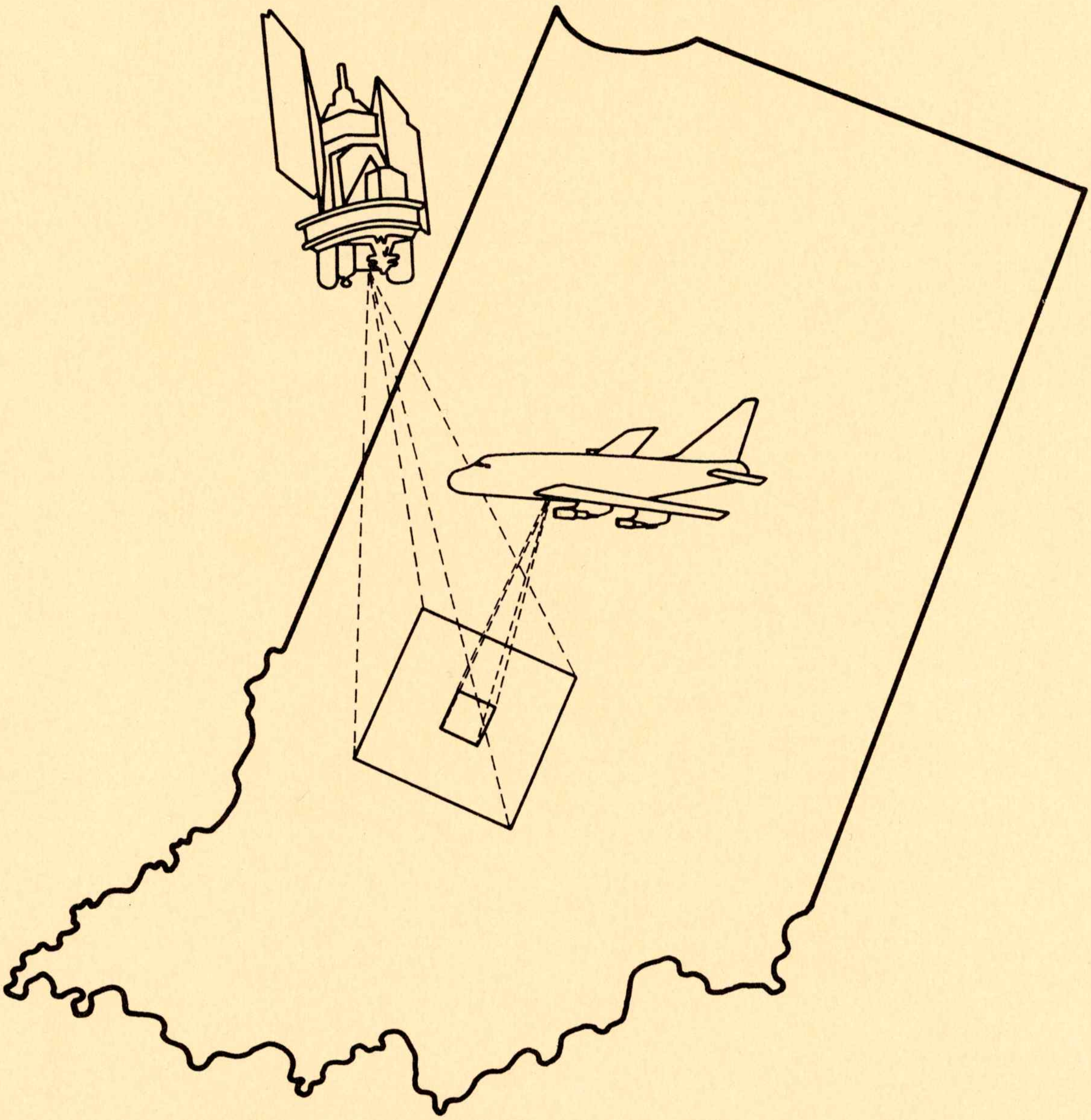
LARS Contract Report 042179

Semi-Annual Status Report

Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana



Laboratory for Applications of Remote Sensing
Purdue University W. Lafayette, Indiana

June 1, 1978 - November 30, 1978 NGL 15-005-186

LARS Contract Report 042179

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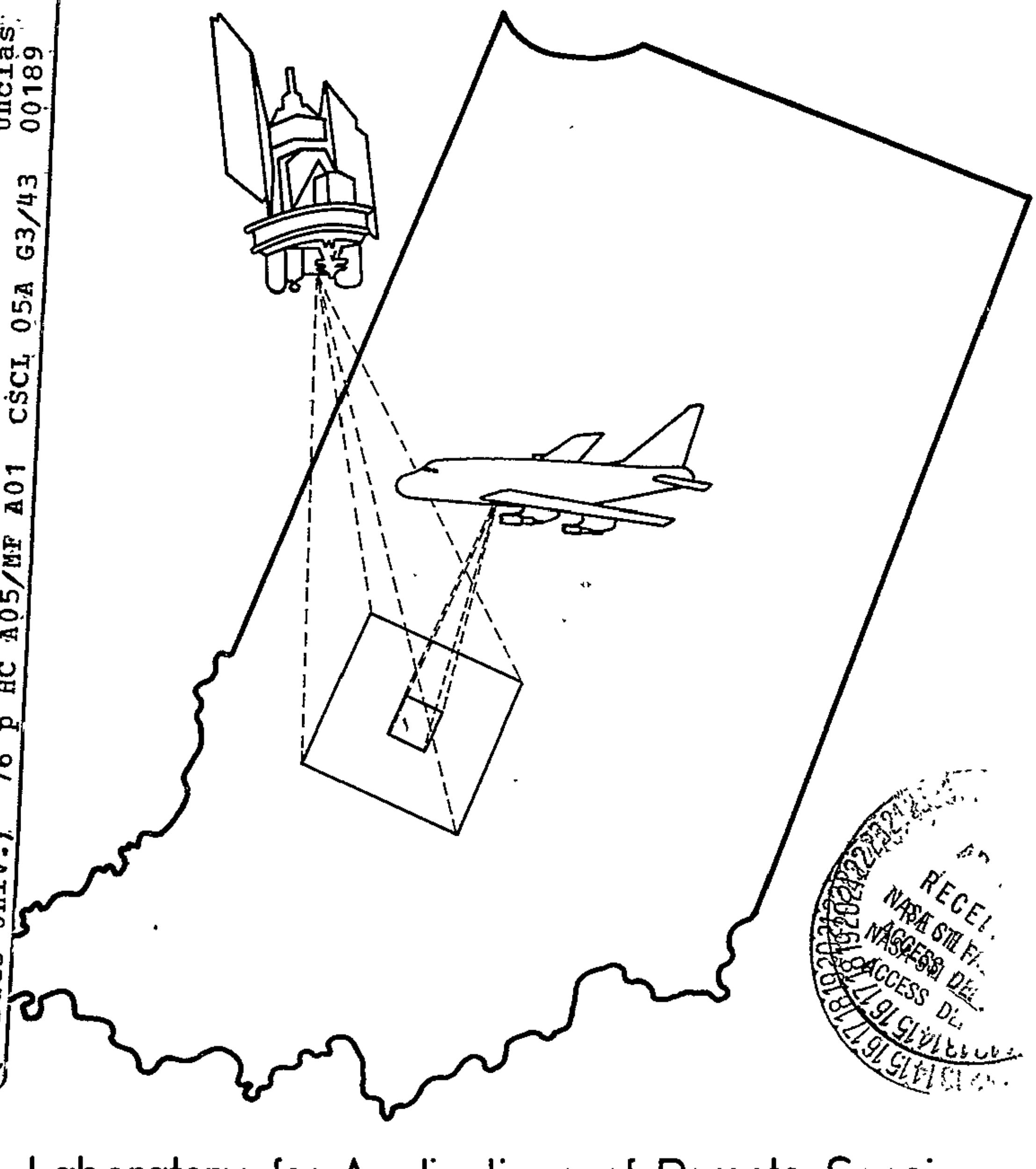

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16. Abstract

This semi-annual status report covers the period from June 1, 1978 to November 30, 1978 and contains a review of the research and applications, completed or in progress, as funded by the Office of University Affairs, NASA and conducted by Purdue University, Laboratory for Applications of Remote Sensing.

This reporting period marks the first half of the sixth year of funding for a proposal entitled "The Applications of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana." As indicated in this title, the purpose of this work is to introduce remote sensing into the user community within the state of Indiana. The user community includes those local, regional and state agencies involved in the decision monitoring and/or managing processes of the state's resources.

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INTRODUCTION

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In order to carry out this work it is not only necessary to initiate projects with these agencies but also it is necessary to meet with and provide information to as many people and groups as well as agencies as possible. During the past six months numerous meetings were held with many different groups.

Among the groups that were contacted and received information about this program were:

Area Planning Commission, Tippecanoe County
Indiana Geological Survey
U.S. Forest Service
Tipton County Commissioners and Engineers
Indiana Department of Natural Resources

a) Division of Reclamation
b) Division of Forestry
c) Division of Properties, Fish and Wildlife
d) Soil and Water Conservation Committee

Soil Conservation Service.

Listed below are the projects that are reported in this document:

Soils Inventory
Wetlands Inventory.

SOIL INVENTORY PROJECT

INTRODUCTION

Soil surveys have become an increasingly used input to agricultural, land use and resource planning decisions. As population and growth pressures increase, so does the need for timely and accurate soils data.

Soil surveying began in the early 1900's by using plane tables to draw both a base map and a soil map. In the late 1920's aerial photography was instituted to aid in soils mapping. These photos were used by the soil surveyor for ground location and as an additional source of information by using the technique of photointerpretation. They were also used as a base map for drawing soil boundaries and are still so used today.

Placing soil boundaries on aerial photography is, however, a subjective procedure. Boundary placement depends upon field investigations, the quality of the photograph and the experience of the soil surveyor. If there was some technique that could reduce the subjectivity of boundary placement, the accuracy of the soil survey could be greatly enhanced. If this same technique could aid in the placement of soil auger borings, the number of borings as well as the area traversed by the surveyor would be minimized. The borings could be placed in areas that were relatively homogeneous hence representative of the dominant soil conditions in the area. Transitional zones and confusing areas would be recognized, therefore, aiding in making decisions about the soil unit to be placed on the map. Soil inclusions and complexes would be readily mapped. This information also would be of great benefit to the user of soil survey information since it is reported that presently the economically feasible level of mapping leaves 30 to 40% soil inclusions within map units. This is significantly higher than the normally accepted 15% level.

Previous investigations have demonstrated the utility of Landsat imagery in the preparation of soil association maps at the county and state level. Other studies have shown promise in identifying such soil parameters as natural, internal drainage characteristics, organic matter differences, textural differences, and differing cultural practices.

Few studies have investigated the use of Landsat data for delineating soils at a more detailed level. Kirschner, et al. (1) concluded that, for a study site in Indiana, digital analysis of Landsat data provided an additional source of information for the soil surveyor and showed promise as an aid in the placement of soil borings and for delineating inclusions. Kaminsky (2) investigated various techniques for producing a detailed soils map by digital analysis of Landsat data. Such digital analysis of the multispectral Landsat data results in unique spectral classes. These classes can be separated into soil and not-soil classes by various techniques. It was the purpose of this study to investigate methods by which these spectral soil classes can be correlated to the actual soils occurring in the area. The spectral soils map and the resulting correlation is not meant to replace the traditional process of soil survey. It will, hopefully, be used as an aid by the field soil surveyor to increase the accuracy and decrease the subjectivity of the soil survey.

To achieve this correlation, a previously produced map delineating the spectral characteristics of the soils for the six parent material areas of Jasper County, Indiana was used. A methodology was developed for correlating soils to spectral data over a relatively wide geographic area. This technique determines the basic soils correlation which will provide the soil scientist and resource planner with a basis for making soil related decisions. In addition, some of the problems in using Landsat data for soil survey were investigated. Finally, the method that was developed may lead to a more intensive investigation into methods for estimating the accuracy of maps produced from remotely sensed data for soils and other purposes.

OBJECTIVES

The objectives of this task were as follows:

1) to investigate methods by which spectral classes can be correlated to actual soils occurring in an area;

2) to use the subsequent correlation as an aid to the field surveyor to increase the accuracy and decrease the subjectivity of the soil survey; and

3) to establish a methodology that provides a rapid correlation of soils to spectral data over a relatively wide geographic area.

METHODS AND MATERIALS

Data

The Landsat data were collected 9 June 1973. The data chosen for classification were relatively free of vegetative cover, interfering clouds, and other undesirable features.

Photographic data were collected on 3 May 1976 at an altitude of 6000 feet. The resulting block of eighty-five photos were at a scale of 1:15,840.

Using these photos as a base, the Landsat data were rectified in a north-south direction and precision registered to ground control points. The spectral data were rescaled to 1:15,840 to make them compatible with the aerial photography. The final accuracy resulted in a one foot error in 751 feet in the east-west direction and a one foot error in 1088 feet in the north-south direction. This represents a 0.1% error in registration.

Geology of Jasper County

While glacial deposits from the Kansan and Illinoian age cover all of Jasper County, it is the effect of the Lake Michigan and Erie glaciers of the early Wisconsin age that dominate the surficial geology of the county. Underlying all glacial deposits are tertiary and quarternary bedrock valleys which are filled by quarternary debris. Coral reef domes, possibly of Silurean or Devonian ages are evident in the western part of the county. These domes sometimes occur within one or two feet of the surface.

Three distinct glacially deposited parent materials are present in Jasper County: outwash, till, and lacustrine.

The outwash deposits found consist of assorted materials that were deposited by rivers, streams, and lakes that were present during the glacial period. These materials are mostly stratified sand and gravel. Sand ridges occurring in the northern section of the county were formed by the action of the wind on the outwash material.

The glacial till is the unsorted material deposited by the glacier. It is generally a mixture of pebbles, sand, and clay and a few large stones. There are three separations of till found in the county. These are: 1) rolling moraine consisting of undulating topography where the slopes are dominantly 4-10%, 2) ground moraine area where Mollisol soils predominate, and 3) ground moraine area where Alfisol soils predominate. The ground moraine areas are nearly level to gently sloping with slopes being less than 4%.

The lacustrine area has typically flat topography. Shorelines of what were the larger lakes are characterized by beaches, bars, and sand dunes. The lacustrine soils are underlaid by clays and silts that are distinctly stratified.

A unique area lies in the northeastern part of the county. In this area both outwash and till have come together. This outwash over till area is characterized by having an underlying material similar to the material found in the rolling moraine area. Over the till, outwash deposits of varying thicknesses occur. The result is that the area is predominantly outwash on the surface but is interspersed with knobs of till material showing through where the outwash material is thin. These knobs are generally an acre or less in size.

These boundaries were digitized and registered to the Landsat MSS data. A parent material map was produced by image interpretation of the Landsat data and verified by field investigation.

Organic deposits are interspersed throughout the county, particularly in the outwash areas. They were not extensive enough to be separated.

Classification

Spectral data were classified by first selecting every fifth data point within each parent material area and analyzing the samples by computer-aided statistical analysis procedures. The resulting statistics were used to classify each data point spectrally within each parent material area. The resulting classification was used as the spectral input for this study.

Selection of Sample Areas

It was decided that a sampling system similar to that used for the 1958-1960 Conservation Needs Inventory (CNI) of the Soil Conservation Service should be employed. In that study, thirty-three quarter sections (160 acres each) were randomly chosen throughout Jasper County by the Iowa Statistics Laboratory. The location and old soil maps of these areas were obtained from the Soil Conservation Service office at Rensselaer, Indiana.

Field investigation revealed that many of the CNI quarter sections did not contain the detail desired in this study. In addition, different names of the soils were used when this mapping was done, hence making the conversion to current soil names difficult and unreliable. Field and soil conditions were not evident on the CNI maps, therefore, eliminating any means of hypothesizing the differences in soil spectral responses. Thus, a random selection of quarter sections throughout the county was mapped. To make the sampling area more complete, some of the quarter sections that had been selected for the CNI study were selected for remapping. All areas mapped are shown in Figure 1. The total area mapped in this study was 4480 acres which is approximately 1.25% of the county. Table 1 shows a breakdown of quarter sections sampled by parent material area.

Table 1. Acreage of Quarter Sections Sampled

Parent Material Area	Approximate Acreage	Acreage Mapped	Percent
Outwash	202,040	1600	0.79
Outwash over till	26,880	480	1.79
Rolling moraine	35,840	480	1.34
Lacustrine	63,360	960	1.53
Ground moraine (Mollisol soils)	16,640	640	3.85
Ground moraine (Alfisol soils)	14,080	320	2.27
TOTAL	358,840	4480	1.25

Collection of Soils Data

The method of free survey, or conventional mapping techniques, and area sampling were employed in this study. The free survey consisted of walking in a random direction over each 160-acre plot, making soil borings where needed and drawing boundaries on a black and white aerial photo. In addition, the spectral map for the area of concern was used to locate areas displaying a unique spectral class.

The procedure used to gather soils data consisted of:

1) Random selection of quarter sections (Figure 1)

2) Mapping of quarter sections by SCS soil scientist and author. (Soil series were noted on an aerial photograph that was accompanied by a corresponding spectral map.)

3) A final map was prepared and an appropriate legend was made.

