To the Graduate Council:

I am submitting herewith a thesis written by Gregory Michael Luke entitled, "A Remote Sensing Survey of a Section of the Chambers Creek Drainage System Near Pickwick Dam, Savannah, Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Engineering Science.

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Graduate Studies and Research

A

A REMOTE SENSING SURVEY OF A SECTION OF THE CHAMBERS CREEK DRAINAGE SYSTEM NEAR PICKWICK DAM, SAVANNAH, TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gregory Michael Luke

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ABSTRACT

The issue of wetland mapping and management has become an important concern to several agencies and land owners in various parts of the United States.

Due to the vast land areas involved, the complexity of the wetland ecosystems, the instability of wetland legislation, the lack of management manpower, and political and economic influences, the tools and techniques used in remote sensing are being used more frequently to provide mapping, monitoring, and management information.

This project used a multistage approach to remote sensing in a practical way to map wetland vegetation along a section of Chambers Creek, and monitor with the use of the Landsat Multispectral Scanner and Return Beam Vidicon Imagery, certain changes in the quantity of wetland vegetation between the months of May and December, 1978.

The analysis of the data showed that the test site was a bottomland hardwood wetland area, and that between the months of May and December, 1978, wetland vegetation was cut and cleared from along the test site area of the creek.

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CHAPTER I

INTRODUCTION

Definition of a Wetland

The task of defining wetlands has proven to be difficult because each state and numerous federal agencies have different definitions based upon their respective areas of interest. (See Appendix for a listing of some of the Wetland Legislation and regulations available for use by various federal agencies). The working definition of wetlands used for this project is: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil condition. Wetlands generally include swamps, marshes, bogs, and similar areas [6].

Early History of the Wetland Problems in Tennessee

In order to get a more complete picture of the significance of some of the wetland areas in Tennessee, it is important to know some of the history of the subject. A brief review is given in this section and was taken from reference [9]. Tennessee is a unique state in that it is divided historically, politically, and even economically-socialogically into three sections; east, middle, and west. Perhaps the only viable comparison would be that of the New England region of the United States where the terms "up East" and "the Cape area" connote specific geographic location. Even there, this concept is used within a regional context, not within the geographic boundaries of a specific state.

The area referred to as West Tennessee has developed a history unique from the other two sections of the state. West Tenessee was first opened for settlement under the terms of the Jackson Purchase of 1818 as a section of the state unoccupied by either whites or Indians. Second, West Tennessee was not broken up by numerous Indian treaties characteristic of Middle and East Tennessee. Third, West Tennessee quickly became, and has remained, the agricultural center of the state.

After 1818 and the Jackson-Shelby Treaty, thousands of settlers poured into West Tennessee. The population of many counties rose to ten of thousands in only a few years. The settlers returned to farming because of the fertility and depth of the soil. The lack of good roads to transport their products forced the use of the numerous Mississippi River tributaries as the main routes of transport.

It was not unusual by the 1830's to see 100 foot, 150 ton steamships, and 100 foot keel boats in the towns of Jackson and Brownsville. Thousands of bales of cotton, hogsheads of tobacco, and bushels of corn were shipped to markets outside the state through these two towns. Several legislative acts were passed to aid in river transportation in West Tennessee and interest by local citizens continued until after the American War of 1860-1864. Large scale river transportation ended in the 1860's for mainly three reasons: (1) the

War of 1860-1864, (2) construction of railroads, and (3) the silting up and filling in of West Tennessee rivers, which is still a problem today [9].

As previously stated, West Tennessee continues to be the agricultural center of the state. The climate, topography, and soils are all conducive to large scale agricultural activity. A direct result is that these characteristics have caused other disadvantages that most directly affect the agricultural community. For example, the periods of highest rainfall occur at the time of planting and harvest, resulting in widespread exposure of topsoil and erosion of this resource. Demands placed upon agriculture to increase production have resulted in planting of fields formerly left in permanent fallow, and use of larger equipment. This means planting fields on uplands, limiting the use of contour farming because of the size of farming equipment and planting of numerous lowland areas. The first two examples increase erosion and fill river channels. The second often results in marginal production of crops. All three examples directly affect the agricultural community over long and short time periods.

The activity contributes to the estimated loss of 42,000,000 tons of soil per year in West Tennessee, in the Obion-Forked Deer River Basin alone [9]. Eventually, the majority of this soil is carried to the Mississippi River, but a vast amount of it is deposited on the bottomland areas known as wetlands. These low lying areas are as characteristics of West Tennessee as are the loess bluffs of the Mississippi River. They (the wetlands) may be locally referred to as sloughs, bogs, marshes or swamps, but all are characterized by their low elevation and standing water over a long period.

River Basin Management Considerations

Draining of these lowlands areas has occurred since the early 1900's. The procedure has been to channelize the streams and rivers, which are surrounded by wetlands. However, this procedure has led to more problems which affect most directly the agricultural community. The following are some of these problems as they are related to water runoff, siltation, and channelization.

1. Flooding - Silt from surrounding agricultural fields raises the level of stream channels and increases the lateral extent of spring floods. In times of 100 year floods, water from the Mississippi River backs into the stream channels and will rise far above the level of the normal spring flood. Once the crest of the flood drops, trapped water often remains behind, held back by channel spoils banks and poor natural drainage systems within the lowlands due to channelization.
2. Raising the Water Table - Trapped standing water in areas usually naturally drained causes the water table in surrounding fields to rise. Often these fields are so supersaturated with water that it is impossible to raise a crop.
3. Entrapment of Water - Water held over long periods of time result in large-scale tree-kill. This condition can be caused

by channeling the stream, which may cause excess surface water to appear, or by blocking the natural flow of water.

4. Loss of Wildlife - Although the consumption of wildlife is not essential to human existence in our modern society, there is no question about the role of wildlife in the overall ecological balance of nature, on which all life forms depend.

5. Increase in Crop Production and Acreage - Since the turn of the century, farming as a way of life has changed into agribusiness [9]. This change has not been forced necessarily by the individual farmer but by the agricultural market that demands more products. This in turn forces the agricultural sector to farm more land, specialize in particular crop production, and use more large agricultural equipment to meet demands. However, this response does contribute to an ever-increasing amount of water runoff, resulting in erosion and silting in the bottoms. The filling of the bottoms with silt results in floodings, and tree and wildlife damage, which directly affects the agricultural sector. This then results in a cyclic situation where the agricultural community is the cause of, as well as the victim of the situation. However, a point that cannot be overstressed is that the agricultural sector is perhaps the major cause of the situation and it also is the sector that best profits by making corrections. In addition, the farmer has the tools, knowledge, and incentive available to remedy the situation.

With these problems as background, study began of the lower portion of Chambers Creek which enters Kentucky Lake approximately one mile downstream of Pickwick Dam (located on the Counce, Tennessee 7.5' Topographic Map). The area of interest starts one mile downstream from State Route 57 and extends to a point approximately one mile upstream from the intersection of Campbell Road and Chambers Creek. The location is shown in Figures 1 and 2. This test site was chosen because the Corps of Engineers was interested in reestablishing the wetlands in the area.

The Appendix information is added to this introduction to give the user of this technique, for wetland monitoring, a better idea of the extent of involvement of various government agencies in the complex problem of wetland management. Management techniques are not clearly defined yet because of the complexity of the wetland ecosystems and the youthfulness of the wetland legislation.

