# TEST PLAN
# FOR
# REMOTE SENSING INFORMATION SUBSYSTEM
# PRODUCTS,
# COASTAL APPLICATIONS TEST SITE

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TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

## 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 formal methods of map evaluation, which includes generation of equivalent products from aerial photography. The first two objectives are addressed in this report. A conceptual design for economic evaluation has previously been developed (Finley, 1979), is included here as Appendix A, and is expanded upon in this report with a description of specific map products to be used for comparison purposes.

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 conceptual and are not derived from hands-on experience with Landsat imagery or image processing hardware and software. Present time schedules call for software required for initial analysis of data over the Coastal Applications Test Site (CATS) to be available in November, 1979.

## 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. 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):

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 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.

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 his knowledge of natural processes, the activities of man, and the known spectral response of land cover in the area of analysis.

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 in a Zoom Transfer Scope is an example of such manual interpretation techniques.

4) The Subsystem should 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 must be available from RSIS which meet specific user needs and are in the form of appropriately scaled and formatted hard-copy maps. 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 and software 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 1, 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. Under Release I of the RSIS system in November, 1979, a tape-transfer will be used between the Univac 1100/41 and the Interdata

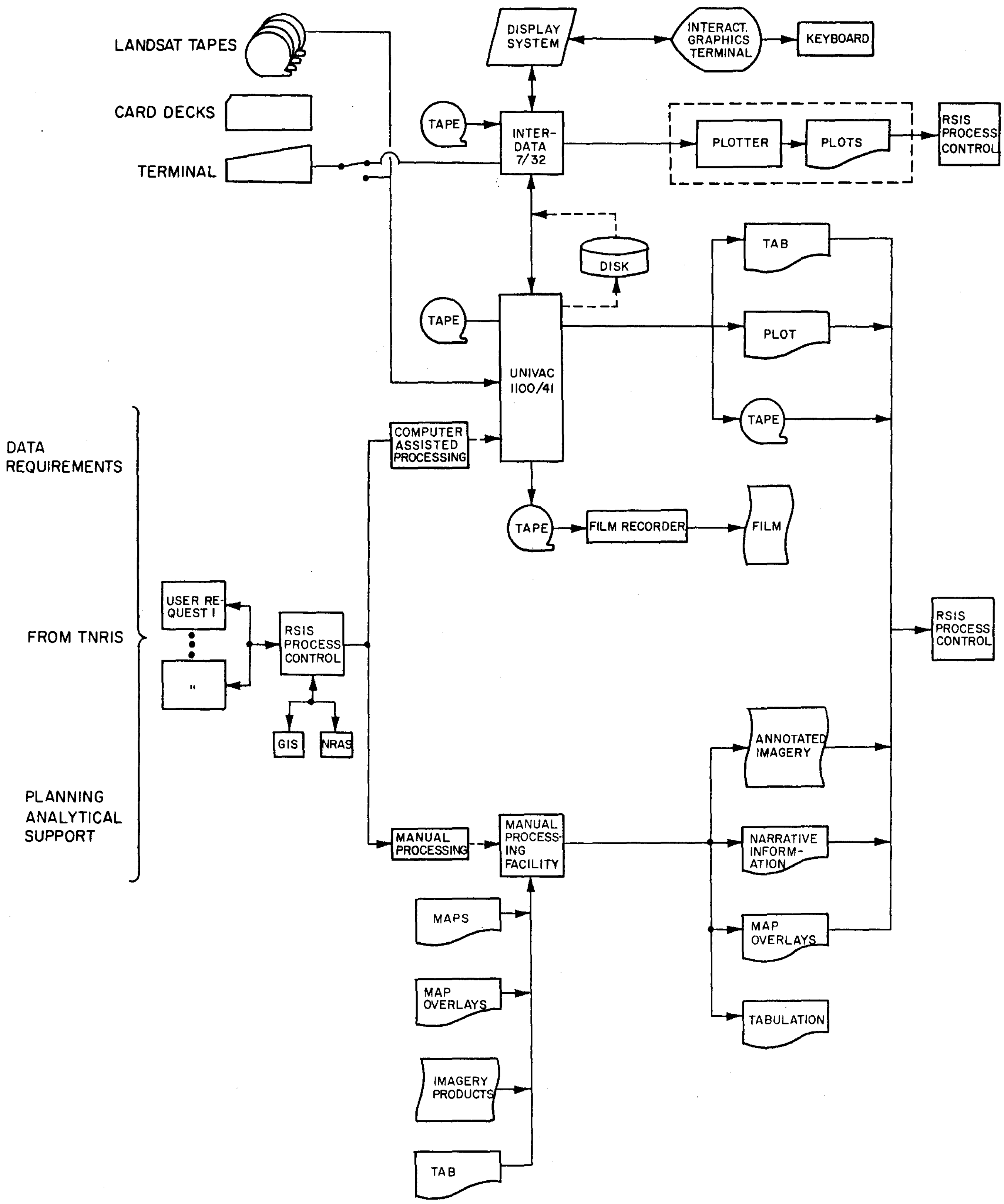


Figure 1. RSIS data processing facility.

7/32 for subsequent display of results on the Ramtek KCRT. The system will not be totally interactive in that an operation such as a reclassification procedure requiring the Univac 1100/41 will require two tape transfers and will also be impacted by the demands of other machine users.

