3.4.4.1 ISTOP and NMIN

The user defines the values of four parameters that control the number and size of clusters generated: ISTOP, NMIN, DLMIN, and STDMAX. ISTOP determines the number of iterations the ISOCLS program performs. NMIN specifies the minimum number of pixels a cluster can have before it is split up and the pixels are distributed among the remaining clusters.

3.4.4.2 DLMIN and STDMAX

DLMIN and STDMAX were more effective than ISTOP and NMIN in determining the number of clusters generated by the ISOCLS program. The number of clusters affects the resolution of the image. DLMIN specifies the minimum distance allowed between clusters in four-dimensional radiance space. If the distance between two clusters is less than DLMIN after a given iteration, the pixels in the two clusters will be combined into one cluster. STDMAX defines the maximum acceptable standard deviation of the radiance values of a cluster. If the standard deviation of a cluster exceeds STDMAX, that cluster will be split into two clusters. The analyst uses trial and error until a set of parameters is found that generates an acceptable number of clusters.

After the optimum parameters were determined for a window, the statistics generated by ISOCLS were used by the RSIS maximum likelihood classifier (ELLTAB) to produce a classified data set. Within this data set each pixel, which had been represented by a set of four radiance values, is now represented by a single class number. A classified data set was produced in this manner for each of the two windows, L01 and N01; these data sets contained all the data used to generate Ramtek displays for the larger windows (L01 and N01) and the small windows (for example, L61 to L66) within the large windows (figs. 3 and 4). But in the cost analysis, the total cost of running ISOCLS is assigned to each map scale.

3.4.5 Determine optimum number of clusters

Previous work in the Texas coastal zone indicated that the optimum number of clusters generated by the ISOCLS program for a coastal area is approximately

16 (Baumgardner and Finley, 1980). Using fewer clusters tended to blur distinctions between recognizable land cover/land use types. More clusters made mapping difficult because the colors become indistinguishable, especially when all pixels of one color are widely scattered. More importantly, when many clusters are present, some clusters defined radiance values that the analyst could not associate with meaningful land cover/land use classes.

Because land cover/land use types may vary from window to window, it is impossible to use the same ISOCLS parameters and to achieve the same results uniformly. The total number, as well as the size, of clusters and standard deviations and mean radiance values of each cluster will vary even when ISOCLS parameters are not changed. Analysts depend on their experience in similar regions to provide an estimate of suitable ISOCLS parameters. If the analysts have no experience in a similar region, then the amount of personnel and computer time used will increase as the number of ISOCLS trials increases.

Even in similar regions, past experience may be of limited use. Although the Lavaca and Nueces Bay areas contain similar land cover/land use types, the same ISOCLS parameters did not generate equal numbers of clusters; this is a result of different radiance value distributions in the two different Landsat scenes. Input parameters of ISTOP=11, NMIN=100, DLMIN=5.0, and STDMAX=3.8 generated 10 and 18 clusters for Lavaca and Nueces Bay areas, respectively. Consequently, different input parameters were used for each study area to generate the optimum number of clusters.

3.4.6 Evaluate ISOCLS statistics

3.4.6.1 Channel 2 versus channel 4 plot

The clusters generated by the ISOCLS program were evaluated by plotting mean radiance values of channels 2 and 4 (MSS bands 5 and 7) (tables 15 and 16) for each of the clusters (figs. 8 and 9). The data points can be roughly

Table 15. Data for clusters in L01 window. Mean radiance values for channels 2 and 4 are plotted in figure 8. Standard deviations greater than 4.0 for cluster 17 preclude its classification with the computer programs.

		MEAN RADIANCE				STANDARD DEVIATION			
		Channel				Channel			
Cluster	Points in Cluster	1	2	3	4	1	2	3	4
1	1,235	22.53	24.71	26.42	10.08	1.91	2.18	2.77	2.27
2	117	32.53	41.78	48.32	20.05	2.13	2.59	2.73	2.01
3	4,621	16.69	12.88	6.33	0.20	1.55	1.60	1.35	.49
4	85	20.48	18.38	57.82	29.18	1.96	2.34	3.14	2.39
5	2,279	20.22	18.93	9.97	0.69	2.29	2.17	2.09	.84
6	2,292	18.36	17.66	39.49	19.27	1.27	2.07	1.88	1.19
7	214	25.69	27.71	50.19	23.26	1.68	2.72	2.81	1.63
8	914	18.18	17.90	31.65	14.23	1.39	2.34	2.57	1.75
9	900	21.53	22.83	36.78	16.58	1.56	2.10	2.10	1.45
10	1,566	18.75	17.97	44.51	21.70	1.09	1.71	1.61	1.04
11	1,239	21.73	21.94	43.60	20.51	1.26	1.57	1.94	1.15
12	1,098	18.36	18.91	21.59	8.22	1.68	2.50	2.77	1.80
13	791	25.10	28.86	33.11	13.56	1.60	2.13	2.20	1.51
14	306	28.78	34.70	39.17	16.34	1.83	2.46	2.83	1.87
15	555	20.51	19.65	48.76	23.55	1.60	1.97	1.50	1.09
16	415	25.07	27.90	43.13	19.32	1.44	2.18	2.18	1.39
17	118	44.94	55.66	63.86	25.94	16.69	18.87	15.52	5.73
18	143	29.46	35.21	48.00	21.04	1.62	2.01	3.08	1.59
19	201	20.21	18.97	52.15	26.25	1.81	2.29	1.25	1.14
	Total 19,089								

Table 16. Data for clusters in N01 window. Mean radiance values for channels 2 and 4 are plotted in figure 9. Standard deviations greater than 4.0 for clusters 2, 4, 7, and 16 preclude their classification.

		MEAN RADIANCE				STANDARD DEVIATION			
		Channel				Channel			
Cluster	Points in Cluster	1	2	3	4	1	2	3	4
1	744	37.87	36.98	30.23	8.76	2.97	3.05	3.76	1.72
2	175	41.95	49.89	54.32	20.54	2.90	3.05	4.42	2.50
3	4,111	24.81	19.24	11.05	1.66	2.74	2.89	2.88	1.19
4	451	65.44	74.72	69.45	24.37	6.36	5.83	4.66	2.41
5	3,458	26.60	26.38	25.41	8.78	3.38	2.48	3.50	2.68
6	1,760	24.87	23.99	45.50	20.48	2.25	2.97	3.56	2.06
7	278	102.69	117.14	111.96	40.82	12.87	9.97	11.53	6.13
8	2,703	27.91	30.38	32.98	12.82	1.76	2.37	2.40	1.35
9	646	30.43	32.58	48.21	20.26	1.79	2.87	2.68	1.78
10	263	52.40	58.15	53.77	18.47	3.55	2.84	3.83	2.38
11	1,485	23.27	22.78	35.41	15.13	1.84	2.35	3.33	2.07
12	455	44.98	45.93	39.88	12.53	2.56	2.74	3.16	1.54
13	532	35.29	40.87	44.32	16.96	2.19	2.57	2.98	1.79
14	133	37.20	41.48	53.56	21.32	2.64	2.48	3.13	1.86
15	260	60.18	66.04	57.68	19.43	3.61	3.17	3.53	2.01
16	286	79.83	92.44	85.07	29.93	4.49	5.75	5.29	2.39
17	1,070	30.07	33.25	40.01	16.19	1.90	3.11	2.24	1.50
18	249	50.88	54.20	46.33	15.20	2.83	2.88	2.27	1.38
	Total 19,089								

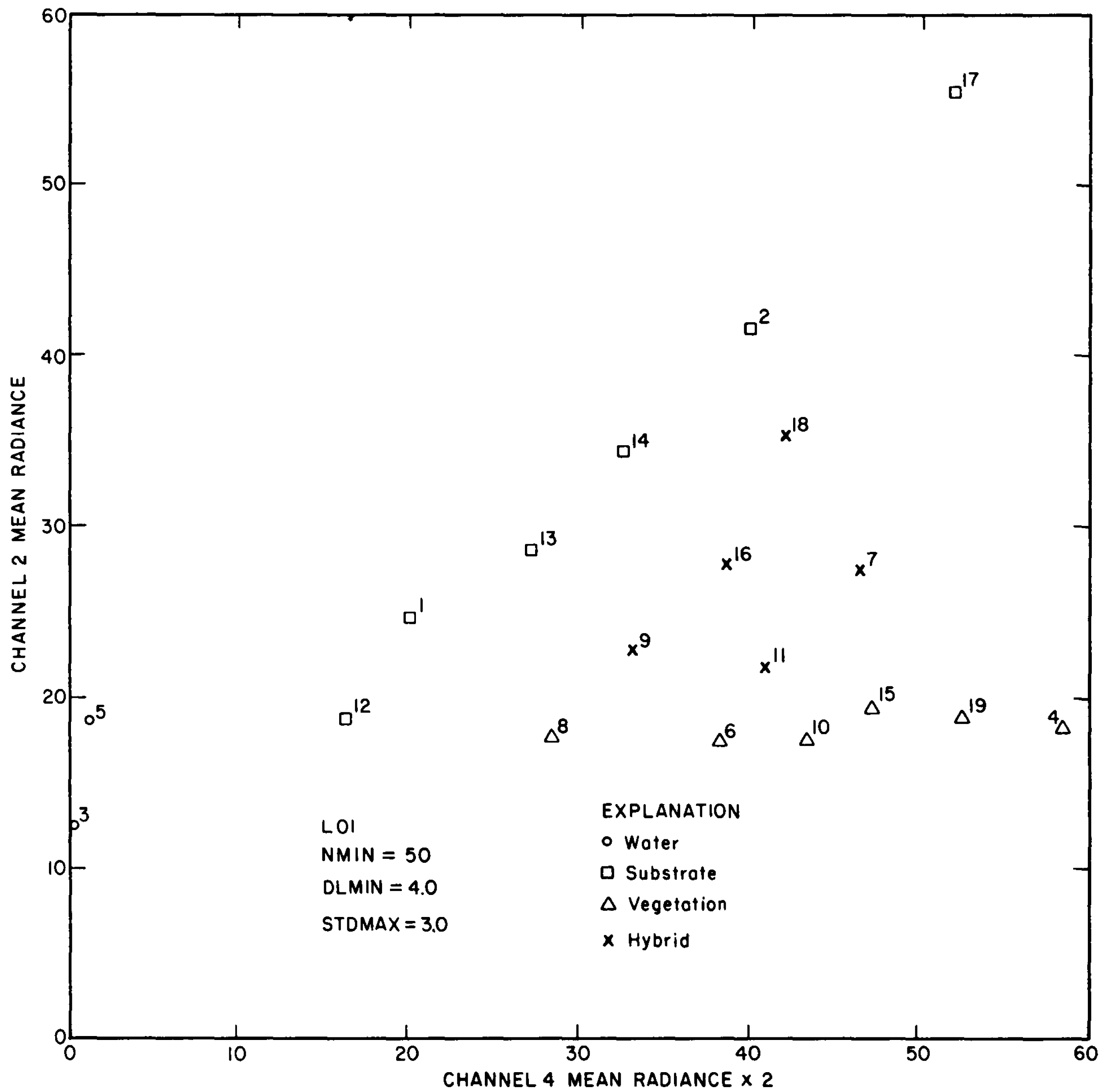

Figure 8. Mean radiance values of Landsat data in channels 2 and 4 (Landsat MSS bands 5 and 7) for the L01 window (fig. 3). NMIN, DLMIN, and STDMAX are parameters used in ISOCLS processing. Compare figure 9.