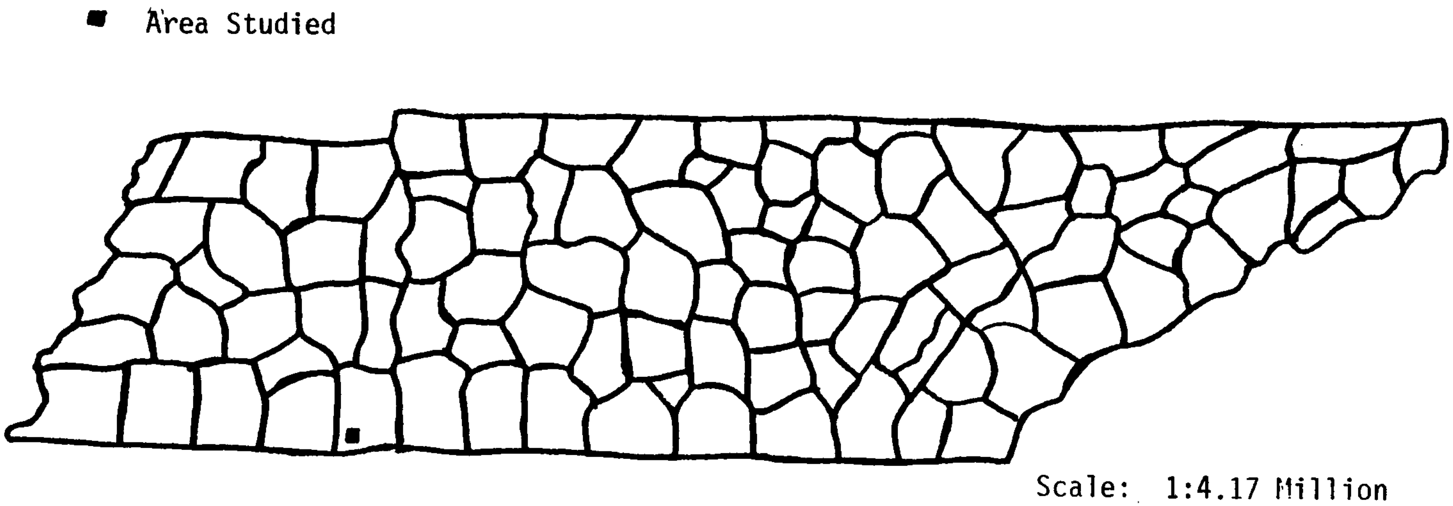

Figure 1. Map of Tennessee showing the location of the area studied.

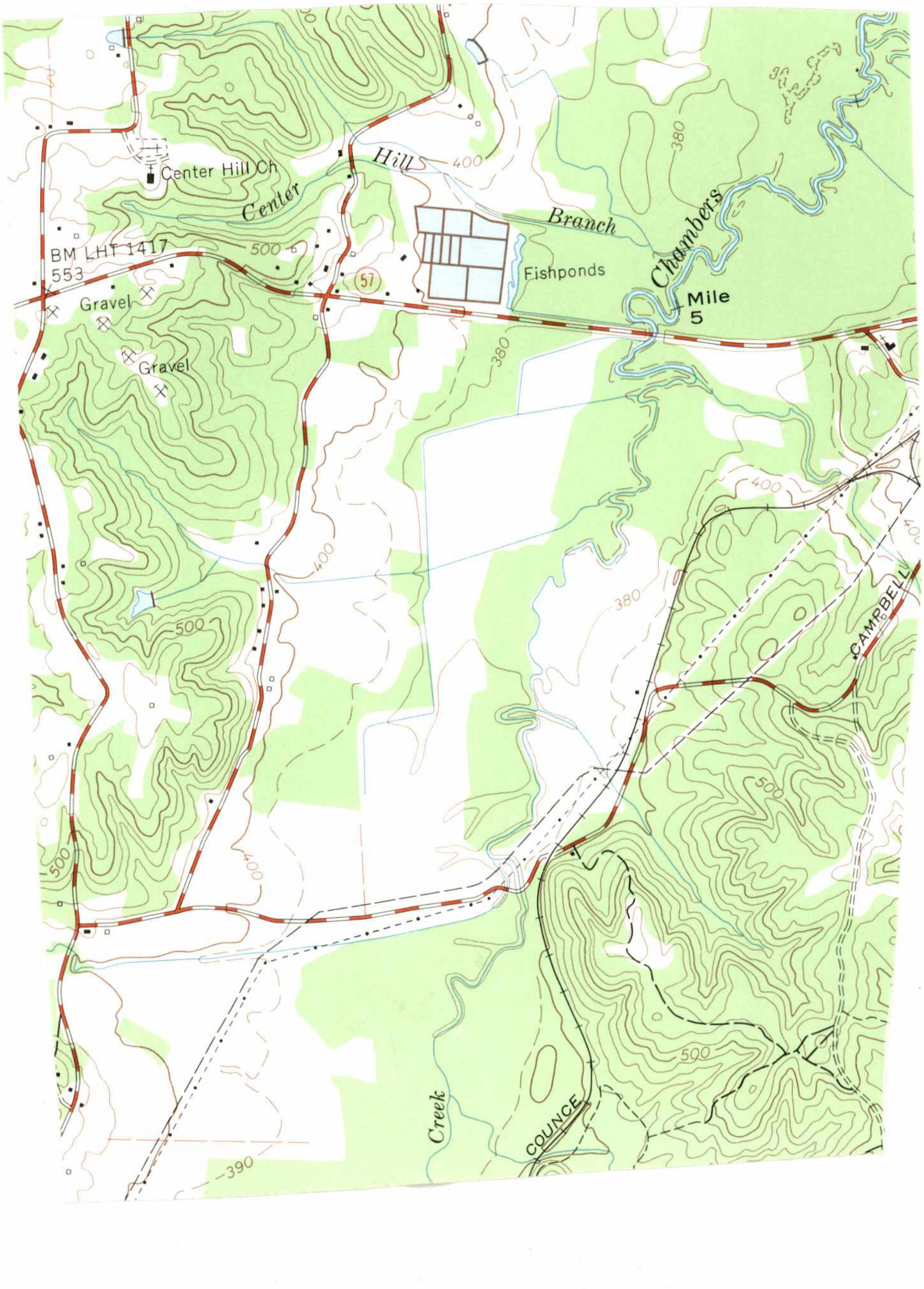

Figure 2. Location of Test Site

CHAPTER II

REMOTE SENSING TECHNOLOGY

Resource Evaluation

The technology of remote sensing has developed most rapidly during a time when man has become increasingly conscious of the need to preserve his environment. Remote sensing affords a practical means for frequent and accurate monitoring of the Earth's natural and cultural resources and of determining the impact of man's activities on the air, water, and land. Data obtained from remote sensors has provided information necessary for making sound decisions and policy regarding resource development and land use. However, the present state of the art only permits the use of a few narrow bands. In addition, the Earth's atmosphere has a disturbing influence on the propagation of radiation which results in a limited number of "windows" unaffected by the atmospheric absorption. The most important windows are:

1. <u>The visible (0.4 - 0.7 μm) and near IR (0.7 - 1.2 μm)</u> - The sensors used in this range include conventional aerial photography cameras and multispectral scanners.
2. <u>Middle IR (1.3 - 3.0 μm) and thermal IR (3.0 - 13.0 μm)</u> - Since no photographic emulsions are available for use at these wavelengths, the sensors used are scanning devices

equipped with detecting cells sensitive to these wave lengths.

3. The microwave region (1 mm to several meters) - The sensors used in the microwave region are of two basic types: active radiation, and passive microwave sensors which detect very low intensity radiation naturally emitted by terrestrial objects at these wavelengths.

Remote Sensing Facilities

A complete remote sensing system must be capable of performing the full sequence of operations that begins with data acquisition and ends with the presentation of thematic results. Data acquisition is performed by sensors such as cameras, scanners, radars, etc., depending on the spectral band concerned. Sensors are carried aloft by platforms which may be aircraft, balloons, or satellites. If a remote sensing survey is to produce satisfactory results, the conditions for data acquisition must be acceptable and the experiment carefully designed to yield maximum information for the theme under study. It is often essential to carry out certain sample measurements on the ground if the survey information content is to be reliably brought forth from the data. Photointerpretation aided by ground sampling, is then performed in the remote sensing facility. The methods of conventional photointerpretation have been adopted for use in other areas of remote sensing where data recorded initially on such media as magnetic tapes are transformed into photographic type prints.

The Landsat-3 Payload

The payload for Landsat 3, described in reference [13] and shown in Figure 3, includes a five-band Multispectral Scanner (MSS) System and a two-camera Return Beam Vidicon (RBV). The Data Collection System (DCS) for relaying remotely collected data from earth based sensors is identical to that carried on board the previous Landsat spacecraft.

The MSS has four bands operating in the reflected solar spectral region which are identical to the bands on Landsat 1 and Landsat 2 including: 0.5 - 0.6 μm (green), 0.6 - 0.7 μm (red), 0.7 - 0.8 μm (red and near-infrared), and 0.8 - 1.1 μm (near-infrared) wavelengths. The scanner on Landsat 3 has an additional fifth band in the thermal IR region from 10.4 to 12.6 micrometers. The fifth band can be operated at any time throughout the orbit. This includes night operation and operations at all solar elevation angles. The first four bands are normally operated only when the solar elevation angle is greater than 10 degrees.