The Interdata 7/32 will, however, be dedicated at selected times for use as part of RSIS and will be hard-wired to the Ramtek KCRT. The analyst will likely wish to work concurrently on the development of several products or on the analysis of multiple areas in order to make most efficient use of dedicated time on the Interdata 7/32. Such a procedure would also avoid excessive amounts of time spent traveling from an office location to the RSIS facilities relative to the total time spent on development of each product. Where possible, image processing software which could be implemented on the Interdata 7/32 would result in a more truly interactive system.

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). These modules are geared to accommodate a tape-transfer interface between the Univac 1100/41 and the Interdata 7/32, and may require selected modifications if a hardware interface is implemented at a later date.

## 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

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

A. PREPROCESSING

1. Contract "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

Table 1.- Concluded

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

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. <u>POSTPROCESSING</u>

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

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

D. <u>OPERATION</u>

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.

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 thus far consists primarily of representatives of TNRIS member agencies whose responsibilities in the Texas Coastal Zone may likely be supported by RSIS. A change in representation is likely 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).

## 2.0 Coastal Applications Test Site

### 2.1 Description

The Coastal Applications Test Site (CATS) is located over the Central Texas coastal region (fig. 2) 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 bayside 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 CATS, data collection has been concentrated in southwest Matagorda Bay, Espirito 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.

