TEST PLAN FOR REMOTE SENSING
INFORMATION SUBSYSTEM PRODUCTS
TEST SITE 1 (COASTAL)

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prepared under
Interagency Contract No. (78-79)-2045

revised under
Interagency Contract No. (80-81)-1676

with the

Texas Natural Resources Information System
and the
Texas Department of Water Resources

under
Order No. T-3499H

from the
Lyndon B. Johnson Space Center
National Aeronautics and Space Administration

February, 1981

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1.0 INTRODUCTION

1.1 Scope and Objectives

This plan describes map products to be generated from Landsat imagery, airborne multispectral scanner imagery, and aerial photography of a test site on the Texas coast. The objectives in producing these maps are (1) to determine the methodology necessary for developing each type of product, (2) to designate the size, scale, level of detail and final format of each map within an initial phase of development of remote sensing products, and (3) to designate specifications for the generation of equivalent products from aerial photography to be used in comparison evaluations.

The map products and data analysis procedures outlined here are based on (1) objectives outlined in the Applications System Verification and Transfer (ASVT) Project Plan (McCulloch and McKain, 1978), (2) state agency coastal information needs and listings of possible products developed in conjunction with the User Advisory Group, and (3) the Remote Sensing Information Subsystem (RSIS) Level I Design and Design Review documents. As such, the descriptions contained herein are primarily conceptual and are derived from only limited hands-on experience with Landsat imagery and digital image processing hardware and software. Present time schedules call for software required for full analysis of data over the Coastal Test Site to be available in early 1981.

1.2 Project Summary

The goal of the ASVT Project Plan (McCulloch and McKain, 1978) is the development of a Texas Natural Resources Inventory and Monitoring System (TNRIMS) consisting of three main parts: (1) the Remote Sensing Information Subsystem, (2) the Geographic Information Subsystem (GIS) and (3) the Natural Resources Analytical Subsystem (NRAS). These Subsystems represent analytical capabilities which are designed to assist agencies of the State of Texas in carrying out their statutory responsibilities in the areas of natural resources and the environment. These Subsystems will offer, respectively, the capability to deal with (1) data derived by remote sensing from satellite and aircraft platforms, (2) geographic data derived from a variety of files of spatial information, and (3) the use of models and assessment routines (Figure 1). TNRIMS will provide these capabilities within the operational framework of an existing 13-member consortium of state agencies, the Texas Natural Resources Information System (TNRIS) Task Force.

Support for the development of TNRIMS comes from the National Aeronautics and Space Administration (NASA) and from Texas state agencies under a cooperative agreement between NASA and TNRIS. Project objectives, management and responsibilities of each participant (NASA and TNRIS) are outlined in a Memorandum of Understanding dated March, 1978. This document, together with the Project Plan, provides further details on the organization of all elements of the project and recounts previous experience with remotely sensed data among Texas state agencies.

1.3 Development and Configuration of RSIS

The prototype Remote Sensing Information Subsystem of TNRIMS, as outlined in the ASVT Project Plan, will be established for testing, evaluation and refinement using data from five test sites within the State of Texas. Development may proceed in the direction of a fully operational system in the applications areas where RSIS is a real and direct benefit to state agencies in carrying out their responsibilities. The Subsystem must include the following capabilities (McCulloch and McKain, 1978):

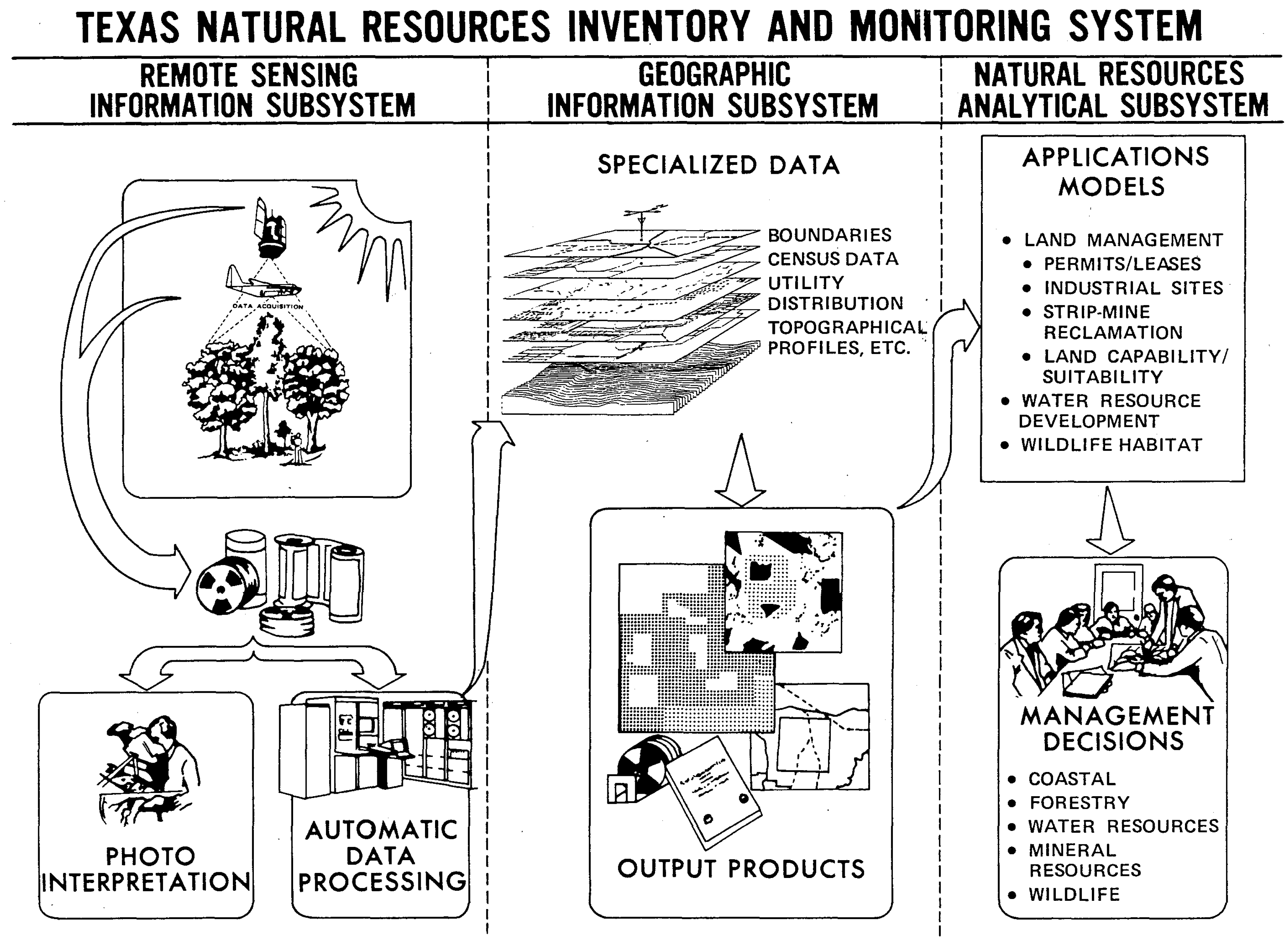

Figure 1. Overview of the Texas Natural Resource Inventory and Monitoring System and Subsystems.

1) Digital data manipulation and data enhancement procedures will allow maximum information extraction from Landsat multispectral scanner (MSS) imagery and airborne MSS imagery. Such procedures should include, for example, removal of image defects, correction of atmospheric effects, band ratioing, contrast stretch, density slicing, and ability to create mosaics from more than one scene of imagery. Time for testing and software refinement must be allowed as each procedure is integrated into RSIS.

2) Interactive, computer-assisted procedures for classification of data on digital tape will permit scaled and registered maps to be generated in a more timely manner compared to batch mode processing. The interpreter is to have a more direct role in guiding analysis based on the user's knowledge of natural processes, the activities of man, and the known spectral response of land cover in the area being analyzed.

3) The Subsystem must support manual image interpretation of Landsat imagery, aircraft photography and auxiliary data to supplement the computer-assisted classification products. The generation of map products to be used with other data on a light table or with a Zoom Transfer Scope is an example of such manual interpretation techniques.

4) The Subsystem should ultimately permit automatic correlation of classification results from established ground truth locations with the results of unsupervised analytical techniques, if this can be proven feasible through test and evaluation.

5) The Subsystem should handle a mix of Landsat data, aerial photography, airborne multispectral scanner data and ground data to support specific needs of user agencies. Types of data and the temporal framework in which they are collected will be evaluated as RSIS is developed using data primarily from the coastal test site.

