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UTILIZATION OF EREP DATA IN GEOLOGICAL EVALUATION, REGIONAL PLANNING, FOREST MANAGEMENT AND WATER MANAGEMENT IN NORTH CAROLINA

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UTILIZATION OF EREP DATA IN GEOLOGICAL EVALUATION, REGIONAL PLANNING, FOREST MANAGEMENT, AND WATER MANAGEMENT IN NORTH CAROLINA

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16. Abstract

S190A and S190B photographs of North Carolina taken during passes of SKYLAB-2 and SKYLAB-3 have been studied as has data from the Multispectral Scanner, S192. Visual and optical techniques were employed during the investigation. Studies concentrated on the usefulness of the photography for land-use inventories, for urban forestry studies, and for special problems related to land use. A skilled photo-interpreter can achieve a 90 percent or better accuracy for vegetative and land-use interpretation, and for many problems the interpretation can be accomplished within a day or two. Acquisition of the data by other means can be much more time-consuming. Agricultural monitoring in the coastal region may be accomplished more accurately and with greater facility than is presently possible if space-acquired imagery of SKYLAB detail were available consistently. Evaluation of the photographs showed limited usefulness of this data for geologic interpretation. Studies of the coastal inlets showed some potential usefulness in updating navigational charts and in developing understanding of the dynamics of the inlets.

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SUMMARY

S190A, S190B and S192 photographs and imagery have been studied using chiefly standard air-photo interpretation techniques supplemented by color additive viewing and density slicing. The EREP data have been found of potential usefulness for natural resource inventory work, water quality monitoring, and land-use mapping for specific problems at scales up to 1:30,000. However, smaller scales are more useful. Distinctions between forest types in North Carolina are limited to conifers, mixed conifer-hardwoods and hardwoods. The orbital data have been tested for efficiency of use for vegetation-mapping in the Coastal Plain and found of potential usefulness, especially for crop inventories.

Geologic interpretation has been limited to detection of lineaments; lithologic differentiation and soil group mapping have proved infeasible in North Carolina except for differentiation of wetland soils in the Coastal Plain.

The data have also been tested for utilization in designing State Parks and in constructing environmental impact statements for airport expansion. It is believed that if they had been available at an early stage of park and airport design, they would have proved of value.

Even an initially relatively inexperienced interpreter can use standard optical techniques for interpretation and under certain favorable circumstances achieve an interpretative accuracy of 90%. An experienced interpreter can achieve better results, approaching an overall accuracy of nearly 100% in many cases. Familiarity with the area being interpreted is a partial key to achieving these levels of accuracy. The synoptic view afforded by the photography enables an investigator to place a particular problem in a regional context, even if the mapping scale that can be attained from the imagery is too small for the problem at hand.

Imagery from the S192 multispectral scanner has proved to be capable of useful discriminations for vegetation and crop analysis. However, for this type of data to be useful, larger scales must

be achieved; also greater cartographic accuracy than is present in the S192 data and lack of distortion must characterize the scanner data.

Although SKYLAB-EREP data could be utilized in solving some of North Carolina's natural resource and land-use inventorying needs, its "one-shot" occurrence caused a lower interest in the project on the part of state agencies than might have occurred if the data had been available on a regular basis. For many uses the greater scale achievable by enlargements of the EREP photography gives it advantages that smaller scale orbital imagery does not have.

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1.0 INTRODUCTION

The general purpose of the North Carolina EREP study was the interpretation and the analysis of EREP data to demonstrate their usefulness to various state and regional governmental agencies. The main emphasis of the demonstration was directed toward utilization of the data for land-use and natural resource planning and management activities. It was an experiment to learn the extent to which the information could be used by these agencies and to learn something of the applicability of the photography and imagery to the work of various agencies. It was expected that techniques and procedures would be developed which would make this source of information understandable to a variety of disciplines and to planning and management personnel concerned with interdisciplinary problems. An important part of the study was to acquaint technical personnel at various levels of government with the data and to find ways of putting them to practical use as expeditiously as possible.

The State of North Carolina was chosen as the general area of investigation so that a variety of test sites might be available for the experiments. Specific test sites in which representative problems germane to a number of disciplines existed were identified initially and proposed as part of the experiment. During the actual SKYLAB flightsdata acquisition was made over a restricted number of the proposed test sites. Weather factors eliminated some of the test sites and restricted the usefulness of some of the data acquired. The data, therefore forced the investigators to concentrate their studies on certain geographically limited areas. As a result, the investigation turned to an evaluation of the imagery that was received for various purposes, using test sites for which imagery was available. In a general way, the imagery was evaluated for all three physiographic provinces of the state. The approximate positions of the tracks of SKYLAB 2 and SKYLAB 3 across the state are shown on the map of Fig. 1 (pg. 12).