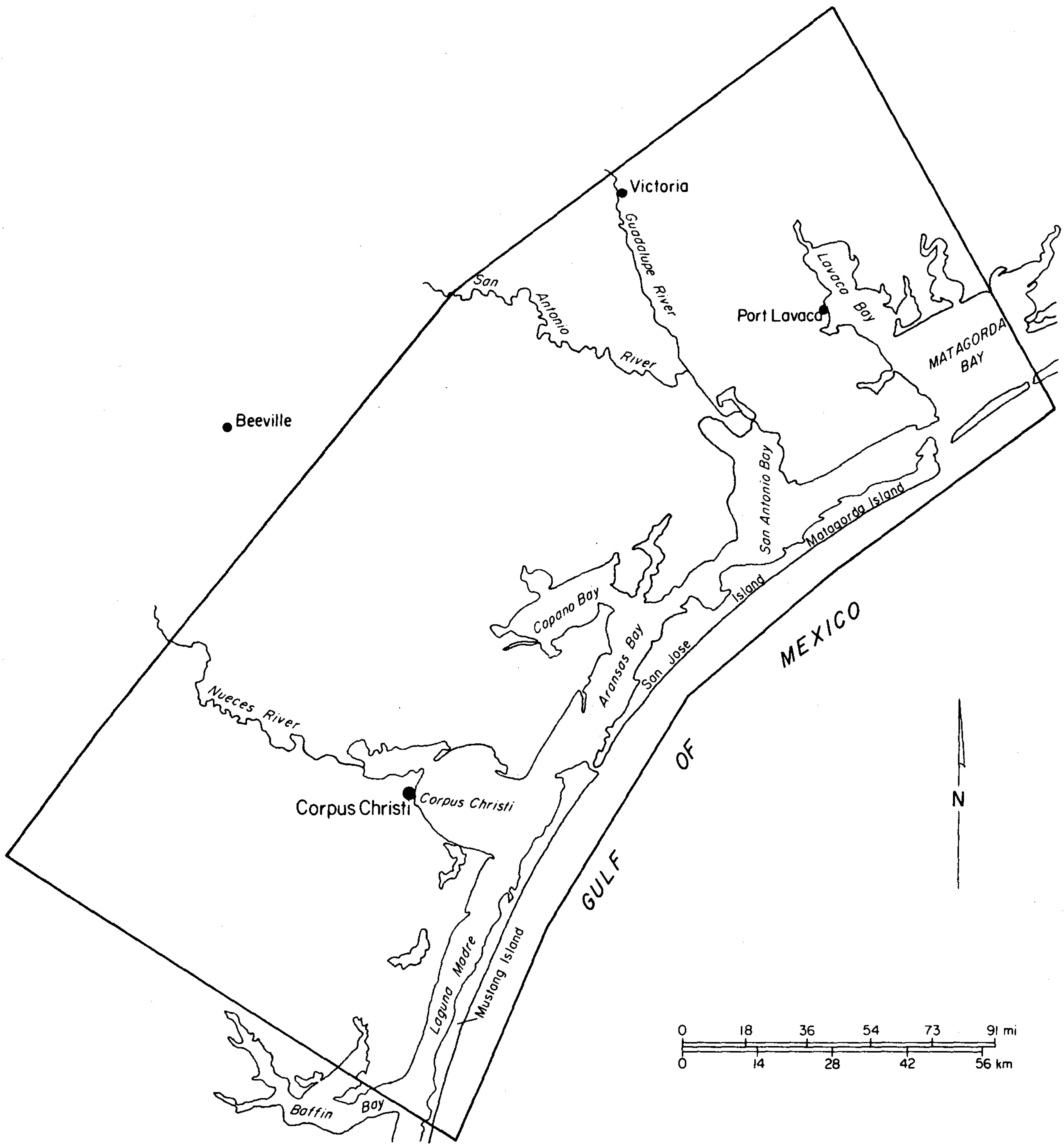


Figure 2. Coastal applications test site boundaries.

## 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. A seemingly 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 has been scheduled for October, 1979 in order 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.

During 1979 two events occurred which may, in part, be evaluated through use of Landsat imagery. These are the oil spill from a well in the Bay of Compeche in Mexico, and the intense rainfall from tropical storm Claudette which fell along the upper Texas coastal plain in late July, 1979. Landsat imagery can provide a synoptic view over open water and adjacent coastal

Table 2. Summary of CATS 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 |

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

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) areas, and the oil is readily seen on band 5 data. These images are primarily useful (when cloud-free) as documentary material because availability of the data follows several days of processing time. Landsat imagery obtained within the week following the tropical storm will be examined to determine any potential value in mapping areas of stream flooding. The intensity of the total storm rainfall (508 to 1016 mm, or 20 to 40 in) may, however, have resulted in ponded water over such wide areas that the limits of stream flooding may not be definable, based on the detection of saturated soil using Landsat imagery.

## 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 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.

#### 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

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. MAN-MADE-FEATURES | | | | | | | | | | | | | | |
| 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 |
| Squatters shacks | | X | | | | | | | | | | | | |
| Beach obstructions | 0 | X | | | | | | | | | | | | |
| State-owned lands | 0 | X | | | | | | | | | X | | | |
| Dam and spillways (location, size, type, condition) | | | 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 | | | |

NOTE: These abbreviated terms actually refer to information requirements which may include several data items (e.g., location, size, type, condition, etc.).

Table 4. (cont.)