6) Products which meet specific user needs and are in the form of appropriately scaled and formatted hard-copy maps must be available from RSIS. Alternatively, digital tapes containing results of classification procedures, enhanced imagery or unconventional false-color composite images must be available for further processing by the user or for conversion to hard copy by other systems.

The capabilities listed above are to be implemented through a specific combination of hardware, software, and analytical procedures comprising RSIS. Details of the system to accomplish data input, preprocessing, processing and data output are given in Brown and others (1979a and 1979b) and include software narrative descriptions, a glossary of terms, and a detailed functional design describing all software components.

The flow of data through this system is outlined in figure 2, which shows three of the principal hardware components: the Univac 1100/41 computer, the Interdata 7/32 minicomputer and the interactive graphics terminal, a Ramtek keyboard and cathode ray tube (KCRT) display device. Most processing of digital Landsat data will require the capabilities of the Univac 1100/41. Results will be transferred to the Interdata 7/32 by hard-wired connection for subsequent display on the Ramtek KCRT. When completed, the system will be totally interactive but will likely need to continue as new techniques and data sources become available.

Actual digital image processing requirements are listed in table 1, and were the basis for the Functional Design Review held on July 19-20, 1979. Software modules corresponding to each requirement are included in Brown and others (1979b). Many of the preprocessing procedures are not yet included in TNRIMS RSIS. Some processing procedures are functioning and have proven very useful.

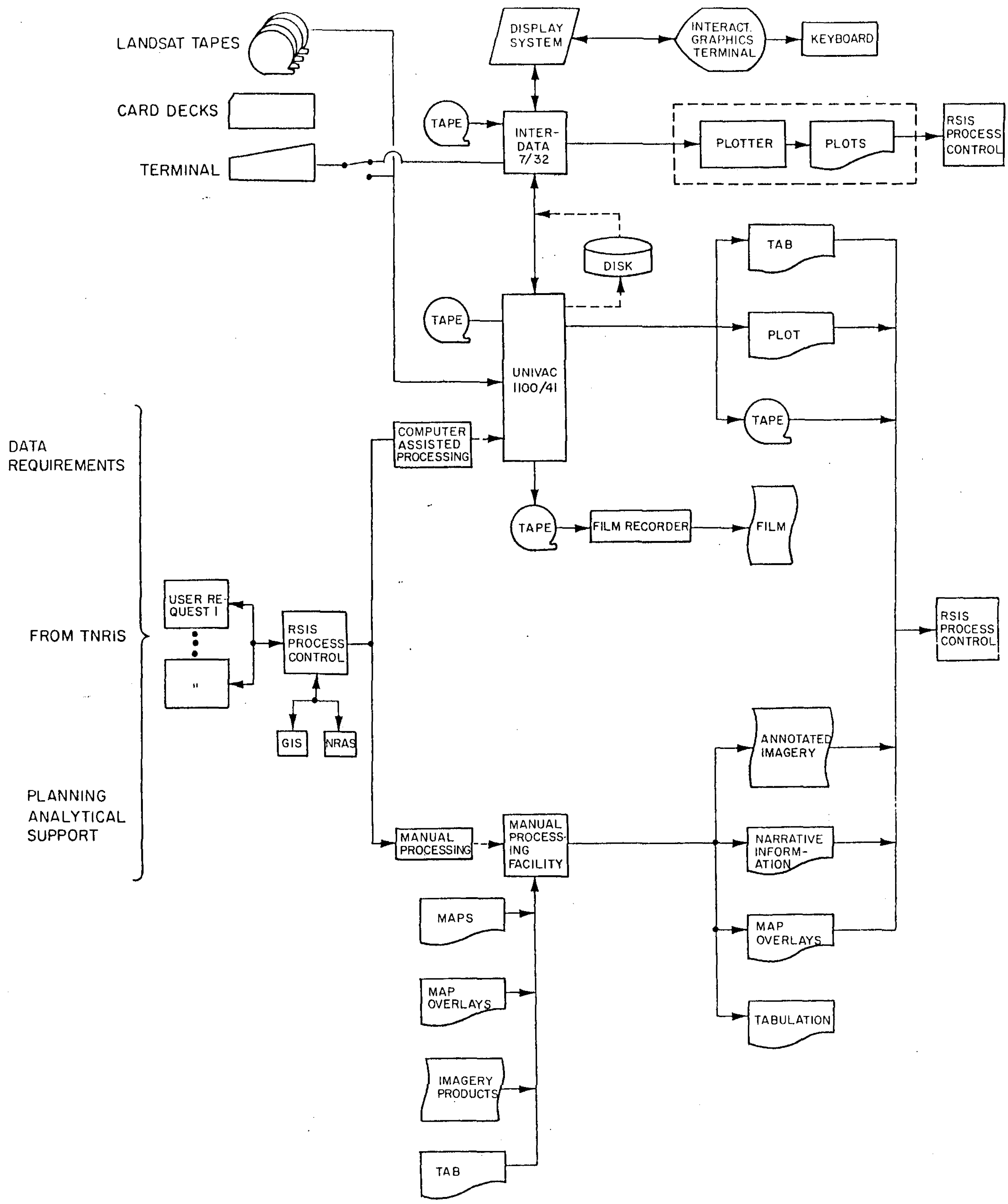

Figure 2. RSIS data processing facility.

Table 1. Digital image processing requirements for the TNRIMS RSIS.

A. PREPROCESSING

1. Contrast "stretching" and related enhancements (e.g., cumulative distribution function data stretch)

2. Radiometric corrections for effects of sun angle, atmosphere, and sensor calibration (to the extent these corrections are not made at EDC on standard products)

3. Geometric corrections for such factors as sensor attitude variations, Earth rotation, image projection, and relevant sensor parameters (to the extent these corrections are not made at EDC on standard products)

4. Mosaicking two or more digital images and removing overlap

5. Band ratioing

6. Eliminating/reducing noise such as bad scan lines and other "cosmetic" defects

7. Accurate registration of digital image to ground control points

8. Edge enhancement

9. Input airborne and Landsat digital image data for subsequent processing

10. Rotation of the digital image to North-South orientation (or through some specified angle)

B. PROCESSING (Through "interactive mode")

1. Density slicing, ratioing, and false color image display

2. "Supervised" multispectral analysis of up to six bands, including selection of training fields by cursor

3. "Unsupervised" or "clustering" multispectral analysis of up to six bands, including

    a. Selection by cursor of areas for collection of statistics

    b. Histogram generation

4. Automated correlation of spectral "clusters" with surface information at pre-selected locations

5. Digital image enhancement during viewing, including color (hue, saturation, and intensity) enhancement

Table 1. - Concluded

6. Change detection through comparison of two digital images and display/output of differences

7. Add alphanumeric annotations to image

8. Expand and reduce image size

C. POSTPROCESSING

1. Video display of multispectral image classification results in false color

2. Generation of black-and-white hard-copy film images, disk storage, line-printer, and magnetic tapes of classification results and enhanced images of individual bands

D. OPERATION

1. One complete interactive display and analysis station is initially required. Utilization will rotate among Project Team members assigned to generate the various products. Full operational use of the RSIS may dictate the need for multiple stations with the possibility of many support processing functions being accomplished at a single site.

2. Resolution and other Subsystem requirements will need to be determined by analysis of the information needs and output products to be generated by the RSIS.

1.4 User Advisory Group

A User Advisory Group has been established as part of the ASVT Project Plan to insure that state agency input regarding the definition, testing, and evaluation of RSIS is incorporated into project work. One of the major responsibilities of the User Advisory Group is to define specific Subsystem output products as the basis for Subsystem evaluation and potential refinement or modification. The group initially consisted of representatives of TNRIS member agencies whose responsibilities in the Texas Coastal Zone were likely to be supported by RSIS. A change in representation is planned as test sites other than the coastal area are considered, and this will help insure that RSIS products are scrutinized for real value in supporting specific operational needs of participating agencies (McCulloch and McKain, 1978).

1.5 State Agency Applications

In addition to the specific types of products which RSIS should be capable of generating, as identified by the User Advisory Group, a primary objective of the Project is to evaluate TNRIMS capabilities for directly supporting the decision making process in the participating agencies. To this end, TNRIS member agencies have identified selected applications from among their operational responsibilities that can potentially be used in developing, testing, and evaluating the System on a statewide basis. An Applications Coordinator is identified within each agency to guide the Project activities relating to their particular applications.

2.0 COASTAL APPLICATIONS TEST SITE (CATS)

2.1 Description

Test Site 1 is located over the Central Texas coastal region (fig. 3) and is approximately 95 by 185 km (58 by 116 mi) in size. This corresponds to parts of the area covered by the Port Lavaca and Corpus Christi volumes of the Environmental Geologic Atlas of the Texas Coastal Zone (McGowen and others, 1976; Brown and others, 1976), with an additional coast-parallel strip located inland of these map areas. Included are modern fluvial, coastal plain, bay margin, bay-lagoon, and barrier island environments.