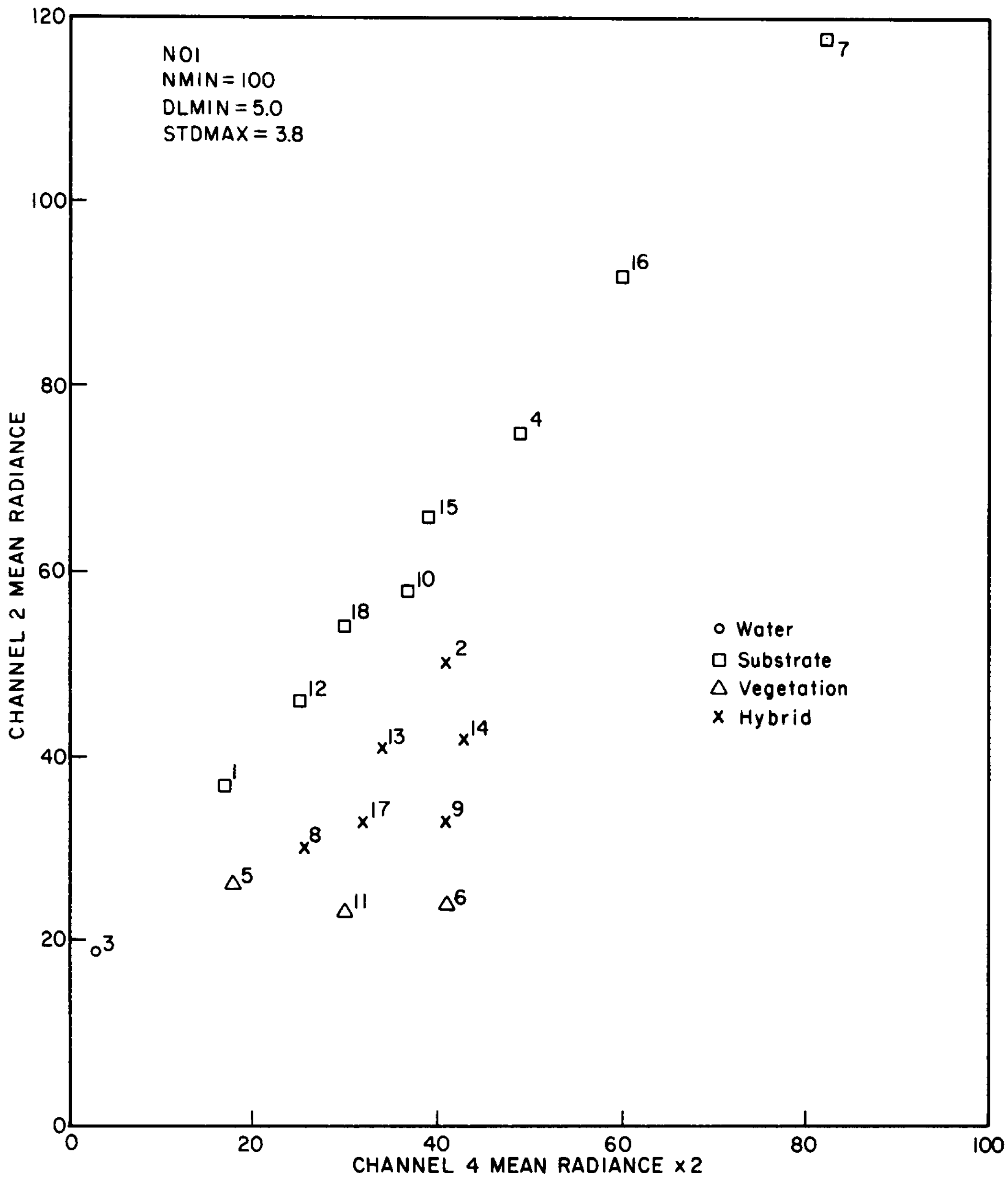

Figure 9. Mean radiance values of Landsat data in channels 2 and 4 (Landsat MSS bands 5 and 7) for the N01 window (fig. 4). NMIN, DLMIN, and STDMAX are parameters used in ISOCLS processing. Compare figure 8.

categorized according to their positions on the graph (E. Weisblatt, personal communication, 1980). Water clusters have low values, typically less than 10 in channel 4 and less than 20 in channel 2 (figs. 8 and 9). Vegetation clusters have uniformly low values in channel 2 and various values in channel 4. As a result they are aligned subparallel to the channel 4 axis (figs. 8 and 9). Clusters that define substrate have variable values in channels 2 and 4 and thereby describe a line at some angle to both axes. Clusters between vegetation and substrate lines have been previously named "hybrid" clusters (Baumgardner and Finley, 1980) and probably represent a mixture of vegetation, bare substrate and, occasionally, water.

3.4.6.2 Undesirable number of clusters

If the clusters were distributed into water, vegetation, and substrate groups, then analysis proceeded. If, however, there were too few or too many clusters to define these groups clearly, or the number of hybrid clusters appeared excessive, the ISOCLS program was rerun with different parameters supplied by the user. When a suitable number of clusters distributed into recognizable groups was produced, a color was assigned to each cluster.

3.4.6.3 Unclassified pixels

At times clusters may have standard deviations higher than 4.0 (tables 15 and 16). These are too large to be used in the production of a look-up table (fig. 5) by the ELLTAB program. These clusters were defined as unclassified and were all assigned the same color. Under optimal conditions, unclassified pixels were kept at about 5 percent of the total to minimize loss of information.

3.4.7 Assign colors

Colors were assigned to each cluster according to the user's estimation of what they represented. For example, blues were reserved for water clusters and bright colors were used for clusters with high radiance values in one or both channels. In this study, colors were chosen from a standardized 62-color "menu" (table 17).

Clusters that plot close to one another were assigned dissimilar colors so that they might be distinguished on the Ramtek CRT screen. These color assignments were only tentative and could be revised when the image was displayed on the Ramtek CRT. This procedure is discussed further in Section 3.4.9.3.

3.4.8 Run CRLCLASS

The program CRLCLASS was the last in a series of eight programs beginning with ISOCLS, set up in a Univac runstream in a batch mode (fig. 5). CRLCLASS accepted user input, such as window and color assignments and scale. It generated a tape file with the class data in a format that was displayed on the Ramtek CRT (the display terminal in fig. 5). Further details are available in Finley and Baumgardner (1980).

3.4.9 Display on Ramtek CRT and generate map

The image data were displayed on the Ramtek CRT screen after the CRLCLASS program was run. At this point, each pixel had a color corresponding to that pixel's spectral class. Details of the display procedure have been described elsewhere (Finley and Baumgardner, 1980). When the image was displayed, the user began a semi-interactive analysis of the image.

3.4.9.1 Color changes

The colors previously assigned to each cluster can be changed at the display terminal (fig. 5), if necessary, to improve the image quality. Clusters may be changed to different colors to provide better contrast with their neighbors, or they may be lumped by assigning the same color to more than one cluster, in order to eliminate unnecessary details that obscure important land cover/land use patterns.

Table 17. Standard color menu used for assigning colors to clusters generated by ISOCLS program. Gun settings refer to 3 color guns in the Ramtek CRT. Unlabeled colors are transitional between neighboring colors.

Color No.	Gun Setting	Color Name	Color No.	Gun Setting	Color Name	Color No.	Gun Setting	Color Name
1	000015	True blue	22	000905	Dull green	43	150000	Red
2	000013		23	000704		44	110000	
3	000011		24	000503	Gray-green	45	090000	
4	000009		25	001500	Bright green	46	050000	Burgundy
5	000007		26	001100		47	030000	Red-brown
6	000005	Midnight blue	27	000700		48	150008	Hot pink
7	000003	Blue-black	28	000300	Forest green	49	110006	Light scarlet
8	000815	Light blue	29	081500	Lime green	50	090005	
9	000713	Light blue-gray	30	061100		51	050003	Magenta
10	000611		31	040700		52	150015	Mauve
11	000407		32	030500	Olive green	53	090009	
12	000305	Dark blue-gray	33	151500	Yellow	54	070007	
13	001515	Aqua	34	131300		55	050005	Lavender-mauve
14	001313		35	090900		56	080015	Lavender
15	001111		36	050500	Yellow-brown	57	060011	Light purple
16	000909		37	030300	Brown	58	040007	
17	000707		38	150800	Orange	59	030005	Dark purple
18	000505	Gray-aqua	39	130700		60	141414	Light gray
19	001508	Pale green	40	110600	Ochre	61	080808	
20	001307		41	050300	Chocolate	62	050505	Dark gray
21	001106		42	030200	Brown			

3.4.9.2 Comparison with other data sources

While the window was displayed on the Ramtek CRT the analyst examined the image and compared it with other data sources. In this study, these sources included the environmental geologic atlas of each study area (Brown and others, 1976; McGowen and others, 1976), the band 5 and band 7 Landsat transparencies, and the false-color composite of the Landsat scene from which each window was extracted. In this way the analyst tentatively defined what land cover/land use categories the clusters represented.

3.4.9.3 Photographic print (map) production

When the analyst was satisfied that the image contained the desired information, a photographic print was produced using the Matrix color graphic camera system (figs. 10 and 11). Polaroid film was used to make a color 8- by 10-inch (20.3- by 25.4-cm) print. Final adjustments in colors on the image were necessary at this stage because colors on the Ramtek CRT screen did not appear exactly the same on the Matrix camera print. The final color scheme was assigned a file name and stored for future use by means of the Interim Interactive Graphics Subsystem (IIGS) program. The color scheme was recalled later and used for other windows of the same study area.

3.4.10 Final classification of clusters

Final classification of clusters was done by overlaying the Matrix camera print with concurrent aerial photographs of the study area. NASA aircraft took the photographs during a joint low-altitude and ground-truth data collection effort that coincided with the satellite overpass on October 1, 1978. The Matrix camera print and aerial photographs were viewed at the same scale by magnifying the print.

Each cluster was classified according to the systems (table 1) proposed by Anderson and his co-workers (1976) and by Finley (1979a). In some cases,

Color no.*	Interpretation
1	barren agriculture, possibly muddy
2	barren spoil; made land; bright, barren agriculture
3	water
4	cropland
5	rangeland; shrubs
6	bar ditches; riparian vegetation; topographically high marsh, wet agricultural fields
7	mixed agriculture; mixed rangeland
8	transportation; suburban; transitional; grass/brush/rangeland
9	low marsh; wet muddy substrate
10	barren, dry agricultural fields
11	reflective, barren agricultural fields (sandy?)
12	residential; commercial; industrial; transportation
13	effluent, very turbid water

*Colors correspond to those shown in sequential order in the color bars in figure 10, and table 30, with repeated colors deleted.

1 2 3 4 5 6 7 8 9 10 11 12 13

Figure 10. Photographic prints of Lavaca Bay study area made with Matrix camera. Size is reduced to about one-fourth that of the original print used in this study. Original scale is shown below the color bar for each window. North is 11° left of vertical. For location of windows see figure 3. A. L01 window; scale ≈ 1:580,000. B. L21 window; scale ≈ 1:290,000. C. L61 window; scale ≈ 1:110,000. D. L62 window; scale ≈ 1:110,000.

Color no.*	Interpretation
1	barren sand; beach; spoil
2	cloud; industrial site
3	water
4	low marsh; irrigated agriculture; algal flat, mud flat
5	brushland; suburban
6	agricultural fields; muddy
7	urban, sparse vegetation
8	barren sand; beach; spoil
9	vigorous vegetation, trees, topographically high marsh
10	agricultural fields; transport
11	urban
12	barren sand; spoil; beach

*Colors correspond to those shown in sequential order in the color bars in figure 11 and table 31, with repeated colors deleted.

1 2 3 4 5 6 7 8 9 10 11 12

Figure 11. Photographic prints of Nueces Bay study area made with Matrix camera. Size is reduced to about one-fourth that of the original print used in this study. Original scale is shown below the color bar for each window. North is 11° left of vertical. For location of windows see figure 4. A. N01 window; scale ≈ 1:580,000. B. N21 window; scale ≈ 1:290,000. C. N61 window; scale ≈ 1:110,000. D. N71 window; scale ≈ 1:110,000.

clusters were given multiple Level II and Level III classifications. This was done where one classification did not describe all pixels of a single cluster. For example, riparian vegetation, bar ditches and topographically high marsh were all part of one cluster in the L01 window (table 18). These classifications can be differentiated on the Matrix print by their shape and location relative to other land cover/land use types (fig. 10).