There are six detectors for each of the four reflective spectral bands and two detectors in the thermal IR band. Since the fifth band has only two detectors compared to the six in the other bands, it has only one-third the resolution of that of the other four bands. The mercury-cadmium-telluride detectors for the thermal IR band are cooled to 110 degrees Kelvin by a radiation cooler which has been added to the scanner.

Because the primary mission of the Landsat 3 RBV is detailed ground mapping, the two panchromatic RBV cameras have a ground resolution of approximately 40 meters. The increase in ground resolution was achieved by doubling the focal length of the lens system. Shuttering and immediate readout reduces image degradation because of the elimination of the need for storing the images on the RBV photosensitive surfaces. See Figure 3.

The left and right RBV's operate simultaneously along the velocity vector of the spacecraft. The fields of view are aligned to view side-by-side nominal 99 kilometer (53 nautical mile) square ground scenes with a 15-kilometer sidelap yielding a 183- by 99-kilometer scene pair. Two successive scene pairs will nominally overlap each MSS frame. The four RBV scenes, which nominally fill each MSS frame, consist of four equal quadrants and are designated A, B, C, and D subscenes. Unlike the three individual cameras on Landsat 1 and 2 that operate in three different spectral bands, the Landsat 3 cameras have a broadband spectral response from 0.5 to 0.75 micrometers.

Remote sensing technology can help provide information about natural areas efficiently and quickly. Several different types of imagery were used for this project, including: low altitude black and white aerial photography, low altitude 35 mm color and color infrared aerial photography, Landsat MSS Imagery, and Landsat RBV Imagery.

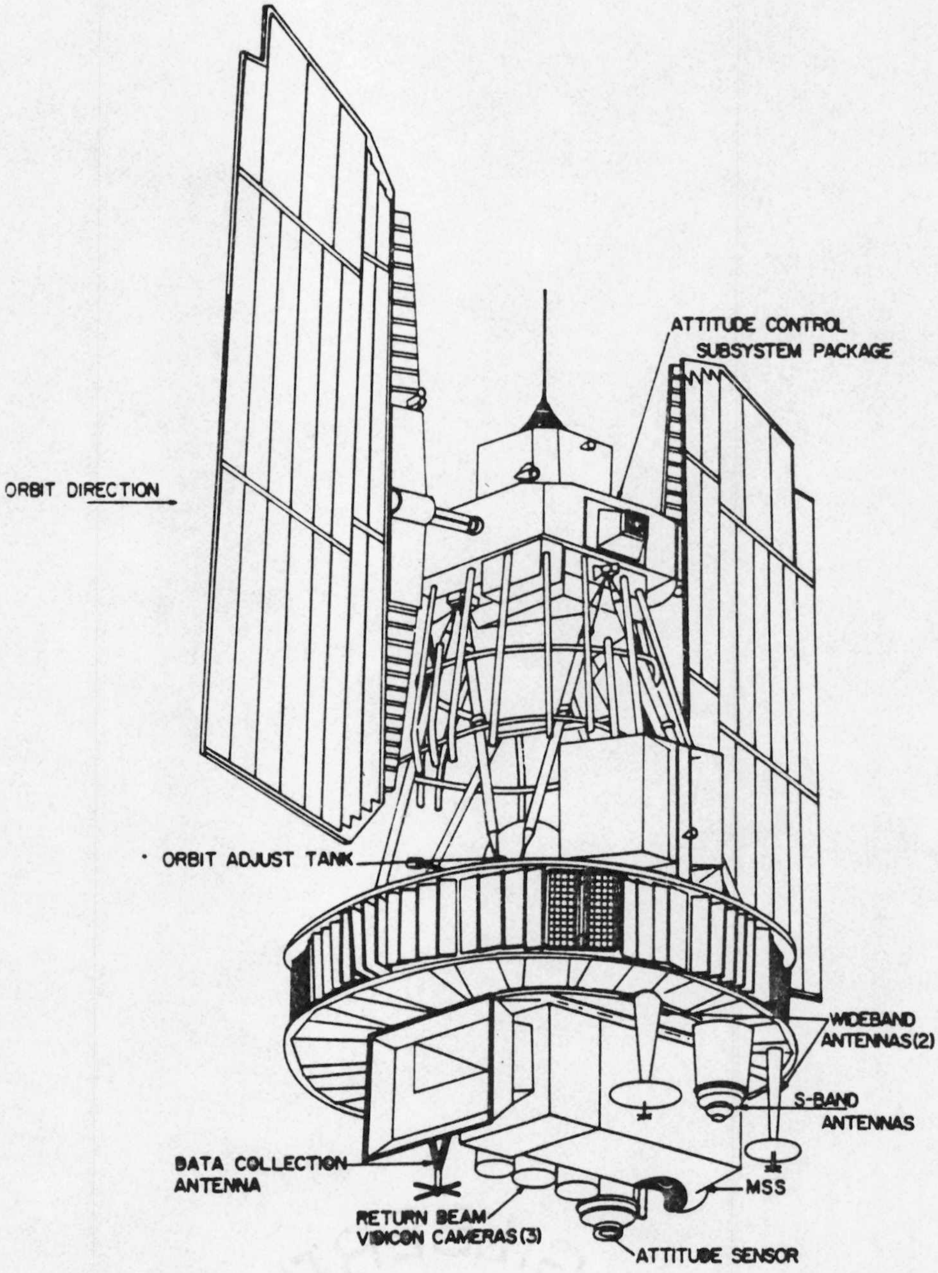

Figure 3. General Configuration of Landsat 3

CHAPTER III

OBJECTIVES

The objectives of the project were designed to meet the information needs of the Corps of Engineers, Nashville, District within the test site area along Chambers Creek. The Corps needed information about the area because local landowners had cleared wetland vegetation along the creek, and the Corps was responsible for regulating and managing wetlands along navigable streams. The project used remote sensing techniques because it was the most economically feasible way to map the area, and the interpretation of photographs taken before the wetlands were changed was the only record of how the area was modified.

The first objective of this project was to determine if the test site along Chambers Creek was a wetland. The vegetation classification system, outlined in reference [3], was used upon recommendation by the Corps of Engineers.

The second objective was to map the vegetation along the Chambers Creek test site using the vegetation classification system recommended by the Corps of Engineers.

The third objective of the project was to show, by using various images, a brief history of the test site concerning the clearing of vegetation from the land along Chambers Creek.

The final objective was to demonstrate the use of the Landsat 3 Multispectral Scanner and Return Beam Vidicon Systems for monitoring changes in the amount of vegetation on a relatively small land area.

CHAPTER IV

PROJECT PROCEDURE

Equipment

The following discussion describes equipment and methods used for this project. The equipment that was used included: magnifying glasses, rulers, mirror stereoscopes, a zoom transfer scope, an overhead projector, slide projector, light tables, and a planimeter. The equipment is shown in the U.T.S.I. Remote Sensing Laboratory in Figure 4.

The interpretor took these items and used them alone or in combination to product different effects and to obtain different perspectives of the image so as to be able to see even the most subtle feature.