Wetlands are present on the bay side of barrier islands, along mainland shorelines, on delta plains and adjacent to coastal lakes. The wetlands are not as extensive as those to the northeast as a result of decreased mean annual precipitation from north to south along the Texas coast. A discussion of (1) climatic gradients and their impact on wetlands, and (2) the relevance of these variations to remote sensing of wetlands is described in Harwood and others (1977).

Within the Test Site, data collection has been concentrated in southwest Matagorda Bay, Espiritu Santo Bay, Mesquite Bay and northern Laguna Madre areas (fig. 2). These areas include: (1) potential industrial sites along western Matagorda Bay with the possibility of increased channel dredging and spoil disposal, (2) extensive wetlands including those of the large washover fans of southern Matagorda and northern San Jose Islands, (3) segments of Mustang and Padre Islands which are rapidly being developed, (4) extensive channel dredging in northern Laguna Madre, and (5) areas of tidal flats and subaqueous grass flats which are difficult to interpret on Landsat imagery.

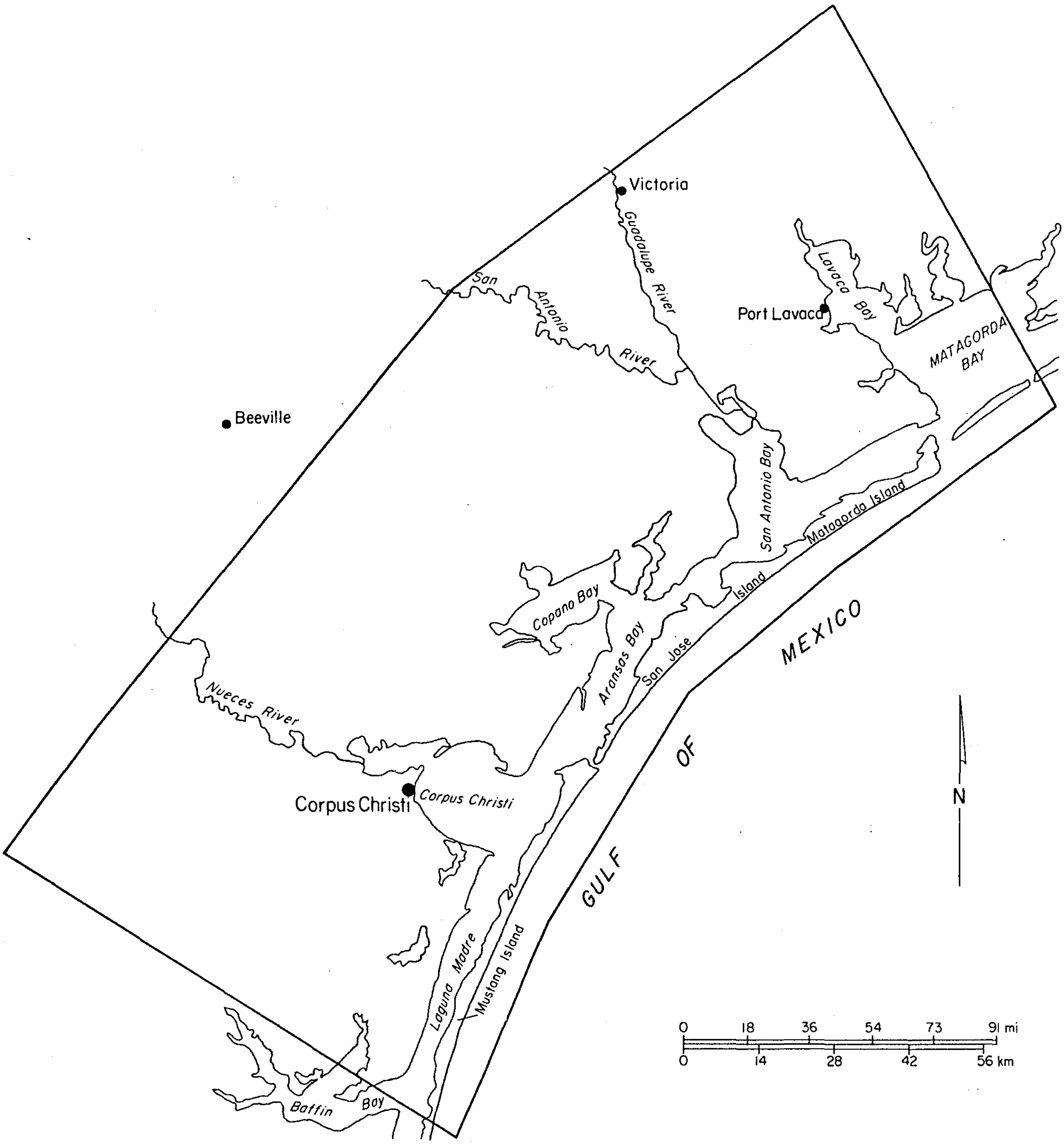

Figure 3. Coastal Applications Test Site boundaries (Test Site I).

2.2 Data Collection

Data collection in the coastal region has been guided by a Data Collection Plan (DCP) (Finley, 1978) prepared for the first data collection effort in September-October, 1978. Subsequent collection efforts have been guided by memoranda and field notebooks issued to Project Team members which provided details on field logistics and parameters to be sampled at specific localities. Table 2 summarizes data collection efforts through September 1, 1979. An excessive amount of cloud cover over the coastal test site resulted in the collection of only 3 data sets for 16 attempts during scheduled Landsat overpasses (19 percent success ratio). Because no data were obtained during the winter of 1978-79, an additional data collection effort was accomplished in February, 1980, to obtain a complete seasonal data set, beginning with the May, 1979, data and ending with a data set during the winter of 1979-80.

The surface data collection efforts have been closely coordinated with the time of the Landsat overpass in order to sample those processes which vary most with time. Emphasis is therefore being placed on atmospheric and hydrologic information (table 3). The Data Collection Plan (Finley, 1978) provides the details of: (1) observations to be made by the Project Team, (2) observations at existing facilities which will provide a framework for the team observations, and (3) the use of published reports and maps.

3.0 REMOTE SENSING INFORMATION SUBSYSTEM PRODUCTS

3.1 Types of Products

The types of products to be used in the evaluation of RSIS are based on the needs of state agencies for information on the coastal region. Preliminary work has been undertaken by the User Advisory Group to identify these needs, and to update those derived from the Texas Remote Sensing Plan (1974) (table 4). These

Table 2. Summary of Test Site I ground data collection.

Date	Locations of sampling	Weather
October 1, 1978	Laguna Madre, Mustang Island (wave data), Mesquite Bay, Espiritu Santo Bay, southwest Matagorda Bay, Colorado River mouth (wave data)	Few clouds, moderate haze affecting data
Winter 1978-79	No data; six overpasses with ground obscured by cloud cover	
May 14, 1979	Laguna Madre, Mesquite Bay, Espiritu Santo Bay, southwest Matagorda Bay	Few clouds, slight haze
August 21, 1979	Espiritu Santo Bay, southwest Matagorda Bay	Numerous clouds, slight haze; data stations appeared to be unobscured at overpass time
October 5, 1979	Laguna Madre, Mustang Island (wave data), Mesquite Bay, Espiritu Santo Bay, southwest Matagorda Bay, and Powderhorn Lake	Excellent conditions; few high clouds, no haze
February 25, 1980	High winds and mechanical trouble with the boat limited data collection in bays. Water samples were taken from the Port Lavaca Fishing Pier, and oblique photos were taken from a helicopter	Few scattered clouds

Table 3. Data to be collected as part of project team field operations.