1.1 Objectives

The objectives of this investigation in terms of problems to be studied were the following:

1. To demonstrate the usefulness of SKYLAB data in land-use planning for the three physiographic provinces of North Carolina: the Coastal Plain, the Piedmont, and the Mountains.
2. To use the EREP data for studying regional geologic problems in these provinces.
3. To evaluate EREP data for developing predictive techniques for hydrologic purposes, both surface and subsurface, and to use the imagery to study fracture patterns and groundwater occurrences in areas of crystalline rocks.
4. To demonstrate the extent to which the EREP data could be used for management of forest and water resources in the North Carolina Piedmont and Coastal Plain.
5. To use the data to pinpoint areas of environmental concern. The EREP data were also to be studied in terms of evaluating coastal processes and coastal geomorphology.
6. To study the distribution and dispersion of suspended materials within the estuaries and lagoons of the coastal area.
7. To perform an educational function in which the potentials of remote sensing techniques and the use of EREP-like data by various regional and local planners were to be demonstrated.

1.2 Procedures and Problems

During the initial stages of the EREP data evaluation it was realized that not all objectives outlined in the proposal could be met because of the constraints put on the study by the nature of

the data itself. Cloud cover obliterated or obscured many potential test sites. Some sites that had been chosen were not photographed; alternate sites that were not particularly suited for an investigation of this nature had to be used. Consequently, some specific problems were identified, and the best test sites possible chosen for investigation.

Although similar to normal aerial photography except for the scale factor, the S190A and S190B photographs have scales which make interpretation by simple visual means somewhat difficult. Therefore, several optical enhancement procedures were used. In addition, photographic laboratory processing was used to bring the original imagery up to a suitable working scale, but in doing so some loss of detail was encountered. It also became evident as the study progressed that some familiarity with aerial photography is necessary before the S109A and S190B imagery can be adequately interpreted. However, the basic training of people with few skills in photographic interpretation takes only a few hours, and they can learn to use this type of imagery effectively after a short period of training.

Following the objectives of the proposal as originally submitted, the investigation evaluated the usefulness of the EREP imagery of North Carolina for the following natural and cultural features and resources: (a) forest, (b) coastal processes, (c) urban change and development patterns, (d) water quality (in the broader sense), (e) geologic structure and (f) environmental evaluation. Additionally, applicability of the imagery to agriculture related problems was studied.

After a representative amount of the imagery had been received, the investigators arranged meetings with people working in various state agencies, with planners for the City of Raleigh, and with other potential cooperators. The purpose of these meetings was to identify problems in which the several agencies were interested and for which the EREP data might be relevant. Also availability of the data was publicized through newspaper stories and radio and TV coverage.

It soon became evident that the imagery by itself was of limited usefulness to most agency personnel because of their interest in geographical areas that were not photographed by SKYLAB. Also, it became evident that the local and regional agencies were interested in the imagery only if it were possible to identify relatively small features.

2.0 GENERAL NATURE OF THE INVESTIGATIONS

The photography and imagery available to this investigation is listed in Table 1.

2.1 Geology

Geologic interpretation of the EREP imagery has been related chiefly to finding the extent to which lineaments could be recognized on it in the three provinces of North Carolina. It has also been utilized to study sedimentary features associated with the inlets in the Outer Banks. An attempt was made to use the imagery to map rock types.

Studies of coastal processes have been limited to an attempt to understand the information that EREP photographs provide about three of the inlets through the North Carolina coastal islands. The nonrepetitive nature of SKYLAB in its pass over the North Carolina coast combined with the extensive cloud cover at the time of the 9 August 1973 pass makes it difficult to evaluate the imagery as a useful tool except in a qualitative sense.

SKYLAB imagery proved of limited usefulness in solving geologic problems in North Carolina. Evaluations of the imagery were made for the Blue Ridge Province in the Asheville area, for the Piedmont, and to a limited extent for the northeastern part of the state, in the Coastal Plain. In addition, one frame of the imagery was examined as a potential contribution to a study related to location of quarry sites along the Coastal Plain/Piedmont boundary.