Determination of Percent Soils for Each Spectral Class

Boundaries were drawn around each spectral class (Figure 2) and transferred to a clear acetate sheet as represented by Figure 3. The acetate sheet was overlaid on the prepared soils map and a dot grid (64 dots per square inch), in random fashion, was then overlaid on the acetate. A dot

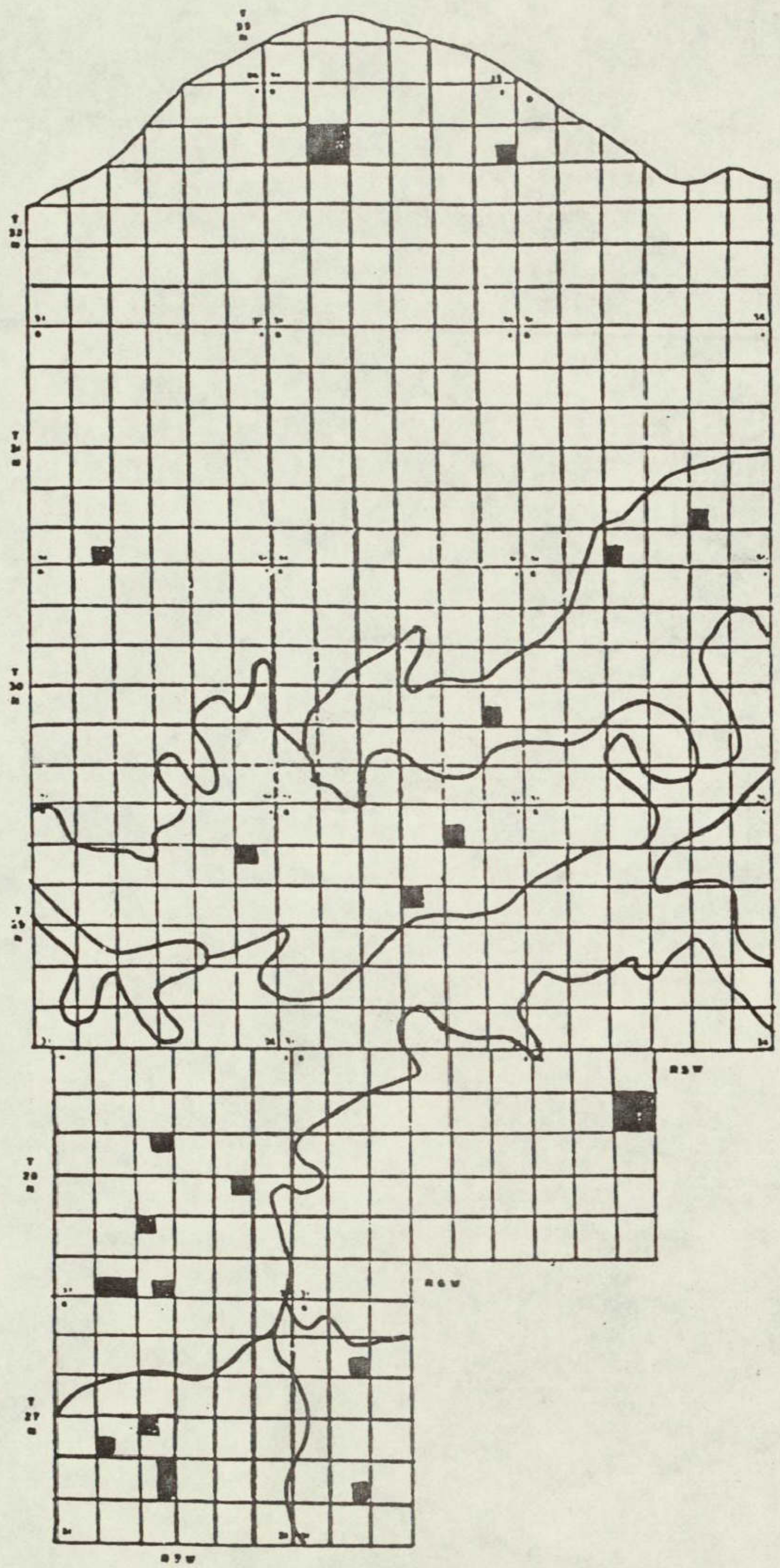


Figure 1. Location of Quarter Sections Mapped.

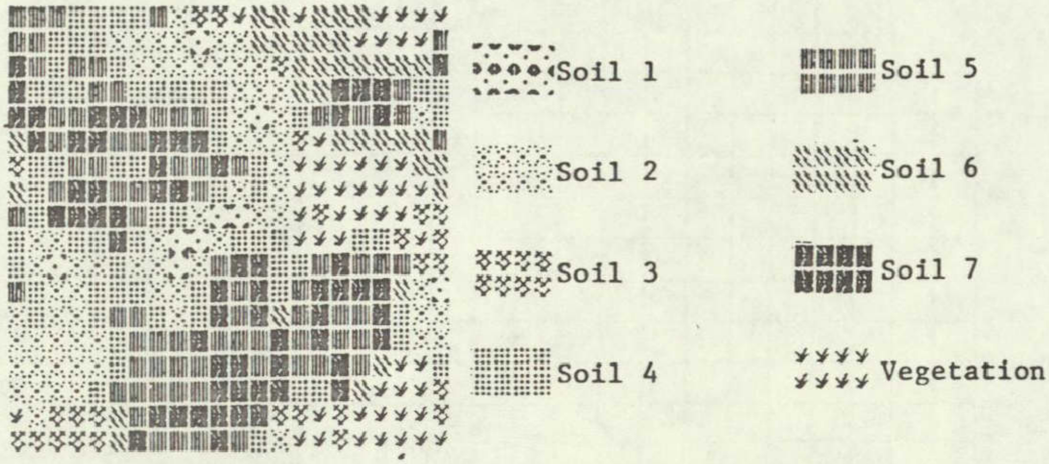
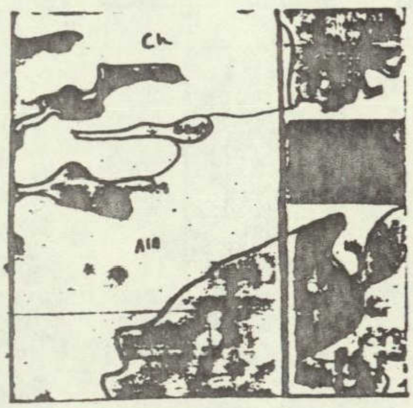


Figure 2. Spectral map of T28N, R7W, Sec. 33, SE¼.



Legend

AlA - Alvin, 0-2% slope
Ch - Chelsea
Gf - Gilford
Ma - Mahalasville
Rr - Rensselaer
St - Starks

Figure 4. Soil map for T28N, R7W, Sec. 33, SE¼.

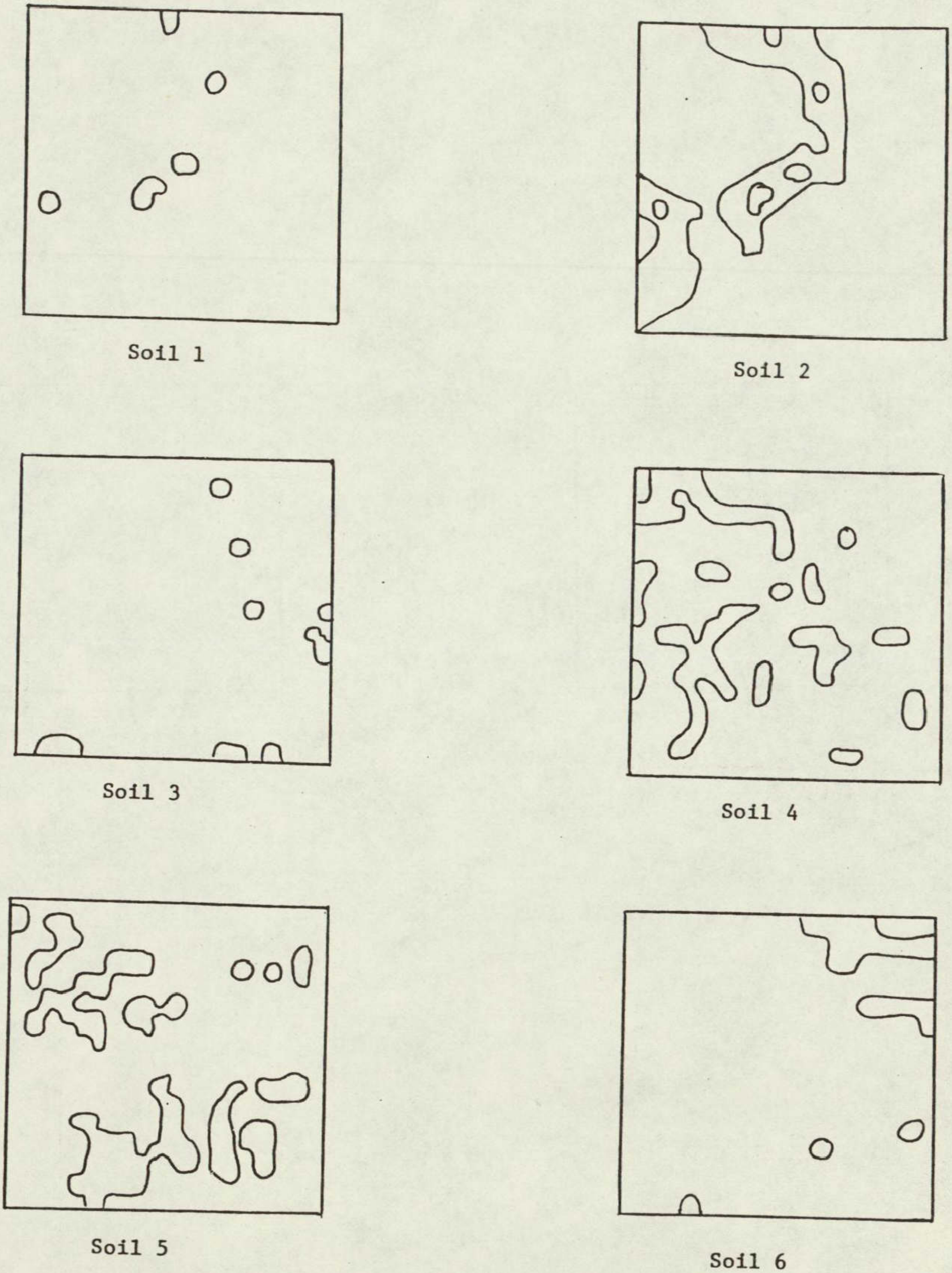
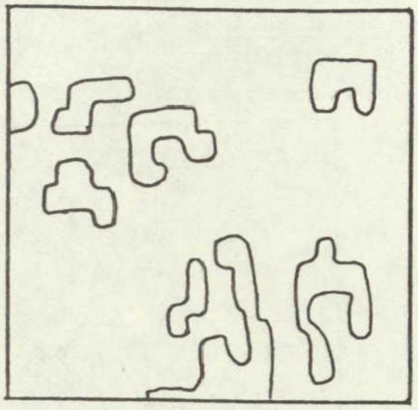
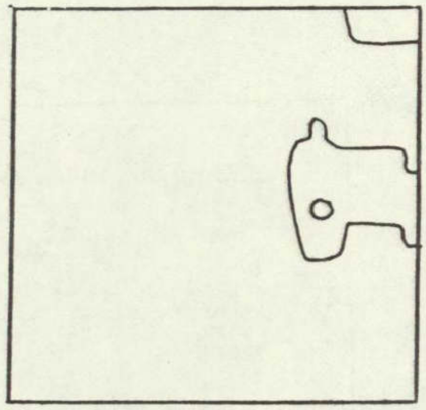


Figure 3. Soil Spectral Classes As Delineated by Boundaries.



Soil 7



Vegetation

Figure 3. (Continued).

count was taken for each spectral class and recorded as in Table 2. The table shows this spectral soil class was composed of Chelsea, Starks, Mahalasville, and Rensselaer which represents 71% poorly drained, 13% somewhat poorly drained, and 16% well drained. The actual soil map is shown in Figure 4.

Table 2. Example Dot Grid Count

Soil Class	Well Drained		Moderately Well Drained		Somewhat Poorly Drained		Poorly Drained		Total
Soil 7	Chelsea:5				Starks:4		Rens:19 Mahal:3		
	Dots	%	Dots	%	Dots	%	Dots	%	Dots
	5	16	-	-	4	13	22	13	31

A dot grid count was completed for each quarter section and results were categorized according to specific quarter sections. The counts could not be summarized by conventional statistical techniques due to the subjective soil sampling methods used.

RESULTS AND DISCUSSION

Twenty-eight quarter sections were mapped representing a total area of 4480 acres or approximately 1.25% of the county.

Soil series were not consistently separated on a countywide basis. However, when internal drainage and parent materials were ascertained, a soil series could be predicted. Soils were grouped by internal drainage classes as defined in Table 3. Each soil spectral class represented one predominant drainage class with minor inclusions of other drainage classes. The same is true with conventional field mapping units that also contain minor inclusions of other drainage classes. Drainage classes could be identified by looking at the relative magnitude across the four spectral channels. The lower the relative magnitude of reflectance, the more poorly drained the spectral classes appeared. Mixed pixels consisting of soil and vegetation responses were noted in the classification within each parent material area. These classes may be the result of emerging crops against a predominant soils background or when a satellite resolution element fell on a boundary of soil and vegetation which results in an average of responses. Figure 5 shows a typical soil relative response curve compared to a vegetation response curve and a soil response curve with some vegetative influence.

Outwash

Outwash soils represent 202,040 acres or about 56.3% of the entire county. Table 4 indicates the percentage of various soils and Figure 6 shows their mean relative responses. Approximately 1600 acres or .79% of the area were sampled in 10 quarter sections, eight of which were contiguous. The following is a prepared legend of associated soils and surface features represented by each spectral response group.

Table 3. Guide for determining natural soil drainage class.

Overall Appearance of the Diagnostic Zone When Moist (Ped Coatings)	Closer Examination of Diagnostic Zone (Ped Interiors)	Drainage Class
A. Soils with ten inches or more of dark-colored surface.		
Gray colors	Gray colors predominate in the 6-inch layer below dark-colored soil material.	Poorly Drained
Gray or brownish colors	Brownish colors predominate in the 6-inch layer below dark-colored soil material, but gray mottles are present.	Somewhat Poorly Drained
Brownish colors	Brownish colors with few or no gray mottles in the 6-inch layer below dark-colored soil material, but with gray mottles above 30 inches.	Moderately Well Drained
	Brownish colors below dark soil material with few or no gray mottles above 30 inches.	Well Drained
B. Other soils.		
Gray colors	Gray colors predominate in the 10 to 18 inch layer.	Poorly Drained
Gray or brownish colors	Brownish colors predominate to 10 to 18 inch layer, but gray mottles are present.	Somewhat Poorly Drained
Brownish colors	Brownish colors with few or no gray mottles in the 10 to 18 inch layer, but with gray mottles between 18 and 30 inches.	Moderately Well Drained
	Brownish colors with few or no gray mottles between 10 and 30 inches.	Well Drained

Note: The term "gray mottles" means that more than 2% of the soil material is gray. (From: Understanding and Judging Indiana Soils. ID-72 Pilot, Agronomy Dept., Purdue University. March 1978.)

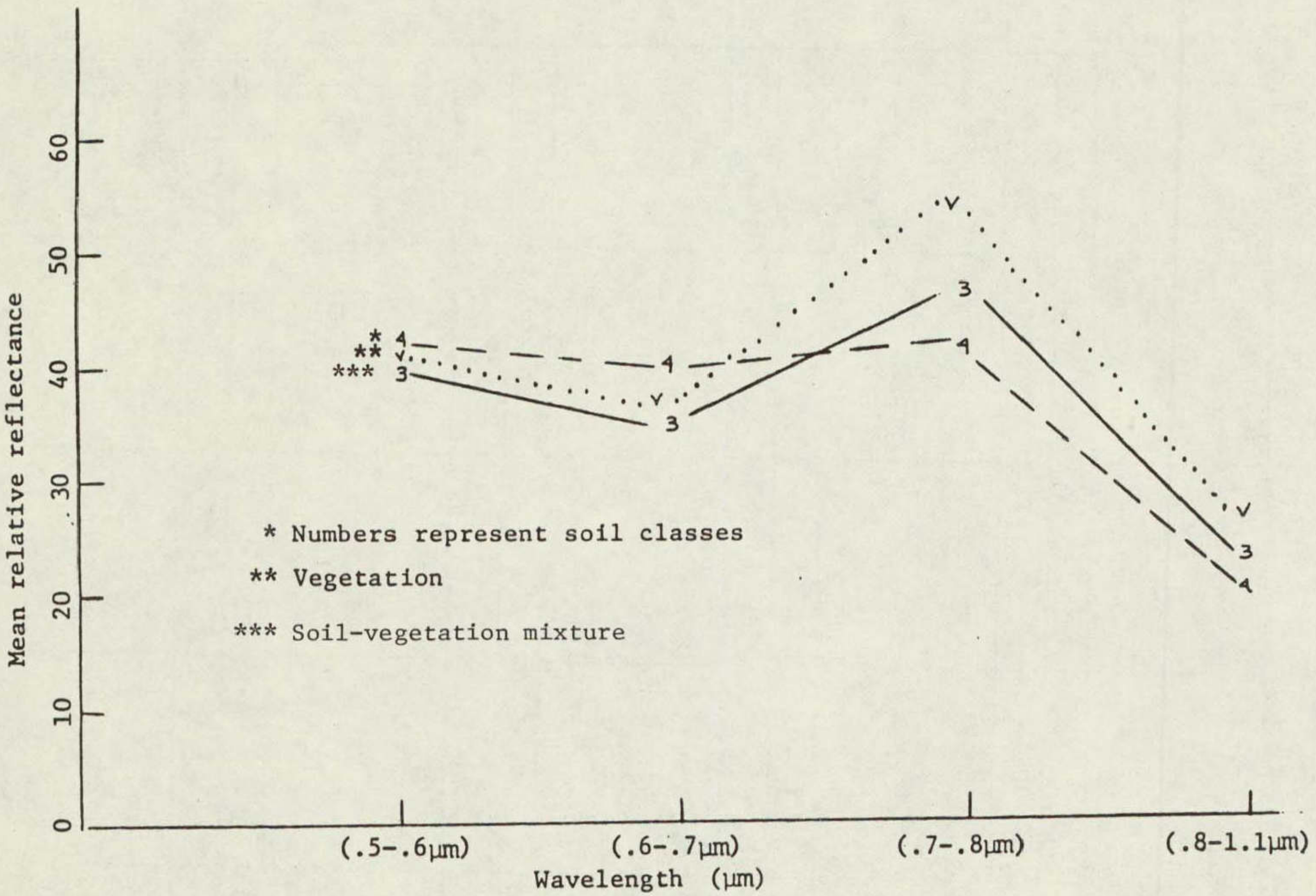


Figure 5. Soil-vegetation confusion class analysis--outwash over till.

Table 4. Dot grid count for outwash area.