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

AGENCY

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3. <u>GEOLOGY</u> | | | | | | | | | | | | | | |
| Rock types | X | X | | X | | | | | X | X | X | X | | |
| Structures | X | X | | | | | | | | | | | | |
| Topography | X | X | | | | | | | X | X | X | X | | |
| Slope | | 0 | | | | | | | | | 0 | | | |
| Aspect | | 0 | | | | | | | | | 0 | | | |
| Substrate | 0 | 0 | | | | | | | | | | | | |
| Mineral sources (type/location) | 0 | 0 | | | | | | | | | | | | |
| 4. <u>HYDROLOGY</u> | | | | | | | | | | | | | | |
| 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. <u>SOILS</u> | | | | | | | | | | | | | | |
| General Mapping (type) | X | X | | X | | X | | | X | X | X | X | | |

Table 4. (cont.)

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6. <u>AGRICULTURE</u> | | | | | | | | | | | | | | |
| Range & pasture mapping | | | | | | | X | | X | | 0 | | | |
| 7. <u>BIOLOGY</u> | | | | | | | | | | | | | | |
| Marsh mapping | | X | X | | | | | | | | X | X | | |
| Grassflat mapping | | X | X | | | | | | | | X | | | |
| Swamp mapping | | X | 0 | | | | | | | | 0 | | | |
| 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 | | | |

Table 4. (cont.)

X = Derived from Texas Remote Sensing Plan, 1974
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| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AGENCY | | | | | | | | | | | | | |
| 8. CSTL. GEOMORPH. | | | | | | | | | | | | | | |
| Subsidence | X | X | X | | | | | | X | X | X | | 0 | |
| Bathymetry | X | X | | | | | | | | X | X | | X | |
| Shoreline mapping | X | X | | | | | | | | | X | X | | |
| Circulations | X | X | X | | | | | | | | X | | 0 | |
| Water quality | X | X | X | | | | | | X | | X | | | |
| Turbidity | X | X | X | | | | | | | | X | | | |
| Water pollution: Source, Quantity, Type) | | | 0 | | | | | | | | 0 | | | |
| Eutrophication (Trophic Level) | | | X | | | | | | | | X | | | |
| Water Pollution Outfall Location | | 0 | 0 | | | | | | | | 0 | | | |
| 9. MANAGEMENT | | | | | | | | | | | | | | |
| Land Resources | 0 | 0 | | | | | | | | | | | | |
| Activity Impact Assessment | 0 | 0 | 0 | | | | | | | | 0 | | | |
| Natural & Scenic Areas: Type, Location, Area | | 0 | | | | | | | | | 0 | | | |

Table 4. (cont.)

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| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9. MANAGEMENT (cont.) | | | | | | | | | | | | | | |
| 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 | | |
| 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 | | | | | | | | | | | | |

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 1 and 2 as defined by the USGS and on Levels 3 and 4 to be defined by the Project Team and User Advisory Group in coordination with other user agencies. In developing Levels 3 and 4, 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. 3) 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