3.5 Costs

Costs for computer-assisted mapping from Landsat imagery were separated into four categories: (1) materials, (2) labor, (3) equipment use, and (4) other expenses (tables 19 through 21). Costs were calculated only on the basis of cost per square mile of land area. The production time for maps listed in table 13 was used to determine the map production rate (land area/time) at a given scale. Then the map production rate was used to determine a cost per unit of land area for all component costs. These expenses were used to calculate the cost of a standard map covering only land area, at a scale compatible with USGS topographic maps (tables 19 through 21).

3.5.1 Materials

Materials used for each study area included the following: one computer compatible tape (CCT) with 1,600 bytes per inch (BPI), one 7.3-inch (18.5-cm) false-color composite (FCC) transparency, one band 5 transparency and one band 7 transparency, an environmental geologic atlas of each study area (Brown and others, 1976; McGowen and others, 1976), a minimum of six USGS topographic maps for generation of the control network (Section 3.4.2), and Polaroid color 8- by 10-inch (20.3- by 25.4-cm) print film. The topographic maps, obtained free of charge by any state agency, are not included in the cost analysis.

All Landsat imagery and computer tapes can be obtained through the TNRIS, using a USGS Landsat Standard Products order form (appendix 4). All prices for

Table 18. Interpretation of Landsat data for L01 window, on the basis of a comparison with color-infrared aerial photographs.

Cluster	Interpretation	Land cover/land use (Anderson and others, 1976; Finley, 1979a)
1	barren agriculture	21, 241
2	barren spoil; bright, barren agriculture; made land	73, 171, 732
3	water	51, 52, 53, 54
4	buildings surrounded by agricultural vegetation	21
5	(same as 3)	(same as 3)
6	rangeland	32
7	(same as 2)	(same as 2)
8	bar ditches; riparian vegetation; topographically high marsh; wet, low reflectance agricultural fields	241, 43, 622
9	mixed agriculture	21
10	(same as 6)	(same as 6)
11	suburban, transportation, transitional land, industrial boundaries	11, 12, 13, 14, 241, 76
12	topographically low marsh; wet, muddy substrate	62, 621
13	barren, dry agriculture, muddy(?)	21, 242
14	bright, barren agriculture, sandy(?)	21, 242
15	(same as 4)	(same as 4)
16	residential, commercial, industrial, transportation	11, 12, 13, 14
17	effluent, very turbid water; unclassified	15
18	(same as 2)	(same as 2)
19	(same as 4)	(same as 4)

Table 19. Cost analysis for generating a 1:250,000-scale map using Landsat-derived data covering 980 mi^2 (2,538 km^2) of land (one 8- by 10-inch [20.3- by 25.4-cm] Polaroid print).*

Materials		Percent
computer compatible tape (CCT) 1,600 BPI	$200.00	
7.3-inch (18.5-cm) positive transparency (black & white) band 5	10.00	
7.3-inch (18.5-cm) positive transparency (black & white) band 7	10.00	
7.3-inch (18.5-cm) false-color composite transparency	15.00	
Environmental Geologic Atlas of the Texas Coastal Zone	8.75	
Polaroid color 8- by 10-inch (20.3- by 25.4-cm) print film (one positive and one negative)	+ 5.30	
	249.05	32
Labor (see table 22 for calculation of rates)		
Research Scientist Associate II @ $0.16/mi^2 x 980 mi^2	156.80	
Research Scientist Associate I @ $0.04/mi^2 x 980 mi^2	39.20	
Engineering Technician III @ $0.16/mi^2 x 980 mi^2	+156.80	
	352.80	46
Equipment use		
Univac 1100/41 (see table 24 for calculation of usage rate) hours of use necessary for map of 980 mi^2 ÷ 1,390 mi^2/hr = 0.705 hr equipment cost to generate map: 0.705 hr @ $156.00/hr	109.90	
Interdata 7/32 (see table 25 for calculation of usage rate) hours of use necessary for map of 980 mi^2 ÷ 330 mi^2/hr = 2.97 hr equipment cost to generate map: 2.97 hr @ $20.00/hr	59.40	
Matrix 4007 camera and processor total cost $20,317 ÷ 10 yr life span = $2,031.70/yr x 1 yr/2,000 work hr = $1.02/hr hours necessary to produce one 8- by 10-inch (20.3- by 25.4-cm) print: 0.083 hr (approximately 5 min) @ $1.02/hr	0.08	
Bausch and Lomb Stereo Zoom Transfer Scope and Richards reel brackets (used for task 13 only) (see tables 10 and 26 for calculations) hours of use necessary for map of 980 mi^2 ÷ 227 mi^2/hr = 4.3 hr equipment cost to check map: 4.3 hr @ 0.65/hr	+ 2.80	
	172.26	22
TOTAL	$774.11	100%

Total cost/mi^2 = $0.79/mi^2

*actual map dimensions 7- by 9-inch (17.8- by 22.9-cm)

Table 20. Cost analysis for generating a 1:125,000-scale map using Landsat-derived data of 245 mi^2 (634 km^2) of land (one 8- by 10-inch [20.3- by 25.4-cm] Polaroid print).*

		Percent
Materials		
computer compatible tape (CCT) 1,600 BPI	$200.00	
7.3-inch (18.5-cm) positive transparency (black & white) band 5	10.00	
7.3-inch (18.5-cm) positive transparency (black & white) band 7	10.00	
7.3-inch (18.5-cm) false-color composite transparency	15.00	
Environmental Geologic Atlas of the Texas Coastal Zone	8.75	
Polaroid color 8- by 10-inch (20.3- by 25.4-cm) print film (one positive and one negative)	+ 5.30	
	249.05	68
Labor (see table 22 for calculation of rates)		
Research Scientist Associate II @ $.13/mi² x 245 mi²	31.85	
Research Scientist Associate I @ $.05/mi² x 245 mi²	12.25	
Engineering Technician III @ $.10/mi² x 245 mi²	+ 24.50	
	68.60	19
Equipment use		
Univac 1100/41 (see table 24 for calculation of usage rate) hours of use necessary for map of 245 mi² ÷ 1,439 mi²/hr = .170 hr equipment cost to generate map: 0.170 hr @ $156.00/hr	26.52	
Interdata 7/32 (see table 25 for calculation of usage rate) hours of use necessary for map of 245 mi² ÷ 247 mi²/hr = .99 hr equipment cost to generate map: 0.99 hr @ $20.00/hr	19.80	
Matrix 4007 camera and processor total cost $20,317 ÷ 10 yr life span = $2,031.70/yr x 1 yr/2,000 work hr = $1.02/hr hours necessary to produce one 8- by 10-inch (20.3- by 25.4-cm) print: 0.083 hr (approximately 5 min) @ $1.02/hr	.08	
Bausch and Lomb Stereo Zoom Transfer Scope and Richards reel brackets (used for task 13 only) (see tables 10 and 26 for calculations) hours of use necessary for map of 245 mi² ÷ 174 mi²/hr = 1.41 hr equipment cost to check map: 1.41 hr @ 0.65/hr	+ .92	
	47.32	13
TOTAL	$365.00	100%

Total cost/mi^2 = $1.49/$mi^2$

*actual map dimensions 7- by 9-inch (17.8- by 22.9-cm)

Table 21. Cost analysis for generating a 1:48,000-scale map using Landsat-derived data of 36 mi^2 (93 km^2) of land (one 8- by 10-inch [20.3- by 25.4-cm] Polaroid print).*

Materials		Percent
computer compatible tape (CCT) 1,600 BPI	$200.00	
7.3-inch (18.5-cm) positive transparency (black & white) band 5	10.00	
7.3-inch (18.5-cm) positive transparency (black & white) band 7	10.00	
7.3-inch (18.5-cm) false-color composite transparency	15.00	
Environmental Geologic Atlas of the Texas Coastal Zone	8.75	
Polaroid color 8- by 10-inch (20.3- by 25.4-cm) print film (one positive and one negative)	+ 5.30	
	249.05	77
Labor (see table 22 for calculation of rates)		
Research Scientist Associate II @ \$0.59/mi^2 x 36 mi^2	21.24	
Research Scientist Associate I @ \$0.22/mi^2 x 36 mi^2	7.92	
Engineering Technician III @ \$0.48/mi^2 x 36 mi^2	+ 17.28	
	46.44	15
Equipment use		
Univac 1100/41 (see table 24 for calculation of usage rates) hours of use necessary for map of 36 mi^2 @ 402 mi^2/hr = 0.090 hr equipment cost to generate map: 0.090 hr @ \$156.00/hr	14.04	
Interdata 7/32 (see table 25 for calculation of usage rates) hours of use necessary for map of 36 mi^2 @ 59 mi^2/hr = 0.61 hr equipment cost to generate map: 0.61 hr @ \$20.00/hr	12.20	
Matrix 4007 camera and processor total cost \$20,317 ÷ 10 yr life span = \$2,031.70/yr x 1 yr/2,000 work hr = \$1.02/hr hours necessary to produce one 8- by 10-inch (20.3- by 25.4-cm) print: 0.083 hr (approximately 5 min) @ \$1.02/hr	.08	
Bausch and Lomb Stereo Zoom Transfer Scope and Richards reel brackets (used for task 13 only) (see tables 10 and 26 for calculations) hours of use necessary for map of 36 mi^2 @ 37 mi^2/hr = 0.97 hr equipment cost to check map: 0.97 hr @ \$0.65/hr	+ .63	
	26.95	8
TOTAL	$322.44	100%

Total cost/mi^2 = \$8.96/mi^2

*actual map dimensions 7- by 9-inch (17.8- by 22.9-cm)

Landsat data were obtained from an official USGS order form. Prices may vary if other sources are used.

Prices of the environmental geologic atlases (Brown and others, 1976; McGowen and others, 1976) were obtained from the publications department, Bureau of Economic Geology, The University of Texas at Austin. Price of the Polaroid color film was obtained from TNRIS.

3.5.2 Labor

Labor costs for this project were calculated for an Engineering Technician (ET) III, a Research Scientist Associate II, and a Research Scientist Associate I. An Engineering Technician III from the Texas Department of Water Resources (TDWR) was responsible for the computer work necessary to derive maps from the Landsat data and is thus included in this cost analysis. Because these maps were photographically produced, a Cartographic Technician II (as reported in Section 2.4.2) was not necessary for this method of map production. Basic requirements for the classification of an Engineering Technician III are the completion of courses in surveying, geology, hydrology, engineering math, or the equivalent. For the classification of a Research Scientist Associate II, basic requirements are a master's degree with major course work in the field of assignment or two years' experience with a bachelor's degree. Basic requirement for a Research Scientist Associate I is a bachelor's degree with major course work in the field of assignment.

3.5.2.1 Salaries

The salary for the Engineering Technician III was taken from the base pay scale for that position at the TDWR, effective February 1981. Salaries for the other positions were taken from the base-pay scale for these positions at The University of Texas at Austin, February 1981. The hourly wages of these positions are:

Engineering Technician III	$7.38
Research Scientist Associate I	8.31
Research Scientist Associate II	9.50

3.5.2.2 Rates of map production

To compute labor costs per square mile it was necessary first to calculate map production rates for each of the tasks involved in the computer-assisted mapping (table 14). Weekly time sheets were kept to document each person's time on each step of map development (appendices 5 through 7). All tasks were not done at each map scale. For example, the control network was produced and the ISOCLS program was done once for each Landsat scene. However, the total cost of these tasks (2 and 4 through 7 of table 14) was assigned to each map scale, as was the total cost of the digital Landsat tape. The reason for doing this is clear: the cost of producing each set of maps at a given scale is computed independently from the cost of producing the maps at other scales of the same area. This is consistent with the cost assessment of materials used in Landsat analysis and with the cost analysis of photointerpretation.