Class	ED - WD		MWD		SPD		VPD		T
	D	%	D	%	D	%	D	%	
Soil 1	Ch: 2 Os: 3 Pn:31				Bb:15 Mr: 8 Td: 4		Md: 3		66
	36	55			27	41	3	4	
Soil 2	Pn:20				Bb: 4 Db:21 Mr: 1 Td: 7 Wk: 5		Gf:24 Md: 3 Rr: 4 Sb: 2		91
	20	22			38	42	33	36	
Soil 3	Pn: 6		Be: 8				Gf: 8 Md: 2		24
	6	25	8	33			10	42	
Soil 5	Pn: 5				Db: 6 Mr: 4		Gf:140 Md: 13		168
	5	3			10	6	153	91	
Soil 6	Mb: 3 Pn: 8				Mr: 8 Sa:12		Gf:190 Ho: 6 Md: 24 Rr: 7 Sa: 2		259
	11	4			20	8	228	88	

Table 4. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 7	Mb: 4 Pn: 2				Bb:10 Db:10 Mr: 2		Gf:134 Md: 16 Mu: 24 Rr: 14		221
	D	%	D	%	D	%	D	%	
	6	3			22	12	188	85	
Soil 8					Mr:10		Ad: 9 Rr:21 Gf:142 Sb:23 Ho: 7 Md: 26 Mu: 16		254
	D	%	D	%	D	%	D	%	
					10	4	244	96	
Soil 9					Db:11		Ad: 5 Gf:576 Md: 21 Mu:125 Rr: 66 Sb: 22		846
	D	%	D	%	D	%	D	%	
					11	1	835	99	
Veg	Pn:53		Be:14		Bb: 2 Mr:38		Gf:271 Mu: 7 Sb: 3		388
	D	%	D	%	D	%	D	%	
	53	14	14	4	40	10	281	72	
Total	137		22		183		1975		2317

Table 4. (Continued).

<u>Soil Key</u>

Ad - Adrian
Bb - Brady
Be - Brems
Ch - Chelsea
Db - Darroch
Gf - Gilford
Ho - Houghton
Mb - Martinsville
Md - Maumee
Mr - Morocco
Mu - Mussey
Os - Oshtema
Pn - Plainfield
Rr - Rensselaer
Sa - Seafield
Sb - Sebewa
Td - Tedrow
Wk - Whitaker

<u>Table Key</u>

ED - excessively drained
WD - well drained
MWD - moderately well drained
SPD - somewhat poorly drained
VPD - very poorly drained
T - Total
D - Dots

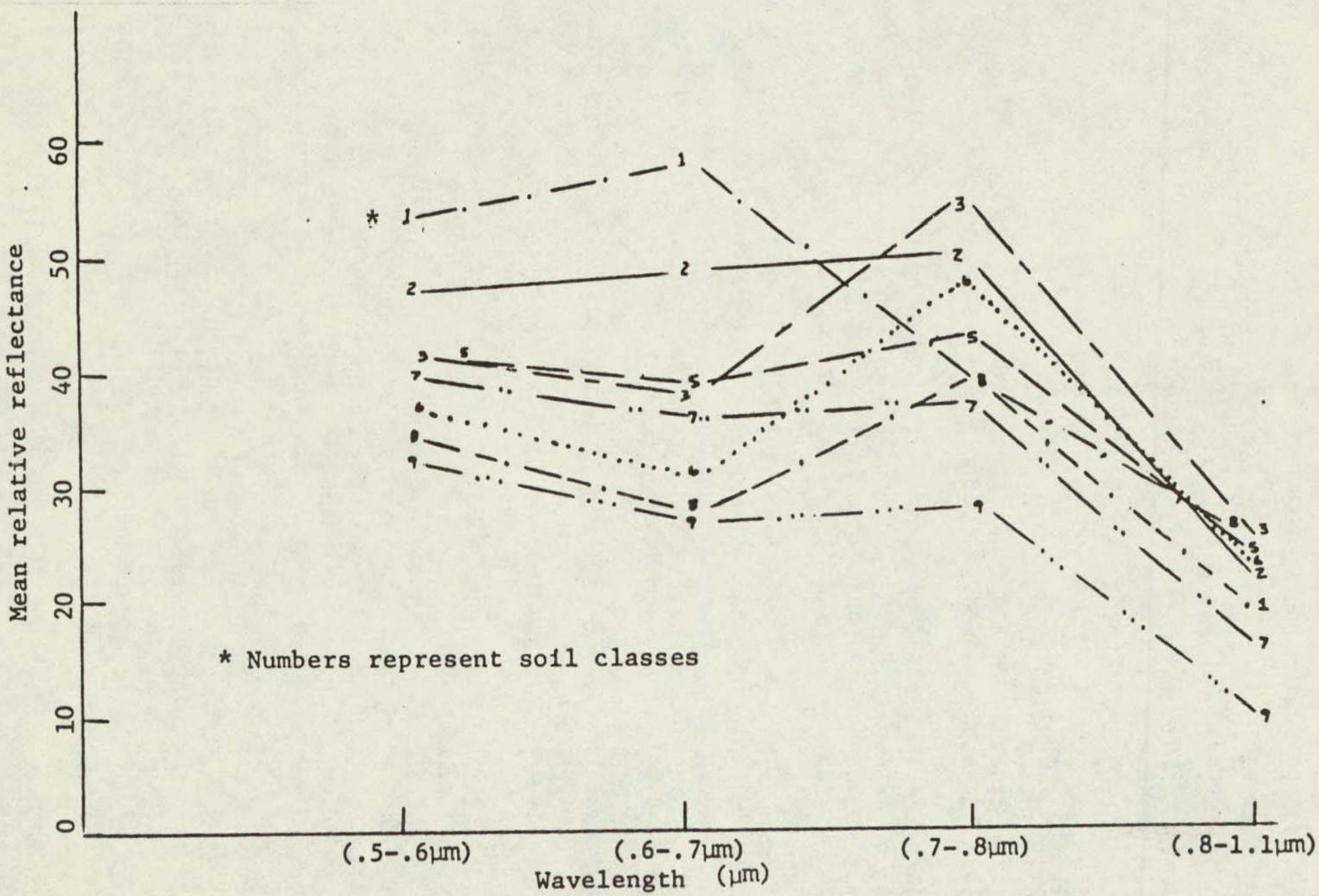


Figure 6. Soil spectral classes--outwash.

Class 1 - This spectral class indicates predominantly excessively drained and well drained soils. Those soils sampled were Plainfield, Chelsea, and Oshtemo. Significant inclusions of somewhat poorly drained soils (Morocco, Brady, Tedrow) and very minor inclusions of very poorly drained soils (Maumee) are found.

Class 2 - This spectral class is dominated by somewhat poorly drained soils including Whitaker, Morocco, Darroch, Brady, and Tedrow. The poorly drained soils are also present as significant inclusions (Gilford, Rensselaer, Maumee, Sebewa). The excessively drained soils (Plainfield) are also significant inclusions.

Class 3 - This spectral class is dominated by the very poorly drained soils including Gilford and Maumee. Significant inclusions of moderately well drained Brems and excessively drained Plainfield are apparent. This class is a soil-vegetation confusion class.

Class 5 - This spectral class is dominated by the very poorly drained soils. Those soils sampled were Gilford and Maumee. Minor inclusions of somewhat poorly drained soils (Darroch, Morocco) and excessively drained soils (Plainfield) are also found.

Class 6 - This spectral class is dominated by the very poorly drained soils including Maumee, Gilford, Sebewa, Houghton, and Rensselaer. Minor inclusions of somewhat poorly drained Morocco and Seafield and well drained Martinsville and excessively drained Plainfield occur. This class is a soil-vegetation confusion class.

Class 7 - This spectral class is predominantly very poorly drained soils including Gilford, Maumee, Mussey and Rensselaer. Minor inclusions of somewhat poorly drained soils (Morocco, Darroch, Whitaker and Brady) are found. An extremely small percentage of well drained and excessively drained soils (Plainfield, Martinsville) were found as inclusions.

Class 8 - This spectral class is predominantly very poorly drained soils including Mussey, Gilford, Maumee, Houghton, Rensselaer, Sebewa and Adrian. Very minor inclusions of the somewhat poorly drained Morocco were sampled. This class is a minor soil-vegetation confusion class.

Class 9 - This spectral class is predominantly very poorly drained soils. Soils sampled included Gilford, Mussey, Rensselaer, Maumee, Sebewa and Adrian. Very minor inclusions of the somewhat poorly drained Darroch were also found. Water is most likely to fall into this spectral class.

Vegetation - The vegetation class is predominantly poorly drained soils including Gilford, Sebewa and Maumee. Inclusions of excessively drained (Plainfield), moderately well drained (Brems) and somewhat poorly drained (Morocco, Brady) were sampled.

Discussion. Class 1 is predominantly well or excessively drained soils while Class 2 shows a predominance of somewhat poorly drained soils. Within Classes 3 and 6 there were mixed pixels of soil and vegetation identified by the spectral response and the spatial association with known classes of vegetation. All other classes were primarily poorly drained soils. Class 8 displayed some vegetation response; however, this was of minor importance.

Outwash Over Till

The outwash over till parent material area contains 26,880 acres or 7.5% of the county area. Table 5 and Figure 7 contain the percentage of soils for each spectral class and the graph of the mean relative reflectances, respectively. The 1.79% or 480 acres of this particular parent material was mapped and correlated to eight spectral classes. Water was classified as class 7.

Class 1 - This spectral class predominantly represents the somewhat poorly drained soils (Whitaker, Morocco). Inclusions of excessively drained soils (Chelsea) and moderately well drained soils (Brems) are present.

Class 2 - This spectral class is dominated by the somewhat poorly drained soils (Whitaker, Tedrow, Seafield, Morocco, Brady). Inclusions of excessively drained (Plainfield, Chelsea) and moderately well drained soils (Brems) are significant. The very poorly drained soils (Rensselaer, Gilford, Maumee) are relatively minor inclusions.

Class 3 - This spectral class is dominantly very poorly drained soils (Rensselaer, Maumee, Muskego, Houghton) with an almost equal representation of somewhat poorly drained soils (Tedrow, Whitaker, Seafield, Morocco). Moderately well drained soils (Brems) represent only minor inclusions. This spectral class is a soil-vegetation confusion class.

Class 4 - This spectral class represents somewhat poorly drained soils (Morocco, Whitaker, Seafield, Tedrow). Very poorly drained soils make up relatively significant inclusions (Houghton, Maumee). Excessively drained soils (Chelsea) and moderately well drained soils (Brems) make up minor inclusions.

Class 5 - This spectral class is dominantly very poorly drained soils (Muskego, Rensselaer, Palms, Maumee, Gilford). Some inclusions of somewhat poorly drained soils (Seafield, Morocco, Whitaker) are apparent. Other inclusions of well drained and moderately well drained soils are minor.

Class 6 - This spectral class is dominantly very poorly drained soils including Palms, Maumee, Gilford, Rensselaer, and Patton. Inclusions of somewhat poorly drained soils (Morocco) are minor.

Class 8 - This spectral class is dominantly very poorly drained soils (Rensselaer, Patton, Maumee, Muskego, Houghton, and Adrian). Very minor inclusions of somewhat poorly drained soils (Morocco) are apparent.

Class 7 - This spectral class is entirely very poorly drained soils (Gilford, Maumee, Houghton, Adrian) including water.

Table 5. Dot grid count for outwash over till.

Class	ED - WD		MWD		SPD		VPD		T
Soil 1	Ch: 4		Be: 3		Mr: 2 Wk:13				22
	D	%	D	%	D	%	D	%	
	4	18	3	14	15	68			
Soil 2	Ch: 5 Pn: 8		Be: 11		Bb: 1 Mr: 4 Sa: 1 Td: 9 Wk:28		Gf: 1 Mu: 1 Rr: 3		72
	D	%	D	%	D	%	D	%	
	13	18	11	15	43	60	5	7	
Soil 3			Be: 3		Mr: 9 Sa: 1 Td: 3 Wk: 3		Ho: 4 Md: 7 Mu: 3 Rr: 7		43
	D	%	D	%	D	%	D	%	
			3	5	19	45	21	50	
Soil 4	Ch: 4		Be: 3		Mr: 7 Sa: 1 Td: 2 Wk:33		Ho: 4 Mu: 5		59
	D	%	D	%	D	%	D	%	
	4	7	3	5	43	73	9	15	
Soil 5	Ch: 1		Be: 2		Mr: 2 Sa: 2 Wk: 8		Gf: 1 Md:10 Pb: 7 Rr:79 Mu:12		124
	D	%	D	%	D	%	D	%	
	1	1	2	1	12	10	109	88	

Table 5. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 6					Mr: 1		Gf: 1 Md: 13 Pb: 26 Pk: 2 Rr:133		176
	D	%	D	%	D	%	D	%	
					1	1	175	99	
Soil 8					Mr: 2		Ad: 9 Rr:21 Ho: 16 Md: 3 Mu: 41 Pk: 3		93
	D	%	D	%	D	%	D	%	
							93	98	
Soil 7							Gf: 3 Ho: 28 Mu: 10 Pk: 9 Rr: 27		77
	D	%	D	%	D	%	D	%	
							77	100	
Veg	Ch: 2 Ph: 6		Be: 19		Mr: 35 Sa: 1		Ad: 5 Gf: 10 Ho: 3 Md: 54		136
	D	%	D	%	D	%	D	%	
	8	6	19	14	36	26	73	54	
Total	30		41		169		562		802

Table 5. (Continued).

Soil Key	Table Key
Ad - Adrian	ED - excessively drained
Bb - Brady	WD - well drained
Be - Brems	MWD - moderately well drained
Ch - Chelsea	SPD - somewhat poorly drained
Gf - Gilford	VPD - very poorly drained
Ho - Houghton	T - Total
Md - Maumee	D - Dots
Mr - Morocco	
Mu - Muskego	
Pb - Palms	
Pk - Patton	
Pn - Plainfield	
Sa - Seafield	
Td - Tedrow	
Wk - Whitaker	

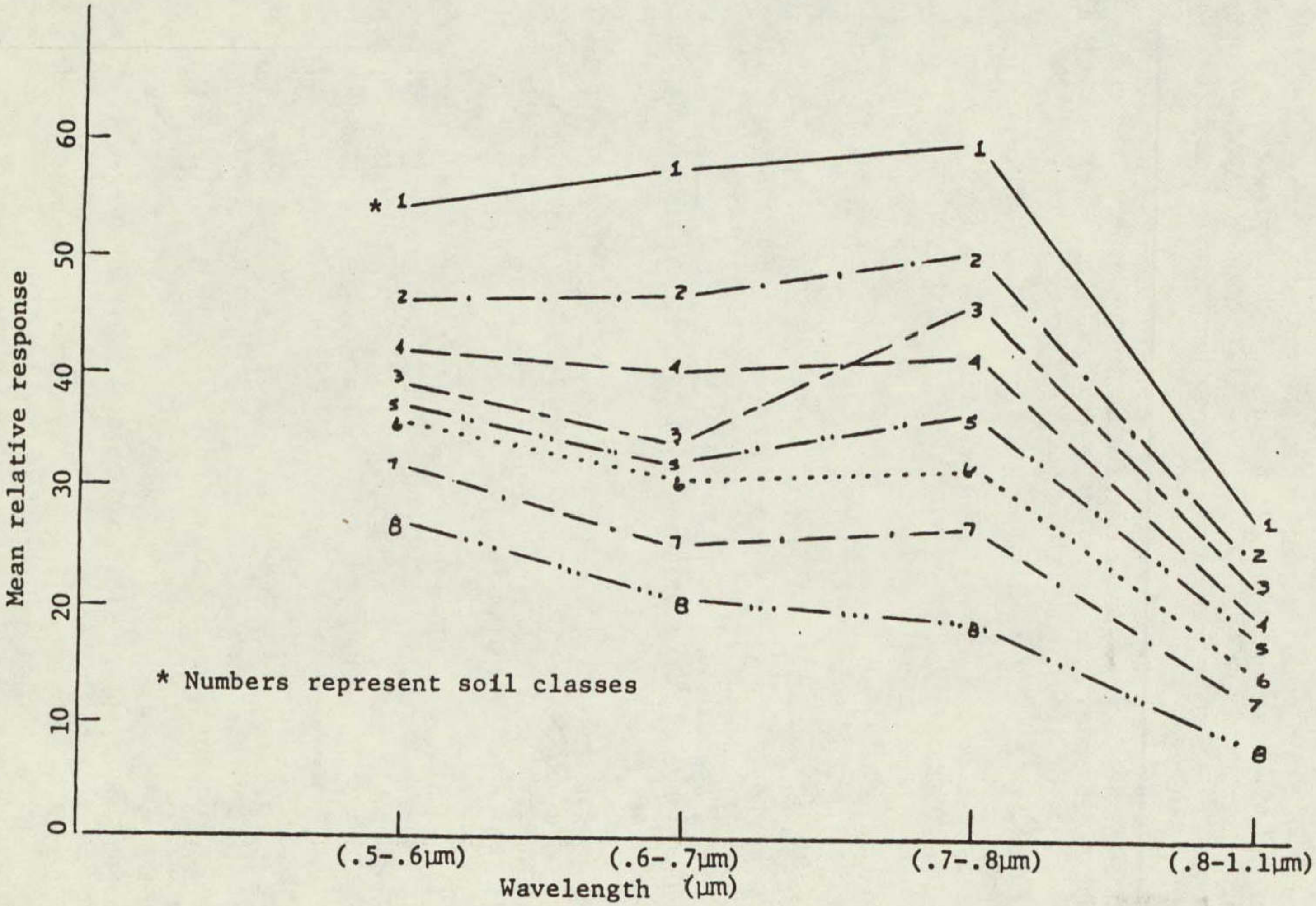


Figure 7. Soil spectral classes--outwash over till.

Vegetation - The vegetation spectral class is dominantly very poorly drained soils but represent significant inclusions of soils of other drainage classes.

Discussion. Interspersed knobs of till created a complex mottled effect that made detailed mapping difficult because of the introduction of small inclusions. Due to the relatively small spatial area of these inclusions, averaging of various soils responses seems evident within the parent material.

Spectral classes 1 and 2 have significant inclusions of excessively and moderately well drained soils but are dominated by somewhat poorly drained soils. No well drained soils were noted which may be due to averaging caused by small inclusions previously mentioned. Classes 1, 2 and 4 may be the result of these averaged reflectances.

Class 3 correlated primarily to vegetation. Classes 5, 6, 7 and 8 are predominantly very poorly drained soils, but Class 5 has a significant number of other soils represented within the class.

Rolling Ground Moraine

The acreage (35,840 acres) or 10% of the county was contained in the rolling ground moraine area of which 640 acres in four quarter sections were mapped. This represented 1.34% of the total area. The percentage of each spectral class is given in Table 6 and the graph of relative responses is shown in Figure 8. The following is a description of the spectral class correlations.