Atmosphere

Relative humidity (wet/dry bulb temperature)

Air temperature

Wind velocity and direction

Bay Waters

Water temperature (surface)

Secchi disc extinction depth

Salinity (or conductivity) (surface)

Current velocity and direction (surface)

Water sample (surface, for suspended materials)

Water sample for chemical parameters and chlorophyll *a*

Ule-Forel color

Shoreline

Longshore drift velocity and direction and wave observation (Gulf shoreline, two locations)

Water level (tidal flat or other bay shoreline using target panels)

Table 4. Summary of state agency Coastal Zone information needs which can potentially be supported by TNRIMS.
X = Derived from Texas Remote Sensing Plan, 1974
0 = Derived from Other Sources

POTENTIAL INFORMATION NEEDS	AGENCY 1 Bureau of Economic Geology	2 General Land Office	3 Water Resources	4 Forest Service	5 Industrial Commission	6 Air Control Board	7 Texas Dept. of Agriculture	8 Railroad Commission	9 Soil & Water Consv. Board	10 Historical Commission	11 Parks and Wildlife	12 Highway Department	13 Coastal and Marine Council	14 Department of Health
1. <u>MAN-MADE FEATURES</u>														
Boundaries	0	0	X						X		X	X	0	
Land grants		0	X						X		X	X		
Gen. land use inven.	X	X	X	X	X	X	X	X	X	X	X	X	0	0
Squatter's shacks		X												
Beach obstructions	0	X												
State-owned lands	0	X												
Dam and spillways (location, size, type, condition)			X								X			
Impoundments			X				X		X		0			
Irrigated fields			X				X		X		0			
Water districts			X											
Population density			X		X	X						X	0	0
Urban land use		X	X									X		
Environ. impacts		0	X	X							0			
Underground pipelines		X							X		0	X		
Fishing sites			X								X			

Table 4. (continued)

X = Derived from Texas Remote Sensing Plan, 1974
0 = Derived from Other Sources

POTENTIAL INFORMATION NEEDS	AGENCY 1 Bureau of Economic Geology	2 General Land Office	3 Water Resources	4 Forest Service	5 Industrial Commission	6 Air Control Board	7 Texas Dept. of Agriculture	8 Railroad Commission	9 Soil & Water Consv. Board	10 Historical Commission	11 Parks and Wildlife	12 Highway Department	13 Coastal and Marine Council	14 Department of Health
Archeological and historic sites		0	0							X	X	X		
Dredging operations		X	0								X			
Road location and condition												X		
Shoreline use	0	X	0								X		0	
Pipeline location		0												
Made land	0	0									0			
Industrial facilities		0			0									0
2. ACTIVE PROCESSES														
Boundary measurements		X	X								X			
Water circulation	X	X	X							X		X	0	
Tides (high/low boundaries)	X	X	X										0	
Land use change		X	X								0			
Return flow irrigation			X								0			
3. GEOLOGY														
Rock types	X	X		X					X	X	X	X		
Structures	X	X												
Topography	X	X							X	X	X	X		
Slope		0									0			

Table 4. (continued)

X = Derived from Texas Remote Sensing Plan, 1974

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Aspect		0									0			
Substrate	0	0												
Mineral sources (type/location)	0	0												
4. HYDROLOGY														
Temperature		X	X								X			
Water quality	X	X	X								X			
Turbidity	X	X	X						X		X			
Surface water (location, area, type)	X	0	X						X		0			
Aquifers		0	0								0			
5. SOILS														
General mapping (type)	X	X		X		X			X	X	X	X		
6. AGRICULTURE														
Range & pasture mapping							X		X		0			
7. BIOLOGY														
Marsh mapping		X	X								X	X		
Grassflat mapping		X	X								X			
Swamp mapping		X	0								0			

Table 4. (continued)

X = Derived from Texas Remote Sensing Plan, 1974

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Algae mapping		0	X								X			
Gen. veg. mapping	X	X	X		X	X			X	X	X			
Ecological conditions		0	0								X	X		
Ecological relationships		0	0								X			
Plankton blooms		X	X							X				
Wildlife habitats		X	0								X			
Fish		X	0								X		0	
Aquatic habitats		0	0								0		0	
Grassland type (location, area, condition)			0								0			
8. CSTL. GEOMORPH.														
Subsidence	X	X	X						X	X	X		0	
Bathymetry	X	X								X	X		X	
Shoreline mapping	X	X									X	X		
Circulation	X	X	X								X		0	
Water quality	X	X	X						X		X			
Turbidity	X	X	X								X			
Water pollution (source, quantity, type)			0								0			

Table 4. (continued)

X = Derived from Texas Remote Sensing Plan, 1974

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Eutrophication (trophic level)			X								X			
Water pollution (outfall location)		0	0								0			
9. <u>MANAGEMENT</u>														
Land Resources	0	0												
Activity impact assessment	0	0	0								0			
Natural & scenic areas: (type, location, area)		0									0			
Solid waste disposal sites: (location, area, & condition) (municipal and industrial)		0												0
Wetlands (location, area)		0									0			
Land suitability	X	0												
Permitting/leasing alternatives		0												
Areas of particular concern		0	0								0	0		

Table 4. (continued)

X = Derived from Texas Remote Sensing Plan, 1974

0 = Derived from Other Sources

POTENTIAL INFORMATION NEEDS	1 Bureau of Economic Geology	2 General Land Office	3 Water Resources	4 Forest Service	5 Industrial Commission	6 Air Control Board	7 Texas Dept. of Agriculture	8 Railroad Commission	9 Soil & Water Consv. Board	10 Historical Commission	11 Parks and Wildlife	12 Highway Department	13 Coastal and Marine Council	14 Department of Health
Natural hazards areas	0	0	0								0	0		0
Existing fed/state parks		0	0								0	0		
Existing landfill sites			0											0
Composite resource areas		0												

needs apply to all three components (RSIS, GIS and NRAS) of TNRIMS, and for several applications data sources with greater resolution than the present Landsat system will be required. The utilization of aerial photography in a machine-processable format will not be part of RSIS, in that no capability to digitize photographs is to be included in the Subsystem. If merging of Landsat data with information derived from photographs is required to meet agency needs, it will be performed by the Geographic Information Subsystem (GIS).

Four broad categories of RSIS output products applicable to the Texas Coastal Zone include land cover/land use maps, water quality maps, water circulation maps, and topographic map revisions. The following paragraphs outline some of the characteristics of these products. The development of these products will be part of the development and testing of RSIS and the basis for product utility evaluations by the User Advisory Group. Specific products will also be prepared as appropriate to support the selected state agency applications which will provide the major focus for test and evaluation of RSIS in Test Site 1.

3.1.1 Land Cover/Land Use Maps

The term "land cover" describes "the vegetational and artificial constructions covering the land surface," according to Burley (1961, in Anderson and others, 1976). For completeness, the definition of land cover might be extended to include natural occurrences of water bodies and areas which are barren of any vegetative cover as the result of natural processes. The term "land use" refers to "man's activities on land which are directly related to the land" (Clawson and Stewart, 1965, in Anderson and others, 1976).

The U. S. Geological Survey (USGS) has developed a land cover/land use classification system specifically for use with remote sensor data (Anderson and others, 1976). The system contains two levels of detail in a hierarchical fashion and can be further refined to additional levels of detail as use of the system dictates. These finer levels of classification are collapsible into the more general levels for optimum use of the system. For purposes of this joint project, and for subsequent use of TNRIMS in an operational mode, the capabilities to generate land cover/land use maps and related products will be based on Levels I and II as defined by the USGS and on Levels III and IV to be defined by the Project Team and User Advisory Group in coordination with other user agencies. In developing Levels III and IV, particular attention will be given to vegetation classes. It should be noted that a mix of levels (i.e., different levels of detail in each major class of land cover/land use) may be contained on a single map product.

In past studies (Harwood and others, 1977; Finley, 1979b), differentiation of certain classes of vegetation presented considerable difficulty. The boundaries between topographically low and topographically high marshes, between the latter and coastal prairie grassland, and between brushland and other types of upland vegetation were not readily defined. The use of class means in each of the four Landsat bands (fig. 4) has been helpful in differentiating some of these land cover types. However, the correlation of spectral reflectivity values with a land cover type was accomplished primarily by correlating the distribution of a particular class with existing maps, such as a map of biologic assemblages from the Environmental Geologic Atlas of the Texas Coastal Zone--Corpus Christi area (Brown and others, 1976). With this technique the information available on the vegetative class is limited, compared to direct measurements (using a hand-held radiometer) of the spectral reflectivity within and between land cover classes. The future acquisition of a capability to obtain reflectivity data in the field could lead to improved capability to delineate wetlands and the ability to relate spectral response to species mixtures. This is particularly important in Texas coastal wetlands which