Table 1

Photography and Imagery Used

Approximate scales of original SKYLAB photography and images

S190A	(70mm)	1:2,900,000
S190B	(4.5-inch - 115mm)	1:950,000
S192		1:720,000

Asheville - Buncombe County; 10 June 1973, 1430Z (0930 EST)

S190A

Rolls	Frames	Wavelength (μm)
07	249-254	0.7 - 0.8
08	249-254	0.8 - 0.9
09	265-270	0.5 - 0.88
10	265-270	0.4 - 0.7
11	249-254	0.6 - 0.7
12	249-254	0.5 - 0.6

S190B

81	352-356	0.4 - 0.7

U-2 Aircraft Photography
Color infrared photographs taken May 1970 (NASA/MSC Mission 128-A, Roll 19) from 65,000 ft. (Approximate scale: 1:130,000)

Coastal (Northeastern) North Carolina; 9 August 1973, 1347Z (0847 EST)

S190A

Rolls	Frames	Wavelengths (μm)
25	026-033	0.7 - 0.8
26	026-033	0.8 - 0.9
27	026-033	0.5 - 0.88
28	026-033	0.4 - 0.7
29	026-033	0.6 - 0.7
30	026-033	0.5 - 0.6

S192 Multispectral Scanner (13 bands between 0.41 and 12.5 μm)

NP3A Aircraft Photography (Mission 253, site 244/018) flown at 10,000 ft. Cloud cover limited usefulness of this data.
Color infrared photography (1:20,000 scale)
Four band, multispectral photography (1:20,000 scale)
RS-14 thermal scanner imagery (1:72,000 scale)

Table 1
(continued)

Piedmont Region; 12 September 1973, 1703Z (1203 EST); 17 September 1973, 1500Z (1000 EST)

S190A

	Rolls	Frames	Wavelength (μm)
12 Sept.	37	114-118	0.7 - 0.8
	38	114-118	0.8 - 0.9
	39	114-118	0.5 - 0.80
	40	114-118	0.4 - 0.88
	41	114-118	0.6 - 0.7
	42	114-118	0.5 - 0.6
17 Sept.	43	108-112	0.7 - 0.8
	44	108-112	0.8 - 0.9
	45	108-112	0.5 - 0.88
	46	108-112	0.4 - 0.7
	47	108-112	0.6 - 0.7
	48	108-112	0.5 - 0.6

S190B

12 Sept.	86	287-296	0.4 - 0.7
17 Sept.	88	146-152	0.4 - 0.7

S192 S192 Multispectral Scanner (13 bands between 0.41 and 12.5 μm)

U-2 Aircraft Photography

Color infrared photography taken 15 September 1973 (NASA Mission 73-157) from 65,000 ft. (approximate scale 1:130,000)

2.1.1 Techniques

Standard photogeologic techniques were used to study the SKYLAB imagery for geologic purposes. The black and white transparencies, the color transparencies, and the color infrared transparencies were all used on light tables and under various magnifying devices. The imagery was studied in a color additive viewer and projected through the viewer onto various base maps. Distinction of various rock units was essentially impossible in the Asheville area and on the Piedmont. The boundary between the Coastal Plain and the Piedmont could be readily distinguished on most of the S190A and S190B imagery. The major usefulness of the imagery geologically seemed to be restricted to the mapping of lineaments. In the northeastern part of the state major geomorphic features of the Coastal Plain are readily recognizable where not obscured by cloud cover, and the pocosins with their wet soils are easily picked out.

2.1.2 Results

As noted before, lineament mapping seemed to be the most useful application of the SKYLAB photography. Many man-made features appear as lineaments and must be separated from those that are geologically important.

Recognition of rock types on the imagery is virtually impossible for both the Piedmont and Blue Ridge provinces of the state, at least in those areas which are covered by SKYLAB photography. The metamorphic rocks which underlie these areas together with their associated soils do not possess signatures significantly different for lithologic separations. In addition, rather extensive vegetative cover and thick layers of weathered material obscure any systematic differences. Where it is possible to make lithologic distinctions, they are chiefly accomplished through the fact that one rock type may be more resistant than another and that the geomorphic expression of a particular rock type may be followed from one outcrop to another by its topographic expression. Lineaments in the Piedmont are reflected in most

cases by stream patterns and/or by water bodies which fill former stream valleys.

2.1.3 Raleigh and Wake County

Geologic studies of part of the North Carolina Piedmont were made for Raleigh and the surrounding area. It was found that the major geologic features were not easily distinguished on the SKYLAB imagery. Boundaries between the Triassic Basin and the adjacent metamorphic rocks could not be easily distinguished, although the Coastal Plain boundary with the Piedmont (the Fall Line) could be mapped in considerable detail.

2.2 Forestry

The EREP investigations in forestry have been carried out by one faculty member assisted from time to time by several graduate students and undergraduate students. Professional cooperation has been secured from other personnel in the university system, the U. S. Forest Service, North Carolina Forest Service, the Planning Department of the Triangle J Council of Governments whose geographic area of responsibility includes Wake County, and from local planning agency personnel.

The study of EREP data in forestry has been directed chiefly to the urban-rural complex of Raleigh and its environs. The emphasis has been upon use of the imagery for evaluating urban area forest cover.