Class 1 - This spectral class represents predominantly well or excessively drained soils. Those soils sampled included Miami, Plainfield, and Martinsville. Significant inclusions of somewhat poorly drained soils (Whitaker) are also found.

Class 2 - This spectral class is dominantly well or excessively drained soils (Miami, Metea, Parr, Martinsville) but represent almost an equal percentage of somewhat poorly drained soils (Whitaker). Minor inclusions of the moderately well drained soils (Celina) and very poorly drained soils (Rensselaer) are found.

Class 3 - This spectral class represents the well drained soils (Miami, Martinsville, Parr). Some inclusions of somewhat poorly drained soils (Odell, Whitaker) are apparent. This class is a soil-vegetation confusion class.

Class 4 - The spectral class predominantly represents well drained soils (Miami, Parr, Sparta, Jasper). Significant inclusions of somewhat poorly (Aubbeenaubee, Odell, Darroch, Whitaker) and very poorly drained soils (Patton, Rensselaer) are found. Minor inclusions of moderately well drained soils (Celina, Crosby) are also present.

Class 5 - This spectral class represents the somewhat poorly drained soils (Odell, Whitaker). Significant inclusions of very poorly drained (Wolcott, Rensselaer) and well drained (Parr, Martinsville) are also represented. Minor inclusions of moderately well drained soils occur (Foresman). This class is a soil-vegetation confusion class.

Table 6. Dot grid count for rolling ground moraine.

Class	ED - WD		MWD		SPD		VPD		T
Soil 1	Mb:23 Mn: 2 Pn: 2				Wk:15				42
	D	%	D	%	D	%	D	%	
	27	64			15	46			
Soil 2	Mb:15 Mg: 4 Mn: 4 Pc: 1		Cc:3		Wk:23		Rr:2		52
	D	%	D	%	D	%	D	%	
	24	46	3	6	23	44	2	4	
Soil 3	Mb: 5 Mn: 3 Pc: 2				Od: 1 Wk: 1				12
	D	%	D	%	D	%	D	%	
	10	83			2	17			
Soil 4	Jc: 2 Mn: 4 Pc:15 Sp: 1		Cc:5 Co:1		Au: 2 Db: 1 Od: 2 Wk: 6		Pk:3 Rr:9		51
	D	%	D	%	D	%	D	%	
	22	43	6	12	11	22	12	23	
Soil 5	Mb: 2 Pc: 4		Fr:2		Od:11 Wk: 1		Rr:2 Wo:5		27
	D	%	D	%	D	%	D	%	
	6	22	2	8	12	44	7	26	

Table 6. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 6	Mb: 2 Mn: 1 Pc:20		Cc:4 Fr:3		Od: 8		Pk:21 Rr:13 Wo: 6		78
	D	%	D	%	D	%	D	%	
	23	29	7	10	8	10	40	51	
Soil 7	Ay: 3 Mb: 1 Pc:13		Cc:2 Fr:2		Od:16		Br:14 Pk:14 Rr:13		78
	D	%	D	%	D	%	D	%	
	17	22	4	4	16	21	41	53	
Soil 8	Pc: 1		Fr:2		Od: 6		Br:14 Pk: 1 Rr:10		34
	D	%	D	%	D	%	D	%	
	1	2	2	6	6	18	25	74	
Soil 9	Ay: 1		Fr:6		Db: 2 Od:16		Br:37 Ho: 2 Pk:32 Rr:17		111
	D	%	D	%	D	%	D	%	
	1	4	6	7	18	16	86	77	
Soil 10							Br:16 Pk: 2 Rr: 5		28
	D	%	D	%	D	%	D	%	
							28	100	

Table 6. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Veg	Mb: 2 Mg: 2 Mn:20				Od:9		Br:16 Pk: 2 Rr: 5		66
	D	%	D	%	D	%	D	%	
	34	52			9	13	23	35	
Total	165		30		120		264		579

Soil Key

Au - Aubbeenaubbee
Ay - Ayr
Br - Brookston
Cc - Celina
Co - Corwin
Db - Darroch
Fr - Foresman
Jc - Jasper
Mb - Martinsville
Mg - Metea
Mn - Miami
Od - Odell
Pc - Parr
Pk - Patton
Pn - Plainfield
Rr - Rensselaer
Wk - Whitaker
Wo - Wolcott

Table Key

ED - excessively drained
WD - well drained
MWD - moderately well drained
SPD - somewhat poorly drained
VPD - very poorly drained
T - Total
D - Dots

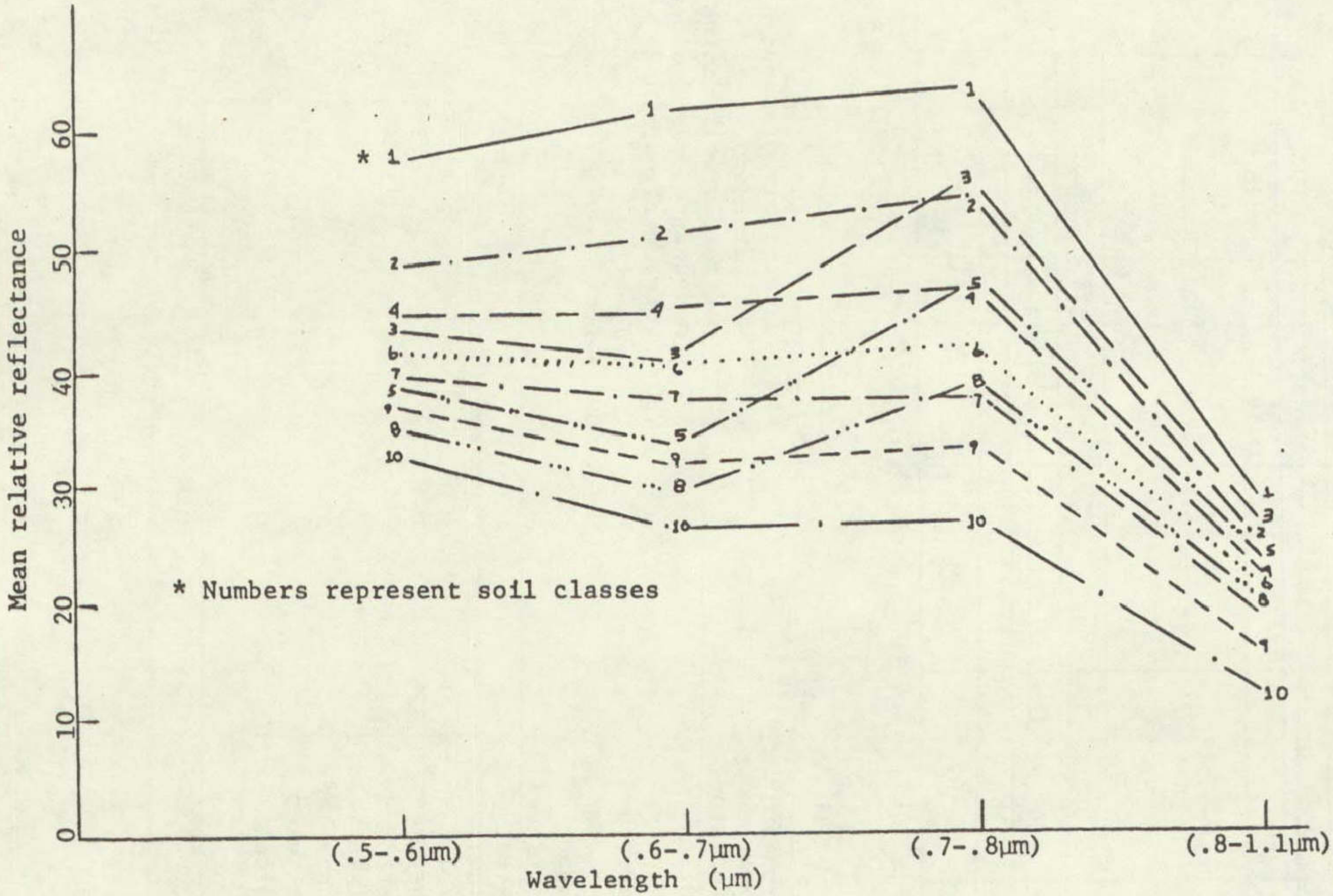


Figure 8. Soil spectral classes--rolling ground moraine.

Class 6 - This spectral class represents very poorly drained soils (Wolcott, Rensselaer, Patton). Significant inclusions of well drained soils (Parr, Martinsville, Miami) are present. Minor inclusions of moderately well drained soils (Celina, Foresman) and somewhat poorly drained soils (Odell) also occur.

Class 7 - This spectral soil class is predominantly very poorly drained soils (Brookston, Rensselaer, Patton) with a high percentage of well drained inclusions (Parr, Ayr, Martinsville). The somewhat poorly drained soils (Odell) also represent significant inclusions. The moderately well drained soils (Celina, Foresman) represent only minor inclusions.

Class 8 - This spectral class is predominantly very poorly drained soils (Brookston, Rensselaer, Patton). A significant portion of somewhat poorly drained soils (Odell) occur. Minor inclusions of well drained soils (Parr) and moderately well drained soils (Foresman) are represented. This is a soil-vegetation confusion class.

Class 9 - This spectral class is dominantly very poorly drained soils (Patton, Houghton, Rensselaer, Brookston). Some inclusions of somewhat poorly drained soils (Odell, Darroch) are significant. Minor inclusions of well drained (Ayr) and moderately well drained (Foresman) also occur.

Class 10 - This spectral class represents only very poorly drained soils (Patton, Houghton, Rensselaer, Brookston).

Vegetation - The vegetation class in this parent material area represents well drained soils (Miami, Metea, Parr, Martinsville). Significant inclusions of very poorly drained soils (Rensselaer, Patton, Brookston) occur. Minor inclusions of somewhat poorly drained soils (Odell) are also represented.

Discussion. Classes 1 through 4 represented predominantly well drained soils although inclusions of all other drainage classes were noted. The area was characterized by mottled patterns of soils with diverse transitions that could have contributed to the greater representation of inclusions.

Class 5 was predominantly somewhat poorly drained while Classes 6, 7, 8, 9, and 10 were representative of poorly drained soils. Again, significant inclusions of other drainage classes were found with these spectral classes.

Classes 3, 5 and 8 were soils with significant inclusions of vegetative responses. The vegetation class correlated well to a well drained soil which contrasts to the outwash area where correlation was made to a poorly drained soil.

Lacustrine

An acreage of 43,360 (17.7% of the county) was found in the lacustrine area of which 960 acres or 1.52% of the area was mapped and correlated to the following spectral classes:

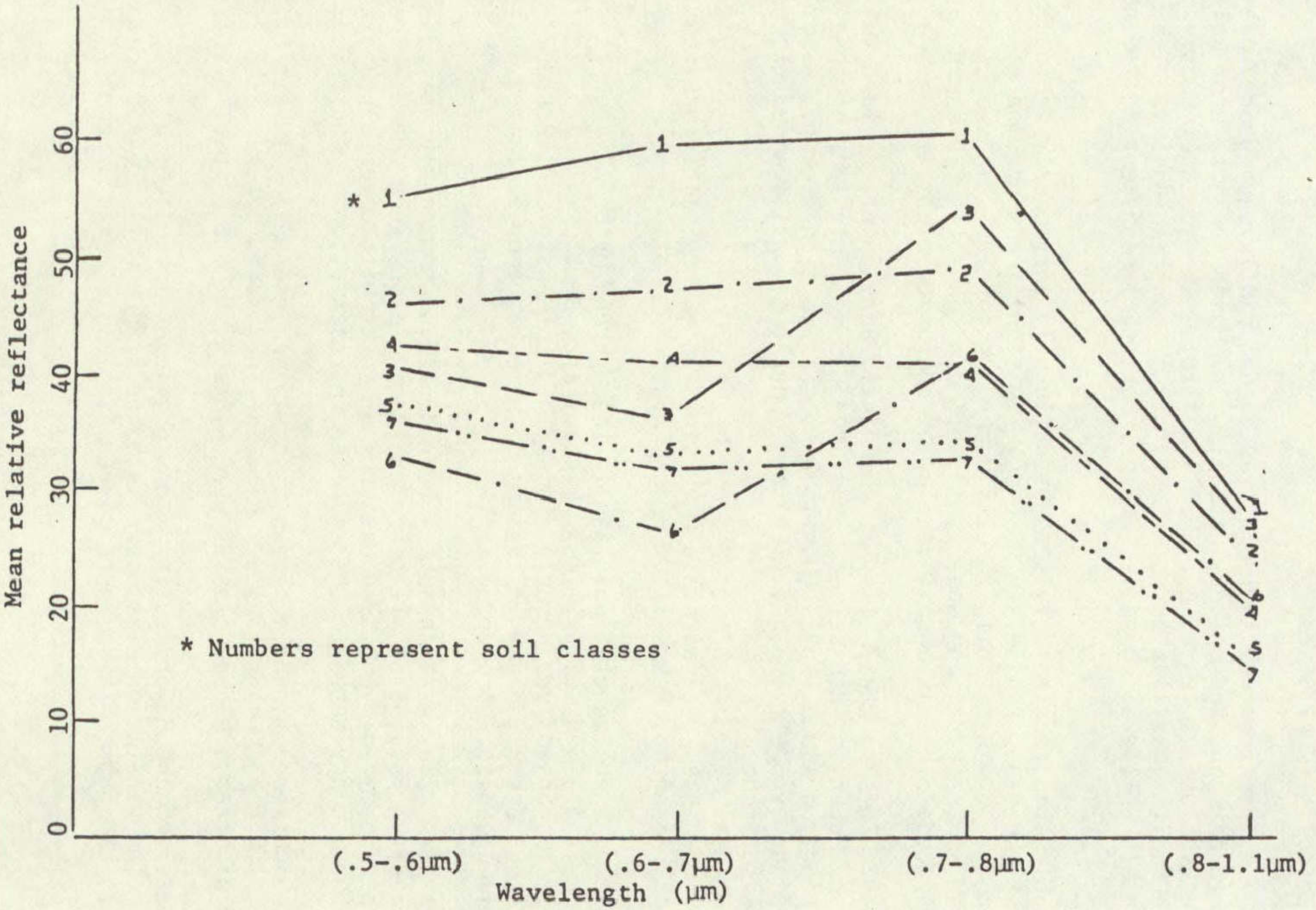


Figure 9. Soil spectral classes--lacustrine.

Table 7. Dot grid count for lacustrine area.

Class	ED - WD		MWD		SPD		VPD		T
Soil 1	Ch: 3 Dk: 3		Al: 3						8
	D	%	D	%	D	%	D	%	
	6	63	3	37					
Soil 2	Ch:15 Dk:32 Jc: 3 Pn: 3		Al:38		Db:18 Td: 1		Rr: 15		133
	D	%	D	%	D	%	D	%	
	61	46	38	29	19	14	15	11	
Soil 3	Ch: 1 Dk: 7 Jc: 2 Pn: 3		Al :12		Rt: 1		Rr: 4		30
	D	%	D	%	D	%	D	%	
	13	43	12	40	1	4	4	13	
Soil 4	Ch: 8 Dk:33 Jc: 7 Sp: 3		Al:29		Db:37 Rt: 5 Td: 1		Ma: 2 Rr:103		233
	D	%	D	%	D	%	D	%	
	51	22	29	13	43	18	110	47	
Soil 5	Ch:13 Jc: 3 Sp: 1		Al:23		Db:76 Od: 1 St: 1 Td: 1		Ma: 14 Rr:156		293
	D	%	D	%	D	%	D	%	
	17	6	23	8	79	27	174	59	

Table 7. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 6	Ch:2 Dk:3		Al: 6				Ma: 5 Rr: 4		20
	D	%	D	%	D	%	D	%	
	5	25	6	30			9	45	
Soil 7	Ch:5 Dk:6		Al: 4		Db:12 Rt: 3 St: 4		Ma: 39 Rr:156		228
	D	%	D	%	D	%	D	%	
	11	5	4	2	19	8	194	85	
Veg	Dk:6 Jc:2 Pn:9		Al:27		Db: 1 Rt: 1		Ma: 2 Rr: 15		63
	D	%	D	%	D	%	D	%	
	17	27	27	43	2	3	17	27	
Total	180		142		163		523		1008

Soil Key

Al - Alvin
Ch - Chelsea
Db - Darroch
Dk - Dickinson
Jc - Jasper
Ma - Mahalasville
Od - Odell
Pn - Plainfield
Rt - Roby
Sp - Sparta
St - Starks
Td - Tedrow
Rr - Rensselaer

Table Key

ED - excessively drained
WD - well drained
MWD - moderately well drained
SPD - somewhat poorly drained
VPD - very poorly drained
T - Total
D - Dots

Class 1 - This spectral class is dominated by well and excessively drained soils (Chelsea, Dickinson) with significant inclusions of the moderately well drained Alvin.

Class 2 - This spectral class is predominantly well and excessively drained soils (Jasper, Sparta, Plainfield, Chelsea, Dickinson) with significant inclusions of the moderately well drained (Alvin) soil. Minor inclusions of somewhat poorly drained soils (Darroch and Tedrow) are found as are very poorly drained soils (Rensselaer).

Class 3 - This spectral class predominantly represents well and excessively drained soils (Jasper, Plainfield, Dickinson, Chelsea). The moderately well drained soils (Alvin) represent an almost equal percentage. Minor inclusions of the somewhat poorly drained soils (Roby) and very poorly drained soils (Rensselaer) are also apparent. This class is a soil-vegetation confusion class.

Class 4 - This spectral class is predominantly very poorly drained soils (Rensselaer, Mahalasville). Inclusions of somewhat poorly drained soils (Darroch, Roby, Tedrow) and moderately well drained soils (Alvin) and well and excessively drained soils (Dickinson, Chelsea, Sparta, Jasper) also occur.

Class 5 - This spectral class is dominated by the very poorly drained soils (Rensselaer, Mahalasville). The somewhat poorly drained soils (Darroch, Starks, Tedrow, Odell) are significant inclusions. Minor inclusions of moderately well (Alvin) and well and excessively drained soils (Chelsea, Jasper, Sparta) also occur.

Class 6 - This spectral class has a wide spread of soils but predominantly represents the very poorly drained soils including Rensselaer and Mahalasville. The well and excessively drained (Dickinson, Chelsea) class is a soil-vegetation confusion class.