Map production rates (mi^2/hr) were calculated for each task by dividing the total land area of all maps at a given scale by the time required to accomplish a particular task (table 22). Cumulative rates were calculated (1) for all tasks performed by the same scientist or technician on maps of the same scale, and (2) for all tasks on maps of a given scale. Rates of map production were calculated only for land areas. Water areas were not included.

In addition to the rates for individual tasks, all tasks were grouped according to the personnel who performed them, and cumulative map production rates were calculated for each scientist or technician (table 22). The map production rate for each member of the research staff was used to calculate labor costs shown in tables 19 through 21. Note that task 13 (table 22) is the only task

Table 22. Labor costs per square mile for generating maps from Landsat-derived data. This is a composite of all maps generated for this project. Only land areas are included in the area measurements. See table 14 for explanation of tasks.

Scale	Task**	Area (mi^2)**	Time (hr)	Rate for task (mi^2/hr)	Applicable salary for task*	Labor cost ($/$mi^2$)
1:250,000	0	1,091	0.23	4,743	1	0.002
	1	1,091	0.23	4,743	1	0.002
	2	1,091	12.05	91	3	0.081
	3	1,091	2.29	476	1	0.020
	4	1,091	1.08	1,010	1	0.009
	5	1,091	1.5	727	3	0.010
	6	1,091	2.0	546	1	0.017
	7	1,091	2.25	485	1	0.020
	8	1,091	10.0	109	3	0.070
	9	1,091	1.54	708	1	0.013
	10	1,091	7.66	142	1	0.067
	11	1,091	0.94	1,160	1	0.008
	13	1,091	4.8	227	2	0.04
Cumulative	0, 1, 3, 4, 6, 7, 9, 10, 11	1,091	18.22	60	1	0.16
	2, 5, 8	1,091	23.55	46	3	0.16
	all tasks	1,091	46.57	23	-	0.36
1:125,000	0	1,059	0.75	1,412	1	0.007
	1	1,059	0.74	1,431	1	0.007
	2	1,059	12.05	88	3	0.084
	3	1,059	3.53	300	1	0.032
	4	1,059	1.08	981	1	0.010
	5	1,059	1.5	706	3	0.010
	6	1,059	2.0	530	1	0.018
	7	1,059	2.25	471	1	0.020
	8	1,059	1.4	756	3	0.010
	9	1,059	0.35	3,026	1	0.003
	10	1,059	1.4	756	1	0.013
	11	1,059	2.45	432	1	0.022
	13	1,059	6.08	174	2	0.05
Cumulative	0, 1, 3, 4, 6, 7, 9, 10, 11	1,059	14.55	73	1	0.13
	2, 5, 8	1,059	14.95	71	3	0.10
	all tasks	1,059	35.58	30	-	0.28

Table 22 (con.)

Scale	Task	Area (mi^2)**	Time (hr)	Rate for task (mi^2/hr)	Applicable salary for task*	Labor cost ($/$mi^2$)
1:48,000	0	255	1.05	242.9	1	0.039
	1	255	1.04	245.2	1	0.039
	2	255	12.05	21.2	3	0.348
	3	255	5.17	49.3	1	0.193
	4	255	1.08	236.0	1	0.040
	5	255	1.5	170.0	3	0.043
	6	255	2.0	127.5	1	0.075
	7	255	2.25	113.3	1	0.084
	8	255	3.0	85.0	3	0.087
	9	255	0.34	750.0	1	0.013
	10	255	1.39	183.5	1	0.052
	11	255	1.5	170.0	1	0.056
	13	255	6.88	37.1	2	0.22
Cumulative	0, 1, 3, 4, 6, 7, 9, 10, 11	255	15.82	16.1	1	0.59
	2, 5, 8	255	16.55	15.4	3	0.48
	all tasks	255	39.25	6.5	-	1.29

**Area combined from both Lavaca Bay and Nueces Bay study areas

+ = Labor costs used in cost analysis, tables 18, 19 and 20.

* { 1 = Research Scientist Associate II: $9.50/hr
2 = Research Scientist Associate I: $8.31/hr
3 = Engineering Technician III: $7.38/hr }

performed by the Research Scientist Associate I, and therefore, it cannot be labeled "cumulative." It is, nevertheless, necessarily included in mapping rate and labor cost calculations.

The total amount of time spent on map production decreases 10.99 hours as map scale gets larger from 1:250,000 to 1:125,000; as map scale reaches 1:48,000, then map production time increases 3.67 hours (table 23). The decrease in map production time between scales of 1:250,000 and 1:125,000 is caused mostly by decreases in time spent on tasks 8 (Run CRLCLASS) and 10 (Analysis). It appears that the analyst's experience with the 1:250,000-scale map enhanced his ability to do tasks 8 and 10 for the 1:125,000-scale map.

The increase in time spent on map production at the 1:48,000-scale results principally from two tasks: 3 (Select window, scale) and 8 (Run CRLCLASS) (table 23). Together these account for 88 percent of the total increase in map production time. Unlike the decreased production time between maps at 1:250,000-scale and 1:125,000-scale, task 8 at 1:48,000-scale required more, not less, work.

The net result of these changes in map production time is that the cumulative rate of map production increases from 23 mi^2/hr (60 km^2/hr) for 1:250,000 scale to 30 mi^2/hr (78 km^2/hr) for 1:125,000 scale, then decreases to 6.5 mi^2/hr (17 km^2/hr) for 1:48,000 scale, as map scale becomes larger. These results are quite different from those obtained for conventional mapping based on aerial photographs (Section 2.4.2.2). In the case of conventional mapping, map production rates decreased steadily as map scale became larger (table 7). Furthermore, the decrease in mapping rates between 1:250,000- and 1:125,000-scale was a result of a decrease in the area mapped. For the Landsat-based maps, the increased map production rate for the same scales resulted from a 24-percent decrease in time spent on map production. The map production rate

Table 23. Changes in time (T) spent on tasks in mapping from digital Landsat data. See table 14 for list of tasks.

	Scale: 1:250,000		1:125,000			1:48,000		
Task	T_1(hr)	%	T_2(hr)	%	T*(hr)	T_3(hr)	%	T**(hr)
0	.23	0.5	.75	2.1	+.52	1.05	2.7	+.30
1	.23	0.5	.74	2.1	+.51	1.04	2.6	+.30
2	12.05	25.9	12.05	33.9	0.0	12.05	30.7	0.0
3	2.29	4.9	3.53	9.9	+1.24	5.17	13.2	+1.64
4	1.08	2.3	1.08	3.0	0.0	1.08	2.8	0.0
5	1.50	3.2	1.50	4.2	0.0	1.50	3.8	0.0
6	2.00	4.3	2.00	5.6	0.0	2.00	5.1	0.0
7	2.25	4.8	2.25	6.3	0.0	2.25	5.7	0.0
8	10.0	21.5	1.4	3.9	-8.6	3.00	7.6	+1.6
9	1.54	3.3	.35	1.0	-1.19	.34	0.9	-.01
10	7.66	16.4	1.4	3.9	-6.26	1.39	3.5	-.01
11	.94	2.0	2.45	6.9	+1.51	1.5	3.8	-.95
13†	4.8	10.3	6.08	17.1	+1.28	6.88	17.5	+.80
0, 1, 3, 4, 6, 7, 9-11††	18.22	39.1	14.55	40.9	-3.67	15.82	40.3	+1.27
2, 5, 8	23.55	50.6	14.95	42.0	-8.60	16.55	42.2	+1.60
Total	46.57	100.0	35.58	100.0	-10.99	39.25	100.0	+3.67

†Performed by Research Scientist Associate I
††Performed by Research Scientist Associate II
•Performed by Engineering Technician III
*Relative to 1:250,000-scale map
**Relative to 1:125,000-scale map

of conventional mapping decreased from scales of 1:125,000 to 1:24,000 because of a 427-percent increase in time spent. For Landsat-based mapping for map scales of 1:125,000 and 1:48,000, the comparative decrease in map production rate largely resulted from a 76-percent decrease in the mapped area.

Cumulative map production rates for Landsat-based maps can be compared with the equivalent rates for maps based on aerial photographs (tables 7 and 22). For maps at scales of 1:125,000 and 1:24,000 (or 1:48,000 for the Landsat-based maps), the computer-assisted mapping is 3.0 and 8.7 times faster, respectively. At a scale of 1:250,000, the conventional mapping is 2.1 times faster than the computer-assisted mapping from digital Landsat data.

3.5.2.3 Labor cost per square mile

Labor costs per square mile of land area mapped (dollars/mi^2) were calculated at three different map scales for each task and for each scientist or technician involved in mapping from Landsat data (table 22). Labor cost for each task was determined by dividing the hourly salary of the individual performing the task by the hourly map production rate for that task. Labor cost per square mile for each scientist or technician was computed by adding the labor costs for all tasks performed by that person. These labor costs were then used to determine labor costs for a map containing only land area (tables 19 through 21).

Total labor cost per square mile was highest ($1.29) for maps at a scale of 1:48,000 (table 22). This represents an increased cost of 4.6 and 3.6 times, relative to the 1:125,000- and the 1:250,000-scale maps, respectively. The increase in cost per square mile is caused primarily by the reduction in map area. Between scales of 1:125,000 and 1:48,000, the mapped land area decreases 76 percent, while personnel time increases only 10 percent.

If more maps at the scale of 1:48,000 were produced, the labor cost per square mile might be reduced, because the time required for tasks 2 and 4 through 7 remains the same at all scales, regardless of the number of maps produced. Therefore, if more land area is mapped, the cost per square mile for these five tasks decreases in the digital mapping procedure.

The contribution of labor costs to total cost of Landsat-based mapping decreases in dollar amount and percentage of total cost as map scale increases (tables 19 through 21). This is primarily a result of the sizeable decrease in map area, because total labor cost per square mile is highest ($1.29/mi^2) at the largest map scale (table 22). For maps based on aerial photographs, labor costs comprise an ever-larger part of total cost as map scale becomes larger (tables 3 through 5).

3.5.3 Equipment expense

Because only governmental agencies are allowed to use the RSIS, equipment/computer expenses reflect the price that TNRIS charges to other governmental agencies (tables 24 and 25). Charges for use of the Univac 1100/41 vary depending on the time of day that work is done. The first shift rate (8 a.m. to 5 p.m.) is the most expensive, and the third shift rate (12 a.m. to 8 a.m.) is the cheapest (table 24). Although both first and third shifts were used during the project, the second shift (5 p.m. to 12 a.m.) rate is used here as an estimated average rate for calculations in tables 19 through 21. The usage rate for the Univac was computed by dividing the land area of a map by the Univac time necessary to generate the map (table 24). The average rate for maps of the same scale was then used to determine the cost of using the Univac for a standard map product having only land area (tables 19 through 21). Changes in average usage rate (mi^2/hr) were primarily caused by changes in map area, not changes in computer time (table 24). Reductions in map area tend to reduce the usage rate

Table 24. Costs and usage rates for Univac 1100/41 data processing.

Computer costs

first shift (8a.m. - 5p.m.): $195/hr

second shift (5p.m. - 12a.m.): $156/hr (cost used in this analysis)

third shift (12a.m. - 8a.m.): $117/hr

Scale	Window	Land area (mi^2)		Total time +SUP sec	hr		Usage rate (mi^2/hr)
1:250,000	N01	505		1,303	.362		1,395
	L01	586	÷	1,523	.423	=	1,385
	Total	1,091		2,826	.785	Avg.	*1,390
1:125,000	N21-41	482		990	.275		1,752
	L21-51	577	÷	1,660	.461	=	1,251
	Total	1,059		2,650	.736	Avg.	*1,439
1:48,000	N61-91	112		1,056	.293		382
	L61-66	143	÷	1,230	.342	=	418
	Total	255		2,286	.635	Avg.	*402

*Usage rate used for cost analysis in tables 19, 20, and 21.