Figure 4. Equipment Used for the Project

Methods

A multistage remote sensing approach was used for this project (Figure 5). The procedure was:

1. A Landsat satellite MSS false color composite image of bands 4, 5, and 7 was used to help determine if the natural overstory vegetation along a certain part of Chambers Creek still existed in May, 1978. A clear plastic overlay was made to go on the image showing important cities, water bodies, state boundaries, and vegetation information. This was accomplished by manual interpretation techniques using a magnifier and comparing colors and shapes of features on the Landsat Image with other images.
2. Then a Landsat Return Beam Vidicon Black and White Image was used to help determine if the natural overstory vegetation along Chambers Creek existed in November, 1978. A clear plastic overlay map was made for the image by manual interpretation techniques.
3. The next phase involved the use of a high altitude false color infrared aerial. The photograph was enlarged to 1:24,000 and an overlay map was made on clear plastic showing two classes of vegetation along the Chambers Creek test site [12].
4. After the high altitude color infrared photograph was analyzed, a vegetation map overlay was made for the set of black

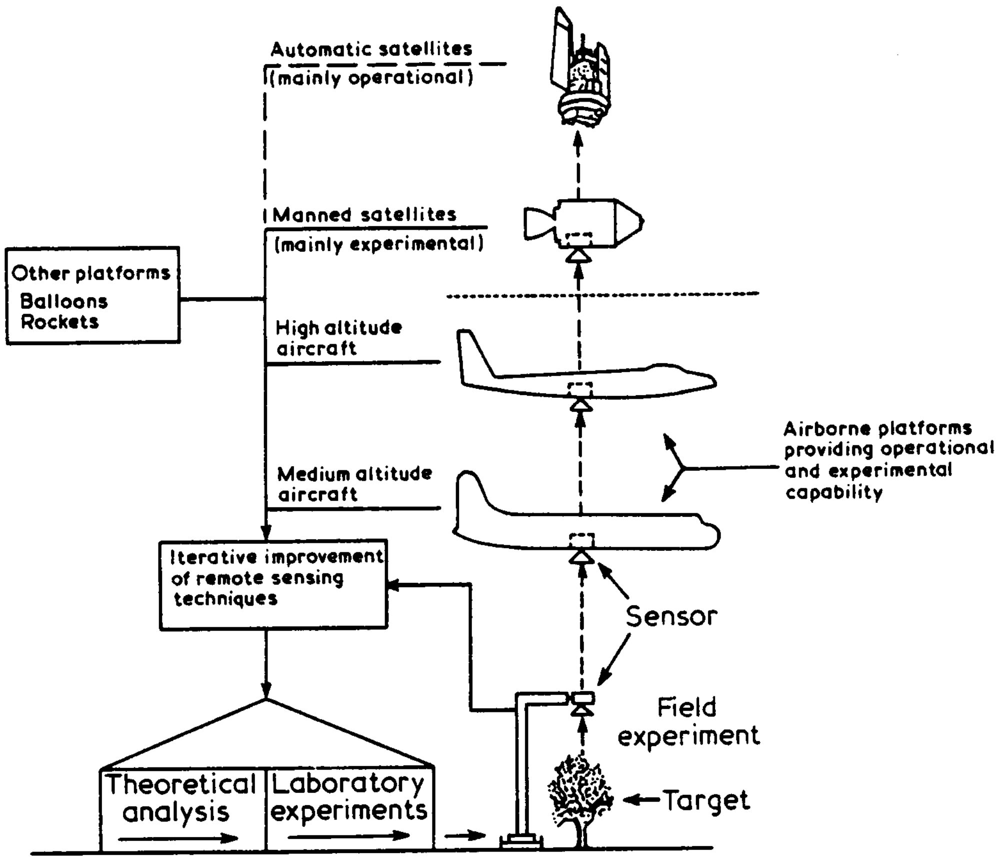

Figure 5. Multistage Approach to Remote Sensing

and white aerial photographs. To aid with the manual interpretation, a set of (TVA) black and white photographs was also used.

5. In order to give the interpreter a better idea of what the test site was like in 1980, a series of color and color infrared 35 mm low altitude aerial photographic slides were taken on April 15 and May 9, 1980. The slides were used to assist in the interpretation of stream patterns, swamp areas, and vegetation identification. Techniques of interpretation were taken from reference [1]. The slide information helped to verify information found on other images.
6. When most of the preliminary maps were made, a field trip was taken to the test site area on July 1, 1980. Participants from the Corps of Engineers and the University of Tennessee Space Institute went to seven different sites near Chambers Creek in the area of Mr. Jim Southern's property to identify vegetation, take soil samples, observe stream patterns and behavior, and verify the maps made of the area. References for [4, 5, 7] provide necessary information for these tasks.
7. After the field trip, the maps were taken back to The University of Tennessee Space Institute (UTSI) Remote Sensing Laboratory and checked to make sure the field trip data was incorporated with the preliminary maps.
8. Soil maps were then used from a book entitled, "Soil Survey of Hardin County, Tennessee," (USDA-SCS) to show soil types

in the area [11].

9. The final products were then drafted and checked for accuracy.

CHAPTER V

SUMMARY OF DATA SAMPLED

The following is a list of the data which was sampled and used for this project. Although not all of the data was interpreted, it was reviewed.

1. Landsat Multispectral Scanner Data

   1:250,000 scale - Landsat 3 image, false color composite date - May 5, 1978.

2. Landsat Return Beam Vidicon Data

   1:108,000 scale - Landsat 3 image B&W; date - November 10, 1978, I.D. 83025015503XA

3. High Altitude Color Infrared Photography

   1:125,000 scale - NASA120 - frames 9347-8; date - November, 1975.

4. Low Altitude B&W Aerial Photography

   March, 1963 (scale 1,000 feet/inch)

   Frame Numbers:

35680	35693	35704	35721	35762
35681	35694	35705	35722	35763
35682	35695	35706	35723	35764
35683	35696	35707	35724	35765
35684	35697	35708	35725	35766

5. <u>B&W Aerial Photography, March, 1968 (scale 2,000 feet/inch)</u>

Frame Numbers:

24-7C-8	13-7C-11
24-8C-9	13-8C-10
13-7C-9	13-8C-11
13-7C-10	13-8C-12

6. <u>B&W Aerial Photography, March, 1973 (scale 2,000 feet/inch)</u>

Frame Numbers:

91864	91869	91865
91870	91866	91871
91868	91908	91909

7. <u>B&W Aerial Photography, February, 1974 (scale 2,640 feet/inch)</u>

Frame Numbers:

96398	97411	96399
96412	96400	96413
96401		

8. <u>B&W Aerial Photography, September, 1975 (scale 2,000 feet/inch)</u>

Frame Numbers:

111198	111213	111200
111313	111202	111305
111209	111317	111212
111394	111396	

9. Very Low Altitude Oblique Aerial Photography

35 mm Color Photography, Corps of Engineers, May 9, 1980 and April 15, 1980.

10. Corrective Data

Topographic Maps	Soil Maps
Reference Books	Personal Interviews

CHAPTER VI

RESULTS AND DISCUSSION

This chapter contains the results and discussions of the different aspects of the Chambers Creek Project. The results are divided into different categories such as: a list of products, a soils report, vegetation maps, field trip, field sites, the Landsat MSS Image Map, and the Landsat Return Beam Vidicon Image Map.

List of Products

1. <u>LANDSAT Multispectral Scanner Image</u> at a scale of 1:250,000 with an overlay map showing landmarks and test site.
2. <u>LANDSAT Return Beam Vidicon Image</u> in black and white at a scale of 1:108,000 with an overlay map showing landmarks and the test site.
3. <u>A NASA high altitude false color infrared photograph</u> enlarged to a scale of 1:24,000 with a vegetation overlay map.
4. <u>A black and white photograph</u> at a scale of 1:24,000 taken in 1975 which fits the same vegetation map overlay used for the false color infrared photograph.
5. <u>A soils map overlay</u> copied from the USDA Soil Conservation Service Soils Maps.
6. <u>A Counce, Tennessee Topographic Map</u> at a scale of 1:24,000 showing field trip test sites.
7. <u>35mm color and false color infrared slides</u> taken during April and May, 1980.

8. Black and white aerial photographs dated:

March, 1963

March, 1968

March, 1973

February, 1974

November, 1975

9. A vegetation map on a portion of the Counce, Tennessee topographic map at a scale of 1:24,000.

Soil Report

The main soil association in the area is Waverly Falaya-Freeland Association [11]. This soil association represents the soils which are nearly level, poorly drained, silty or sandy on flood plains, and low terraces. A list of all soils in the test site and surrounding area is given in Table 1.

The soils present within the study area are shown in the Figure 6 map and soils present in the study area and the surrounding area are shown in the Figure 7 map.

In the study area, two soil series are present:

1. Waverly series

   Waverly Silt Loam (Wb)

   Waverly Fine Sandy Loam (Wa)

2. Collins series

   Collins Silt Loam (Ch)

   Collins Fine Sandy Loam (Cf)

The Waverly Series consists of poorly drained, strongly acidic soils on the bottom lands. These are nearly level soils, consisting of mixed sediments washed from upland soils. The water table mostly remains at the surface level, and the soils are strongly acidic. The strong acidity results from the decay of vegetation on the surface when excessive stagnant water is present. This shows that these soils represent wetland soils. These soils also include the areas which are permanently swampy.