Class 7 - This spectral class is dominantly very poorly drained soils (Rensselaer, Mahalasville). The somewhat poorly drained soils (Darroch, Roby, Starks), moderately well drained soils (Alvin), and well and excessively drained soils (Chelsea, Dickinson) all make up minor inclusions.

Vegetation - The vegetation class is dominated by the moderately well drained soils (Alvin). The well and excessively drained soils (Plainfield, Jasper, Dickinson) and the very poorly drained soils (Rensselaer, Mahalasville) are equally represented. The somewhat poorly drained soils (Roby, Darroch) represent minor inclusions.

Figure 9 is a graph of the relative response of spectral classes while Table 7 indicates the percentage of composition of spectral classes to soils.

Discussion. Spectral classes 1, 2 and 3 are dominated by well to excessively drained soils with significant inclusions of somewhat poorly drained soils. Classes 4, 5, 6 and 7 are poorly drained soils with inclusions of other drainage classes. Class 4 has a broad range of represented classes and, therefore, could represent a transitional phase. The vegetation class, for this parent material, was dominated by somewhat poorly drained soils.

Ground Moraine, Alfisols

The Alfisol ground moraine area represents 14,080 acres (3.9% of the county) of which 2.27% or 320 acres were mapped and compared to spectral classes. Described below are the subsequent comparisons.

Class 1 - This spectral class represents predominantly well drained soils (Octagon). The moderately well drained soils (Corwin) represent significant inclusions. The somewhat poorly drained soils (Darroch) represent relatively minor inclusions.

Class 2 - This spectral class represents a wide range of soil drainage classes but has an equal percentage of moderately well drained (Corwin) and somewhat poorly drained (Darroch, Odell) soils. The well and excessively drained soils (Chelsea, Octagon) represent significant inclusions while the very poorly drained soils (Rensselaer) are only minor inclusions.

Class 3 - This spectral class is predominantly somewhat poorly drained soils (Odell). The moderately well drained soils (Corwin) represent significant inclusions. This class is a soil-vegetation confusion class.

Class 4 - This spectral class represents moderately well drained soils (Corwin, Montmorenci). The very poorly drained soils (Rensselaer, Brookston) are significant inclusions as are the somewhat poorly drained soils (Odell). The excessively drained soils (Chelsea) represent only minor inclusions.

Class 5 - This spectral class represents the very poorly drained (Brookston) and somewhat poorly drained soils (Odell) equally. Excessively drained soils (Chelsea) are significant inclusions. This class is a soil-vegetation confusion class.

Class 6 - This spectral class is predominantly the very poorly drained soils (Brookston, Rensselaer). The moderately well drained soils (Corwin) and somewhat poorly drained soils (Odell) are significant inclusions. The excessively drained soils (Chelsea) are only minor inclusions.

Class 7 - This spectral class is predominantly very poorly drained soils (Rensselaer, Brookston). The somewhat poorly drained soils (Darroch, Odell) represent significant inclusions. The moderately well drained (Corwin) and excessively drained (Chelsea) soils are minor inclusions.

Class 8 - This spectral class is predominantly very poorly drained soils (Brookston, Rensselaer). Excessively drained soils (Chelsea) and somewhat poorly drained soils (Odell) represent minor inclusions. This soil class is a soil-vegetation confusion class.

Class 9 - This spectral class is predominantly very poorly drained soils (Brookston, Rensselaer). Moderately well drained soils (Corwin) and somewhat poorly drained soils (Odell) both are minor inclusions.

Class 10 - This spectral class is predominantly very poorly drained soils (Brookston, Rensselaer). The somewhat poorly drained soils (Odell) represent relatively significant inclusions. Moderately well drained soils represent minor inclusions.

Class 11 - This spectral class is dominantly very poorly drained soils (Brookston). The somewhat poorly drained soils (Odell) represent significant inclusions. The moderately well drained soils represent minor inclusions.

Vegetation - The vegetation class, as found on the sample quarter sections, is entirely well drained soils (Chelsea).

Table 8 shows the dot grid count of soils while Figure 10 is a graph of the mean relative responses of specific spectral classes used in the area.

Discussion. The Alfisol area, although the smallest parent material, was represented with the largest number of spectral classes that proved to contain a wide range of soils within each class. There has been a wide range of cultural practices found in the area which may have contributed to the diversity. Relatively few points were used to classify the area which could also have contributed to the problem.

Class 1 seems to represent well drained soils while Classes 2 and 4 show a broad range, and Classes 3, 5 and 8 are combinations of soil and vegetation responses. Classes 6 and 7 show poorly drained characteristics while Classes 9, 10, and 11 are very poorly drained. The vegetation class was entirely well drained.

Ground Moraine, Mollisols

Table 9 indicates the relative percentage composition of the soil spectral classes for the ground moraine, Mollisol area. These soils include approximately 16,640 acres, representing 4.6% of the entire county. The curves of the spectral responses are shown in Figure 11.

In this parent material area four quarter sections (640 acres) were mapped, representing 3.85% of the ground moraine, Mollisol area. The composition of the eight spectrally separable classes and the combined vegetation class is described below. No separate class was developed for water; therefore, water bodies are classified as soil 8.

Class 1 - This spectral class represents predominantly somewhat poorly drained soils including Odell and Conover. There are also a high percentage of well drained (Parr) and moderately well drained (Corwin, Montmorenci) inclusions. A minor amount of inclusions of very poorly drained soil(Wolcott) are found.

Class 2 - This spectral class is also dominated by the somewhat poorly drained soils (Odell, Conover). The very poorly drained soils (Wolcott) represent significant inclusions, as do the moderately well drained soils (Montmorenci, Corwin). The well drained soils represent only minor inclusions.

Table 8. Dot grid count for ground moraine, Alfisols.

Class	ED – WD		MWD		SPD		VPD		T
Soil 1	Oc:10		Co: 6		Db:2				18
	D	%	D	%	D	%	D	%	
	10	56	6	33	2	11			
Soil 2	Ch: 1 Oc: 3		Co:5		Db:2 Od:3		Rr:1		15
	D	%	D	%	D	%	D	%	
	4	27	5	33	5	33	1	7	
Soil 3			Co:3		Od:9				12
	D	%	D	%	D	%	D	%	
			3	25	9	75			
Soil 4	Ch: 4		Co:15 Mo: 2		Od:7		Br:6 Rr:3		37
	D	%	D	%	D	%	D	%	
	4	11	17	46	7	19	9	24	
Soil 5	Ch: 2				Od:3		Br:3		8
	D	%	D	%	D	%	D	%	
	2	24			3	38	3	38	

Table 8. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 6	Ch:1		Co:13		Od: 9		Br:21 Rr: 4		48
	D	%	D	%	D	%	D	%	
	1	2	13	27	9	19	25	48	
Soil 7	Ch: 2		Co: 6		Db: 1 Od:10		Br:45 Rr: 2		66
	D	%	D	%	D	%	D	%	
	2	3	6	9	11	17	47	71	
Soil 8	Ch: 2				Od: 1		Br:18 Rr: 3		24
	D	%	D	%	D	%	D	%	
	2	8			1	4	21	88	
Soil 9			Co: 7		Od: 8		Br:50 Rr: 5		70
	D	%	D	%	D	%	D	%	
			7	10	8	11	55	79	
Soil 10			Co: 3		Od: 5		Br:30 Rr: 1		39
	D	%	D	%	D	%	D	%	
			3	8	5	13	31	79	

Table 8. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 11			Co:3		Od:7		Br:30		40
	D	%	D	%	D	%	D	%	
			3	7	7	18	30	75	
Veg	Ch:30								30
	D	%	D	%	D	%	D	%	
	30	100							
Total	55		63		67		222		407

Soil Key

Br - Brookston
Ch - Chelsea
Co - Corwin
Db - Darroch
Oc - Octagon
Od - Odell
Mo - Montmorenci
Rr - Rensselaer

Table Key

ED - excessively drained
WD - well drained
MWD - moderately well drained
SPD - somewhat poorly drained
VPD - very poorly drained
T - Total
D - Dots

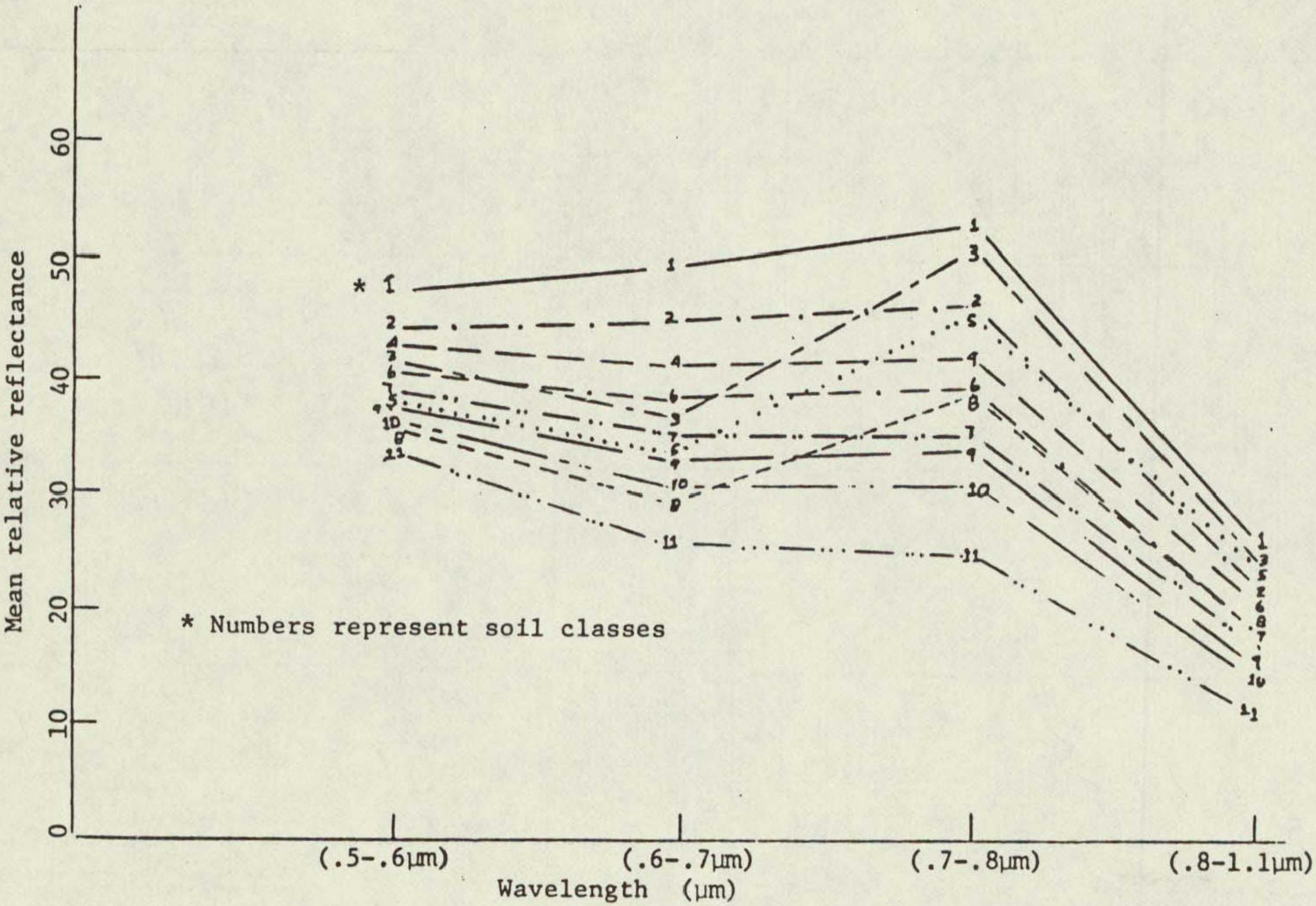


Figure 10. Soil spectral classes--ground moraine, Alfisols.

Table 9. Dot grid count for ground moraine, Mollisols.

Class	Ed - WD		MWD		SPD		VPD		T
Soil 1	Jc: 1 Pc:26		Co:12 Mo: 9		Cn:33 Od:37		Wo: 7		124
	D	%	D	%	D	%	D	%	
	26	21	21	17	70	56	7	6	
Soil 2	Pc: 2		Co:14 Mo: 4		Cn:48 Od:13		Wo:33		114
	D	%	D	%	D	%	D	%	
	2	1	18	16	61	54	33	29	
Soil 3	Pc: 5		Co: 3		Cn: 6 Od:11		Wo:10		35
	D	%	D	%	D	%	D	%	
	5	14	3	8	17	49	10	29	
Soil 4	Pc: 9		Co: 6 Mo: 4		Cn:28 Od:20		Wo:38		105
	D	%	D	%	D	%	D	%	
	9	8	10	10	48	46	38	36	
Soil 5	Pc: 7		Co: 1		Cn:13 Od:10		Wo:17		48
	D	%	D	%	D	%	D	%	
	7	15	1	2	23	48	17	35	

Table 9. (Continued).

Class	ED - WD		MWD		SPD		VPD		T
Soil 6	Pc: 4		Mo:4		Cn:28 Od:16		Wo:92		144
	D	%	D	%	D	%	D	%	
	4	3	4	3	44	30	92	64	
Soil 7					Cn: 4		Wo:51		55
	D	%	D	%	D	%	D	%	
					4	7	51	93	
Soil 8							Wo: 8		8
	D	%	D	%	D	%	D	%	
							8	100	
Veg	Pc:10		Co:3		Cn:12 Od:21		Wo:20		68
	D	%	D	%	D	%	D	%	
	10	15	5	7	33	49	20	29	
Total	63		62		300		276		701

Table 9. (Continued).

Soil Key	Table Key
Cn - Conover	ED - excessively drained
Co - Corwin	WD - well drained
Jc - Jasper	MWD - moderately well drained
Mo - Montmorenci	SPD - somewhat poorly drained
Od - Odell	VPD - very poory drained
Pc - Parr	T - Total
Wo - Wolcott	D - Dots

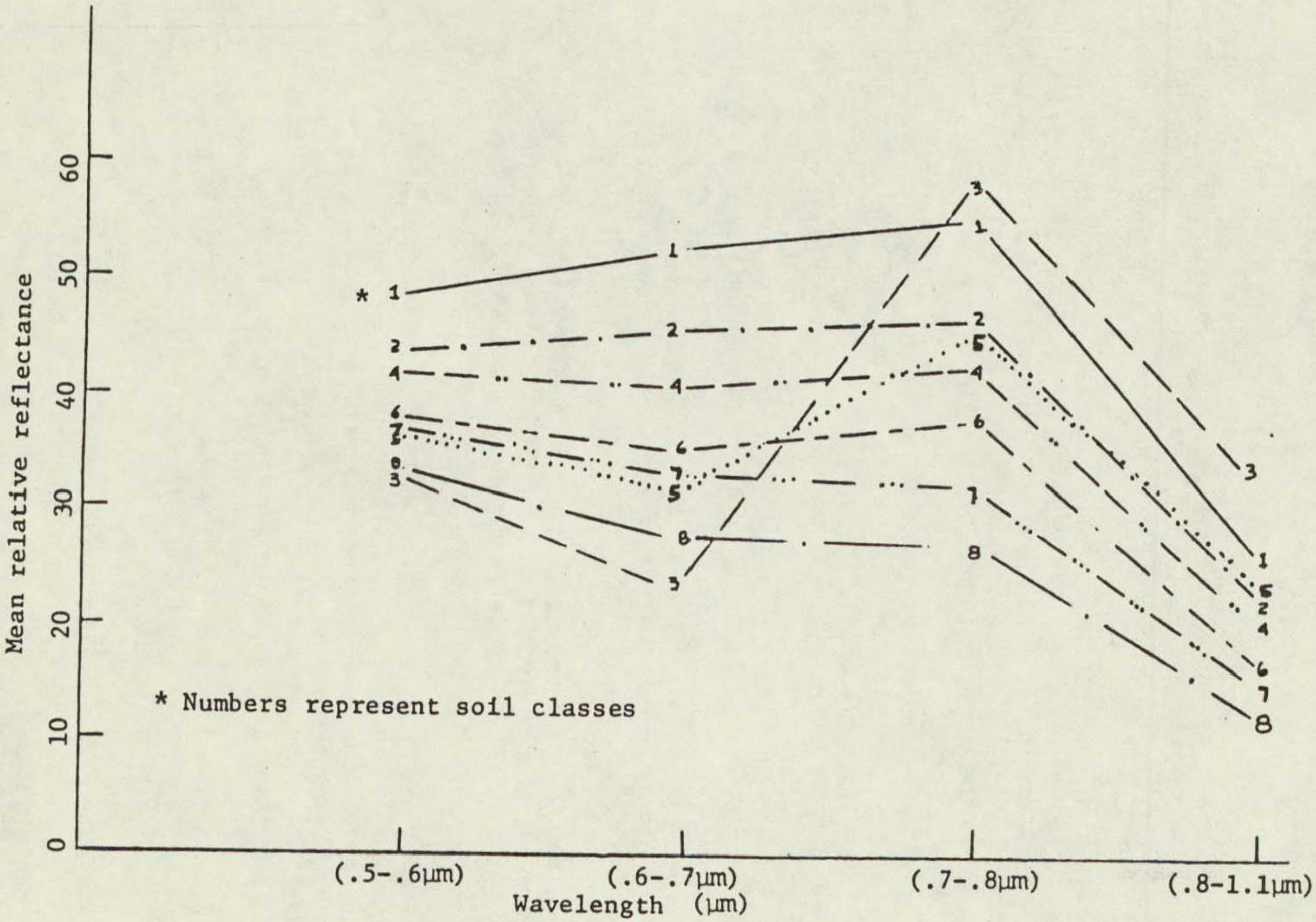


Figure 11. Soil spectral classes--ground moraine, Mollisols.

Class 3 - This spectral class is dominantly somewhat poorly drained soils (Odell, Conover). There are also significant inclusions of very poorly drained soils (Wolcott). Well drained (Parr) and moderately well drained soils (Conover) are also present. This class is a soil-vegetation confusion class.

Class 4 - This spectral class is predominantly somewhat poorly drained soils (Odell, Conover). There are significant inclusions of very poorly drained soils (Wolcott). Relatively minor inclusions of well drained (Parr) and moderately well drained (Corwin) soils also occur.