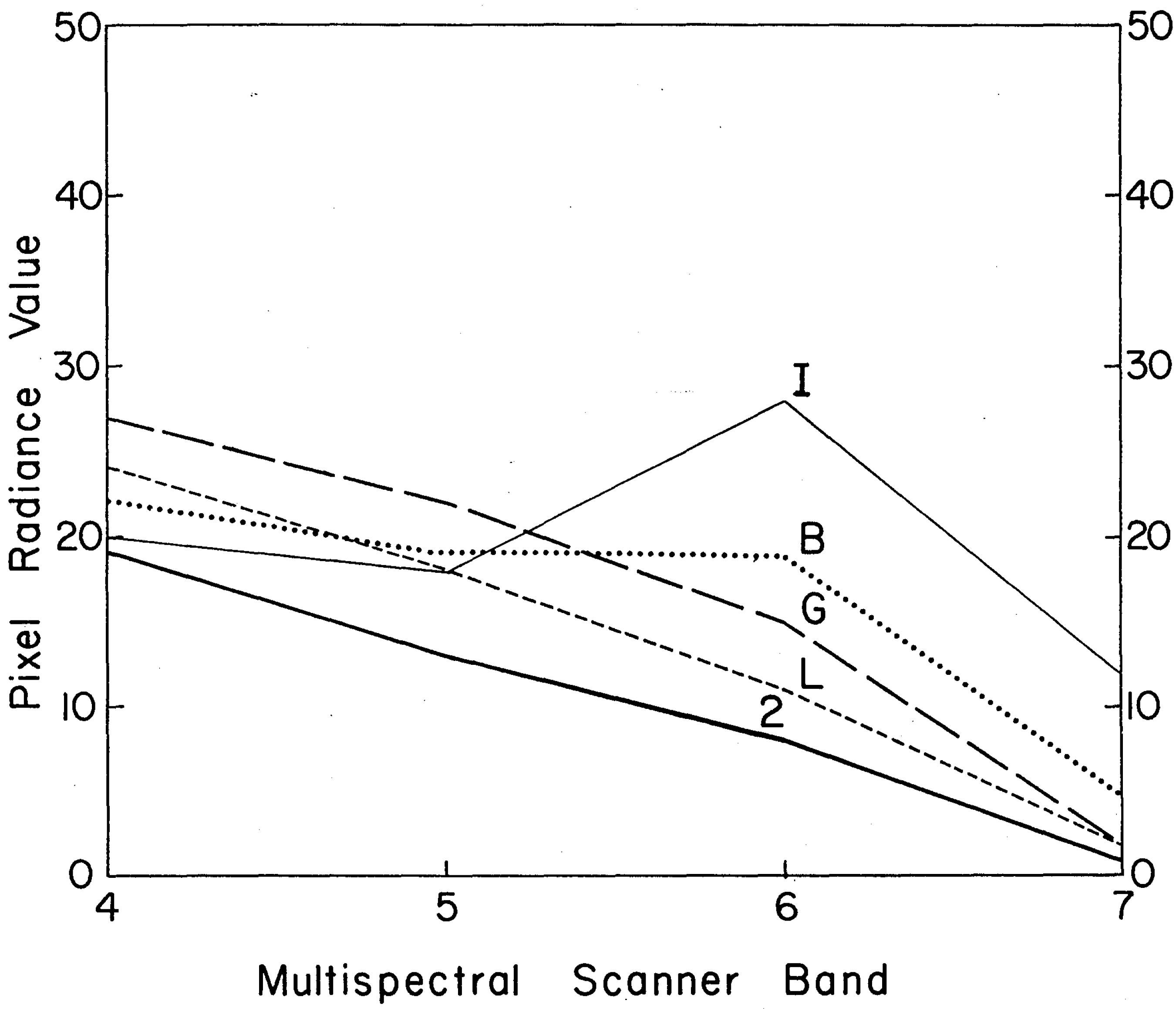

Figure 4. Radiance values for Harbor Island area land cover classes. I = low marsh, mangrove; B = low marsh; G, L = subaqueous grassflat; 2 = water.

are much less uniform than the intensively studied wetlands of the southeastern United States.

3.1.2 Water Quality Maps

For many purposes various water bodies including lakes, rivers, reservoirs, bays, and estuaries are classified according to levels of constituents contained in the water. For example, combinations of chlorophyll a, total suspended solids, salinity, carbon, nitrogen, phosphorus, and oxygen, to specified levels, may be used to classify water bodies on a scale from oligotrophic to mesotrophic to eutrophic. Related factors which may be used in this type of water quality classification include surface temperature and transparency (e.g., as derived from Secchi disk depth measurements). Many of these water quality parameters are manifested as reflectances in electromagnetic radiation which can be recorded by remote sensors. Changes in the quality of water bodies over time or across a particular water body thus may be indicated by changes in reflectance level which may be detected with due attention to data acquisition, processing, and analysis procedures.

The delineation of water quality can only be reasonably accomplished using computer-assisted processing, as compared to manual image interpretation, wherein the spectral characteristics of small groups of pixels can be examined in detail. The Data Collection Plan (Finley, 1978) anticipated correlation of temperature and turbidity, easily obtainable with the capabilities of Landsat-3, with chemical constituents which may not be readily detectable. The failure of the thermal-infrared channel on Landsat-3 shortly before field data collection began seriously set back this attempt. Thermal-infrared data from the airborne multispectral scanner may be substituted in this effort. The airborne scanner, with its larger number of bands and narrower bandwidths, has recently been successfully applied to monitoring dumping of chemical wastes (Ohlhorst and

Bahn, 1979; Johnson and others, 1979). This application will primarily be the responsibility of TNRIS staff.

3.1.3 Water Circulation Maps

Variations in the particulate constituents contained in water bodies often can be recorded by airborne and satellite multispectral scanners. The resulting turbidity patterns can be used to determine the distribution of suspended sediments and other constitutents and to infer surface-water circulation. Water circulation maps can thus potentially be derived from analysis of turbidity patterns that depict such features as the occurrence of tidal plumes, the direction of surface-water flow within the turbid region, and the sources of turbidity. During field data collection samples have been taken for analysis of total suspended sediment concentration. These results, along with Secchi disc extinction depths, will be related to the variation in reflectivity of bay and lagoonal water bodies and the turbidity patterns evaluated as indications of surface water circulation.

The blowout of an oil well in the Bay of Campeche, Mexico, and subsequent wide distribution of oil around the western and northwestern Gulf of Mexico, point to the need for knowledge of surface water circulation. Results of previous studies (Harwood and others, 1977; Finley and Baumgardner, 1980) indicate that circulation patterns can be readily inferred. In computer-assisted land cover analysis more categories of turbid water were often delineated than were actually necessary to make an interpretation. Manual interpretation of hardcopy imagery avoids dealing with an excessive number of turbid-water classes; however, manual procedures cannot yield results at scales larger than 1:125,000. Interactive computer-assisted analysis, through RSIS, will allow the interpreter to quickly combine classes that are redundant and generate maps at scales larger than 1:125,000, if necessary. The lower limit of scales available has not been determined, due to software limitations. This application will primarily be the responsibility of TNRIS staff.

3.1.4 Topographic Map Revisions

The standard topographic map series produced by USGS (e.g., 1:24,000- and 1:250,000-scale maps) are occasionally revised with regard to elevation and contour information and somewhat more frequently regarding natural and cultural features (e.g., roads, railroads, urban areas, forest cover). The RSIS will provide a means for updating natural and cultural features as overlays to the standard maps, using remote sensing data to supplement periodic USGS revision, providing more timely products to the users. At present, scale limitations and incomplete registration of data hamper the implementation of this capability.

The need for revised maps occurs frequently in the Texas coastal region. Residential, commercial and industrial development is occurring at a rapid pace and some areas are significantly altered by dredging of navigation channels and creation of made land. The revision of topographic contours will not likely be a function of RSIS. This application will primarily be the responsibility of TNRIS staff.

3.1.5 Wetlands Certification

The General Land Office selected "Wetlands Certification" as the application on which to focus test and evaluation of TNRIMS in Test Site 1 (Coastal). The General Land Office was assigned the responsibility of designating critical wetlands, that is, wetlands that are of such public value and so threatened by the possibility of alterations that they should be purchased by the state to preserve their natural values. Three things must be considered to determine which wetlands are critical: the value of wetland functions to society, the permanence of each wetland area, and the degree to which each is threatened by alteration.

Wetlands serve a variety of functions that are beneficial to society. Some of these functions are: nursery habitat for commercial and sports species; adult fishery habitat for some species; source or buffer storage area for organic and inorganic materials of importance to estuaries; sediment entrapment; site of aquifer recharge; waterfowl and wildlife habitat; sink for heavy metal ions; natural capability to process moderate levels of waste or spilt material; buffer to wave action for shoreline stabilization; and temporary storm water storage buffer.

Not all wetlands serve each function, nor do all wetlands serving a particular function do so to the same degree. The Land Office, in cooperation with TNRIS, is currently researching the functions of wetlands by examining the characteristics of wetlands known to serve specific functions. Various attributes of these wetlands are being studied so that the functions performed can be associated with a set of measurable characteristics such as tidal amplitude, vegetation type, salinity, land slope, and proximity to point-source discharges.