The vegetation consists chiefly of water-tolerant oaks, sweet gum, birch, willow, maple, and cypress.

The Collins Series are moderately drained and are nearly level soils along the narrow drainways, consisting of sediments washed from soils on uplands. The depth of the water table in wet seasons becomes zero. The soils are strongly acidic which means these soils represent wetland environment.

The presence of the soil types, described above, associated with the types of vegetation present, showed that the area is mostly filled with water in wet seasons. During other seasons, the water table was also close to the surface which meant the area represented a wetland area.

TABLE 1

SOIL TYPES IN THE TEST SITE AND SURROUNDING AREA

Symbol	Name
Am	Almo silt loam
Cf	Collins fine sandy loam
Cg	Collins loam, local alluvium
Ch	Collins silt loam
DcB3	Dexter clay loam, 2-5% slopes, severly eroded
DcC3	Dexter clay loam, 5-8% slopes, severly eroded
DcD3	Dexter clay loam, 8-12% slopes, severly eroded
DeD	Dexter loam, 8-12% slopes
EtC3	Etowah gravelly silty clay loam, 5-8% slopes, severly eroded
Fa	Falaya loam, local alluvium
Fm	Falaya silt loam
FrB2	Freeland loam, 2-5% slopes, eroded
FrB3	Freeland loam, 2-5% slopes, severly eroded
FrC2	Freeland loam, 5-8% slopes, eroded
FrC3	Freeland loam, 5-8% slopes, severly eroded
Ga	Gravelly alluvial land

TABLE 1 (Continued)

Symbol	Name
Gm	Gullied land, loamy materials
Gs	Gullied land, sandy materials
Mc	Mantachie fine sandy loam
PaB2	Paden silt loam, 2-5% slopes, erosion
PaB3	Paden silt loam, 2-5% slopes, severely eroded
PaC3	Paden silt loam, 5-8% slopes, severly eroded
PkB	Pickwick silt loam, 2-5% slopes
PkB2	Pickwick silt loam, 2-5% slopes, eroded
PkC	Pickwick silt loam, 5-8% slopes
PkC2	Pickwick silt loam, 5-8% slopes, eroded
PkE	Pickwick silt loam, 12-25% slopes
PwB3	Pickwick silty clay loam, 2-5% slopes, severely eroded
PwC3	Pickwick silty clay loam, 5-8% slopes, severely eroded
PwD3	Pickwick silty clay loam, 8-12% slopes, severely eroded
Px	Pickwick-gullied land complex
Rb	Robertsville silt loam
RfF	Ruston fine sandy loam, 25-45% slopes
RuD3	Ruston sandy clay loam, 8-12% slopes, severely eroded
ScB2	Sequatchie fine sandy loam, 2-5% slopes, eroded

TABLE 1 (Continued)

Symbol	Name
ShC3	Shubuta clay loam, 5-8% slopes, severely eroded
SmC	Shubuta fine sandy loam, 5-8% slopes
SmC2	Shubuta fine sandy loam, 5-8% slopes, eroded
SmD	Shubuta fine sandy loam, 8-12% slopes
SmE	Shubuta fine sandy loam, 12-25% slopes
SmF	Shubuta fine sandy loam, 25-45% slopes
Ta	Taft silt loam
Vb	Vicksburg loam, local alluvium
Wa	Waverly fine sandy loam
Wb	Waverly silt loam
WcC3	Waynesboro clay loam, 5-8% slopes, severely eroded
WcD3	Waynesboro clay loam, 8-12% slopes, severely eroded
WcF3	Waynesboro clay loam, 12-35% slopes, severely eroded
WfB	Waynesboro fine sandy loam, 2-5% slopes
WfC	Waynesboro fine sandy loam, 5-8% slopes
WgD3	Waynesboro gravelly clay loam, 5-12% slopes, severely eroded
WgE3	Waynesboro gravelly clay loam, 12-25% slopes, severely eroded
WmC	Waynesboro gravelly sandy loam, 5-8% slopes
WmD	Waynesboro gravelly sandy loam, 8-12% slopes

TABLE 1 (Continued)

Symbol	Name
WmE	Waynesboro gravelly sandy loam, 12-25% slopes
WnD	Waynesboro very gravelly sandy loam, 5-12% slopes
WnE	Waynesboro very gravelly sandy loam, 12-25% slopes
WnF	Waynesboro very gravelly sandy loam, 25-45% slopes
WoB	Wolftever silt loam, 2-5% slopes, eroded