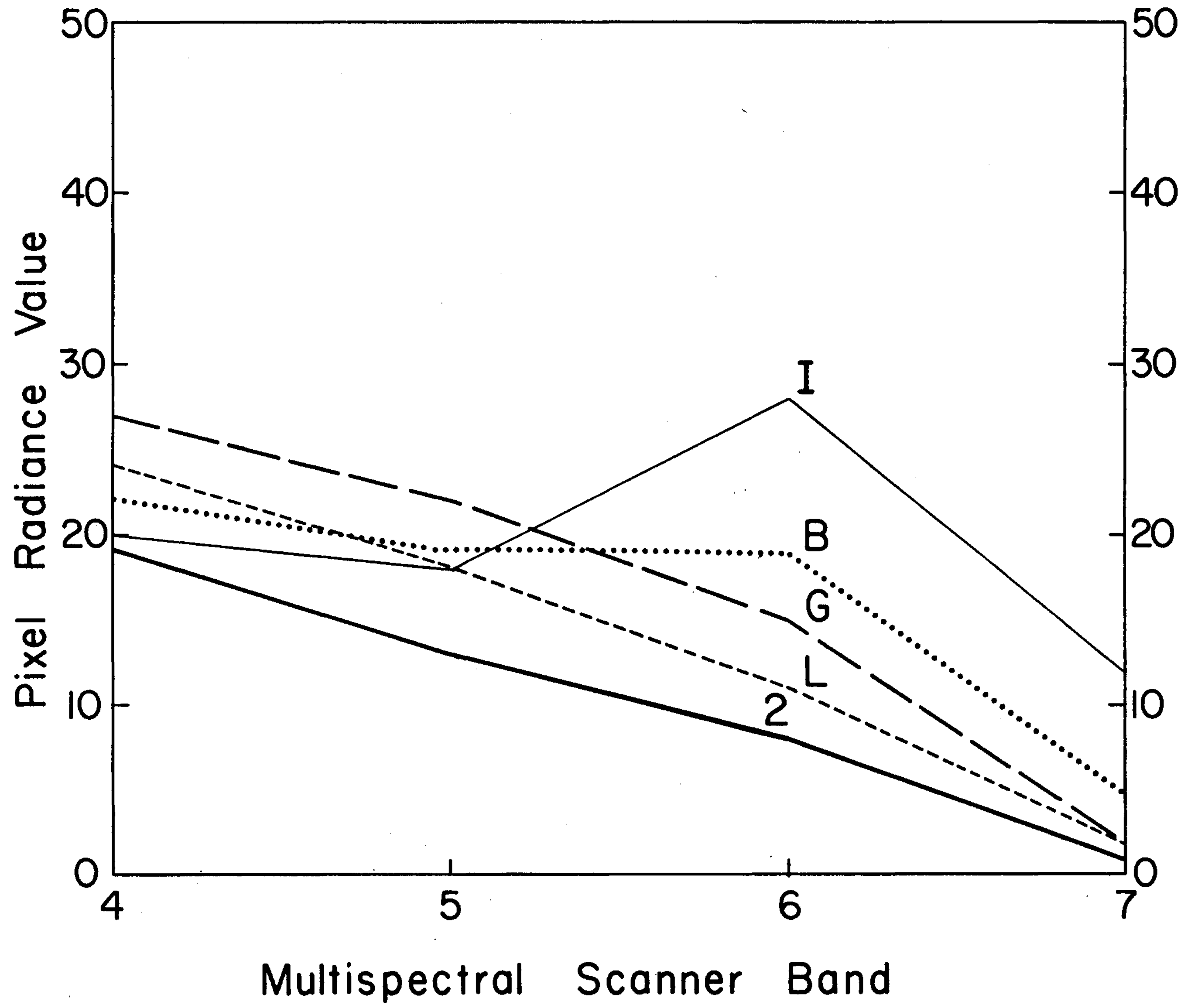


Figure 3. Radiance values for Harbor Island area land cover classes. I = low marsh, mangrove; B = low marsh; G, L = subaqueous grassflat; 2 = water.

as a map of biologic assemblages from the Environmental Geologic Atlas of the Texas Coastal Zone (Brown and others, 1976). By 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 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 (Olhorst and Bahn, 1979; Johnson, and others, 1979).

### 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 constituents 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, points to the need for knowledge of surface water circulation. Results of previous studies (Harwood and others, 1977; Finley and Baumgardner, in press) 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 hard-copy 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.

### 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.

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.

## 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 continues 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 special resolution. These products (table 6) are not to be taken, at this time, either as definite agency needs or as capabilities required of RSIS.