The objective is to define each function by a set of quantifiable or semi-quantifiable variables. When the functions have been defined in this manner, measurements of variables can be made and combined in a computational procedure to delineate functional units. These units can then be mapped using the Geographic Information System currently under development by TNRIS. Remote sensing is important to this procedure, because it is anticipated to be one of the major data sources.

When the various wetland functions have been mapped, the functions will be rated with respect to importance for particular geographic regions. A second and third series of maps will be produced depicting classes of wetland permanence and classes of likelihood of alteration. These portions of the project have not yet been started; however, they will be the result of a crude classification system consisting of possibly three or four classes of permanence and possible alteration.

The culmination of the project will be the compilation of maps derived from the first three phases of the project. The overlaid maps should allow the agency to locate wetland areas that are high in functional value, are anticipated to be permanent features if not directly altered, and are in danger of immediate alteration. These areas will be potential candidates for designation as critical wetlands. They will then be the object of field checking and possibly acquisition by the state.

Since Landsat is expected to supply part of the information used in wetlands certification, procedures will be developed that can be used routinely and economically. This is dependent upon accurate registration of data displayed on the Ramtek KCRT, functional large-scale displays, and the production of hardcopy data from the Ramtek KCRT. As the definition of requirements for TNRIMS support to the wetlands certification application proceeds, specific products required from RSIS will be identified. These will include land cover/land use maps of selected coastal wetlands and possibly special studies of the frequency of wetland inundation.

3.2 Land Cover/Land Use Classification

The coastal Landsat project administered by the Texas General Land Office (Harwood and others, 1977) led to a land cover/land use classification adapted to the Texas coastal environment. Patterned after the multilevel system of Anderson and others (1976), fourteen of the Level II categories are specifically oriented toward uniquely coastal geologic processes and biologic assemblages.

The User Advisory Group reviewed this classification and added categories at Levels III and IV reflecting specific agency needs (table 5). Whether these categories can successfully be delineated with RSIS remains to be evaluated; other categories may be added as the User Advisory Group and the individual Applications Coordinators continue to review the development of the Texas Natural Resource Inventory and Monitoring System.

3.3 Output Product Characteristics

The output products and product characteristics suggested to the User Advisory Group by the Project Manager are listed in table 6. The User Advisory Group has not met to consider these further. Note that several of the categories indicate the maximum area likely to be covered by a single product, or the most frequent update time which might possibly be necessary. Present remote sensing capabilities do not meet some of the suggested requirements for spatial resolution. These products (table 6) are not to be taken, at this time, either as definite agency needs or as capabilities required of RSIS. The User Advisory Group and the Applications Coordinator will define the specific characteristics desired in each product type, including information content (and level of detail), accuracy, and format. Present (January, 1981) color output products are limited by the film format accepted by the Matrix camera and by the area of coverage possible on the Ramtek KCRT at a given map scale.

3.4 Product Format

The final format of RSIS products is dependent upon the mechanism for generating hard-copy images from digital data. A Matrix Color Camera System will be available to make color positive (Polaroid) prints, or color film positives and negatives for production of images as displayed on the Ramtek KCRT

Table 5. Land cover and land use classification system for the Texas Coastal Zone.

LEVEL I CATEGORIES	LEVEL II CATEGORIES	LEVEL III CATEGORIES	LEVEL IV 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	2411 Return-Flow Irrigation
	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	4311 Post Oak-Live Oak Woodland
	42 Evergreen Forest Land		
	43 Mixed Forest Land		
5 Water	51 Streams and Canals	511 Non-Turbid	
	52 Lakes	512 Slightly-Turbid	
	53 Reservoirs	513 Moderately-Turbid	
	54 Bays and Estuaries	514 Highly Turbid/Very Shallow	
	55 Open Marine Waters (Gulf)	521 Non-Turbid	
		522 Slightly-Turbid	
		523 Moderately-Turbid	
		524 Highly Turbid/Very Shallow	
		531 Non-Turbid	
		532 Slightly-Turbid	
		533 Moderately-Turbid	

Table 5. (continued)

LEVEL I CATEGORIES	LEVEL II CATEGORIES	LEVEL III CATEGORIES	LEVEL IV CATEGORIES
5 Water (cont.)		534 Highly Turbid/Very Shallow	
		541 Non-Turbid	
		542 Slightly-Turbid	
		543 Moderately-Turbid	
		544 Highly Turbid/Very Shallow	
		551 Non-Turbid	
		552 Slightly-Turbid	
		553 Moderately-Turbid	
		554 Highly Turbid/Very Shallow	
6 Wetland	61 Forested Wetland	621 Topograhically 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		

Table 6. Possible output products and product characteristics for RSIS.

OUTPUT PRODUCT CHARACTERISTICS

POSSIBLE OUTPUT PRODUCTS	SPATIAL RESOLUTION REQUIREMENTS	PRODUCT SCALE	MAXIMUM AREAL COVERAGE DESIRED FOR ONE PRODUCT	MAXIMUM AREA OVER WHICH PRODUCTS MAY BE REQUIRED	MAXIMUM PRODUCT UPDATE FREQUENCY	FORMAT
Level I Land Cover/ Use	80-200 m	1:250,000	Same boundaries as AMS quad (1:250,000)	Entire Coastal Zone	Annual	Map, Map overlay, Tabular Digital
Level II Land Cover/ Use	40-200 m	1:100,000 1:125,000	Same boundaries as USFWS and BEG maps	Entire Coastal Zone	Annual	Map, Map overlay Tabular Digital
Level III Land Cover/ Use	5-40 m	1:24,000	Same boundaries as quad map	Entire Coastal Zone	Annual or as needed	Map, Map overlay Tabular Digital
Level IV Land Cover/ Use	5-40 m	1:10,000	10 km X 10 km	Selected areas	As needed	Map, Map overlay, Tabular Digital
Level I-IV Land Cover/ Use Change	Same as source maps	Same as source maps	Same as source maps	Same as source maps	Same as source maps	Same as source maps
Lake/Bay/ Estuary Water Quality	2-200 m	1:24,000	Same boundaries as quad map	Entire Coastal Zone	Annual	Map, Map overlay, Tabular

Table 6. (continued)

POSSIBLE OUTPUT PRODUCTS	SPATIAL RESOLUTION REQUIREMENTS	PRODUCT SCALE	MAXIMUM AREAL COVERAGE DESIRED FOR ONE PRODUCT	MAXIMUM AREA OVER WHICH PRODUCTS MAY BE REQUIRED	MAXIMUM PRODUCT UPDATE FREQUENCY	FORMAT
Water Circulation (Turbidity)	40-200 m	1:24,000 to 1:250,000	Same boundaries as quad map	Entire Coastal Zone	Monthly	Map
Topographic Map Revisions	5-40 m to 40-200 m	1:24,000 to 1:250,000	Same boundaries as quad maps	Entire Coastal Zone	Annual (for planimetric features)	Map, Map overlay, Digital

display. The capacity of this device to produce an accurate and cartographically acceptable product of the appropriate dimensions and colors needs to be investigated; it is unclear at this time whether such a product from the KCRT could serve as more than an interim work product. Evaluations of other possible approaches for generating hard-copy output products are also being conducted, including the use of electrostatic printers and the TDWR computer graphics capabilities.

RSIS output products will be annotated with pertinent information on scale, content, orientation, explanation, date and source of original data, minimum mapping unit, and other information. Software will be available to add alphanumeric annotations directly on the image. The classified results (land cover/land use) will also be output to tape in a format acceptable to the TNRIS Geographic Information System (GIS) for further processing. The User Advisory Group and the Applications Coordinators will be asked to review and comment on early RSIS products in order to optimize product size and format. Dimensions and reproducibility of the wide range of colors possible with the Ramtek KCRT will depend on the method used to generate hard-copy images from digital data.

4.0 TEST PRODUCTS

4.1 Description

Test products for each of the four types of output identified for development using RSIS will be part of the development and evaluation of the Subsystem. These four types of output are maps of land cover/land use, water quality, surface water circulation, and topographic map revisions. Development of the latter three product types will primarily be the responsibility of TNRIS staff. Using table 6 as a guide, the location, scale and extent of coverage for each of these products can be considered for the coastal test site. The type of products to support the wetlands certification application will be defined by the General Land Office Applications Coordinator.

4.1.1 Land Cover/Land Use Maps

The primary map bases available for land cover/land use mapping are at scales of 1:250,000 and 1:24,000. However, in the Texas Coatal Zone a 1:125,000-scale base is also available as a product of the Environmental Geologic Atlas of the Texas Coastal Zone (Brown, project coordinator). Using RSIS, Level I land cover/land use maps can therefore be compiled which match 1:250,000- and 1:125,000-scale map bases. Level II land cover/land use maps are most appropriately scaled at 1:125,000 or 1:24,000, and the latter may also be the most suitable scale for Level III maps. Where the greatest detail is desirable for a limited area, 1:24,000 would be the largest appropriate scale for Level III/Level IV mapping when Landsat imagery is the sole data source.