Class 5 - This spectral class is dominantly somewhat poorly drained soils (Odell, Conover). Very poorly drained soils (Wolcott) represent significant inclusions. Minor inclusions of well drained (Parr) and moderately well drained (Corwin) soils are present. This class is a soil-vegetation confusion class.

Class 6 - This spectral class is dominated by very poorly drained soil (Wolcott). Significant inclusions of somewhat poorly drained soils are also present (Odell, Conover). Minor inclusions of well drained (Parr) and moderately well drained soils occur.

Class 7 - This spectral class is predominantly very poorly drained soils (Wolcott). Minor inclusions of somewhat poorly drained soils (Conover) are also present.

Class 8 - This spectral class represents very poorly drained soils entirely.

Vegetation - This spectral class represents a broad range of soils. Somewhat poorly drained soils (Odell, Conover) predominate but well drained soils (Parr) and very poorly drained soils (Wolcott) are significant inclusions.

Discussion. Soil spectral classes in this parent material area show a wide range of percentages of all drainage classes of soils. This trend is consistent with the wide range of drainage classes found in the other till parent material areas.

Of all spectral classes found in this parent material area none dominantly represent well drained or moderately well drained soils. Classes 1, 2, 3, 4 and 5 are dominated by the somewhat poorly drained soils with varying amounts of inclusions in the other drainage classes. In all cases these inclusions are significant.

Classes 3 and 5 are soil-vegetation confusion classes. The spectral curves of these two soils are presented in Figure 11. Class 6 is increasingly poorly drained with significant inclusions of somewhat poorly drained soils. Classes 7 and 8 are dominantly very poorly drained soils with only minor inclusions of other soil drainage classes. The vegetation class was predominantly somewhat poorly drained soils, but there were significant inclusions of soils of other drainage classes. This vegetation class indicates no trend when compared to the vegetation classes in the other parent material areas.

Surface Condition Affecting Spectral Response

In many instances there were distinct spectral classes that were found to represent the same soil. For example, it is evident in the outwash area (Table 4) that soil spectral classes 8 and 9 represent basically the same group of soils: Gilford, Mussey, Maumee, Adrian, Sebewa and Rensselaer. Combinations of these two classes were proposed earlier for display on the final spectral map. Likewise, combinations of distinct spectral classes for other soils in other parent material areas were recommended because of similar compositions. The question, then, is if these spectral classes represent the same soils, why are they spectrally distinct.

Unfortunately, since the Landsat data were collected in June 1973, the photography in May 1976, and the field observations and mapping performed in the spring of 1978, the reasons behind the differing spectral responses can only be speculated upon. This was done by noting conditions in the field that, in the opinion of the author, could possibly affect the spectral response of soil.

Soil-vegetation complexes seem to pose the most widespread problem in the interpretation of remotely sensed data for soil survey. If these classes are known, however, they can be used in an interpretative manner with the surrounding soil classes.

Surface moisture conditions were, in at least one instance, noticed to change the soil spectral response. In one area a poorly drained Gilford series was spectrally represented as a very poorly drained soil. It was noted, however, that the surface of the soil was extremely wet. Upon further investigation, it was found that this field did not have a tile drainage system, hence retained the moisture longer than an adequately drained Gilford soil.

Presence of an exposed subsurface horizon has also been noted to affect spectral response. In one instance the spoils from a ditch, a much lighter colored subsurface horizon, were exposed on top of a more poorly drained soil. The result is that the spectral data indicate a more well drained soil. While this is a confusion factor in instances such as this, the delineation of an exposed subsurface horizon has been found by others to be a potentially powerful tool in mapping severe soil erosion.

Clean washed sand occurring on the surface has also been found to affect spectral response, particularly in the outwash area. In one area a somewhat poorly drained Tedrow soil appeared as a very bright soil. This contradicts the trend of poorer drainage with decreasing magnitude of spectral reflectance. Field checking revealed large amounts of clean, washed medium sands in the lower spots of the furrows. After cultivation the sand is separated from the finer particles by the action of falling rain. The cleaned sand particles are bright, hence reflect brightly.

A similar effect was noted because of crusting of the soil. In one instance noted, the soil was fall plowed and had formed a crust over the winter. During the spring preparation of the soil the farmer disked a portion of the soil, therefore, breaking the crust. The result was a darker surface color and a lower spectral reflectance for the area disked.

SUMMARY AND CONCLUSIONS

In this study soils found within Jasper County, Indiana were correlated to a spectral soils map produced by computer-aided analysis of Landsat MSS data. The spectral map, completed in a previous study, contained fifty-two spectral soil classes in six parent material areas. From the resulting correlation, a descriptive legend was developed for each soil spectral class.

To achieve the correlation, twenty-eight 160-acre sites were randomly chosen throughout the county. The soils at these sites were inventoried by combining conventional soil mapping techniques and area sampling. The field mapped areas were located on the spectral map and by overlaying the spectral map, the conventional soil map, and a dot grid, a count of the relative amount of soils for each spectral class was made. Percentages were calculated and a descriptive legend for each soil spectral class was developed. These descriptive legends identify the dominant soils represented by the spectral class, as well as soils that are significant inclusions.

In addition to developing a legend for each soil spectral class, various factors involved in the analysis and interpretation of remotely sensed data for soil survey were identified. These factors included: soil-vegetation complexes, crusting of the surface soil, subhorizon exposure, soil surface moisture, organic matter content, texture, and free sand on the surface. Of these, the soil-vegetation complexes presented the most widespread problem in interpreting the spectral data. The other factors all altered the spectral response of the soil to some degree, but their influence appeared rather localized.

Specifically, the findings and conclusions of this research are:

1. Of the sampling techniques considered a combination soil mapping and area sampling offered the most practical method for gathering soils data.

2. Using the dot grid count a relative percentage composition of soils can be calculated for each spectral class. From these percentages, a legend describing the dominant soil(s) and inclusions can be developed.

3. The internal drainage class seems to be correlated with magnitude. For every parent material area, the more poorly drained soils had a lower magnitude of reflectance. Likewise, the better the drainage, the greater the magnitude of reflectance.

4. Soil spectral classes seem to be predominantly one internal drainage class.

5. While soil series were not consistently spectrally separable in this study, it is felt that if the soil surveyor knows the internal drainage (from the spectral map) and parent material for a particular area, a prediction of a soil series (or group of soil series) can be made for that area.

6. Soil-vegetation complexes can occur in the calculation of spectral statistics. Preliminary investigation of these soil-vegetation combination classes indicate that they are affected by vegetation to varying degrees. It is recommended that combination classes of soil and vegetation be maintained because of potential loss of useful soil information if deleted.

7. Distinct soil spectral classes can be very similar in soil series composition. These distinct spectral classes are likely to be attributable to overriding surface conditions such as crusting, subsurface horizon exposure, sand on the surface, or an extremely wet surface.

In summary, the major soil characteristics affecting spectral reflectance, hence the mapping of soils using Landsat data, are:

a. Soil series and related internal drainage;

b. Presence of vegetation that does not mask but strongly influences soil spectral reflectance;

c. Surface moisture conditions at the time of data collection;

d. Crusting conditions at the time of spectral data collection;

e. Free washed sand on the surface;

f. Surface texture;

g. Organic matter content; and

h. Subsurface horizon exposure, including erosion.

SUGGESTED RESEARCH

Results of this research indicate that Landsat data can be utilized in soil survey. Some improvements that may increase the use and reliability of the Landsat data are:

1. Develop a sampling scheme of soils that is more amenable to a quantitative analysis. This would include:

    a. Determining the minimum area and/or sample size to adequately sample any area;

    b. Determining the method of sampling, i.e., simple random sampling or stratified random sampling;

    c. Determining, if stratified random sampling is used, what the units should be, i.e., parent material, topography.

2. If possible, coordinate the time of all data collection within, at least, one season. For example, collect the Landsat data, aerial photography, and ground soil mapping within the spring of one year.

3. Determine the need for incorporating ancillary data such as parent material areas, into a spectral soils map. If the need is present, at what point does the cost of incorporation become prohibitive? Is there a limit on geographical size for incorporation of ancillary data? Is incorporation of more than one type of ancillary data necessary and/or practical?

4. Improve the techniques of registration of the Landsat data to ground control points as well as improving the ability for locating points on the ground in relation to the Landsat data.

5. Although no consistent correlation was present in this study between vegetation and soils, it is assumed that mapping native vegetation as soil indicator species is possible in other areas of the country and the world. A study performed in an appropriate area could do much to determine the validity of this assumption.

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INDIANA WETLANDS INVENTORY

INTRODUCTION

During April 1978, LARS staff met with personnel from the Indiana Department of Natural Resources (IDNR) to discuss the Department's interests in utilizing remote sensing technologies to map Indiana's wetlands. The result of this meeting was the development of a joint feasibility study between LARS and the IDNR, Division of Fish and Wildlife to assess the merits of computer-aided Landsat classification technology for wetland inventory and management.

This report describes the progress made on that study to date. In the past six months, staffs of both organizations have worked closely together on the preliminary stages of this feasibility study. Considerable time has been spent in the field to understand the dynamics of freshwater ecosystems. Color infrared photography has been collected for use as ground truth in conjunction with the Landsat computer-aided analysis studies. This photography has already been used to generate a wetlands habitat map for the Division. In addition, field spectral measurements of specific wetland types were collected and analyzed to determine if these types are spectrally distinct.

SELECTION OF A STUDY AREA

Over the past one hundred years, more than one million acres of Indiana wetlands have been drained for use as cropland. Most of the remaining wetlands consist of small areas dispersed throughout the northern third of the state. The area selected for study is representative of the various vegetational and hydrologic conditions found in Indiana. LARS and IDNR personnel selected the Pigeon River State Fish and Wildlife Area for this project.

The Pigeon River State Fish and Wildlife Area is located in northern LaGrange and Steuben Counties (see Figure 1). The Wildlife Area and surrounding lands are dotted with numerous small wetlands and lakes formed during the Wisconsin glaciation. Much of the land owned by IDNR had been drained for agriculture. Upon acquisition the state decided to allow these lands to revert to their natural conditions. Hence, the wildlife area consists of lands in varying degrees of wetness and different vegetational composition. Ecologically, this area provides an excellent opportunity for studying vegetational succession.

The six major wetland types in Indiana are all present in the Pigeon River test site. These wetland types are described in Table 1. Although none of these are unique to the study area, some of the Pigeon River wetlands are noteworthy.

The largest tamarack bog in Indiana lies in the central portion of the wildlife area east of Mongo Reservoir. This marks the southern extent of tamarack (Larix laricina) in the United States. Rare herbaceous plants and wildflowers such as the showy lady's slipper (Cypripedium reginae) are often found within the bog.

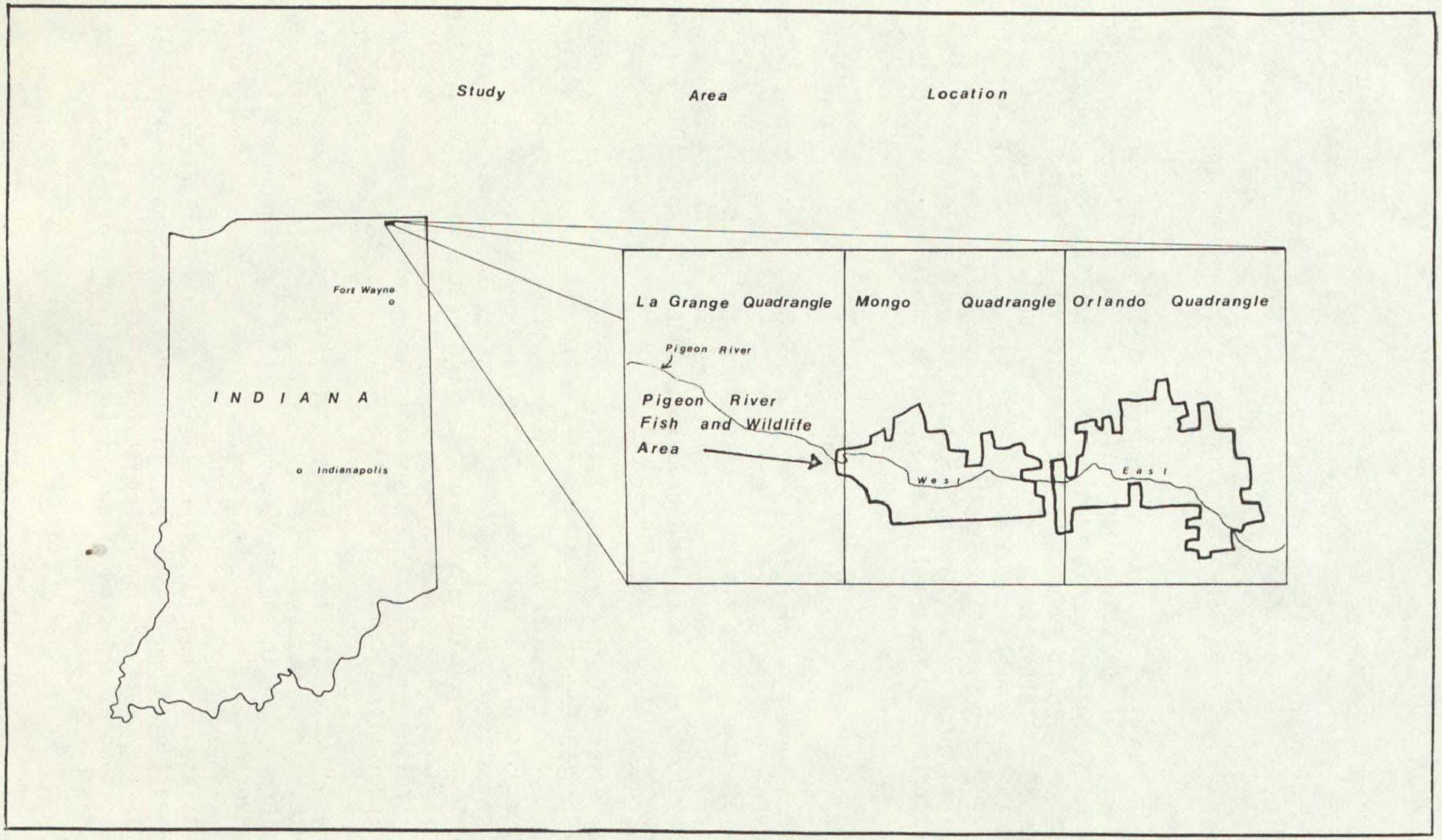

Figure 1. Location of the Pigeon River Wetlands Study Site.

Table 1. Description of Pigeon River Study Area wetland types.

Type			Description
3	-	Shallow Marsh	- Soil waterlogged for much of growing season. - Inundated in spring with as much as 6" water. - Vegetation consists of rooted herbaceous hydrophytes (grasses, sedges, smartweed).
4	-	Deep Marsh	- Soil covered with 1½-3' water (permanently flooded) - Vegetation consists of submergent plants, floating-leaved plants, herbaceous species (spatterdock, white water lily, cattail, bulrushes)
5	-	Open Water	- Water of variable depth - Vegetation consists of submergent species only (vascular plants)
6	-	Shrub Swamp	- Dominated by woody vegetation less than 6 m in height - 6^3 - soil waterlogged, dogwood, willow, button brush - 6^4 - soil covered with 1½-3' of water, blueberry, winterberry, choke berry.
7	-	Wooded Swamp	- Seasonally inundated with water (flood plains) - Dominant vegetation 6 m in height and greater (aspen, swamp white oak, silver maple
8	-	Bog	- Saturated with water floating (?) - Vegetation consists of needle leaf deciduous (Tamarack)

Additional wetlands are being created by natural and man-related activities. Beaver dams along tributary streams have resulted in the inundation of bottomland hardwoods. As flood intolerant trees die, tolerant shrubs have invaded the sites and tolerant hardwoods such as the swamp white oak (Quercus bicolor) and silver maple (Acer saccharum) have become dominant. The creation of these shrub/hardwood swamps are particularly important for wood duck breeding and nesting cover.

As the drainage tile in agricultural fields along the river floodplain collapse, wet meadows and eventually shallow marshes are formed. IDNR personnel have planted some of these marshes with reed canary grass. Other fields display natural succession with the invasion of sedges and aquatic grasses. Very wet sites may be bull-dozed to create nesting mounds for Canada Geese and other waterfowl.

During the nineteenth century, three small hydro-electric dams were constructed along the Pigeon River creating the Ontario and Nasby Mill Ponds and Mongo Reservoir. An extensive deep marsh has formed through much of the reservoir since the time of the dam construction. The Nasby Dam collapsed in 1976. The sudden draw down of water has resulted in the creation of a large shallow swamp.

The Pigeon River Study Area is a dynamic community. The site is appropriate for this investigation because the area contains all wetland types found in Indiana. In addition, these wetland types are at various stages of plant succession and wetness. For these reasons the LARS and IDNR staff have selected the Pigeon River Fish and Wildlife Area as the study site to investigate the use of computer-aided analysis of Landsat data to identify and evaluate wetlands in Indiana.

FIELD INVESTIGATIONS

Considerable time has been spent at the Pigeon River Fish and Wildlife Area to become acquainted with the site and to study the freshwater ecosystem. In May 1978, several members of the LARS and IDNR staffs flew to Pigeon River to meet with the state wetlands biologist. At that time several members flew over the test site in a light aircraft to familiarize themselves with the general surroundings. Subsequent field trips have involved detailed ground surveys of wetlands and the major waterway. These surveys have been useful when selecting sample points for the field spectral measurements, and training areas for the Landsat computer classification.

More recent field work has centered around the photo-interpretation portion of this project. A key for identifying wetlands in Indiana was developed by comparing the aerial photos with known points on the ground. Several days were spent at Pigeon River field checking the completed wetland cover type map. These procedures will be discussed in detail in subsequent sections.

DATA COLLECTION

Several forms of data are necessary for the completion of this project. These include color infrared (CIR) aerial photos, field spectral measurements of wetland types and Landsat multispectral scanner data tapes.

Aerial photography of the wildlife area and surrounding lands was collected by IDNR, Division of Water on June 27, 1978. CIR photos were taken using a Ziess RMK-5 nine inch format mapping camera with a six inch lens. Photo scale is approximately 1:24,000 - commensurate with USGS 7½ minute topographic quadrangles. This scale was selected to insure that the desired minimum mapping unit of one acre for the type map could be achieved. The photography was collected with 60% forward overlap in order to provide stereo coverage. The aerial photos were used to generate a wetlands covertype map of the Pigeon River Wildlife Area. In addition, they shall be used as ground truth information for the Landsat computer classification.

