REMOTE-SENSING APPLICATIONS TO ENVIRONMENTAL ANALYSIS

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Environmental legislation has forced the highway planner to look for new aids to help provide input for the complex environmental reports now necessary for highway location approval. This paper reviews two remote-sensing methods used to date by the Florida Department of Transportation for environmental data acquisition and analysis. A corridor study prepared by photo interpretation and the use of infrared scanning for water temperature studies and underground void detection are explained in detail. The results of these studies confirm that remote-sensing techniques can contribute significantly toward furnishing factual answers to many environmental problems.

•WITH passage in 1969 of the National Environmental Policy Act, a new era began in highway location. No longer was the highway engineer able to make a decision based primarily on economics for highway location. The law required that an extensive report of the environmental impact of a project on the surrounding area be prepared. Project justification, corridor alternatives, environmental factors, and long-term effects of the project must be outlined and explained in detail before final location approval is granted by the Federal Highway Administration.

To provide data to highway planners for the preparation of the environmental impact statements, as well as for special environmental studies, the topographic office of the Florida Department of Transportation established a remote-sensing unit in 1970. This unit is staffed with personnel who have expertise in the areas of highway engineering, engineering geology, forestry, biology, and geography and who have training in remote-sensing techniques. To date, this unit has made extensive use of two remote-sensing methods of data acquisition and analysis: basic photo interpretation from black-and-white photography and thermal infrared scanning analysis.

BASIC PHOTO INTERPRETATION

The first project undertaken by the remote-sensing unit was the mapping of a 4-mile wide, 40-mile long corridor using photo interpretation of black-and-white photography. This mapping was to be used to study the location of I-75 east of Tampa, Florida.

The general intent of this project was to locate and identify features to a degree of detail consistent with some of the information needs for preparation of the environmental impact statement. Five separate phases of mapping were deemed necessary to provide the required information: land use, key features, property boundaries, drainage, and engineering soils.

Aerial photographic mosaics (scaled at 1 in. = 1,000 ft) were used as base maps for delineating the preceding five categories. This base allowed for an adequate degree of detail while maintaining a convenient sheet size.

Land Use

For the land use map to reflect the actual use of the terrain, a use classification system is required. The classification system must be broad enough to include all important uses of land and also one that can be used accurately and consistently at a photo scale of 1 in. = 2,000 ft. To meet this requirement, a system was developed that included 96 different identifiable land uses grouped into 12 major divisions. Of the 96 uses, 51 were actually used in the I-75 project. Figure 1 shows an example of the land use map; the classifications used are given in Table 1.

Key Features

The land use maps, with their classification consisting of 51 categories, give quite a detailed picture of current land use. There are, however, certain categories that greatly influence the location of a highway. In order to emphasize the location of these more important features, a key features map was produced. This map delineates only 30 of the original 51 land use categories (Fig. 2).

Property Boundaries

This map set provides the planner with information concerning the limits of individually owned parcels of land and their approximate areas in acres. The aerial mosaic is used as the base map on which the properties are delineated. Property information was extracted from tax maps of the area. Figure 3 shows a typical property map.

Drainage

Impact statements require the planner to include a detailed explanation of the effect the project location will have on water pollution, drainage, and the water table. The drainage map will provide the planner with input for this phase of the report. This map details the existing drainage pattern within the study area. Again, the aerial mosaic was used as a base map. An explanation of the different types of lines used in delineating the drainage is shown on the drainage map (Fig. 4).

Engineering Soils

The soil maps provide a general description of the engineering soil types along the corridor. The classification was developed so that a very general correlation could be made with the AASHO classification. A sheet of the soils mapping is shown in Figure 5.

With the exception of the property information that came from tax maps, all information was obtained by photo interpretation. The interpreters used black-and-white contact prints (scaled at 1 in. = 2,000 ft) and a stereoscope with two and four power lenses. The data were then transferred to the base maps. The remote-sensing unit produced the 65 map sheets in 13 weeks using 240 man-hours. Even though our planners had made use of aerial mosaics for route study for many years, they were not trained interpreters; therefore, only minimal information was obtained. The general consensus of the planners who used this corridor study was that it contributed significantly toward furnishing factual answers now necessary in highway location.

THERMAL INFRARED SCANNING

Water Temperature Study

In March of 1971, the city of Tallahassee requested the assistance of the U.S. Department of Transportation in a study to determine the distribution effect of the thermal effluent into the St. Marks River from its electric generating facility. After reviewing the problem, a decision was made to use thermal infrared scanning because of its potential to differentiate variations in temperature of surface water within a degree centigrade.