+SUP = standard unit of processing

Table 25. Costs and usage rates for operation of Interdata 7/32 minicomputer system.

Minicomputer charge = $20/hr

Scale	Window	Land area (mi^2)		Total time (hr)			Usage rate (mi^2/hr)
1:250,000	N01	505		1.33			380
	L01	586	÷	1.97	=		297
	Total	1,091		3.30		Avg.	330*
1:125,000	N21-41	482		1.63			296
	L21-51	577	÷	2.66	=		217
	Total	1,059		4.29		Avg.	247*
1:48,000	N61-91	112		2.05			55
	L61-66	143	÷	2.30	=		62
	Total	255		4.35		Avg.	59*

*Usage rate used for cost analysis in tables 19 through 21.

and increase computer cost per square mile. However, because map area decreases as usage rate decreases, the cost of using the Univac for a standard map area decreases as map scale becomes larger (tables 19 through 21).

The cost of using the Interdata minicomputer system is the same regardless of the time of day (table 25). The usage rate for this equipment was determined the same way as that for the Univac. The total usage time for maps at the same scale includes the time used to create color schemes, even though this was done only for the L01 and N01 maps. This is done to determine costs for maps at each scale independent of maps produced at other scales. This is the logical equivalent of assigning the same material cost to each scale of maps.

The minicomputer usage rate declines as map scale gets larger (table 25). For the 1:125,000-scale maps this is primarily a result of an increase in the time used to generate the maps. However, for the 1:48,000-scale maps the decrease in usage rate is mostly a result of a substantial decrease in map area.

As usage rate of the Interdata decreases, the cost per square mile to operate it increases (table 25). However, because map area is also decreasing, the total cost to operate the Interdata decreases as well from $59.40 at a scale of 1:250,000 to $12.20 at a scale of 1:48,000 (tables 19 through 21).

The Matrix 4007 camera and processor were used to generate the photographic prints used as maps in this study. The cost of this equipment is prorated over a 10-year life span as was done with the optical equipment used during photointerpretation (table 10). The resultant hourly cost of operation of the Matrix system is $1.02 (tables 19 through 21). The time required to produce a photographic print from this system is the same, regardless of map scale. Therefore, the equipment cost for the use of the Matrix system is the same ($0.08) at all scales (tables 19 through 21).

The Bausch and Lomb Stereo Zoom Transfer Scope and Richards reel brackets were used for checking accuracy (task 13, table 14). The usage rate for this equipment was calculated in the same way as the other equipment previously mentioned. The usage rate declines continuously as map scale gets larger (table 26), because land area decreases and usage time increases. Between scales of 1:250,000 and 1:125,000 the usage rate diminishes 23 percent mostly as a result of a 27-percent increase in usage time. However, between scales of 1:125,000 and 1:48,000, the major cause of the 79-percent decline in usage rate is a 76-percent decline in map area.

When applied to the standard map sizes in tables 19 through 21, these usage rates show a continual decline in the cost of using this equipment as map scale gets larger. This decline is primarily due to a decrease in map area.

On the whole, the cost of equipment use and the percentage of total cost that equipment expenses constitute declines as map scale becomes larger (tables 19 through 21). Of the three cost categories, equipment use consistently accounts for the least amount of total cost. Because equipment use cost (dollars/mi^2) is calculated on the basis of a ratio (usage rate = mi^2/hr), it can decrease as a result of decreases in map area or mapping time. In this study, the decrease in total equipment use cost that occurs as map scale gets larger is consistently the result of a decrease in map area, not a decrease in mapping time.

3.5.4 Other costs

Other costs considered for computer-assisted mapping included field checking and report production costs.

3.5.4.1 Field checking

As discussed in Section 2.4.4.1, field checking would cost essentially the same for either method of mapping, and thus this cost was not included in the comparison.

3.5.4.2 Report production

See Section 2.4.4.2.

Table 26. Cost and usage rates for Bausch and Lomb Stereo Zoom Transfer Scope and Richards reel brackets used in Landsat data accuracy check (task 13).

Equipment cost: $.65/hr (see table 10)

Scale	Land area viewed (mi^2)	Total time (hr)	Usage rate (mi^2/hr)
1:250,000	1,091	4.8	227
1:125,000	1,059	6.08	174
1:48,000	255	6.88	37

3.6 Accuracy check of mapping from Landsat imagery

3.6.1 Random dot method

As with interpretation of aerial photographs, the interpretation of Landsat imagery was verified using the random dot method. A grid was made with dots located randomly on a clear acetate sheet. These dots were placed according to the random dot grid used for the accuracy check of the interpretation from aerial photographs. The density of two dots per square inch was maintained.

The random dot overlay was placed on the Matrix camera print. A checker independent of the interpreter then used a Bausch and Lomb Stereo Zoom Transfer Scope to compare each Landsat-derived Matrix print with NASA aircraft color-infrared (CIR) photography (Mission 389, October 10, 1978, and Mission 411, October 5, 1979) of the same area. The area beneath each dot was examined for classification, and a record was kept of all dots examined. When the checkers disagreed with an interpretation, they put the correct category number in the category column of the area originally mapped (appendix 3). Unlike the verification procedure described in Section 2.5.1, the maps derived from Landsat data were not corrected. This would have required reclassifying all areas having the same color as the one being corrected. When checking was complete, each category was tallied; a ratio of number wrong per category to total number per category was noted. Then the total number wrong over the total number of points examined was used to calculate the percentage of incorrect interpretations (appendix 3). Only interpretation of land categories was examined (table 27). Overall accuracy for maps of any one scale was calculated by dividing total number of correct points by total number of points verified for all maps of that scale. This overall accuracy is not the same as an average value for all maps of the same scale. No water categories were examined.

Table 27. Accuracy values for interpretation of Landsat-derived data using the random dot method. See figures 3 and 4 for location of map areas.

Study area	Scale	Window		Number of categories sampled	Accuracy (%) correct
Lavaca Bay	1:250,000	L01	overall accuracy L01	12	78.5
	1:125,000	L21		12	83.2
	1:125,000	L31		12	70.0
	1:125,000	L41		13	85.7
	1:125,000	L51		8	88.2
			overall accuracy L21-L51		80.1
	1:48,000	L61		10	81.5
	1:48,000	L62		11	91.6
	1:48,000	L63		9	75.5
	1:48,000	L64		11	85.8
	1:48,000	L65		10	82.1
	1:48,000	L66		9	94.4
			overall accuracy L61-L66		84.7
Nueces Bay	1:250,000	N01	overall accuracy N01	11	91.4
	1:125,000	N21		9	93.2
	1:125,000	N31		8	84.2
	1:125,000	N41		11	82.4
			overall accuracy N21-N41		86.6
	1:48,000	N61		9	85.0
	1:48,000	N71		10	87.1
	1:48,000	N81		10	84.5
	1:48,000	N91		11	74.2
			overall accuracy N61-N91		83.6

Average accuracy = *84.1

*Does not include "overall accuracy" values

3.6.2 Fitzpatrick-Lins method

After checking interpretation, the level of confidence in accuracy of interpretation was determined (see Section 2.5.2 for an explanation of this method). Tables 28 and 29 show the accuracy values determined for the Lavaca Bay and Nueces Bay study areas, respectively. Eleven maps in the Lavaca Bay area and eight maps in the Nueces Bay area were analyzed for the interpretation accuracy of land areas only. Of the 11 maps in the Lavaca Bay study area, ten were below the level of 95-percent assurance of an 85-percent accuracy. Of the eight maps in the Nueces Bay study area, six were below the level of 95-percent assurance of an 85-percent accuracy. (These maps are indicated in tables 28 and 29 by an asterisk.) Anderson and others (1976) recommended an accuracy of greater than 90 percent for regulation of land use activities or for tax assessment. None of the maps derived from digital Landsat data meet Anderson's criterion (tables 28 and 29). (These results will be compared with those for maps from aerial photographs in Section 4.2.)

3.6.3 Discussion

A major problem discovered during the accuracy check of Landsat-derived data was that several clusters had overlapping classifications (tables 30 and 31). These clusters represented more than one type of land cover or land use. Often one cluster would include sparsely vegetated, muddy agricultural lands and sparsely vegetated, very wet marshland. One example is cluster 5 in the Nueces Bay mapping (table 31). The cluster classification for Lavaca Bay area is found in table 30.

Landsat image analysis distinguished land cover categories better than land use categories. Land cover was adequately classified as in the above example of wet, muddy substrate. However, land use categories were often misclassified or not distinguishable from widely varying land cover types, such as agricultural fields versus marshland.

Table 28. Accuracy values for the Lavaca Bay study area using the Fitzpatrick-Lins (1980) method. Only interpretation of land categories was checked.

Scale	Window	p	$\hat{p}$	n
1:250,000	L01	*70.3	78.5	79
1:125,000	L21	*76.6	83.2	101
	L31	*61.3	70.0	86
	L41	*78.5	85.7	77
	L51	*72.4	88.2	+17
Mean		72.2	81.8	70
1:48,000	L61	*74.3	81.5	92
	L62	86.7	91.6	107
	L63	*64.8	75.5	53
	L64	*80.1	85.8	120
	L65	*75.1	82.1	95
	L66	*82.7	94.4	+18
Mean		77.3	85.2	81
Mean		74.8	83.3	77

p = the accuracy of the map expressed as a percent

$\hat{p}$ = the sample value of p or number of points correct/total number of points

n = the sample size

*Accuracy is below the level of 95-percent assurance of an 85-percent accuracy

+Map area composed of more than 85-percent water

Table 29. Accuracy values for the Nueces Bay study area using the Fitzpatrick-Lins (1980) method. Only interpretation of land categories was checked.

Scale		Window	p	$\hat{p}$	n
1:250,000		N01	85.2	91.4	70
1:125,000		N21	88.2	93.2	88
		N31	*75.4	84.2	57
		N41	*75.7	82.4	102
	Mean		79.8	86.6	82
1:48,000		N61	*78.9	85.0	107
		N71	*80.8	87.1	93
		N81	*78.1	84.5	103
		N91	*64.2	74.2	62
	Mean		75.5	82.7	91
Mean			78.3	85.3	85

p = the accuracy of the map expressed as a percent

$\hat{p}$ = the sample value of p or number of points correct/total number of points

n = the sample size

*Accuracy is below the level of 95-percent assurance of an 85-percent accuracy.

Table 30. Land cover/land use classification of clusters derived from ISOCLS for Lavaca Bay study area.

Land cover/Land use category*	Original cluster no.	Interpretation
11	11,16	Residential
12	11,16	Commercial and services
13	11,16	Industrial
14	11,16	Transportation, communications and utilities
15	17	Industrial and commercial complexes
171	2,7,18	Made land
21	1,4,9,13,14,15,19	Cropland and pasture
241	1,8,11	Irrigated fields
242	13,14	Non-irrigated fields
32	6,10	Shrub and brush rangeland
43	8	Mixed forest land
5	3,5	Water
62	12	Nonforested wetland
621	12	Topographically low marsh
622	8	Topographically high marsh
73	2,7,18	Sandy areas other than beaches
732	2,7,18	Dredge spoil (barren)
76	11	Transitional areas

*From table 1

Table 31. Land cover/land use classification of clusters derived from ISOCLS for Nueces Bay study area.