Numerous field reflectance measurements were taken over wetlands in the Pigeon River study area to acquire some knowledge of wetland spectral characteristics before commencing with the computer-aided analysis. The six previously mentioned wetland types and several mixed classes were sampled (see Table 2).

Spectral reflectance was measured using the EXOTECH-100 Landsat ground truth radiometer. The Model 100 has a 15° field of view precision scope co-aligned with four spectral channels. Measurements of electromagnetic radiation are made in the same wavelength bands as the Landsat multispectral scanner. The Model 100 and a 35 mm camera were mounted on a Bell Ranger helicopter. A Fluke Data Logger was attached to the radiometer which was carried inside the helicopter and used to record the spectral measurements. The helicopter was flown five hundred feet above ground level so that measurements were taken on a ground cell approximately .3 acres in size.

A stratified random sampling procedure was used to locate the measurement plots. A previous field trip was made to survey the Fish and Wildlife Area to locate large homogeneous wetland types and mixed areas. On June 19, 1978, random spectral measurements were taken over these large sampling areas using the EXOTECH-100 mounted on the helicopter.

Landsat multispectral scanner data will be used to classify wetlands in the Pigeon River study area using computer-aided analysis techniques. At present, LARS is awaiting the arrival of a computer compatible tape of a June 9, 1978 Landsat overpass. When the data tape is received, LARS will reformat the data and begin analysis.

INTERPRETATION OF CIR PHOTOS

The consistent identification of ground cover types on CIR aerial photos is dependent upon the availability of a reliable key used for identification. The Key for Identification of Indiana Wetlands from CIR Aerial Photos (Table 3) was developed during this portion of the project. Several frames with representative samples of wetland cover types were printed and taken into the field during one ground survey. Selected points on the photos were compared to the ground cover. Each photo point was described by texture, tone, color and ecological setting. These descriptions were then compiled to describe the various wetlands types listed in the key.

Table 2. List of wetland and mixed classes sampled in field spectral measurements.

Symbol	Class
T-3	Shallow Marsh
T-4	Deep Marsh
T-5	Open Water
T-6	Shrub Swamp
T-7	Hardwood Swamp
T-8	Tamarack Bog
M-1	Water/Vegetation Mix, site contains less than 30 percent vegetation.
M-2	Water/Vegetation Mix, site contains more than 30 percent but less than 60 percent vegetation.
M-3	Water/Vegetation Mix, site contains more than 60 percent but less than 90 percent vegetation.
M-4	Tamarack and Hardwood Mix of equal proportions.

Table 3. Key for Identification of Indiana Wetlands from CIR Aerial Photos

Cover	Color*	Remarks on Color	Texture	Stereoscopic Viewing	Environmental Setting
Type 3 wetlands	A) Reddish-pink B) 12. slightly red C) 5 R 5/10	Mottling occurs because of varying degrees of wetness.	smooth	Little or no relief.	Grassy meadows within flood plains or around lakes, sometimes occurs in depressional areas.
Type 4 wetlands (predominantly spatterdock and grasses)	A) Pink to reddish-pink B) Varies from 3. deep pink to 12. slightly red C) 2.5 R 6/10, 2.5 R 5/10		fluffed (similar to mounds of shaving cream)	Vegetation floating on water appears raised slightly above surface.	Occurs within lake boundaries. Floating vegetation perdominates.
Type 4 wetlands (predominantly cattails)	A) Reddish brown B) 43. medium reddish brown C) 7.5 R 4/10	Color may be mottled red or brown depending on density and degree of wetness.	granular	Vegetation raised slightly above water surface (when in association with open water).	May occur in meadows when in transition between Types 3 and 4, or within lake boundaries.
Type 5 wetlands (open water)	A) Black B) 267. black or 175. very dark greenish-blue C) 7.5 R 4/10	Color varies according to suspended sediments (causing lighter shades) and bottom materials.	glass-like	Little or no relief.	Lakes, rivers and seasonally flooded depressions.
Type 5 wetlands (duck weed)	A) White to pale pink B) 263. white to 4. light pink C) 5 R 9/1, 5 R 8/4		silk-like	Little or no relief.	Duckweed may cover large extents of open water.
Type 6 wetlands	A) Red to dark red B) 13. deep red to 41. deep reddish brown C) 5 R 4/12, 7.5 R 3/4		cotton-like	Shrubs have small rounded crowns. Lower in height than hardwoods. Individual crowns may not be visible because of high density.	Type 6 wetlands are found along rivers, lake shores and in depressional areas.
Type 7 wetlands	A) Red B) 11. very red C) 7.5 R 4/12		billowed	Tall vegetation. Large rounded crowns. Often individual crowns are distinguishable.	Occurs along rivers and seasonally flooded depressional areas such as beaver activity sites.
Type 8	A) Reddish brown B) 44. dark red brown C) 7.5 R 3/6		granular	Narrow pointed crowns.	Usually occurs along lake shores, sometimes near rivers.

* A) Interpreter's definition
B) Inter-Society Color Council, National Bureau of Standards color nomenclature
C) Munsell Color Chart

PIGEON RIVER FISH AND WILDLIFE AREA -- WEST

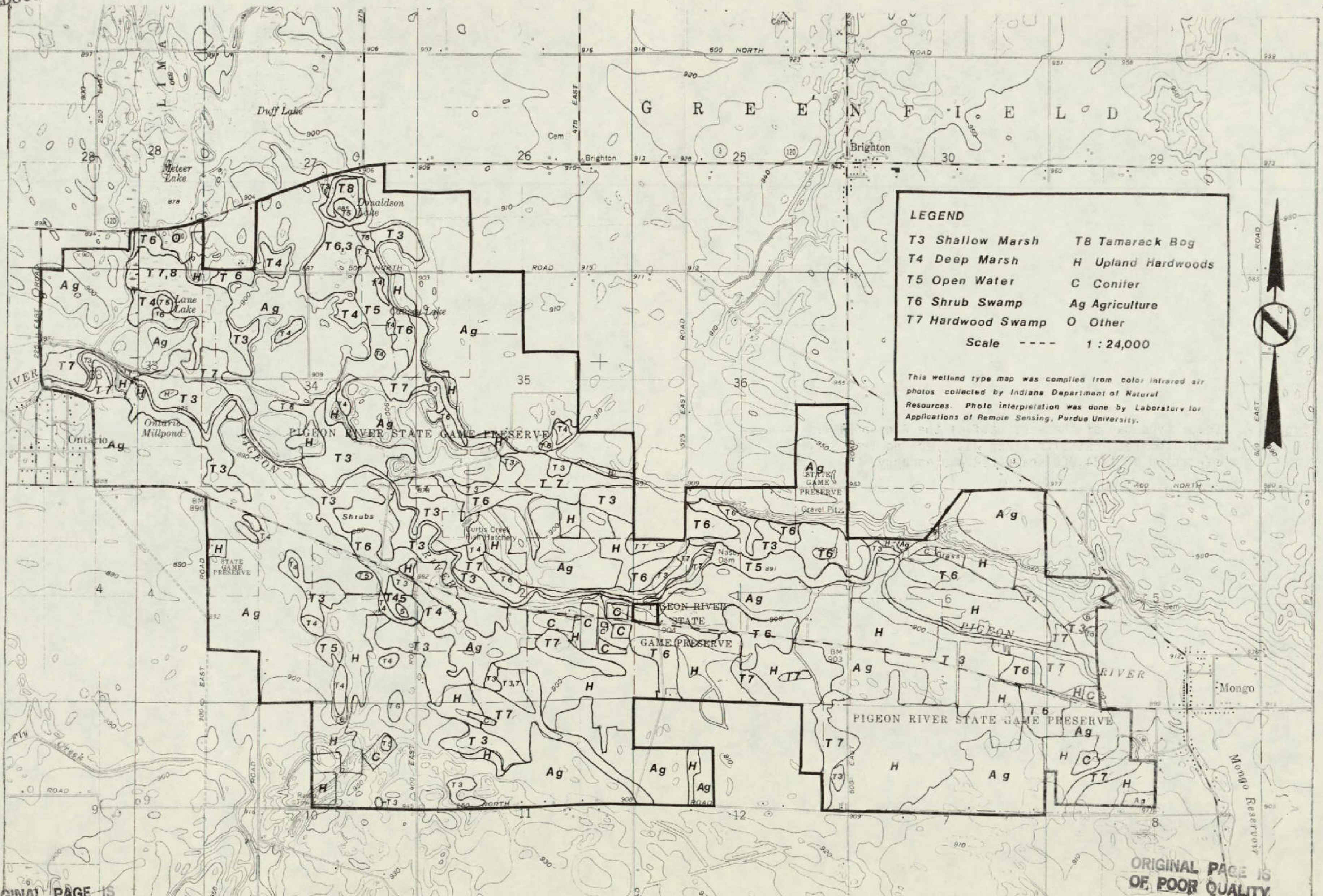

Figure 2. Cover type map of the West half of the Pigeon River Wildlife Area Test Site. Map was prepared from interpretation of 1:24,000 scale CIR photography.

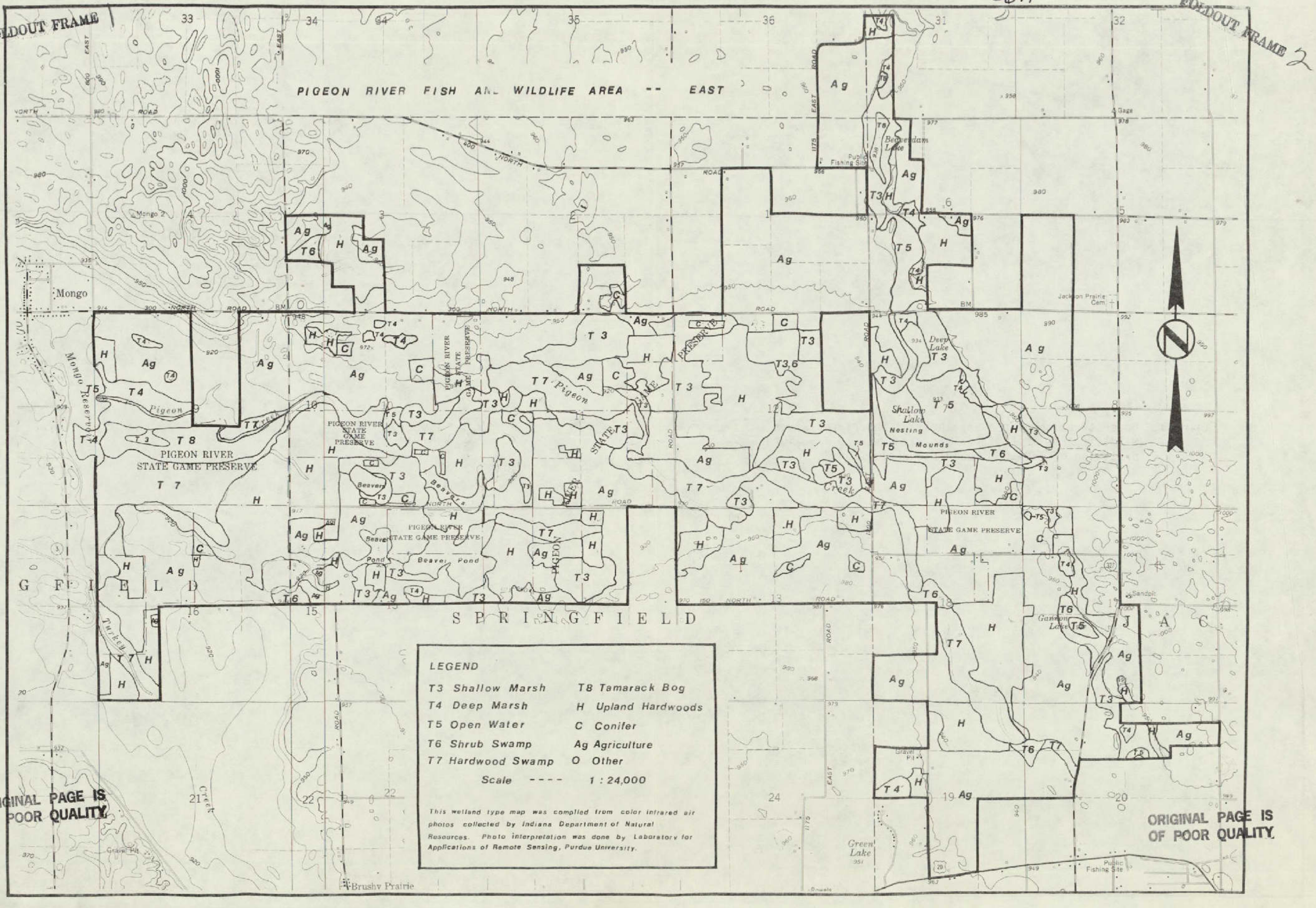
PIGEON RIVER FISH AND WILDLIFE AREA -- EAST
LEGEND
T3 Shallow Marsh
T4 Deep Marsh
T5 Open Water
T6 Shrub Swamp
T7 Hardwood Swamp
T8 Tamarack Bog
H Upland Hardwoods
C Conifer
Ag Agriculture
O Other
Scale ---- 1 : 24,000
This wetland type map was compiled from color infrared air photos collected by Indiana Department of Natural Resources. Photo interpretation was done by Laboratory for Applications of Remote Sensing, Purdue University.
PIGEON RIVER STATE GAME PRESERVE
SPRINGFIELD
Mongo
Beaverdam Lake
Deep Lake
Shallow Lake
Nesting Mounds
Gannon Lake
Green Lake
Pigeon Creek
Turkey Creek
Beaver Pond
Public Fishing Site
Jackson Prairie Cem
Brushy Prairie
Gravel Pit
Sandpit

Figure 3. Cover type map of the East half of the Pigeon River Wildlife Area Test Site. Map was prepared from interpretation of 1:24,000 scale CIR photography.

Upon completion of the key, a wetlands type map was generated from the CIR photos. Areas not positively identified as to cover type were recorded for later field identification. Interpretation was carried out using a mirror stereoscope with 3x magnification. Each cover type was outlined on acetate overlaying the photo with a 2 x 0 rapidograph pen. The photo transparency and overlay were then mounted on a Bausch and Loome Zoom Transferscope and the cover type boundaries were transferred onto the respective USGS 7½ minute topographic quadrangles.

The initial wetland maps were then taken into the field for verification. Questionable sites were immediately identified on the ground. Following this, four equally spaced transects were made across the cover type maps. Points along the map and on the ground were compared to qualitatively assess the accuracy of interpretation.

After the field verification was completed, draft copies of the wetlands cover type map were prepared for IDNR, Division of Fish and Wildlife. LARS is now awaiting comments and suggestions from IDNR personnel. Reduced copies of the cover type maps are shown in Figures 2 and 3.

The acreage of wetland habitat in the Pigeon River Fish and Wildlife Area was estimated from the cover type maps. A dot grid was used to calculate acreages. The wildlife area contains 3381 acres of wetlands. This can be broken down into the various habitat types listed in Table 4.

FIELD SPECTRAL MEASUREMENTS

Field spectral measurements of the wetland classes listed in Table 2 show that wetland spectral characteristics are typical of vegetation and water responses. The mean spectral reflectance of each class sampled at Pigeon River is plotted against individual wavelength bands in Figure 4. Classes containing vegetation exhibit a decrease in the percent reflectance within Band 2 (.6-.7 μm). This is consistent with research findings that leaf chlorophyll absorbs red light. These same classes show a sharp increase in infrared reflectance typical of plants.

A discriminant analysis was used to determine if the wetland classes are differentiable by their spectral responses. The analysis distinguishes between the different wetland classes by forming several linear combinations of the percent reflectance in different spectral bands. These equations are called discriminant functions. Each class is identified by a set of function values unique to that class. The discriminant functions used to describe the wetland data are given in Table 5.

Eigenvalues reflect the ability of each function to separate the wetland classes. In this analysis, discriminant function 1 and 2 account for nearly ninety-eight percent of the variability within the discriminating variables. The differentiation of the classes is primarily achieved using these functions.

The contributions of the spectral reflectance in each wavelength band to the function is indicated by the function coefficients. For example, discriminant function 1, Band 4 (infrared) has the greatest influence on

Table 4. Area of cover types found in Pigeon River Fish and Wildlife Area.