Six overflights were made during a 24-hour period. These flights occurred at 11:50 a.m., 5:00 p.m., and 7:30 a.m. the following morning at altitudes of 500 and 1,000 ft. The thermal imagery was acquired using a scanner manufactured by Daedalus Enterprises, Inc. Concurrent absolute temperature recordings were also made along the flight lines using a radiometer manufactured by Barnes Engineering Co.

The evaluation of the data was based primarily on the radiometric profile that was recorded simultaneously with the thermal imagery. Because we did not have access

Figure 1. Land use map.

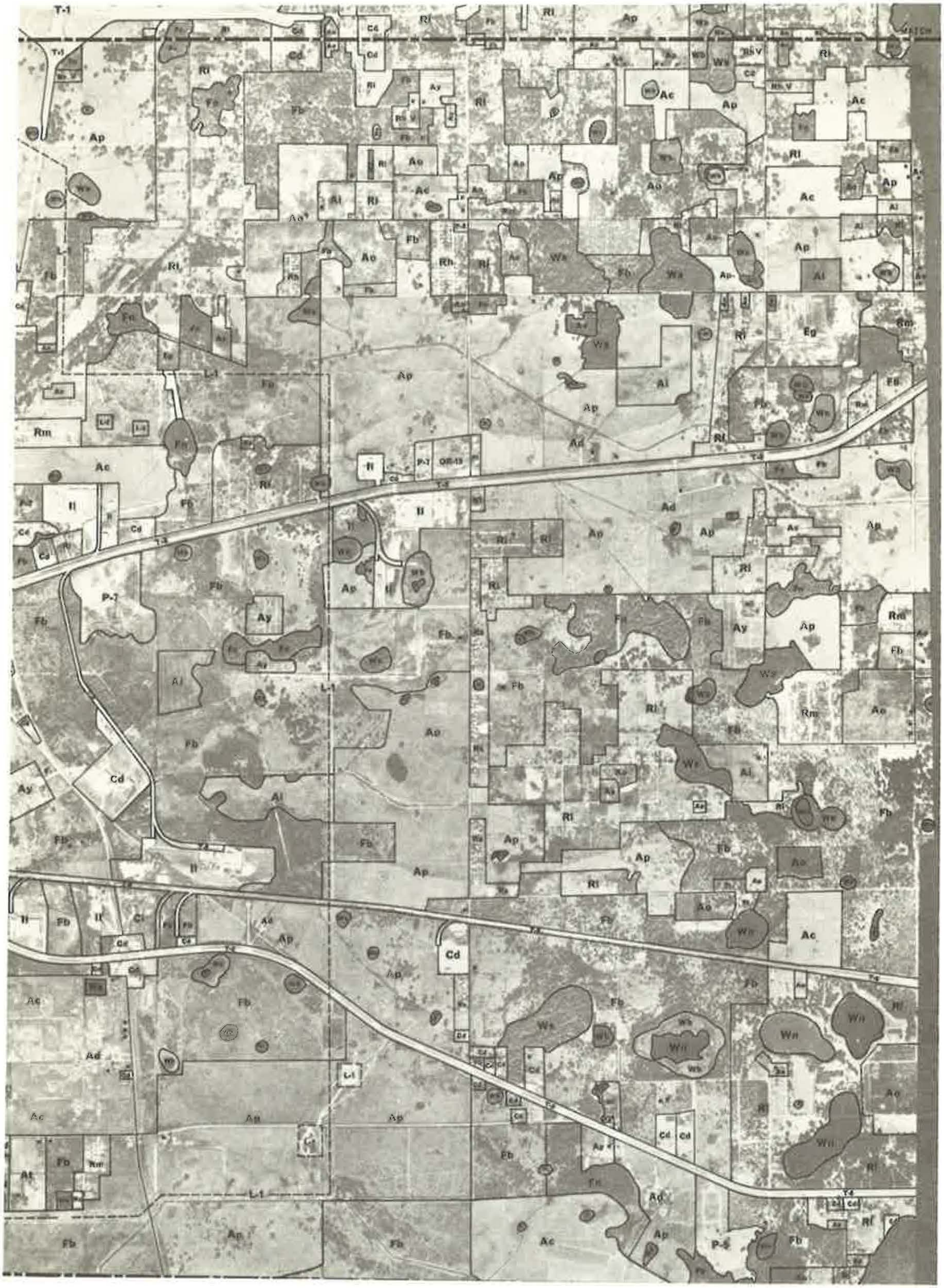
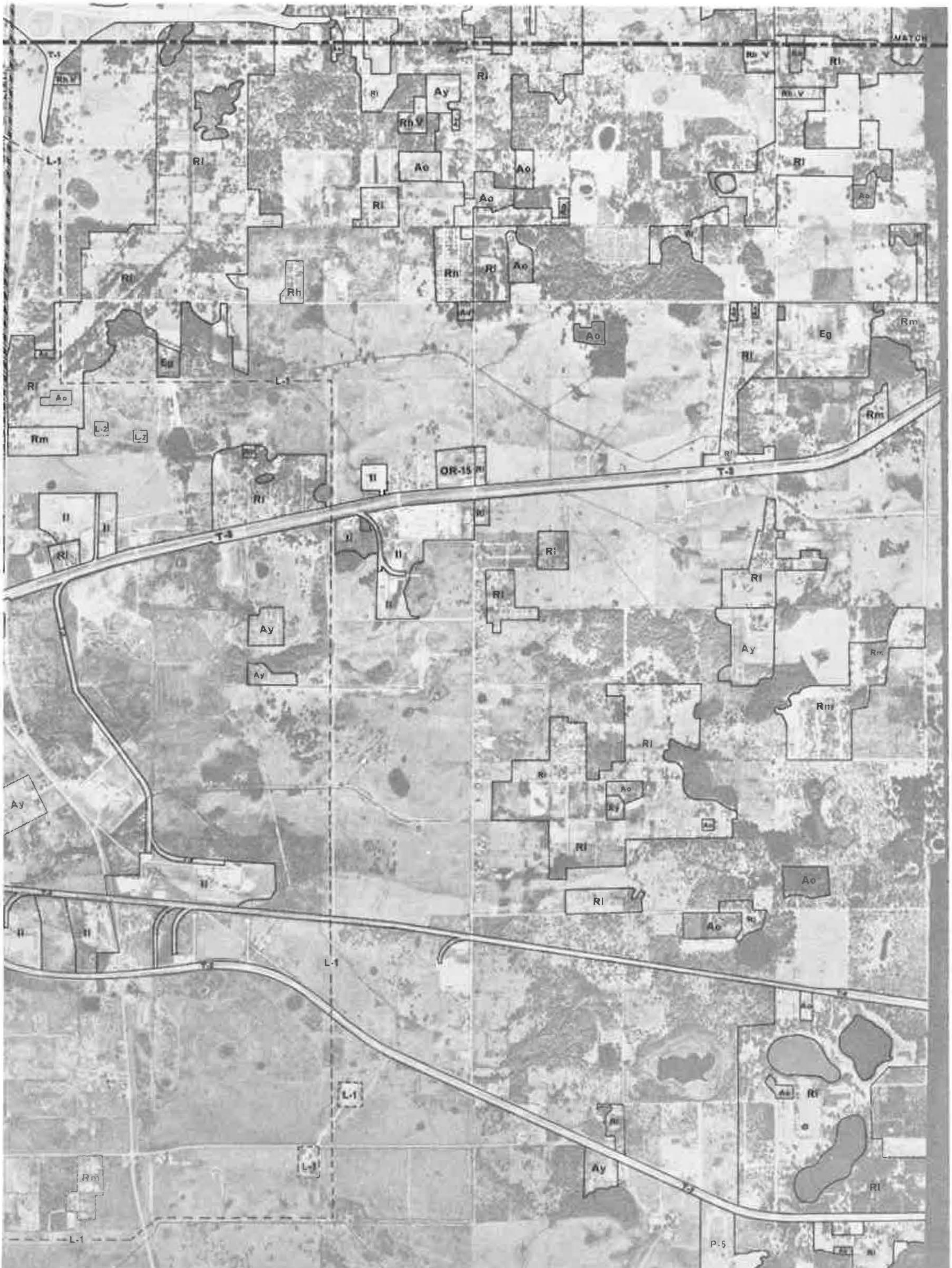


Table 1. Land use classification for Figures 1 and 2.