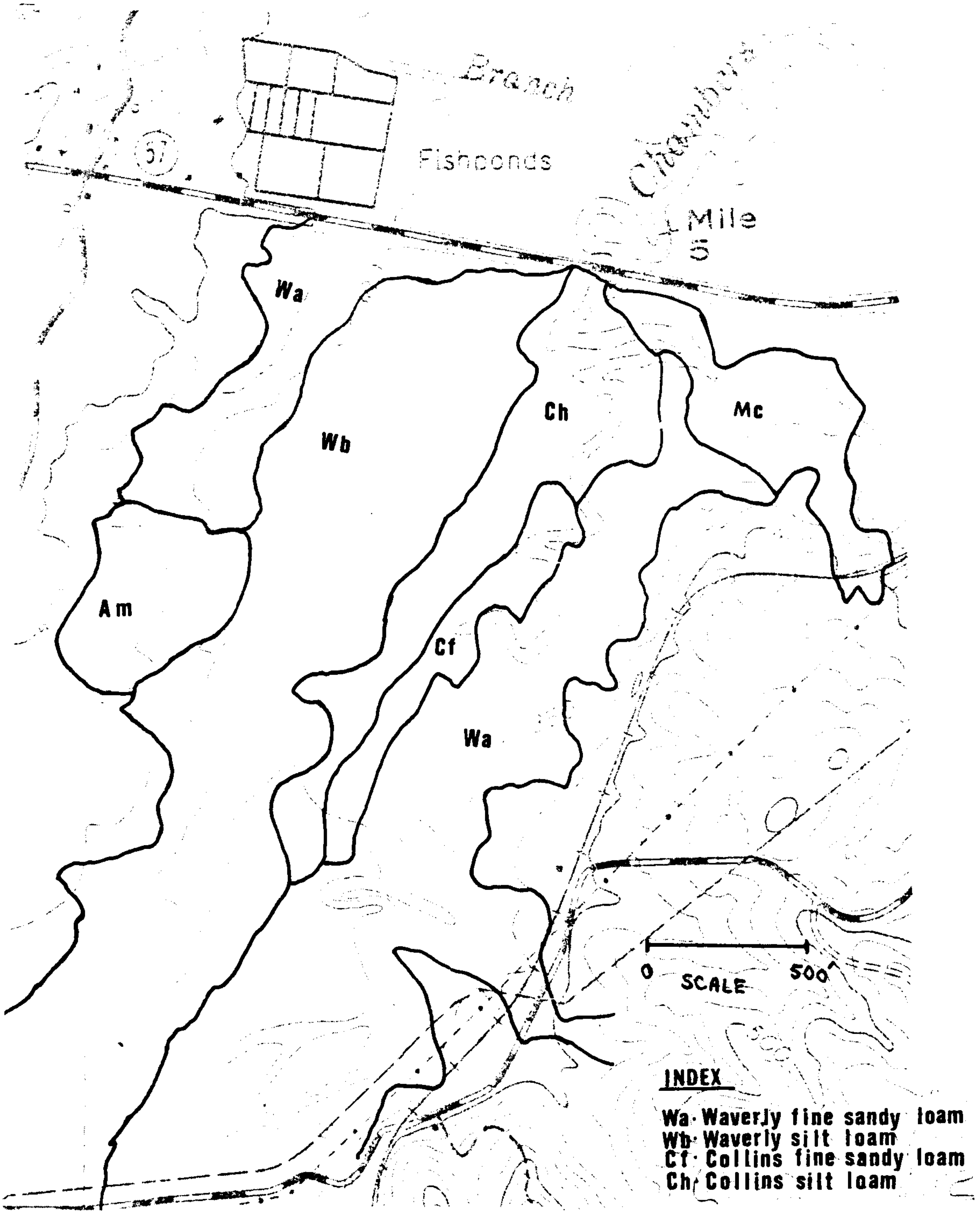

Figure 6. Soils Located in Test Site Area

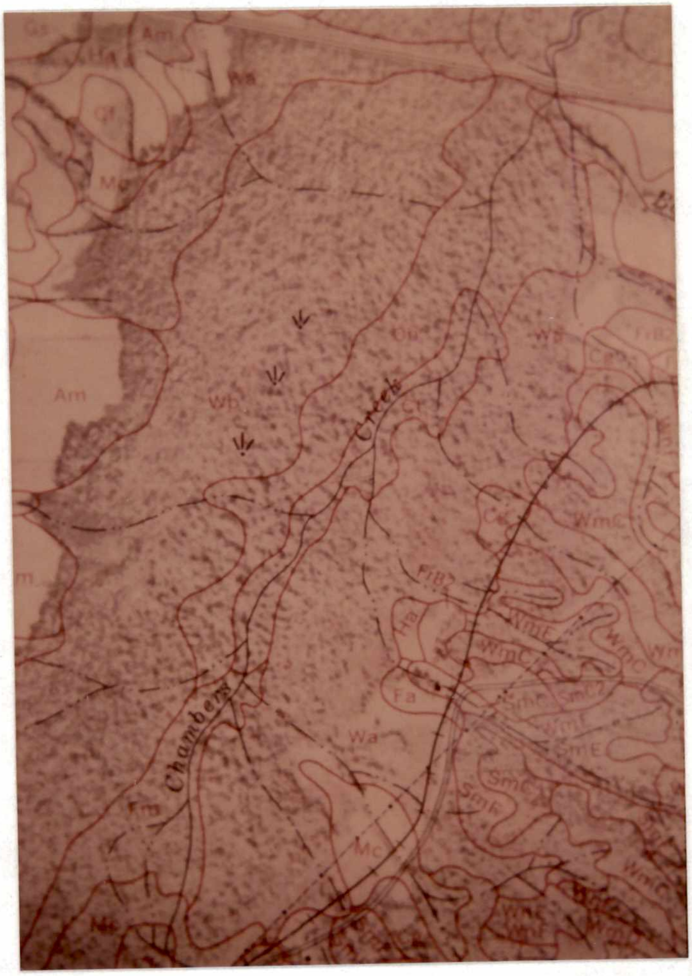

Figure 7. Soil Series Present In Surrounding Area

Vegetation Maps

The 35 mm color and false color infrared slides, the black and white aerial photographs, the high altitude false color infrared aerial photographs, a topographic map, and soil maps were used to map the vegetation within the test site along Chambers Creek.

The first phase of the vegetation analysis was to review the USDA Soil Conservation Service Soil Maps to determine if the soils in the test site were wetland soils [11]. The soil maps showed that the soil types were wetland soils, each having certain hydrological characteristics and general vegetation characteristics. Vegetative and hydrological information was taken from reference [2]. This information gave the first clues that the test site area might be a wetland.

The second step was to have a wetland vegetation classificaton system to use while mapping the test site area, which was shown by the soils maps to be a wetland environment. The classification system shown in Table 2 was recommended by the Corps of Engineers and was outlined as follows in reference [3].

1. <u>Bottomland Hardwood (FW-1)</u> - Wetland dominated by mixed hardwood species and flooded annually during winter and/or early spring. Flooding may be brief or for long periods. The ground is usually exposed in summer and fall although soil may be saturated or covered locally with a few centimetres of water.
2. <u>Swamp (FW-2)</u> - Semipermanently or permanently flooded wetland dominated by woody vegetation such as water tolerant deci-

TABLE 2

TENNESSEE VALLEY REGION WETLAND CLASSIFICATION SYSTEM
TVA - USGS SYSTEM

Wetland Classes	Wetland Subclasses
FW-1 Bottomland Hardwood	(FW-1a) Upper Bottomland Hardwood
FW-1 Bottomland Hardwood	(FW-1b) Lower Bottomland Hardwood
FW-2 Swamp	(FW-2a) Forested Swamp
FW-2 Swamp	(FW-2b) Shrub Swamp
FW-2 Swamp	(FW-2c) Dead, Woody Swamp
M-1 Marsh	(M-1a) Wet Meadow
M-1 Marsh	(M-1b) Emergent Marsh
M-1 Marsh	(M-1c) Seasonally Emergent Marsh
M-2 Seasonally Dewatered Flats	(M-2a) Vegetated
M-2 Seasonally Dewatered Flats	(M-2b) Non-Vegetated
OW-1 Open Water	(OW-1a) Vegetated
OW-1 Open Water	(OW-1b) Non-Vegetated

duous trees, aquatic shrubs or saplings, or dead trees and shrubs.

3. Marsh (M-1) - Wetland dominated by herbaceous emergents. Flooding may be seasonal (generally for long periods in late winter and spring), semipermanent or permanent, or it may be temporary with soils remaining saturated for most of the year.

4. Seasonally Dewatered Flats (M-2) - Flats located along the margins of streams and reservoirs and covered with water during most of the year. They may be uncovered for varying amounts of time in periods of low water or by artificial lowering of water levels (generally during late summer or fall). These flats become vegetated when exposed for a sufficient period of time before the first killing frost.

5. Agriculture Subject to Flooding (M-3) - Lowland areas usually under cultivation during the growing season but generally flooded each year during winter and early spring.

6. Open Water (OW-1) - Water up to 3.3 m deep usually associated with any of the other wetland classes. Surface vegetation (rooted floating-leaved or free-floating aquatics) and/or submergent aquatics may be present.

The two subclasses which were appropriate for the study area were:

1. Lower Bottomland Hardwoods (FW-1b) - This subclass is routinely inundated each year from midwinter into early spring (December - March). It often borders or encompasses rivers, oxbow lakes, and swamps. The "poorly drained river bottom" forest type is analogous to this subclass. This is typically the more extensive Bottomland Hardwood subclass. Where drainage has occurred in wetlands classed as Forested Swamp, species composition will differ from those given below. However, as the water regime will be similar to Lower Bottomland Hardwood, the wetland should be classified. Typical species include:

Nyssa slyvatica Marsh.	Black gum
Fraximum pennsylvanica Marsh.	Green ash
Populus deltoides Marsh.	Cottonwood
P. heterophylla L.	Swamp cottonwood
Salix nigra Marsh.	Black willow
U. alata Michx.	Winged elm
U. rubra Muhl.	Slippery (red) elm
Liquidambar styraciflua L.	Sweet (red) gum
Catalpa speciosa Warder	Catalpa
Carya cordiformis (Wang.) I. Koch	Pignut hickory
C. ovata (Mill.) K. Koch	Shellbark hickory
Quercus lyrata Walt.	Overcup oak
Q. michauzii Nutt.	Swamp chestnut oak

Q. phellos L.	Willow oak
Q. palustris Muench.	Pin oak
Q. nigra L.	Water oak
Acer rubrum L.	Red maple
A. saccharinum L.	Silver maple
A. negundo L.	Box elder
Betula nigra L.	River birch

2. Subclass 1. Forest Swamp (FW-2a) - Living trees cover at least 30% of the area. These typically are water tolerant, deciduous species, but where drainage has been blocked, more mesic or even upland species may be found. When this occurs, the area can be called a Forested Swamp because water regime takes precedence over species composition. If the drainage is improved, this class will progress to Dead Woody Swamp. Typical species include:

Taxodium distichum L.	Bald cypress
Nyssa aquatica L.	Water tupelo
Quercus palustris Muench.	Pin oak
Q. lyrata Watt.	Overcup oak
Fraxinum pennsylvanica Marsh.	Green ash
Betula nigra L.	Black willow
Acer rubrum L.	Red maple
A. sacharinum L.	Silver maple
Gleditsia aquatica Marsh.	Water locust

Cephalanthus occidentalis L.	Buttonball
Populus heterophylla L.	Swamp cottonwood
C. acquatica (Michx. f.) Nutt	Bitter pecan

The third phase of the mapping involved the identification of patterns on the photographs which identified certain types of vegetation or certain environmental conditions. These patterns on the photographs are known as signatures. An example of a signature is the smooth red-dish texture, east of Campbell Road, shown in Figure 8 on the November, 1975 infrared photograph, which can be identified as pine or evergreen trees. Some of the signatures used for this project are:

1. Light gray patterns visible in Figure 9 on the 1974 B&W photos along the Chambers Creek stream pattern, identified as the wetter areas of wetland vegetation.
2. The lighter blue area along the Chambers Creek on the 1975 false color infrared photograph, visible in Figure 8, denoting wetter areas.
3. The pink color along Chambers Creek, visible in Figure 8, which identifies those areas as dryer vegetation sites.
4. The thin curvey bluish black line, visible in Figure 8, which identifies the Chambers Creek stream pattern as an oxbow-type channel in some places.