Whereas the 1:250,000-scale map is often at a scale too small for some applications of land cover/land use mapping, the 1:125,000 scale has been large enough to facilitate comparison with 7.5-minute quadrangle maps. This was the case in the previous Landsat coastal study (Harwood and others, 1977), during which computer-assisted Landsat products at 1:24,000 scale were compared and interpreted simultaneously with 1:125,000-scale products of manual image interpretation. It is unfortunate that this intermediate scale will only be available for the Coastal Test Site during the ASVT Project. Products at 1:125,000 will be most similar to 1:100,000-scale maps which will ultimately be available as metrication of small-scale map bases is undertaken.

Mapping of urban environments at Level I and Level II can best be undertaken for the Corpus Christi vicinity at 1:250,000 and 1:125,000 scales. This is one of the urban areas within CATS. USGS 7.5-minute quadrangle maps in the

Corpus Christi area were originally issued in 1968 and were photorevised in 1975; the Oso Creek NE quadrangle near Corpus Christi shows areas of ongoing residential development. Products generated by RSIS could be used to document urban land use changes over periods of 5 and 7 years, respectively, for these areas.

Agricultural land and rangeland are found in large blocks throughout the test site. Most of the best land for crops, over the Pleistocene interdistributary muds, are under cultivation and little change in use of these areas is expected with time (Finley, 1979b). Sandy substrates are more often used for rangeland. Landsat data can be used to monitor burning as a rangeland management practice, if these data are of significance to state agency needs. Thus far this requirement has not been established. In past use of Landsat imagery it was found difficult to distinguish gradations between herbaceous rangeland and forest land where shrubs and brush occur. The more advanced capabilities of RSIS along with appropriate ground data, including spectral information, will help delineate these land cover types.

The coastal wetlands of Texas have been mapped by the Bureau of Economic Geology for the Environmental Geologic Atlas of the Texas Coastal Zone (Brown, project coordinator) and are being reevaluated using another classification scheme for the U.S. Fish and Wildlife Service. A basic inventory of wetlands is therefore hardly necessary when using a tool of lower resolution than the photography utilized in these studies. The need, however, is to be able to monitor changes in wetlands and determine rapidly if any impact has occurred, for example, from the creation of made land or other disposal of dredged materials. Level III categories (table 5) are appropriate to this task at a map scale of 1:24,000. Texas coastal nonforested wetlands are diverse in species content and include areas of ponded water and barren substrate which are spatially averaged over the minimum resolution elements of the Landsat sensors. This is true over a marsh at Pass Cavallo (Grass Island) and, to a lesser extent, for a marsh at the entrance to Powderhorn Lake which are being studied during Landsat ground data collection exercises. The objective of these studies is to evaluate seasonal spectral response of the plant species as well as to determine how any differences in water levels affect Landsat imagery over a nonhomogeneous wetland area.

Barren areas of high reflectance, such as beaches, dunes, dredge spoil, and some tidal flats, have been relatively easy to delineate on land cover/land use maps prepared by manual and computer-assisted methods. Problems have occurred in defining waterlines around these categories, and, in digital analysis, multiple classes consisting solely of boundary pixels have been produced. To better define land/water boundaries, ground targets which can be seen on 1:5,000 and 1:30,000 photography collected during Landsat overpasses have been deployed during data collection. These targets are placed with one edge on the waterline, to be mapped on the photography and are correlated into the Landsat imagery. It appears that some boundary pixels are mainly the result of reflectance from shallow subaqueous areas and the true shoreline lies landward of these pixels. This technique for the documentation of waterlines will be tested using data from Test Site 1.

4.1.2 Water Quality Maps

The use of Landsat or airborne multispectral scanner (MSS) data to determine water quality parameters will be the most difficult product for RSIS to generate. For parameters other than total suspended solids and the delineation of unusual chemical constituents (particulate iron in an ocean dump; Ohlhorst and Bahn, 1979), use of MSS data, airborne or satellite, to characterize water quality has met with limited success. Yarger and McCauley (1975) found that chlorophyll levels up to 8 μg/l were not detectable in Kansas reservoirs using Landsat band ratios. Because phosphate was somewhat correlated with suspended solids, these authors did find some MSS band-ratio correlation with phosphate. Otherwise, potassium, phosphate and nitrate at concentrations of 20, 2, and 10 ppm, respectively, were not correlated with reflectances determined from Landsat data.

The ground data collection program in the coastal test site includes sampling of carbon, phosphorus and nitrogen in several forms, and chlorophyll a. If multispectral data could not be directly correlated with these parameters, then indirect correlation through delineation of turbidity and temperature would be attempted. A flood-tidal plume from the Gulf of Mexico into coastal bays and lagoons may have differed in these chemical constituents; however, with failure of the thermal infrared channel on Landsat-3, only correlation with turbidity is now possible. Yarger and McCauley (1975) did find a slight negative correlation of chlorophyll with the Landsat MSS band 5/band 4 ratio for concentrations over 8 μg/l but considered it unreliable due to insufficient data. Data from Espiritu Santo and Matagorda Bays on May 14, 1979, show chlorophyll a values from 5 to 18 μg/l, with 8 of 10 determinations at or above 9 μg/l. Turbidity may, however, interfere with correlation of MSS response to chlorophyll a content.

The Data Collection Plan (Finley, 1978) for CATS emphasized collection of water quality data in coordination with Landsat overpasses. A total of 30 stations in northern Laguna Madre, Mesquite Bay, Espiritu Santo Bay and southwest Matagorda Bay were occupied during overpasses on October 1, 1978, and May 14, 1979, for study of water quality including sampling of total suspended solids. At 18 of these stations additional sampling for chemical parameters (carbon, phosphorus and nitrogen) was carried out. Pixel groups from Landsat MSS imagery overlying these stations will be digitally processed and correlation attempted with chemical constituents. Results will be displayed on 1:24,000-scale maps covering those portions of coastal waters sampled.

4.1.3 Water Circulation Maps

The surface circulation of coastal waters can be inferred from patterns of turbidity seen on Landsat MSS band 5 imagery. Turbidity acts as a natural tracer which defines tidal inlet and river plume expansion, longshore current flow, and current patterns within coastal bays (Finley and Baumgardner, 1980). Band ratios (4/5 and 5/6) can be utilized to estimate relative concentration of suspended sediment within a turbid water body; knowledge of exact amounts of suspended sediment is not required for this application.

Manual interpretation of Landsat band 5 imagery has been useful with four classes of turbidity mapped at a scale of 1:125,000 (Finley, 1979b). Using the hard-copy image as a guide, computer-assisted analysis at a scale of 1:24,000 could be used to help define surface water circulation around an existing structure or a proposed development site. Past experience suggests that computer-assisted analysis will generate more classes of turbid water than can be reasonably interpreted, and that classes will have to be combined during analysis.

4.1.4 Topographic Map Revisions

Testing of the digital map revision capability will result in products at a scale of 1:24,000 only, unless a specific request for revised 1:250,000 maps is received. Because Landsat standard paper prints are available at a scale of 1:250,000, revisions at that scale would be best accomplished manually, without computer-assisted analysis. Parts of Corpus Christi for which photorevised 7.5-minute quadrangle maps have recently been released (see section 4.1.1) are areas where land cover/land use mapping can be applied to topographic map revision.

This capability is aimed at producing revisions showing cultural features and physical changes, such as dredged channels and made land, without revision of topographic contours.

Quadrangle maps which have recently (1973-1975) been revised on the basis of aerial photography provide an excellent test for the RSIS Landsat-based capability. Relative to the unrevised map, a Landsat-based revision should show all changes noted on the updated map, and delineate those changes now evident on aerial photography flown over Test Site 1 (1978-1979) in coordination with Landsat overpasses.

4.1.5 Wetlands Certification

The wetlands certification process requires that the condition of each defined wetland area be reviewed periodically in light of the certification criteria. The evaluation of condition will be carried out, in part, by use of the RSIS to generate land cover/land use maps of the wetland and adjacent areas. The development, test, and evaluation effort will lead to a definition of the specific levels of information required for each classification category, as well as providing other product specifications (map scale, etc.). In addition, the development of basic information files (one-time descriptions of slowly changing features) necessary for certification analysis may require use of RSIS for the preparation of specialized products. A product still under development is a map showing the frequency of inundation for wetlands. This map is to be prepared from Landsat data (and aircraft photography, if available) representing different tidal conditions.