Classification	Specific Use	Code
Residential	High density (less than 1/8 acre)	Rh
	Medium density (1/8-1/2 acre)	Rm
	Low density (greater than 1/2 acre)	Rl
	Shoreline developments	Rs
	Under construction	Ru
	Inactive (street pattern, weeds, no houses)	Ri
	Apartment buildings (Rh-z)	Z
	Trailer parks (Rh-v)	V
Agriculture	Groves or orchards	Ao
	Specialty farms (horticulture, aquatic agriculture)	Av
	Cattle and dairy farms	Ad
	Horse farms	Ae
	Hog farms	Ah
	High intensity cropland	At
	Cropland (improved pasture)	Ac
	Pasture (unimproved)	Ap
	Inactive	Ai
Commercial	Shopping center	Cc
	Commercial strip development	Cs
	Industrial business	Cd
Industrial	Light manufacturing	Il
Extractive industries	Gravel, sand, clay	Eg
	Minerals	Em
Public facilities	Education institutions	P-1
	Religious institutions	P-2
	Health institutions	P-3
	Cemeteries	P-5
	Water supply, sewage treatment	P-6
	Dumps, junk yards	P-7
	Fire towers	P-10
Outdoor recreation	Golf courses	OR-1
	Developed public parks	OR-8
	Race tracks	OR-9
	Outdoor museums and monuments	OR-12
	Community recreational facilities	OR-13
Transportation	Four-lane roads	T-2
	Railroad	T-8
	Abandoned railroad	T-9
	Personal airport	T-12
	Noncommerical	T-13
Communications	Transmission lines (power and telephone)	L-1
Forestland	Rangeland	Fb
	Fully stocked natural stand	Fn
	Plantation (planted woodlands)	Fp
Wetland	Marsh	Wb
	Swamp	Ws
	Marine	Wm
Water	Natural (greater than 1 acre)	Wn
	Artificial (greater than 1 acre)	Wc
	Streams and rivers (greater than 100 ft)	Wr
	Natural ponds (less than 1 acre)	n
	Artificial ponds (less than 1 acre)	p

Figure 2. Key features map.



Note: Symbols are same as given in Table 1 except Ay is specialty farms, OR-10 is outdoor museums and monuments, and OR-15 is community recreational facilities.

Figure 3. Property boundaries map.

Figure 4. Drainage map.

Figure 5. Soils map.

Engineering soils classification: C is silty or clayey sand, R is fine sand, Rx is fine sand (clean and very well drained), F is clayey soils, P is peat and muck, H is man-made land (filled area), and ◌ is sinkhole.

to a densitometer, no attempt was made to determine temperatures in other portions of the imagery. It was felt that the temperature profile along the center of the imagery provided sufficient data for this study. A sample of the imagery is shown in Figure 6.

From the temperature data extracted from the imagery of the six overflights, we found that the maximum temperature increase in surface water within the river was only 4 C. This increase could be attributed directly to the effluent from the power plant because a delimiting line between the two temperature zones was very evident.

Underground Cavity Location

At the present time, the remote-sensing unit is involved in an extensive research project directed toward the location, by remote-sensing techniques, of limestone voids that occur in the general vicinity of existing and proposed bridge foundations. Thermal infrared scanning is being investigated extensively to determine its usefulness in delineating these sink-prone areas.

A portion of US-19 just north of Chiefland, Florida, has been chosen as a test site for this investigation because of recent sink and solution pipe activity in the area. Thermal imagery was taken during the night of November 16, 1971, at an altitude of 1,000 ft in a bandwidth range of 8 to 14 microns. From this imagery, 70-mm positives were made.

After visual analysis of the positive film with the aid of a light table and magnifying glass, several anomalous patterns were delineated. The anomalies selected were generally "cool" patterns. This selection was based on the hypothesis that the ground surface temperature should cool more rapidly if an underground cavity or deep fissure in the bedrock exists below.

The true ground conditions associated with the surface anomalies were established by a boring program. Anomalous trends were transferred from the 70-mm positives to enlarged photographs so that the exact position of the anomaly could be scaled for field location of the drill sites. Figure 7 shows an enlargement of the thermal imagery with the anomalous areas delineated. (As mentioned, the anomalies were selected using the 70-mm positive and magnifying glass. They are not obvious on the enlargement.) Sixteen borings were made in the selected areas, twelve of which encountered either deep fissures in the bedrock or cavities above the water table. Thus, the apparent correlation between thermal anomalies and subsurface solution activity is 75 percent reliable. Considering the extremely crude method used to interpret the thermal imagery, this correlation appears to be excellent. The overall success of this test has definitely established the utility of thermal scanning, combined with interpretation and analysis by qualified personnel, for locating areas of high sink activity.