Land cover/land use category*	Original cluster no.	Interpretation
11	6	Residential
13	15	Industrial
14	13,17	Transportation, communication, utilities
16	9	Mixed urban or built-up land
17	14	Other urban or built-up land
21	5,8,9,13,17	Cropland or pasture
241	5,8,11	Irrigated fields
32	6	Shrub and brush rangeland
431	11	Oak woodland
5	3	Water
623	5	Tidal flat
72	1,10,12,18	Beaches
73	1,10,12,18	Sandy areas other than beaches
732	1,10,12,18	Dredge spoil (barren)

*From table 1

Some inaccuracies might have been partly corrected by generating more clusters at the ISOCLS stage of Landsat data processing (fig. 5). By using different input parameters, the analyst can generate as many as 40 clusters, which can then be consolidated, reducing the total number of clusters. However, it is unlikely that this method would have successfully differentiated, for example, between sparsely vegetated wet substrate in a marsh and sparsely vegetated wet substrate in cropland or pasture.

The computer programs used in this study collect similar radiance levels into the same cluster, without regard to their geographic location (for example, marsh versus wet cropland). This limits the usefulness of the maps generated in this manner. Either clusters (colors) have to be assigned multiple classifications or the user has to tolerate a lower accuracy.

3.6.3.1 Lavaca Bay study area

Matrix camera prints were made for the Lavaca Bay study area at all three scales: 1:250,000 (one print), 1:125,000 (four prints), and 1:48,000 (six prints) (figs. 3 and 10). Overall interpretation accuracy was better at the largest scale (1:48,000) than at a scale of 1:125,000 or 1:250,000 (table 27).

Several factors may contribute to this result. At Ramtek scales smaller than approximately 1:81,000 (Matrix print scale of 1:136,800), the ratio between Landsat and Ramtek sample spacings is greater than one-to-one. As a result, at regular intervals, Landsat pixels are eliminated from the data so that the remaining data will fit on the Ramtek screen. At a Ramtek scale of 1:148,000 and a Matrix scale of 1:250,000 the ratios between line and sample spacings are 1:0.97 and 1:1.82, respectively. Consequently, approximately one-fourth of the available Landsat data is not displayed on the Ramtek CRT or is not reproduced on the Matrix print. This may result in lower mapping accuracy at smaller scales if numerous land cover/land use classes of small areal extent are randomly sampled during accuracy checking, because the classes may be much reduced in size or eliminated altogether on the Ramtek screen.

Overall accuracy may also be better at largest scales because the colors of small features are easier to distinguish at a scale of 1:48,000, and the 1:48,000-scale photos cover a smaller, more uniform area and contain fewer land cover/land use categories (table 27).

3.6.3.2 Nueces Bay study area

Matrix camera prints were made at three scales for the Nueces Bay study area (figs. 4 and 11): 1:250,000 (one print), 1:125,000 (three prints), and 1:48,000 (four prints). Overall accuracy was greatest at the 1:250,000-scale, and the least accuracy was at the 1:48,000-scale (table 27). This is the opposite of what occurred in the Lavaca Bay study area. In comparing the two areas at 1:250,000-scale, Nueces Bay area (N01) appears to be much more uniform overall in land cover types than Lavaca Bay area (L01) (figs. 10 and 11). The Nueces Bay area consists mainly of large blocks of uniform land cover, urban, and wetland categories, while the Lavaca Bay area has a scattered mixture of rangeland, various substrates (for example, muddy, sandy), agricultural land, wetland, and urban categories. One would expect a higher degree of accuracy from an area of larger, more uniform land cover types.

Even though they represented fairly uniform land cover types, the larger scale maps of Nueces Bay had a lower degree of accuracy because of large errors in two categories. Cluster 17 (table 31) had a 23.4-percent error on the 1:48,000-scale map and a 31-percent error on the 1:125,000-scale map. Cluster 15 had a 60-percent error on the 1:48,000-scale map and a 44.4-percent error on the 1:125,000-scale map. Both categories had large numbers of incorrect samples on the 1:125,000-scale and 1:48,000-scale maps, but they had only one incorrect sample each on the 1:250,000-scale map. Because these categories were not accurately defining specific land cover types, their inadequacy was reflected to a greater degree at larger scales where they were sampled more frequently.

4.0 COST AND ACCURACY COMPARISON AND CONCLUSIONS

4.1 Cost comparison

The maps made in this study were produced at scales that are compatible with existing USGS topographic maps. Because of differences in methods of map production and resulting map formats, individual maps based on Landsat data do not cover as much area as maps derived from aerial photographs (tables 2 and 13). In addition, it was impossible to make a Matrix camera print at a scale of 1:24,000 using Landsat digital data. To eliminate the effect of variable map sizes, costs must therefore be compared on a cost-per-unit-area basis. However, first it is necessary to examine the components of the costs for each mapping method.

4.1.1 Components of costs based on aerial photographs

For maps based on aerial photographs, as map scale gets larger the cost per square mile ratio increases 13.7 times; the increase is caused primarily by labor costs that constitute larger percentages of total map cost as scale increases (table 32, column A). Not only do labor costs compose larger percentages of total cost as map scale increases, but there is an actual increase in labor cost for the 1:125,000-scale map over the 1:250,000-scale map (tables 3 and 4). This cost increase primarily results from the increased cost per square mile of tasks 3, 4, and 5 (table 7). The cost per square mile for these tasks increases 23, 12, and 6.7 times, respectively, whereas the mapped area decreases 4 times, resulting in a net increase in labor costs. The cost per square mile of labor at 1:24,000 scale increases for all three staff positions (12 to 15 times), but the map area decreases even more (35 times), so that there is a net decrease in total labor cost compared with the 1:125,000-scale map (tables 4 and 5).

Table 32. Cost per square mile of land for maps generated from aerial photographs and digital Landsat data.

Scale	Item	Data base: Column A aerial photographs cost/mi^2	percent	Column B Landsat digital data cost/mi^2	percent
1:250,000	Materials	$.59	82%	$.25	32%
	Labor	.12	17	.36	46
	Equipment	.01	1	.18	22
	Total	$0.72*	100%	$.79	100%
1:125,000	Materials	$.54	46%	$1.02	68%
	Labor	.62	53	.28	19
	Equipment	.01	1	.19	13
	Total	$1.17	100%	$1.49	100%
1:48,000	Materials	**		$6.92	77%
	Labor			1.29	15
	Equipment			.75	8
	Total			$8.96	100%
1:24,000	Materials	$1.28	13	**	
	Labor	8.31	84		
	Equipment	.26	3		
	Total	$9.85	100%		

*If complete rolls of film were purchased, the total cost per square mile would be reduced to $0.43 (see table 3).
**Map not generated at this scale.

Labor cost per square mile increases at larger map scale because more time is spent per unit area of the map on each aspect of interpretation of aerial photographs (table 7). This is not surprising because detail also increases as map scale gets larger, requiring more personnel time for photointerpretation and subsequent tasks.

Although labor costs are increasing, other costs are decreasing or remaining stable both in dollar amount and in percentage of total map cost (tables 3 through 5). The decrease in the cost of materials results from a decrease in the number of photographs purchased. The decrease in equipment costs is caused by a decrease in the time the equipment is used.

4.1.2 Components of costs based on digital Landsat data

For maps based on Landsat data, the increase in cost per square mile that occurs as map scale gets larger is caused primarily by the cost of materials (table 32, column B). The material costs remain the same for all three scales while map area decreases (tables 19 through 21). As a result, the cost per square mile ratio is 12.7 times greater at scale of 1:48,000 than at 1:250,000. As other costs decrease, the cost of materials constitutes a larger percentage of the total cost (tables 19 through 21) and of the cost per square mile (table 32).

Unlike labor costs for maps based on aerial photographs, total labor cost on maps derived from Landsat data declines progressively as map scale becomes larger (tables 19 through 21). The costs per square mile for the Research Scientist Associate (RSA) II and the Engineering Technician (ET) III decrease about 20 to 35 percent for the 1:125,000-scale maps from the costs of the 1:250,000-scale maps (table 22) while the cost per square mile for the RSA I increases 25 percent. Costs per square mile for all three staff positions increase 340 to 380 percent for the 1:48,000-scale map from the costs of the smaller scale maps (table 22). As a result, total labor cost per square mile decreases slightly, then increases considerably as map scale becomes larger (table 32, column B). The decrease in labor cost per square mile for the RSA II and ET III positions occurs because of an absolute decrease in the time required for their work at a scale of 1:125,000 (table 22). Likewise, the increase in labor cost per square mile for these positions on the 1:48,000-scale maps occurs partly as a result of increased time required for their tasks (tables 22 and 23), as well as an 85-percent decrease in mapped land area.

Equipment expenses comprise, at most, 22 percent of the total cost of mapping from digital Landsat data (tables 19 through 21). The absolute amount and percentage of total cost decline progressively as map scale gets larger. The cost per square mile increases abruptly for the 1:48,000-scale map because map area decreases more than cost (table 32, column B).

4.1.3 Comparison of cost per square mile

Here it is appropriate to reiterate the principal assumptions that underlie the costs used in this comparison. First, where applicable, equipment expenses for analysis of digital Landsat data are those that would be assessed other state agencies by the TNRIS for use of computer facilities. Any research team that does not qualify for those rates would have different equipment costs. Second, the equipment cost for interpretation of aerial photographs is based on purchase and amortization of new equipment. If equipment is already on hand these expenditures could be reduced. Third, both Landsat data and aerial photographs are priced at the cost of reproduction of original photographs or data tapes as of August 1981.

Table 32 shows that for both methods of map production the cost per square mile rises as the scale of the map increases from 1:250,000 to 1:24,000 or to 1:48,000. Higher total cost per square mile reflects increases in different component costs. For the maps based on aerial photographs, the cost increase primarily results from large increases in the labor cost per square mile (table 32, column A). For maps derived from digital Landsat data, however, the total cost per square mile increases mostly because materials cost per square mile increases (table 32, column B).

The map scale determines the most economical mapping method. At a scale of 1:250:000, total cost per square mile for maps based on aerial photographs is 9 percent less than the cost for maps based on Landsat data (table 32). More economy can be realized for maps based on aerial photographs by purchasing these photographs in complete rolls. Total cost per square mile can be reduced to $0.43, 46 percent less than the cost of Landsat-based maps (Section 2.4.1 and footnotes for tables 3 and 32). At a scale of 1:125,000, the maps based on Landsat data cost 27 percent more per square mile than the maps based on aerial photographs. The reverse is true at the largest scale for both methods. The 1:48,000-scale maps based on Landsat data cost 9 percent less per square mile than the 1:24,000-scale maps derived from aerial photographs (table 32).

The total cost per square mile increases about the same for both methods as map scale increases. A map derived from aerial photographs costs 13.7 times more per square mile at a scale of 1:24,000 than at 1:250,000. A map derived from Landsat data costs 11.3 times more per square mile at a scale of 1:48,000 than at 1:250,000.

4.2 Accuracy comparison

The level of confidence of an 85-percent accuracy of interpretation was calculated for maps derived from Landsat data and for maps based on aerial photographs. Sixteen of 19 maps derived from Landsat data were below the 95-percent confidence level (tables 28 and 29). Five out of 17 maps based on aerial photographs were below this level (table 12). Six of the 17 maps derived from aerial photographs have accuracies of 90 percent or better, but none of the maps derived from Landsat data are this accurate. These data indicate that this method of making land cover/land use maps from Landsat data is less accurate than conventional mapping from aerial photographs. The average map accuracy, prior to the computation of confidence levels, is 84.1 percent for the maps derived from Landsat data. This is 4.6 percentage points lower than the average accuracy of 88.7 percent for maps derived from aerial photographs.

The 84.1-percent accuracy for the Landsat-based mapping represents a significant improvement in the capability to analyze Landsat imagery. Previous efforts, prior to the development of RSIS, yielded only a 73-percent accuracy when checked by similar methods (Harwood and others, 1977). This improvement in accuracy suggests that an integration of digital processing techniques and manual interpretation will yield optimum, accurate results for many users of land cover/land use maps, especially in view of the above stated confidence levels.