4.2 Procedures

The development and documentation of "prototype" procedures for preparation of test products began with a thorough review of procedures documented in the literature. This review took into account the results of the July, 1979, RSIS Functional Design Review and associated documentation (Brown and others, 1979). The final documented procedures will become a part of the RSIS capability for specific applications in coastal environments and also will provide a basis for developing RSIS procedures to be used in other environments and with different applications (forestry, wildlife, etc.)

4.3 Product Number/Location/Coverage

One map product of each type listed in table 8 will be prepared using the RSIS. Additional maps may be prepared as needed to evaluate important variations in surface features, consistent with available Project staff, time, and funds. The minimum number of products necessary to fully evaluate the wetlands certification application will be prepared. The location and coverage of each map product will be defined by the Project Team after review of table 6 and other materials.

4.4 Responsibility/Schedule For Product Generation

The Bureau of Economic Geology, under interagency contract with TNRIS, will prepare those products needed for support of the General Land Office wetlands certification application. They will prepare other products defined above as staff, time, and funds permit. TNRIS staff will provide supplemental support to this effort as appropriate. It is anticipated that the wetland certification products will be completed by March or April, 1981.

5.0 EVALUATION OF TEST PRODUCTS

5.1 Purpose

Evaluations of the cost, accuracy, and utility of selected products generated by the RSIS will result in specific instructions for improving the individual products themselves to better support the user's needs. The evaluation results also will provide a basis for improving the various RSIS components (hardware, software, procedures) which in turn should enhance the quality of products to be generated from the Subsystem in the future.

5.2 Economic Evaluation Plan

The objective of the analysis proposed in the Economic Evaluation Plan (Finley, 1979a) is to compare the cost and accuracy of map production using existing methods with map production using RSIS. Existing, or conventional, methods imply use of the aerial photography taken in conjunction with Landsat ground data collection for mapping through photointerpretation techniques. The comparison of these results with those derived through RSIS will be made on the basis of (1) cost of map production, (2) accuracy as determined by a comparison with existing maps and other data, (3) an approximation of the cost of data acquisition, and (4) utility as determined by the User Advisory Group and Application Coordinator. The latter step is significant in that it reflects the user's assessment of remote sensing techniques and the resulting products. Greater detail on the objectives of the economic evaluation and the methodology involved are in the Plan itself.

5.3 Comparison Products

Comparison products will be generated by conventional photointerpretation at scales and levels of detail similar to RSIS test products. Color and color-infrared photographs at scales of 1:120,000 and 1:30,000 were acquired by NASA in conjunction with ground data collection and have been used in comparison mapping.

For Level I the map base used was Army Map Service, Beeville and Corpus Christi sheets, and scale adjustment of the photographs to the 1:250,000 base was made through a Bausch and Lomb Zoom Transfer Scope. Time sheets were kept during mapping for tasks included in the procedure (table 7). Additional time was spent preparing a photo index prior to the start of data interpretation. A minimum mapping unit of 5.76 hectares, equivalent to a 2-by-2-mm block on the photographs was adopted, and a total of 81-1/4 hours was necessary to carry the mapping through task 4 (table 7). Few difficulties were encountered in mapping seven Level I units over the test site.

Table 8 outlines comparison products to be generated for CATS. Photography acquired over the Texas Coastal Zone at scales of 1:60,000 or larger may be used in addition to photography of the entire test site at 1:120,000 to generate comparison products such as 1:24,000-scale topographic map revisions.

A Level I (1:250,000) land cover/land use map has been prepared for the entire Test Site I area. The wetlands certification application will be tested in the Nueces-Corpus Christi Bay and Lavaca Bay areas, while procedures development has focused on Pass Cavallo and the Guadalupe River delta. Table 9 lists the January, 1981, status of all comparison products. Any additional products to be prepared will be determined by the Project Manager.

6.0 ACKNOWLEDGMENTS

This plan was originally prepared under Interagency Contract No. (78-79)-2045 and was revised under Interagency Contract No. (80-81)-1676 between the Texas Natural Resources Information System/Texas Department of Water Resources and the Bureau of Economic Geology, Robert J. Finley, Principal Investigator. The text was reviewed by E. G. Wermund and L. F. Brown, Jr. Assistance in preparation was provided by Marcie Machenberg and typing was under the direction of Lucille Harrell. Illustrations were prepared under the direction of J. W. Macon and by the Texas Natural Resources Information System.

Table 7. Mapping time sheet (sample).

Name Elmo Brown — Position Res. Asst.

Monday, Jan. 29 — through Friday, Feb. 2, 1979

Area: CATS — Level I — Scale: 1:250,000

	Task	Hours	Task	Hours	Task	Hours
MONDAY	2	4 1/2				
TUESDAY	2	1 1/4				
WEDNESDAY						
THURSDAY						
FRIDAY						

Task Code

0: Preparation of base map

1: Study of supporting materials

2: Interpretation

3: Checking interpretation

4: Map clean-up and annotation

5: Checking scribe sheet

6: Preparing final work copy

Table 8. Comparison products for CATS by general type.

Map Theme	Level	Scale	Data Source	Area or Coverage
Land cover/ land use	I	1:250,000	1:120,000-scale photographs	Entire test site.
Land cover/ land use	II	1:125,000	1:120,000-scale photographs	Selected segment of test site perpendicular to coastline.
Land cover/ land use	II,III	1:24,000	1:120,000-scale photographs, supplemented by 1:30,000-scale data, if applicable	Selected 7.5-minute quadrangles with maximum diversity.
Land cover/ land use (especially wetlands)	III,IV	1:24,000 or 1:12,000	1:30,000-scale photographs, supplemented by 1:5,000-scale data, if applicable	Selected segments of 7.5-minute quadrangles designed to parallel potential site-specific applications of RSIS. Pass Cavallo and Powderhorn Lake area wetlands will be mapped.
Water quality	n.a.	1:24,000 or 1:12,000, as appropriate	1:30,000-scale photographs, supplemented by 1:120,000-scale data, if applicable	Interpretations of turbidity and water color over sampling stations only are applicable to this product.
Surface water circulation and turbidity distribution	n.a.	1:125,000 or 1:24,000, as appropriate	1:120,000-scale photographs, supplemented by 1:30,000-scale data, where applicable	Selected segments of test site including tidal inlets of Pass Cavallo and Aransas Pass.

Table 8. (continued)

Map Theme	Level	Scale	Data Source	Area or Coverage
Topographic map revision	n.a.	1:24,000	1:120,000-scale and 1:60,000-scale aerial photographs	Victoria and Corpus Christi areas for urban categories; Pass Cavallo area for wetlands and shoreline change; North Padre and Mustang Island areas for suburban and recreational development.

n.a. = not applicable

Table 9. Status of specific comparison mapping products completed for CATS as of February 2, 1981.

Map Name	Scale	Level	STATUS: Mapped	Checked	Scribed	Colored
Test Site 1 (complete)	1:250,000	I	X	X		
San Antonio Bay area	1:125,000	II	X			
Nueces-Corpus Christi Bay area	1:125,000	II	X			
Lavaca Bay area (east shore)	1:125,000	II	X			
Nueces-Corpus Christi Bay area quadrangles						
Robstown/Edroy (partial)	1:24,000	III	X	X	in progress	
Annaville/Odem (partial)	1:24,000	III	X	X	in progress	
Corpus Christi/Taft (partial)	1:24,000	III	X			
Portland/Gregory (partial)	1:24,000	III	X			
Lavaca Bay area (east shore) quadrangles						
Port Lavaca/Point Comfort (partial)	1:24,000	III	X			
Keller Bay (partial) and Olivia (complete)	1:24,000	III	X	X	X	
La Salle (partial)	1:24,000	III	X			
Lolita (complete)	1:24,000	III	X			
La Ward (partial)	1:24,000	III	X			
Turtle Bay (partial)	1:24,000	III	X	X	X	X

Table 9. (continued)

Map Name	Scale	Level	STATUS			
			Mapped	Checked	Scribed	Colored
Port O'Connor	1:24,000	III	X	X	X	X
Pass Cavallo	1:24,000	III	X	X	X	X
Austwell	1:24,000	III	X	X	X	X
Oso Creek NE	1:24,000	III	X	X	X	X
Victoria East	1:24,000	II	X			

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FIGURE CAPTIONS

Figure 1. Overview of the Texas Natural Resource Inventory and Monitoring System and Subsystems.

Figure 2. RSIS data processing facility.

Figure 3. Coastal Applications Test Site boundaries (Test Site I).

Figure 4. Radiance values for Harbor Island area land cover classes. I = low marsh, mangrove; B = low marsh; G, L = subaqueous grassflat; 2 = water.