## 3.4 Product Format

Final format of RSIS products is dependent upon the mechanism for generating hard-copy images from digital data. Tapes may be sent to the

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

| LEVEL I CATEGORIES | LEVEL II CATAGORIES | 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 | |

Table 5. (cont.)

| LEVEL I CATEGORIES | LEVEL II CATAGORIES | LEVEL III CATEGORIES | LEVEL IV CATEGORIES |
|---|---|---|---|
| 5 Water (cont.) | | | |
| | | 522 Slightly-Turbid | |
| | | 523 Moderately-Turbid | |
| | | 524 Highly Turbid/Very Shallow | |
| | | 531 Non-Turbid | |
| | | 532 Slightly-Turbid | |
| | | 533 Moderately-Turbid | |
| | | 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 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. | | |

Table 6. Possible output products and product characteristics for RSIS

| POSSIBLE OUTPUT PRODUCTS | OUTPUT PRODUCT CHARACTERISTICS | | | | | |
|---|---|---|---|---|---|---|
| | SPATIAL RESOLUTION REQUIRE-MENTS | PRODUCT SCALE | MAXIMUM AREA COVERED BY ONE PRODUCT | MAXIMUM AREA OVER WHICH PRODUCTS MAY BE REQUIRED | MAXIMUM PRODUCT UPDATE FREQUENCY | FORMAT |
| Level I Land Cover/ Use | 80-200m | 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 | 40-200m | 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 | 5-40m | 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 | 5-40m | 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 | 2-200m | 1:24,000 | Same boundaries as Quad map Zone | Entire Coastal | Annual | Map, Map overlay, Tabular |
| Water Body Circulation (Turbidity) | 40-200m | 1:24,000 to 1:250,000 | Same boundaries as Quad Map | Entire Coastal Zone | Monthly | Map |
| Topographic Maps | 5-40m to 40-200m | 1:24,000 to 1:250,000 | Same boundaries as Quad Maps | Entire Coastal Zone | Annual (for cultural features) | Map, Map overlay, Digital |

NASA/Johnson Space Center for conversion to film transparencies on the production film converter (PFC). Commercial organizations are also capable of providing this service. Devices are available to make color positive prints, or color negatives for production of an enlarged print, directly from the Ramtek KCRT display. The capacity of one such device to produce an accurate and cartographically acceptable product is currently being investigated, but it is unclear whether such a product directly from the KCRT could serve as more than an interim work product.

RSIS output will be annotated with pertinent information on scale, orientation, explanation, date and source of original data, and minimum mapping unit, among others. Software will be available to add alphanumeric annotations directly on the image. The User Advisory Group will be asked to review and comment on early RSIS products in order to optimize product 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 Number and 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. 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.

#### 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 Coastal 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). Level I land cover/land use maps can therefore be compiled, using RSIS, 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, 1:12,000 may be an appropriate scale for Level III/Level IV use simply because it is a simple multiple of the smaller 1:24,000-scale 7.5-minute quadrangle map.

Whereas the 1:250,000-scale map is often at too small a scale for some applications of land cover/land use mapping, the 1:125,000 has been large enough to facilitate comparison with 1:24,000 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 Applications 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 map bases is undertaken.

Mapping of urban environments at Level I and Level II can best be undertaken for the vicinities of Corpus Christi at 1:250,000 and 1:125,000 scales and for Victoria at 1:250,000 scale only. These are the two major 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, and quadrangles in the Victoria area were originally issued in 1951 and 1952, and were photorevised in 1973. The Oso Creek NE quadrangle near Corpus Christi, and the Victoria East quadrangle both show 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. 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, as are map scales of 1:24,000 and 1:12,000 over areas of one 7.5-minute quadrangle or less. 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 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 which, once mapped on the photography, will be 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 will be tested using data from CATS.

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, correlation with turbidity only 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 $\mu$g/l but considered it unreliable due to insufficient data. Data from Espiritu Santo and Matagorda Bays on 14 May 1979 show chlorophyll a values from 5 to 18 $\mu$g/l, with 8 of 10 determinations at or above 9 $\mu$g/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- or 1:12,000-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, in press). 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 4 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 and Victoria 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 CATS (1978-1979) in coordination with Landsat overpasses.

4.2 Procedures

The development and documentation of prototype procedures for preparation of test products has begun with a thorough review of procedures documented in the literature. This review is currently underway (September, 1979), and takes into account the results of the July, 1979, Functional Design Review and associated documentation (Brown and others, 1979). The effort to have as much processing capability as possible reside in the Interdata 7/32 will affect the analytical procedures to be used. It is anticipated that further review of the test products to be generated for CATS will be undertaken by the User Advisory Group prior to the time that data analysis begins in November, 1979.