After the stream pattern was identified and the vegetation mapped (Figure 10) using the classification system previously outlined, the field trip was taken to verify the results of the vegetation map. The

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Figure 8. Color Infrared Aerial Photograph

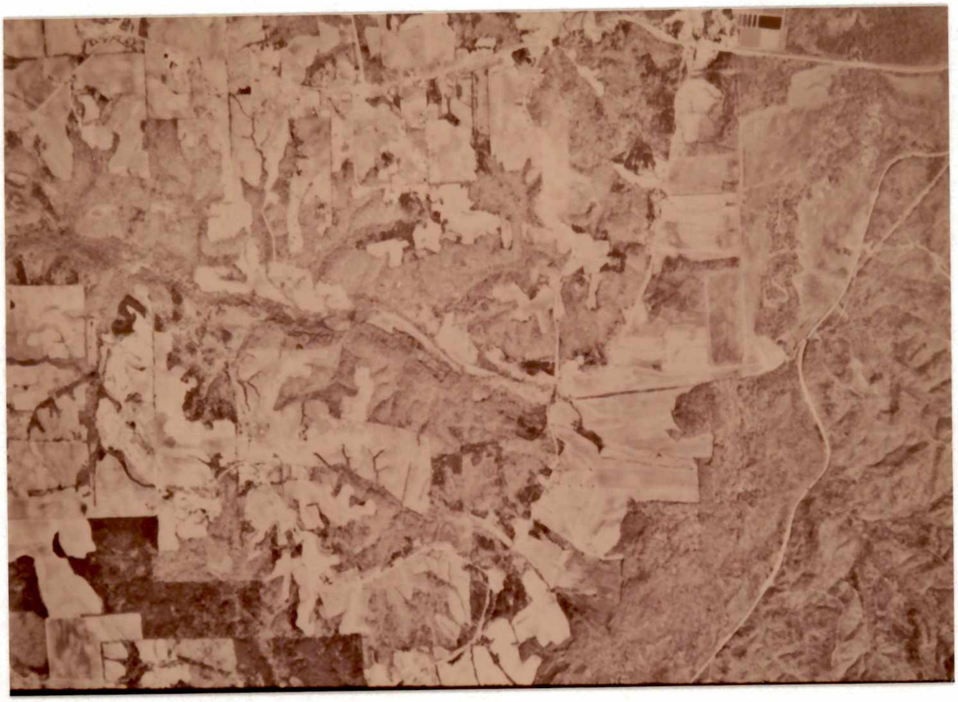

Figure 9. Black & White Aerial Photo Taken February, 1974.

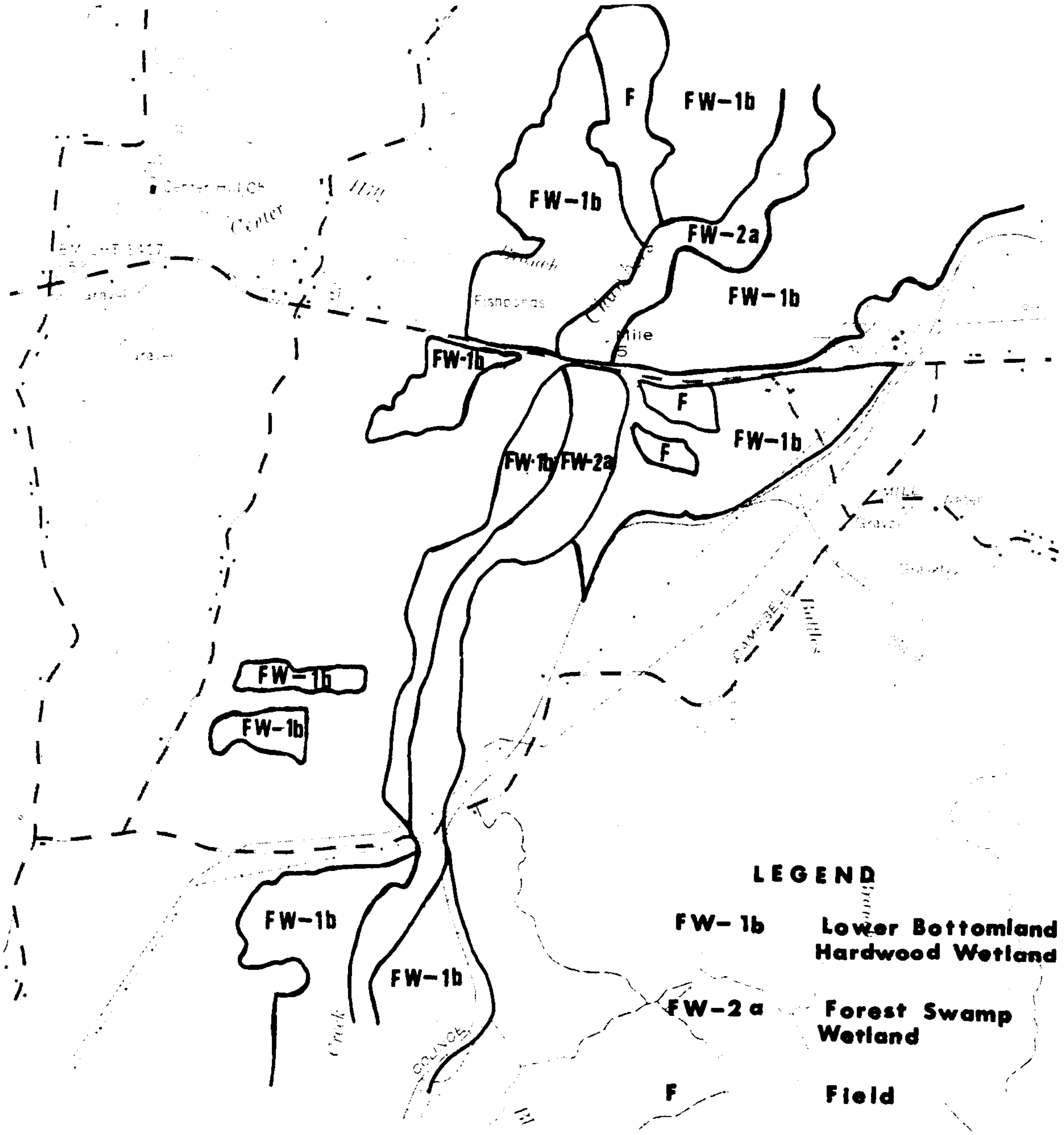

Figure 10. Vegetation Map of Test Site Area

Figure 11. Field Trip Site Locations

Field Sites

Site #1 (Located before reaching a tributary of Chambers Creek)

Vegetation:

1a. Overstory	1b. Understory
Sweet gum	Hackberry
Tupelo gum	Swamp white oak
Red maple	

Comments: This area was wet and muddy, showing a washed-out effect on the ground vegetation. Beyond it, a small stream was located, and beyond the stream was a stand of beech trees.

Site #2 (Located at a tributary near Chambers Creek)

Vegetation:

2a. Overstory	2b. Understory
Beech	Hackberry
Red maple	
Hickory	

Comments: The ground was very wet and crayfish holes were plentiful. Beaver damage was seen on some of the trees, showing bark missing from around the bases, etc. The tributary stream was very muddy and some tree cutting and brush piling was done along the stream. Arrowhead and pickerel weed were observed.

Site #3 (At Chambers Creek)

Vegetation:

3a. Overstory

Beech

Water oak

Sweet gum

Yellow poplar

Overcup oak

3b. Understory

Young poplar

Comments: The ground was very moist showing evidence that the area had a high water table or was wet from an overflowing stream.

Site #4

Vegetation:

4a. Overstory

Red maple

River birch

Sycamore

4b. Understory

Small brush or shrub like vegetation

Comments: This site was a little bit dryer than the others.