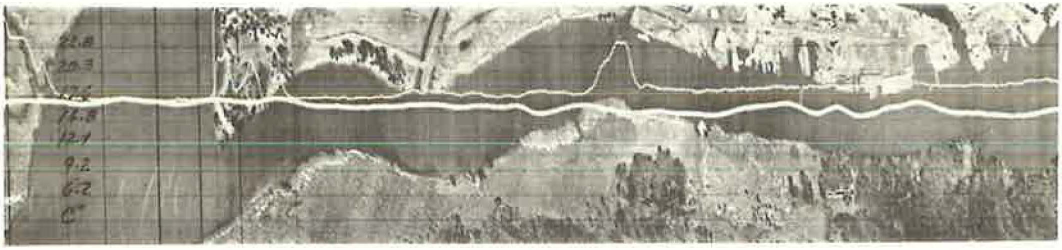
The NASA test facility, Bay St. Louis, Mississippi, has made available to us the use of their microdensitometer. We are now in the process of performing microdensitometer analysis on the thermal imagery. If this analysis confirms the apparent success of our program to date, we will be ready to proceed with plans to implement scanning as a means of detecting underground voids hazardous to highway and bridge locations.

SUMMARY

The field of remote sensing has experienced rapid growth during the past several years. Increasing concern toward the preservation of our surrounding environment has directly affected this growth. Today, the remote-sensing scientist has at his disposal a broad variety of remote-sensing instruments for data acquisition. The sophistication of these sensors tends to overshadow the most important phase of this field, interpretation and analysis.

In order to obtain the maximum result from sensor data, we must use a team of talented personnel with diversified backgrounds. Using the team approach, data analysis of the geology, forestry, biology, and geography of a study area can be used to give a more complete study.

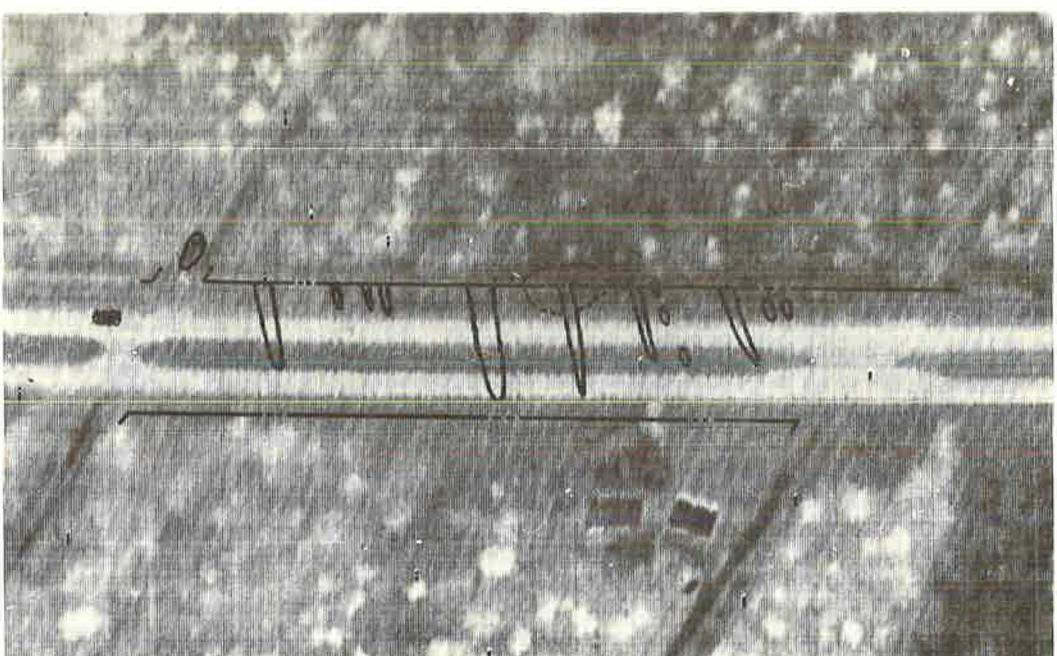
Figure 6. Imagery map.



70mm positive of thermal imagery of St. Marks River
Flown at 11:50 am - altitude 500 feet

70mm positive of thermal imagery of St. Marks River
Flown at 11:46 am - altitude 1000 feet

Figure 7. Thermal imagery map.



The remote-sensing unit of the Florida Department of Transportation is now contributing valuable information for use in solving environmental problems. As the personnel of this unit gain experience with the many sensors and become more knowledgeable of the physical features of Florida, remote sensing will be invaluable as a tool for environmental analysis.