## 5.0 EVALUATION OF TEST PRODUCTS

### 5.1 Economic Evaluation Plan

The objective of the analysis proposed in the Economic Evaluation Plan (Appendix A) 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 photo interpretation 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. 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 (Appendix A).

### 5.2 Comparison Products

Comparison products will be generated at a scale and level of detail similar to the RSIS test products outlined in section 4 of this report. Thus far, a Level I, 1:250,000-scale land cover/land use map of the entire coastal test site has been generated from 1:120,000-scale color-infrared photography dated October 1, 1978. This photography was flown by NASA as part of the ASVT Project in conjunction with the first ground data collection effort and a Landsat-2 overpass.

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 & Lomb Zoom Transfer Scope. Time sheets were kept during mapping for six 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 summarizes 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.

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 | 4½ | | | | |
| TUESDAY | 2 | 1¼ | | | | |
| WEDNESDAY | | | | | | |
| THURSDAY | | | | | | |
| FRIDAY | | | | | | |

Task Code

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.

| 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. |

*mapping completed

n.a. = not applicable

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# Appendix A

# Economic Evaluation Plan

TNRIS/NASA JOINT PROJECT (ASVT)

ACCOUNTING REQUIREMENTS

A. OBJECTIVES

1. To document the type and level of support to the Project.
2. To document the cost of generating each product from the RSIS, GIS, and NRAS.

B. ACCOUNTABLE AREAS

1. NASA (Proposed)

   a. Staff (Contract Support/Consultation)
   b. Hardware Procurement
   c. Software Procurement
   d. Remote Sensing Data (By Data Set)
      (1) Aircraft Data
      (2) Landsat Data
   e. Ground Truth Data (By Data Set)
   f. PFC Products
   g. Civil Service Support
   h. SR & T
   i. Travel
   j. Other (Specify)

2. TNRIS/TDWR

   a. Hardware Procurement/Rental/Usage (and related Software)
   b. Facilities Use (Building/Utilities/other)
   c. Remote Sensing Data (By Data Set)
      (1) Aircraft
         (a) Air Photos
         (b) Other
      (2) Satellite
         (a) Landsat
         (b) Other
   d. Ground Truth Data (By Data Set)
   e. Cartographic Data (By Data Set)
   f. Reports/Documents/Misc. Data and Information (By Data Set)
   g. Computer Time (By Product/Task)
      (1) Univac
      (2) Interdata
   h. Supplies
   i. Photo/Litho/Xerox Reproduction (non-personnel) (by product where appropriate)

j. Consultation (Specify Tasks Performed)
k. Staff Time
  (1) Project Team
    (a) Data Collection (By Data Set)
      1 Ground
      2 Aircraft
      3 Satellite
    (b) Data Handling (Index/Store/Retrieve) (By Data Set)
      1 Ground
      2 Aircraft
      3 Satellite
    (c) Data Analysis (By Product/Task)
      (1) Computer - Assisted
      (2) Image Interpretation
    (d) Documentation
    (e) Training
    (f) Travel
  (2) User Advisory Group
  (3) Steering Committee
  (4) Executive Board
  (5) TDWR (Library/Graphic Arts/Motor Pool/Secretarial/Others)
  (6) TNRIS Task Force/RS & C Committee
l. Software Procurement
m. Training (non-personnel)
n. Travel (non-personnel)

3. UNIVERSITY

a. Consultation (By Task)
b. Data Analysis (By Product)
c. Data Collection (By Data Set)
d. Training

4. INDUSTRY

a. Hardware
b. Software
c. Consultation
d. Data Collection
e. Training
f. Reproduction

C. REPORTING

1. Monthly (In Detail)
2. Quarterly (Major Categories)
3. Annually (Total)
4. Costs Per Product (As Needed)
5. Costs Per Task/Source (As Needed)
6. Other Cost Data (As Needed/Available)