Site #5 (At railroad tracks)

Vegetation:

5a. Overstory

Sweetgum

Pine

Poplar

Red oak

5b. Understory

Sumac

Comments: This site along the road was dryer than some of the others. In the direction of site #6, sweetgun, pine, poplar, red oak, shagbark hickory, and sycamore trees were located.

150 yards farther toward site #6. Description: Wetter ground with small beech, red maples, hickory, and sweetgum, thick groundcover with willow oak, and cow oak. Onward about 50 to 75 yards toward Chambers Creek, the area became wetter supporting cocklebur, sedge and pickeral weed.

Site #6 (Along Chambers Creek)

Vegetation:

6a. Overstory

Water oak
Birch
Beech
Overcup oak
Sycamore

6b. Understory

No notable understory present

Comments: the area had wet sandy deposits along the stream with evidence the water stays in this area frequently, and flooding occurs. The ground vegetation consisted of various grasses and were muddy in appearance.

Moving toward Site #7.

Beyond a landowner's house, a soybean field was crossed. At the edge of the field, rushes, cattails, sedges, button balls, alder, red maples, and white oaks were observed. The area resembled a wet meadow wetland. As the field team left the wet meadow area into the woods walking toward site #7, tupelo gum and maples were observed in an area of standing water which showed evidence of flooding with very little ground vegetation.

Site #7 (near Chambers Creek)

Vegetation:

7a. Overstory	7b. Understory
Willow	Alder
River birch	Beech
Willow oak	Birch
Water oak	Box elder

Comments: The area along the tributary gets wetter under the trees near the streambank. This area represents a sort of boundary between a Bottomland Hardwood Wetland and a modified Forest Swamp Wetland.

The Landsat Image Map

The Landsat satellite image taken May 14, 1978 was used at an approximate scale of 1:250,000 in comparing the changes in the amount of vegetation present on the test site on the dates of February, 1974, November, 1975, and May, 1978. A false color composite image using bands 4, 5, and 7 was used for the interpretation. The vegetation appeared red on the image, with the dominant vegetation classes possible being Agricultural Land, Mixed Hardwood Forests, and Evergreen Forests. It was not the intention of this study to classify the vegetation that was shown by the satellite image, but only to show the pattern of overstory vegetation that existed along Chambers Creek in the test site, and the possible changes in the amount of vegetation. Therefore, the various shades of red, which were vegetation types were not analyzed in great detail. The resulting map is shown in Figure 12.

The 1974 and 1975 black and white aerial photographs and the 1975 false color infrared photograph showed that a Bottomland Hardwood Wetland area with a modified Forest Swamp Wetland situation existed along Chambers Creek at the time of these photographs. (See the Vegetation Map Section). The pattern of wetland vegetation along the creek was analyzed so that it could be compared to the vegetation patterns shown on the Landsat image. The primary vegetation pattern along the stream was a wetland forest on either side of Chambers Creek through the test site. This same pattern of vegetation showed up on the Landsat image as a narrow medium red line. Although some modifications may have been made away from the creek, the primary wetland pattern was still present along the creek in May, 1978.

The Landsat Return Beam Vidicon Image Map

The Landsat RBV image taken November 11, 1978 was used at an approximate scale of 1:108,000 in comparing the changes in the amount of vegetation present in the test site on the dates of February 1974, November 1975, May 1978, and November 1978.

Results showed that the amount of overstory vegetation along Chambers Creek decreased during the time from May to November of 1978. The decrease in vegetation can be seen in Figure 13 on the RBV image which showed a whitish-gray color denoting cleared land. Figure 14 shows the more recent situation where the area south of the State Route 57 has been cleared of wetland vegetation.

Figure 12. Landsat 3 MSS Image Map

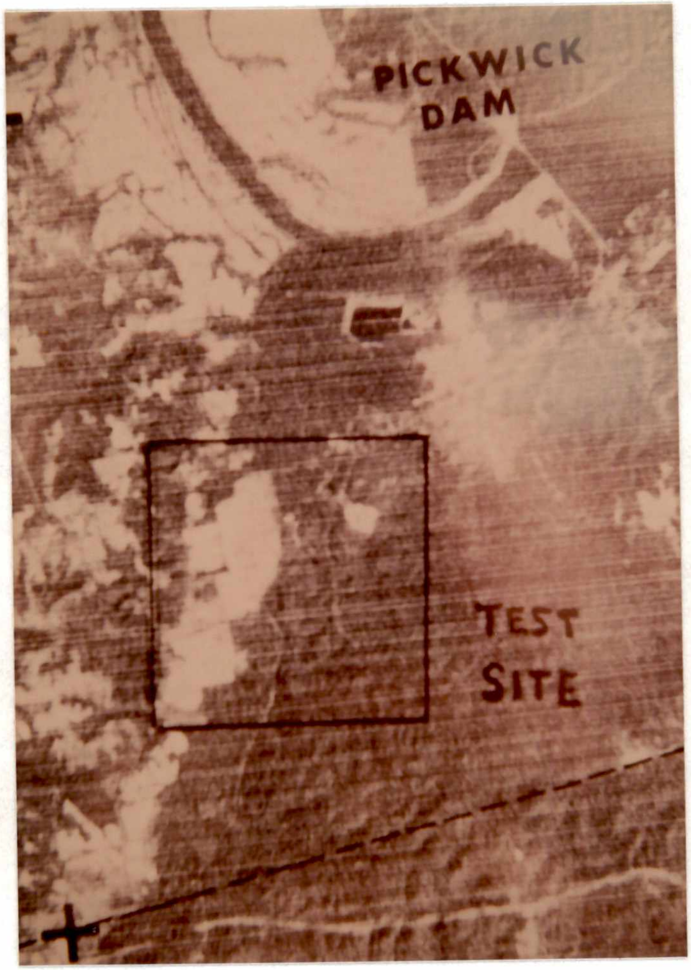

Figure 13. Landsat 3 RBV Image Map

Figure 14. B&W Aerial Photo of Test Site Area Taken in March, 1980

CHAPTER VII

SUMMARY OF RESULTS

The results of this project show that the test site area along Chambers Creek consists of Lower Bottomland Hardwood and Forest Swamp Wetlands. The black and white and false color infrared aerial photos were very useful for vegetation mapping and environmental analysis work. The lighter shades of gray on the black and white photos and the blue color on the false color infrared photos along Chambers Creek show the general separation between the forest swamp and standard bottomland hardwood categories.

The results from the Landsat Maps show that the area along Chambers Creek from Highway 57 to the Campbells Road Bridge was cleared of vegetation between May, 1978 and November, 1978. The Landsat Multispectral Scanner Image distinctly shows a thin red line of vegetation along the creek in May and the Return Beam Vidicon Image shows a clear white area in November, 1978, which proves that the forest swamp bottomland hardwoods were cleared between May and December, 1978.

This project demonstrates the practical application of Landsat Imagery for monitoring changes on the earth's surface. The Multispectral Scanner and the Return Beam Vidicon Systems can be used together to provide information which may be useful to agencies interested in regulating changes in the environment. This remote sensing approach to wetland mapping and monitoring is economically feasible and can be done in a relatively short period of time.

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APPENDIX

APPENDIX

WETLAND LEGISLATION OR REGULATIONS

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The Deepwater Port Act of 1974 (33 U. S. C. 1501 et seq.).

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The Endangered Species Act of 1973 (16 U. S. C. 1531 et seq.).

Executive Order 11990, Protection of Wetlands, dated May 24, 1977.

Executive Order 11988, Floodplain Management, dated May 24, 1977.

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Marine Mammal Protection Act of 1972 (16 U. S. C. 1361 et seq.).

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VITA

Gregory Michael Luke was born in Newmartinsville, West Virginia on November 27, 1948, the son of Sylvia R. and Ryland R. Luke. He attended high school in Parkersburg, West Virginia and entered West Virginia University at Norgantown, West Virginia where he received a Bachelor of Science degree in Forestry in May of 1972. After two years of working with the State of Ohio as an environmentalist and three years of working with the State of West Virginia and the National Aeronautics and Space Administration as coordinator of a Landsat Satellite research project, he accepted a graduate research assistantship at The University of Tennessee Space Institute and began study toward a Master's degree in Engineering Science.

He is married to the former Miss Virginia Katharine Stidham, who is from El Paso, Texas.