There is no correlation between map scale and map accuracy, especially for the Landsat-derived maps. Nor is there any correlation between sample size (n) and map accuracy (tables 12, 28, and 29). It seems clear, then, that the source of map inaccuracy is the mapping method, not the method of checking interpretation nor the differences in map scales.

In this study, maps from Landsat data are much more generalized than maps interpreted from aerial photographs. Thus accuracy results for Landsat-derived maps can be misleading because several classifications of land cover/land use fall into the same cluster defined by digital processing. In contrast, maps derived from aerial photographs have more specific classifications, yet the accuracy of RSIS products may now be acceptable if other reasons exist for using Landsat imagery rather than aerial photographs.

4.3 Conclusions

When choosing a mapping method for a particular project, the product's function should be considered as well as cost and accuracy. Maps made from aerial photographs are more detailed, with boundaries unconstrained by the geometric format of Landsat pixels. This method of map-making is good for detailed non-seasonal studies such as shoreline erosion, changes in wetlands (for example, filling-in or expansion), changes of boundary lines, and accurate areal measurements. Some disadvantages of using aerial photographs are that photographs are usually not taken with great frequency, that coverage of a given area may not be complete, that photographs of a particular area may not be taken all at the same time, and that their interpretation involves much more time.

Maps made using the present RSIS capabilities for computer-assisted interpretation of Landsat data have less detail, and boundaries are not as distinct. This method better delineates land cover (although land cover is very general) than land use. Land use interpretation is less accurate using Landsat data than using aerial photographs. The computer makes no judgment about location, size, or shape; thus, it does not always distinguish between several important land uses (such as beach versus industrial complex versus barren spoil; muddy substrate agricultural land versus topographically low wetland; rangeland versus suburban areas). However, using this method, maps can be generated for repetitive studies, because Landsat overpasses occur every 18 days for any particular area. The frequency of obtaining usable data will be lower, however, owing to cloud cover and possible sensor malfunction. This method is good for seasonal analyses, generalized studies such as crop yield (Colwell and others, 1977), urban area expansion (Todd, 1977), and vegetation reclamation of an area (U.S. Environmental Protection Agency, 1975). In addition, mapping costs range from 9 percent less to 27 percent more than costs of aerial photointerpretation at comparable scales.

Before choosing a map-making method, one should consider (1) cost (availability of funds and personnel), (2) time constraints, (3) map accuracy needed, (4) level of detail, and (5) use of the product. The advantages of each mapping method are summarized in table 33. The Landsat-derived mapping method is advantageous because of repetitive coverage, simultaneous coverage of large areas, faster interpretation of Landsat data at scales of 1:48,000 and 1:125,000, and lower cost per square mile at 1:48,000 scale. The capabilities of RSIS now permit state agencies to use Landsat imagery effectively when it is the most appropriate data source. The aerial photo-derived map method is advantageous because of its high resolution, accuracy and detail of interpretation, faster interpretation at 1:250,000-scale, and lower total cost per square mile for 1:250,000-scale and 1:125,000-scale map generation. Total cost per square mile for 1:24,000- and 1:48,000-scale maps cannot be directly compared owing to the scale differences. Future improvements in RSIS may allow production of Landsat-derived maps at a 1:24,000 scale and in a format comparable to a 7.5-minute quadrangle sheet. This improvement would tend to close the cost gap between the 1:24,000- and 1:48,000-scale products included in this study (table 32) by increasing equipment and materials cost for the Landsat-based map. The user's need for a particular type of product or set of products and production time would then become the overriding concerns in view of similar costs and map formats.

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Table 33. Checklist of some advantages of mapping by different methods.

Criterion	Landsat-derived	Aerial photograph-derived
High resolution of data		X
Repetitive coverage at a high frequency	X	
Simultaneous coverage of a large area	X	
Faster interpretation at scales of 1:48,000 and 1:125,000	X	
Faster interpretation at a scale of 1:250,000		X
Accuracy of interpretation		X
Detail of interpretation		X
Lower cost/mi^2 at 1:48,000 scale	X	
Lower cost/mi^2 at 1:125,000 scale and 1:250,000 scale		X

X = most satisfactory

The manuscript was prepared by word processing under the direction of Lucille C. Harrell and edited under the direction of Susann Doenges. Illustration, design, and paste-up were prepared under the direction of Dan F. Scranton, Chief Cartographer.

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7.0 APPENDICES

1. Order form for NASA aircraft photography.
2. Sample of weekly time sheet for mapping from aerial photographs.
3. Sample of map accuracy tally sheet showing results of accuracy check.
4. Order form for Landsat standard products.
5. Sample of log sheet for recording time spent on tasks during interpretation of Landsat digital data.
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7. Sample of product identification sheet used during processing of Landsat digital data.

Appendix 1. Order form for NASA aircraft photography.

ORDER FORM

NASA AIRCRAFT PHOTOGRAPHY

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NAME MR. / MS. ____________ (FIRST) (INITIAL) (LAST) DATE ____________

COMPANY ____________ (IF BUSINESS ASSOCIATED) COMPUTER ACCOUNT NO. (IF KNOWN) ____________

ADDRESS ____________ PHONE (Bus.) ____________

CITY ____________ STATE ____________ ZIP ____________

PHONE (Home) ____________

SHIP TO ____________ YOUR REF. NO. ____________ (P.O. GOV'T ACCT. OR OTHER)

PLEASE TYPE OR PRINT PLAINLY

PHOTO IDENTIFICATION NO.	PRODUCT CODE	FIRST FRAME	LAST FRAME	NO. OF FRAMES	NO. OF COPIES	QTY.	UNIT PRICE	TOTAL PRICE

TOTAL ABOVE A ____

TOTAL FROM PREVIOUS SHEETS B ____

TOTAL COST C ____

STANDARD PRODUCTS

FILM SOURCE

BLACK & WHITE PRODUCTS	B & W 70MM	B & W 5 IN.	B & W 9 IN.	B & W 9 x 18 IN.	UNIT PRICE
55.8mm (2.2in.) FILM POSITIVE	11				$ 3.00
55.8mm (2.2 in.) FILM NEGATIVE	01				$ 4.00
55.8mm (2.2 in.) PAPER					
11.4cm (4.5 in.) PAPER		22			$ 3.00
11.4cm (4.5in.) FILM POSITIVE		12			$ 4.00
11.4cm (4.5in.) FILM NEGATIVE		02			$ 5.00
22.9cm (9 in.) PAPER	23	23	23		$ 3.00
22.9cm (9 in.) FILM POSITIVE			13		$ 5.00
22.9cm (9 in.) FILM NEGATIVE			03		$ 6.00
22.9x45.7cm (9x18 in.) PAPER				31	$ 6.00
22.9x45.7cm (9x18 in.) FILM POSITIVE				14	$10.00
22.9x45.7cm (9x18 in.) FILM NEGATIVE				04	$12 00
45.7cm (18 in.) PAPER	24	24	24		$10.00
68.6cm (27 in.) PAPER			25		$15.00
91.4cm (36 in.) PAPER			26		$20.00

FILM SOURCE

COLOR PRODUCTS	COL 70 MM	COL 5 IN.	COL 9 IN.	COL 9 x 18 IN.	UNIT PRICE
55.8mm (2.2 in.) FILM POSITIVE	51				$10.00
55.8mm (2.2 in.) PAPER					
11.4cm (4.5 in.) PAPER		62			$ 7.00
11.4cm (4.5 in.) FILM POSITIVE		52			$12 00
22.9cm (9 in.) PAPER	63		63		$ 7.00
22.9cm (9 in.) FILM POSITIVE			53		$15.00
22.9x45.7cm (9x18 in.) PAPER				69	$20.00
22.9x45.7cm (9x18 in.) FILM POSITIVE				56	$30.00
45.7cm (18 in.) PAPER	64	64	64		$25.00
68.6cm (27 in.) PAPER			65		$30.00
91.4 cm (36 in.) PAPER			66		$50.00

NOTE: NUMBERS IN OPEN BLOCKS REFLECT PRODUCT CODES

PAYMENT MADE BY:

- CHECK, MONEY ORDER ☐
- PURCHASE ORDER ☐
- GOVERNMENT ACCT. ☐

*Refer to item "T" on reverse side.

UNIT PRICES SUBJECT TO CHANGE

COMMENTS: ____________

FORM: 9-1940 (April 1978)

Return Completed Form To:

U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
FTS: 784-7151
Comm: 605/594-6511

For Additional Information or Assistance Please Contact One of the Following Offices of the National Cartographic Information Center (NCIC).

U.S. Geological Survey
National Cartographic Information Center
507 National Center
Reston, VA 22092
FTS: 928-6045
Comm: 703/860-6045

U.S. Geological Survey
Eastern Mapping Center
National Cartographic Information Center
536 National Center
Reston, VA 22092
FTS: 928-6336
Comm: 703/860-6336

U.S. Geological Survey
Mid-Continent Mapping Center
National Cartographic Information Center
1400 Independence Road
Rolla, MO 65401
FTS: 276-9107
Comm: 314/364-3680

U.S. Geological Survey
Rocky Mountain Mapping Center
National Cartographic Information Center
Stop 504, Denver Federal Center
Denver, CO 80225
FTS: 234-2326
Comm: 303/234-2326

U.S. Geological Survey
Western Mapping Center
National Cartographic Information Center
345 Middlefield Road
Menlo Park, CA 94025
FTS: 467-2426
Comm: 415/323-8111

U.S. Geological Survey
National Cartographic Information Center
National Space Technology Laboratories
NSTL Station, MS 39529
FTS: 494-3541
Comm: 601/688-3544

PLEASE CONTACT THE NEAREST NCIC OFFICE FOR INFORMATION CONCERNING THE AVAILABILITY OF CARTOGRAPHIC PRODUCTS OTHER THAN IMAGERY.

HOW TO ORDER NASA AIRCRAFT PHOTOGRAPHY

This order form is to be used for ordering all NASA AIRCRAFT PHOTOGRAPHY. Photo Identification numbers can be transcribed directly from a computer listing. When ordering from other reference sources, be sure to specify the MISSION, ROLL, and FRAME NUMBER for the desired photograph(s).

Please provide the following information in the indicated areas of the order form:

A. List your complete NAME, ADDRESS, ZIP CODE, and name of your COMPANY if applicable.

B. If you desire to have the products mailed to an address or individual other than yourself, please complete the "SHIP TO" address.

C. List a PHONE NUMBER where you can be contacted during business hours.

D. If you have had previous business with the EROS DATA CENTER, please list your ACCOUNT NUMBER, if known.

E. Enter the complete PHOTO IDENTIFICATION NUMBER. This can be transcribed directly from the COMPUTER LISTING. If the source of information is from another source, specify the MISSION, ROLL NUMBER and FRAME NUMBER.

F. Review the STANDARD PRODUCTS TABLE on the order form and determine the type of product desired. CARE must be exercised in insuring that the FILM SOURCE reflected in the tables correlates with the FILM SOURCE listed on the COMPUTER LISTING.

G. Enter the PRODUCT CODE of the type product being ordered from the STANDARD PRODUCTS TABLE.

H. Enter the FRAME NUMBER in the FIRST FRAME column. (See instructions for interpolation of a frame from a PHOTO STRIP) If two or more consecutive frames are being ordered, enter the FIRST FRAME of the series in the FIRST FRAME column and the LAST FRAME in the LAST FRAME column.

I. Enter the NUMBER OF UNIQUE FRAMES being ordered. Example: FIRST FRAME - 116; LAST FRAME - 119; NO. OF FRAMES is 4.

J. Enter the NO. OF COPIES being ordered of the FRAMES you have identified.

K. The COMMENTS portion is completed only when a CUSTOM PRODUCT is desired and you want to specify the parameters. Cost determination is normally based on three times the standard cost.