Cover Type	Area (Acres)	
Shallow Marsh	1,051	
Deep Marsh	246	
Open Water	345	
Shrub Swamp	452	
Hardwood Swamp	1,105	
Bog	75	
Other Wetlands	107	
Total Wetlands		3,381
Hardwoods	2,091	
Conifers	168	
Agriculture	5,639	
Other	50	
Total Non-wetland		7,948
Total Land Area		11,329 Acres

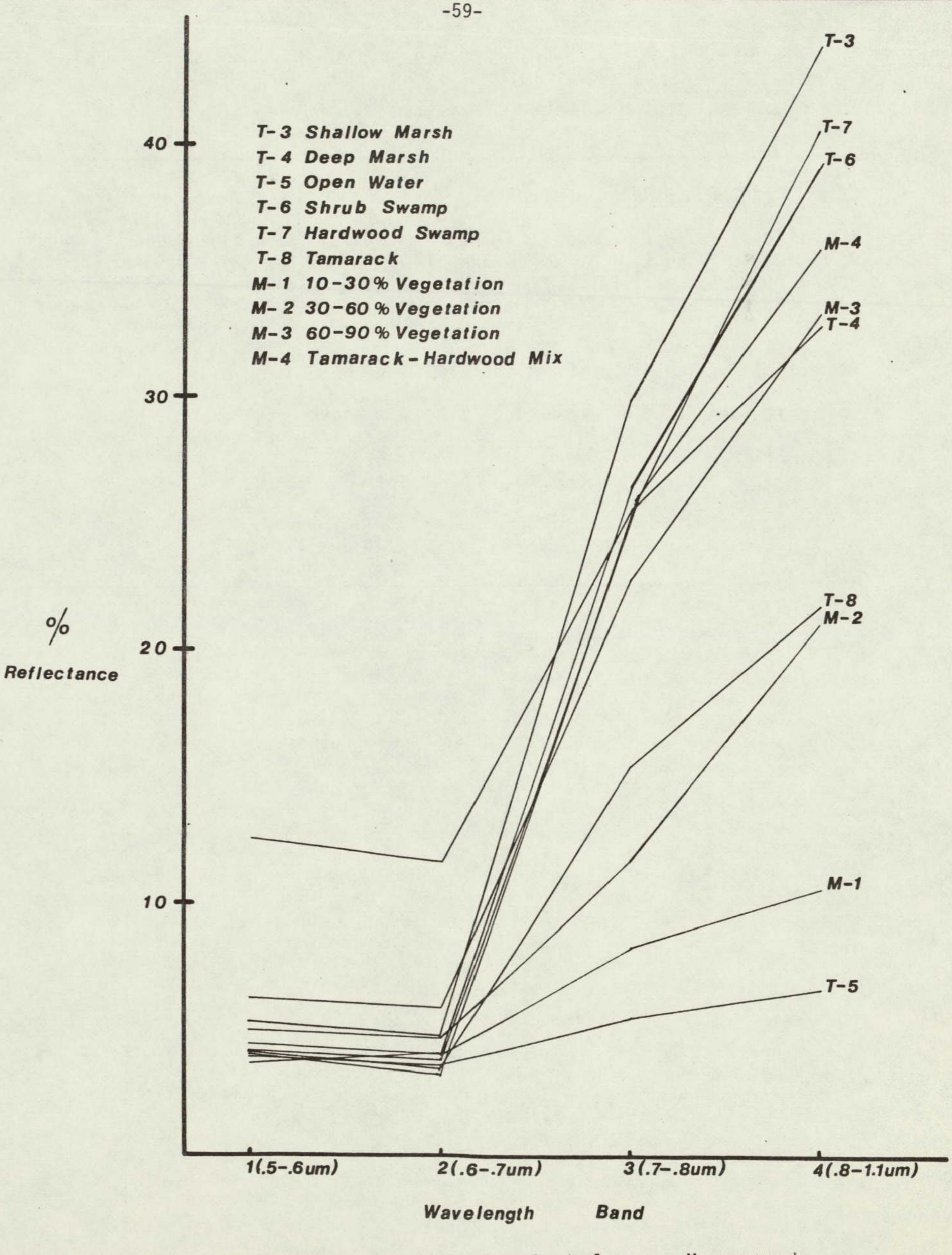

Figure 4. Spectral Characteristics of wetland classes. Measurements were taken in each wavelength band only.

Table 5. Results of Discriminant Analysis on Wetland Classes.

Discriminant Functions:

1. -0.48095 (Band 1) + 0.01953 (Band 2) + 0.01757 (Band 3) - 0.86227 (Band 4)
2. 0.99650 (Band 1) - 0.02295 (Band 2) - 0.46646 (Band 3) - 0.09742 (Band 4)
3. -2.40338 (Band 1) + 1.65273 (Band 2) + 4.82345 (Band 3) - 4.53712 (Band 4)
4. 3.29991 (Band 1) - 3.76096 (Band 2) + 2.13738 (Band 3) - 2.22448 (Band 4)

Statistics on each discriminant function:

Discriminant Function	Eigenvalue	Relative Percentage
1	4.92505	66.13
2	2.38103	31.97
3	0.10373	1.39
4	0.03754	0.50

the function value while Band 1 has a moderate effect and the other wavelengths are negligible by comparison. The green wavelength band (Band 1) dominates in Function 2 whereas the nearer infrared wavelength (Band 3) has only moderate influence on the function value. Wetland classes might, therefore, be described by using a combination of Bands 1, 3, and 4.

The interrelationship between classes can be observed by plotting the function values for each class. Figure 5 is a plot of discriminant score 1 vs. discriminant score 2. Although the discrimination is statistically significant, several class function values appear very close. Hardwood swamp, shrub swamp and the tamarack-hardwood mix all have nearly identical function values. This indicates that there may be some difficulty when classifying these wetlands using the LARSYS maximum likelihood classifier. This is clearly shown in the discriminant classification.

The samples used to derive the discriminant function were "reclassified" into predicted classes using a discriminant classification. By classifying the samples and comparing the predicted class membership with the actual class membership, one can empirically measure the success in discrimination by the proportion of correct classifications.

Results listed in Table 6 show that the percent of class samples correctly identified is approximately 54 percent. Deep marsh is the most easily identified class with 7 out of 8 samples correctly identified. Shallow marsh, open water, hardwoods, and mixed classes with less than 60 percent vegetation are classified with above 60 percent accuracy. Considerable classification error is caused by the overlap among shrub swamp, shallow marsh, hardwood swamp, tamarack-hardwood mix and the mixed class with greater than 60 percent vegetation.

The discriminant analysis results indicate that to distinguish between wetland classes, Bands 1, 3 and 4 provide the greatest information content. However, even when these wavelengths are used in a discriminant classification, confusion between classes is likely.

The LARSYS maximum likelihood classifier employs discriminant functions in the classification algorithm. However, the classifier is modified by the incorporating probability functions into the decision rule. The inclusion of this information alters classification results significantly. Wetland classes which are confused in the discriminant classification may be separable in the classifier.

A LARSYS statistics deck was created using the means and within group covariance matrices computed for the different wetland classes in the discriminant analysis. The statistics deck was used in two LARSYS programs, BIPLOT and SEPARABILITY, to understand how classes would react in a LARSYS maximum likelihood classification.

The program BIPLOT plots the mean response of a class in a selected channel against the mean response of another channel. An option provided in the program plots the classified feature space of each class for the selected channels. The statistics were first run through a transformation in which the information within Bands 1 and 2, and the information within

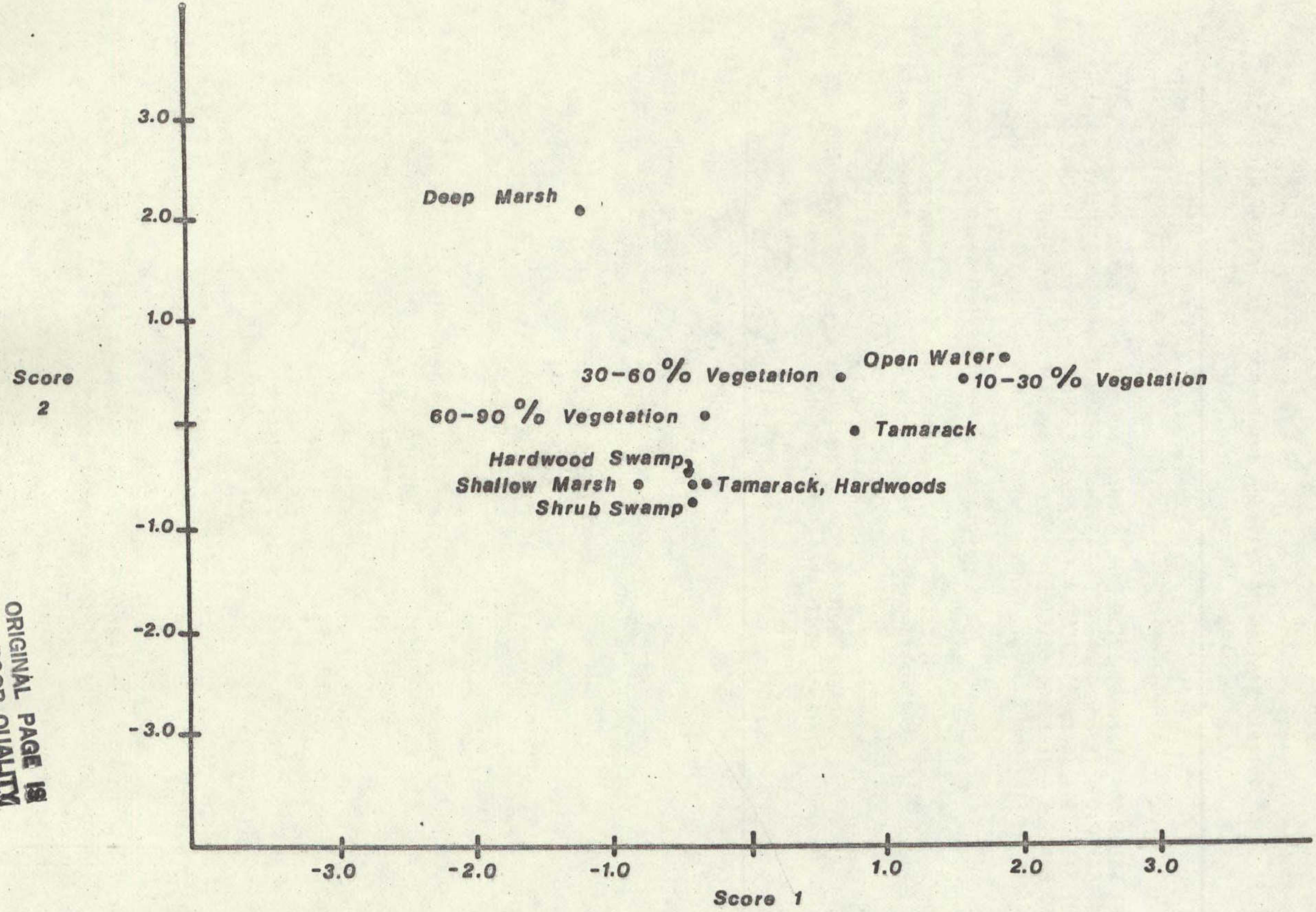

Figure 5. Plot of discriminant score 1 vs. discriminant score 2 for wetland classes.

Table 6. Predicted Group Membership

Class	No. of Cases	No. Correctly Identified	No. Confused with Class
Shallow Marsh	8	5	1(Hardwood Swamp) 2(Mixed Class 3)
Deep Marsh	8	7	1(Mixed Class 3)
Open Water	5	3	1(Tamarack) 1(Mixed Class 1)
Shrub Swamp	9	1	4(Shallow Swamp) 2(Hardwood Swamp) 2(Mixed Class 3)
Hardwood Swamp	9	6	2(Shallow Marsh) 1(Shrub Swamp)
Tamarack Bog	8	5	3(Mixed Class 2)
Mixed Class 1	5	3	2(Open Water)
Mixed Class 2	6	4	2(Tamarack Bog)
Mixed Class 3	11	6	1(Deep Marsh) 1(Shrub Swamp) 2(Hardwood Swamp) 1(Tamarack)
Mixed Class 4	5	0	3(Shrub Swamp) 2(Hardwood Swamp)

Percent of "grouped" cases correctly classified: 54.05%

Bands 3 and 4 were mathematically combined to create two new channels of data - visible and infrared. When BIPLOT is run using the transformed statistics deck, a graph of the classification space is printed out with the visible bands plotted against the infrared bands. The resultant plot is a coincident bispectral plot in which all information from the four original channels is represented.

The classification space plot allows one to visualize which classes are easily discriminated and which classes are not (see Figure 6). In the case of the ten wetland classes, Types T-4, T-5, T-8 and Mixes, M-1, M-2, and M-3 are easily distinguishable from all other classes. The classification space of wetland Type 3 lies near the upper boundary of a classification space covered by Types 6, 7 and Mix 4. These latter classes may not be easily separated given the current information.

Another method of conceptualizing the degree of separability among wetland classes is provided in the LARSYS program SEPARABILITY. This program calculates the distance between all pairs of classes for all possible wavelength channel combinations. The measurement used, called transform divergence (DIV) is calculated from the mean response and covariance for each class. Divergence values vary from zero (identical classes) to 2000 (highly separable classes).

The original statistics deck containing the means and covariances in each spectral band for ten wetland classes were used for this program. The weighted interclass divergence (DIJ) for each pair of classes was computed for every possible combination of two, three and four channels of data. The program is set up so that the first channel combination printed is the optimum for classification. Table 7 lists the results of the SEPARABILITY function.

When only two channels of data are selected, Bands 2 and 4 are considered optimum. Classes T-3, T-6, and T-7 were found to be non-separable at the threshold value of DIJ-1200. This threshold value was arbitrarily set as the cut-off value for classification purposes. Class M-3 was also non-separable from T-3 and T-6. When three channels were selected, Bands 1, 2, and 4 were considered optimum for classification purposes. Only classes T-3 and T-6 were non-separable. The use of information from all four channels of data left all wetland and mixed classes separable.

The information obtained from the LARSYS programs indicates that wetland classes may in fact be identified from Landsat multispectral scanner data. The results of these programs will be used when selecting training areas for the subsequent classification. In addition, they will be compared to classification results to determine if field spectral measurements can actually be used to predict classification results.

IDENTIFICATION OF WETLANDS FROM LANDSAT MULTISPECTRAL SCANNER DATA

The computer compatible tapes of the June 9, 1978 (Scene ID 21234-15185) Landsat overpass has not yet reached LARS. Therefore, no current classification results can be reported. An in-house data set from June 1973 was used to produce a preliminary classification of the Pigeon River Fish and

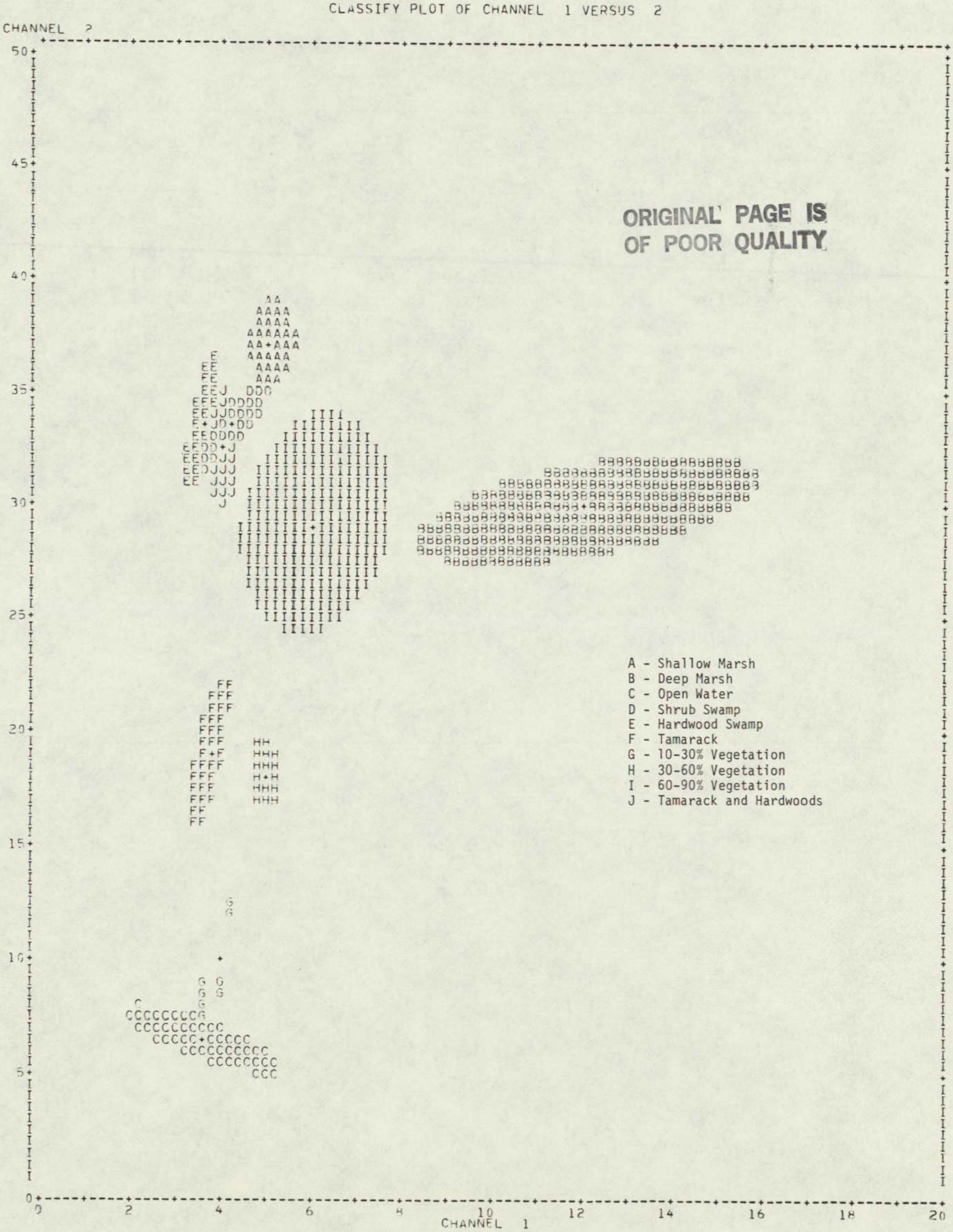

Figure 6. Classification space associated with each wetland class in the LARSYS classifier.

Table 7. Results of SEPARABILITY Function

Two Channel

Optimum Channel Combination: Band 2 and Band 4
Non-separable classes:

T-3, Shallow Marsh & T-6, Shrub Swamp	DIJ = 284
T-3, Shallow Marsh & T-7, Hardwood Swamp	DIJ = 851
T-3, Shallow Marsh & M-3, Water/Veg. Mix	DIJ = 871
T-6, Shrub Swamp & T-7, Hardwood Swamp	DIJ = 490
T-6, Shrub Swamp & M-3, Water/Veg. Mix	DIJ = 710

Three Channel

Optimum Channel Combination: Band 1, Band 2 and Band 3
Non-separable classes:

T-3, Shallow Marsh & T-6, Shrub Swamp	DIJ = 696

Four Channel

Optimum Channel Combination: Band 1, Band 2, Band 3, Band 4
Non-separable classes:

None

Wildlife Area. Because no concurrent ground truth is available, it is difficult to assess the accuracy of this classification. However, some general comments can be made.

Most wetlands can be identified in the Landsat classification. There appears to be some confusion in distinguishing between different wetland types and between some wetland and upland cover types. For example, bottomland hardwood swamps are not separable from upland hardwood stands. The difficulty in identifying wetland types may be a product of differences in wetness between 1978 and 1973. What appears as a shallow marsh today may have been a deep marsh five years ago when there was an extremely wet spring. This latter problem points to the need for concurrent ground truth with the Landsat data when attempting a computer classification.

FUTURE WORK

Future efforts will concentrate on using a current Landsat data set to classify wetlands in northern Indiana. Two approaches will be taken for the classification. The first approach will use the maximum likelihood classifier and multispectral data exclusively to identify wetlands. In the second approach an ancillary data channel will be created containing soils information. The layered classifier will be used to identify wetlands using the combined spectral and soils data.