L. Multiply the NO. OF FRAMES by the NO. OF COPIES and enter the result in the QUANTITY column.

M. Enter the UNIT PRICE of the product as reflected in the STANDARD PRODUCTS TABLE.

N. Multiply the figure in the QUANTITY column by the figure in UNIT PRICE column and ENTER the result in the TOTAL PRICE column.

O. REPEAT the above for each product ordered.

P. TOTAL the costs of all products ordered on that order form and enter the NET result in BLOCK A. (TOTAL ABOVE.)

Q. If more than one order form is required, enter the sum of the figures in BLOCKS A in BLOCK B of the last order form.

R. Enter the SUM of BLOCK A and BLOCK B in BLOCK C. (TOTAL COST).

S. Indicate the TYPE of payment being made with a CHECK MARK. Make all drafts payable to U.S. GEOLOGICAL SURVEY. DO NOT SEND CASH.

T. Mail ORDER FORM(S) and PRE-PAYMENT to the EROS DATA CENTER. IF PAYMENT HAS BEEN PREVIOUSLY FORWARDED TO ANOTHER FACILITY, PLEASE FORWARD THIS ORDER TO THAT FACILITY FOR PROCESSING.

Appendix 2. Sample of weekly time sheet for mapping from aerial photographs.

MAPPING TIME SHEET

Name ______________________________ Position _________________________

Monday, ___________________________ through Friday, __________________

Area: _______________ Level: _______________ Scale: _______________

	Task	Hours	Task	Hours	Task	Hours
MONDAY						
TUESDAY						
WEDNESDAY						
THURSDAY						
FRIDAY						

Task Code

0: Map base preparation

1: Study of supporting materials

2: Interpretation

3: Checking interpretation

4: Map clean-up and annotation

5: Scribing

6: Checking scribe sheet

7: Preparing final work copy

Appendix 3. Sample of map accuracy tally sheet showing results of accuracy check.

MAP ACCURACY TALLY

Categories	11	12	13	14	21	32	33	43	61	62	71	72	73	75	76	131	171	241	312	621	622	623
	XX	XX	XX	XX	XX	XX	XX	XX				XX	X			XX					XX	
	X	XX	XX	XX	XX	XX	XX	XX				XX	(72)			X					XX	
			X	XX	XX	(43)	XX	(32)					(72)								XX	
					XX	XX	XX	XX														
					(32)	XX		XX														
					(32)	XX		XX														
					XX	(43)		XX														
					(32)	XX																
					XX	(43)																
					XX	(43)																
					(32)	XX																
					XX	XX																
					XX	XX																
					XX	XX																
					XX	XX																
					XX																	
					(32)																	
					(32)																	
	0/3	0/4	0/5	0/6	6/30	4/26	0/8	1/13				0/4	2/3			0/3					0/6	

Land accuracy only
13/111 = 12% error
88% correct
X = correct tally
◯ = incorrect tally, correct category noted.

Appendix 4. Order form for Landsat standard products.

ORDER FORM

LANDSAT STANDARD PRODUCTS

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NAME MR. MS. ______ (FIRST) (INITIAL) (LAST) DATE ______

COMPANY ______ (IF BUSINESS ASSOCIATED) COMPUTER ACCOUNT NO. (IF KNOWN) ______

ADDRESS ______

CITY ______ STATE ______ ZIP ______ PHONE (Bus.) ______

PHONE (Home) ______

SHIP TO ______

YOUR REF. NO. ______ (P.O. GOV'T ACCT. OR OTHER)

PLEASE TYPE OR PRINT PLAINLY

SCENE IDENTIFICATION NUMBER	PRODUCT CODE	PHOTOGRAPHS ONLY: MSS BANDS 4	5	6	7	NO. OF EACH	QTY.	UNIT PRICE	TOTAL PRICE

TOTAL ABOVE | A

TOTAL FROM PREVIOUS SHEETS | B

TOTAL COST | C

STANDARD PRODUCTS TABLE

BLACK AND WHITE PRODUCTS

NOMINAL IMAGE SIZE	PRODUCT MATERIAL	PRODUCT CODE	PRICE
55.8mm (2.2 in.)	Film Positive	11	$ 8.00
55.8mm (2.2 in.)	Film Negative	01	10.00
18.5cm (7.3 in.)	Paper	23	8.00
18.5cm (7.3 in.)	Film Positive	13	10.00
18.5cm (7.3 in.)	Film Negative	03	10.00
37.1cm (14.6 in.)	Paper	24	12.00
74.2cm (29.2 in.)	Paper	26	20.00

FALSE COLOR COMPOSITE PRODUCTS

NOMINAL IMAGE SIZE	PRODUCT MATERIAL	PRODUCT CODE	PRICE
18.5cm (7.3 in.)	Paper	63	$12.00
18.5cm (7.3 in.)	Film Positive	53	15.00
37.1cm (14.6 in.)	Paper	64	25.00
74.2cm (29.2 in.)	Paper	66	50.00

PRICES SUBJECT TO CHANGE.

COLOR COMPOSITE GENERATION

NOMINAL IMAGE SIZE	PRODUCT MATERIAL	PRODUCT CODE	PRICE
18.5cm (7.3 in.)	Printing Master	59	$50.00

NOTE: Not applicable for RBV Subscenes. Printing Master is retained by EDC. Cost of products from this composite must be added to total costs.

COMPUTER COMPATIBLE TAPES (CCT)

TRACKS	BPI	FORMAT	MSS All Bands Available: PRODUCT CODE	PRICE	RBV Single Subscene: PRODUCT CODE	PRICE	Set of Four RBV Subscenes: PRODUCT CODE	PRICE
9	800	TAPE SET	183-B	$200.00	183-C	$200.00	183-D	$400.00
9	1600	TAPE SET	184-B	200.00	184-C	200.00	184-D	400.00

PAYMENT MADE BY:

CHECK, MONEY ORDER ☐

PURCHASE ORDER ☐

GOVT. ACCOUNT ☐

COMMENTS: ______

FORM: 9-1938 (August 1978)

Return Completed Form To:
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
FTS: 784-7151
Comm: 605/594-6511
TWX: 910-668-0310

For Additional Information or Assistance Please Contact One of the Following Offices of the National Cartographic Information Center (NCIC).

U.S. Geological Survey
National Cartographic Information Center
507 National Center
Reston, VA 22092
FTS: 928-6045
Comm: 703/860-6045

U.S. Geological Survey
Eastern Mapping Center
National Cartographic Information Center
536 National Center
Reston, VA 22092
FTS: 928-6336
Comm: 703/860-6336

U.S. Geological Survey
Mid-Continent Mapping Center
National Cartographic Information Center
1400 Independence Road
Rolla, MO 65401
FTS: 276-9107
Comm: 314/364-3680

U.S. Geological Survey
Rocky Mountain Mapping Center
National Cartographic Information Center
Stop 504, Denver Federal Center
Denver, CO 80225
FTS: 234-2326
Comm: 303/234-2326

U.S. Geological Survey
Western Mapping Center
National Cartographic Information Center
345 Middlefield Road
Menlo Park, CA 94025
FTS: 467-2426
Comm: 415/323-8111

U.S. Geological Survey
National Cartographic Information Center
National Space Technology Laboratories
NSTL Station, MS 39529
FTS: 494-3541
Comm: 601/688-3544

PLEASE CONTACT THE NEAREST NCIC OFFICE FOR INFORMATION CONCERNING THE AVAILABILITY OF CARTOGRAPHIC PRODUCTS OTHER THAN IMAGERY.

HOW TO ORDER STANDARD LANDSAT DATA

This order form is used to order all standard Landsat data. Necessary order information can normally be extracted from a computer listing of available data or from other Landsat references.

Please provide the following information in the indicated areas of the order form:

A. List your complete NAME, ADDRESS, ZIP CODE, and name of your COMPANY if applicable.

B. If you desire to have the products mailed to an address or individual other than yourself, please complete the "SHIP TO" address.

C. List a PHONE NUMBER where you can be contacted during business hours.

D. If you have had previous business with the EROS DATA CENTER, please list your COMPUTER ACCOUNT NUMBER if known.

E. Enter the complete SCENE IDENTIFICATION NUMBER. This number can be transcribed directly from the COMPUTER LISTING or from a Landsat catalog.

F. Review the STANDARD PRODUCTS table on the front of the ORDER FORM and determine the type of product desired.

G. Enter the PRODUCT CODE of the type product being ordered from the STANDARD PRODUCTS table.

H. If ordering MSS photographs, check columns for bands you desire and also indicate the copies of each band in the NUMBER OF EACH Column. It is not necessary to mark for RBV Subscenes since each has its own SCENE ID. Check the CCT box only if a digital tape is being ordered. In selecting the tape format, make sure that you consider your equipment and usage. Please complete the QUANTITY Column. Count the number of MSS bands checked, multiply by the figure in the NUMBER OF EACH Column and enter the RESULT in the the QUANTITY Column.

I. Enter the UNIT PRICE of the type product as reflected in the STANDARD PRODUCTS table.

J. Multiply the figure in the QUANTITY Column by the UNIT PRICE and enter the result in the TOTAL PRICE Column.

K. Repeat steps E through J for each product ordered.

L. TOTAL the costs of all products ordered on this order form and enter the net result in BLOCK A (TOTAL ABOVE).

M. For a single order form, enter the Figure in BLOCK A in BLOCK C (TOTAL COST). If more than one order form is required, on the last order form enter the sum of the figures in BLOCKS A in BLOCK B and then total BLOCK A and BLOCK B in BLOCK C (TOTAL COST).

N. The COMMENTS portion is completed only when special consideration is desired in printing i.e. print for water detail, desert detail, etc. which does not necessarily fall in the CUSTOM PRODUCT category. If a CUSTOM PRODUCT is desired the COMMENTS portion will also be used and the cost determination will be normally based on three times the standard cost.

O. PHOTOGRAPHIC and DIGITAL TAPE products are available in other formats but require special ordering procedures. If interested, please call the EROS Data Center for further instructions.

P. Include type of payment (purchase order, check or money order). Make all drafts payable to U.S. GEOLOGICAL SURVEY. DO NOT SEND CASH.

Q. Mail ORDER FORM(S) and PRE-PAYMENT to the EROS DATA CENTER. IF PAYMENT HAS BEEN PREVIOUSLY FORWARDED TO ANOTHER FACILITY, PLEASE FORWARD THIS ORDER TO THAT FACILITY FOR PROCESSING.

*U.S. G.P.O. 1978-768-776/28 REG. # 6

Appendix 5. Sample of log sheet for recording time spent on tasks during interpretation of Landsat digital data.

TIME DATA FOR COMPUTER-ASSISTED LANDSAT ANALYSIS

Analyst's initials __________

Date ________________________

Time costs

Product	Task	Hours

Material costs and other expenses

Product	Task	Type of expense	Cost

Appendix 6. Sample of log sheet for recording computer charges during interpretation of Landsat digital data.

COMPUTER CHARGE SHEET

Product	Date	Start time	Computer charge

Appendix 7. Sample of product identification sheet used during processing of Landsat digital data.

PRODUCT IDENTIFICATION SHEET

Analyst __________ Position __________ Agency __________

Product ________ Area ____________________ P/R ____________________

Scene ID ____________________ Window ____________________

Run # ____________________ Scale ____________________

Date ____________________

Analyst __________ Position __________ Agency __________

Product ________ Area ____________________ P/R ____________________

Scene ID ____________________ Window ____________________

Run # ____________________ Scale ____________________

Date ____________________

Analyst __________ Position __________ Agency __________

Product ________ Area ____________________ P/R ____________________

Scene ID ____________________ Window ____________________

Run # ____________________ Scale ____________________

Date ____________________