2.3 Land-Use Planning

The main effort expended in the land-use planning aspect of the investigation has been to demonstrate how EREP-type data can be utilized in making decisions about land-use inventories and in identifying critical areas of environmental concern. The results of this study indicate that imagery of this type can be used methodically, intelligently, and with some degree of accuracy for many regional land-use planning activities. Test sites included

the Asheville-Buncombe County area, the Winston-Salem/Greensboro area, the Raleigh area, and part of coastal northeastern North Carolina.

2.4 Hydrology and Water Resources

Little systematic effort was made to study the usefulness of EREP S190A and S190B photography for hydrologic and water resources purposes in the present investigation. Although a few of the major lakes in North Carolina have been photographed from SKYLAB, the absence of groundtruth data and the fact that many of the lakes were partially cloud-covered when SKYLAB passed over limits the usefulness of the SKYLAB information for hydrologic studies in North Carolina.

2.5 Agricultural Studies

One study evaluated SKYLAB-type photography for making crop inventories in coastal North Carolina. The limited study of the S192 imagery made during this investigation indicates that this type of imagery can be useful for crop assessment in North Carolina.

3.0 TECHNIQUES

During the course of this study most of the effort has been directed toward application of relatively simple techniques that can be used by local planners and resource managers who have no access to sophisticated equipment. Simple projection techniques using standard slide, overhead, and opaque projectors have been used. Stereoscopic viewing with readily available equipment has been one of the interpretative practices. Color additive viewing has been used with the black and white S190A imagery. Combinations of color infrared, color, and multispectral black and white photographs from S190A experiment have been used in the color additive viewer. Studies of the photography have been carried out with pocket and mirror stereoscopes, Wild mirror stereoscope, an Old Delft scanning stereoscope, binocular microscopes, a Bausch

and Lomb Zoom 70 stereo-microscope, and a Bausch and Lomb Zoom transferscope. Transparencies and prints have been used successfully as have both positives and negatives. The color additive viewer has proved to be a useful tool for studying much of the imagery, but one of the simplest interpretation techniques has been the use of a standard binocular microscope and interpretation of the 70mm (S190A) or 4.5 inch (S190B) transparencies as they were received from NASA.

Density slicing has been employed with mixed results. In this technique the densities of various parts of a transparency are measured by an optical sensor which converts the signal through an analogue system to a color code displayed on a color TV tube. Each color represents a density level on the transparency. Theoretically, if a density level represents a phenomenon, then the scene can be better interpreted and understood with the aid of the color display.

The technique was useful for interpreting water depths in the coastal inlets and for identifying crops and vegetation. However, it was of limited usefulness in studying land-use patterns around urbanizing areas in the Piedmont and Blue Ridge provinces of the state.

4.0 INVOLVEMENT OF AGENCIES

Initially considerable effort was expended in the education of personnel of various state and local agencies. EREP photography was displayed and demonstrated to those who were interested. It was discussed both formally and informally with potential user groups, and as wide a dispersal of information about SKYLAB as possible was made, including investigator participation on radio and TV interviews. However, the interest in the SKYLAB experiment was very intermittent, was generally superficial, and unless the investigators could provide an answer to a very specific problem or question, such as one of land-use change since the most recent aerial photography was made, there was no general interest in the imagery. Also the very limited geographic distribution of the photographs made it impossible to attract a broader potential user group to its use.

5.0 TEST SITES

The map of Fig. 1 shows the location of the several test sites. Descriptions of the investigations pertaining to each of the test sites follows. Conclusions reached from the individual investigations are discussed with the respective investigation. Since photographic quality and an individual investigator's experience with the photography and the features looked for were different with each investigation, conclusions about the utilitarian aspects of the photography may apply only to a given experiment; yet from the several experiments a broad pattern of usefulness and limitations on usefulness of the photography emerges.

6.0 SCALE, RESOLUTION AND INTERPRETIVE TECHNIQUES

6.1 Evaluation of Different Kinds of Photography

This portion of the evaluation of photography is based on experiences in the forestry phases of photo analysis. Stereopairs and single frames, color or high resolution color, and color infrared (CIR), and three sizes of transparencies: 70mm (S190A), 4.5-inch (S190B) and 9-inch enlargements of the S190A material were studied.

A general evaluation of stereopairs (indicated by a double number, e.g., 46-110/111) and single frames is given in Table 2.

The quality classes are identified as follows:

Excellent: water bodies and their boundaries easily seen and identified; soil conditions identified by differences in tone or color; forest stands easily seen and differ in tone one from the other; urban land uses differentiated readily; detail of streets and buildings down to individual dwellings is readily visible.

Good: some degrading in detail of land-use boundaries, street patterns, and ground cover. Shorelines of water bodies often are indistinct. Forest cover differences are difficult to recognize.

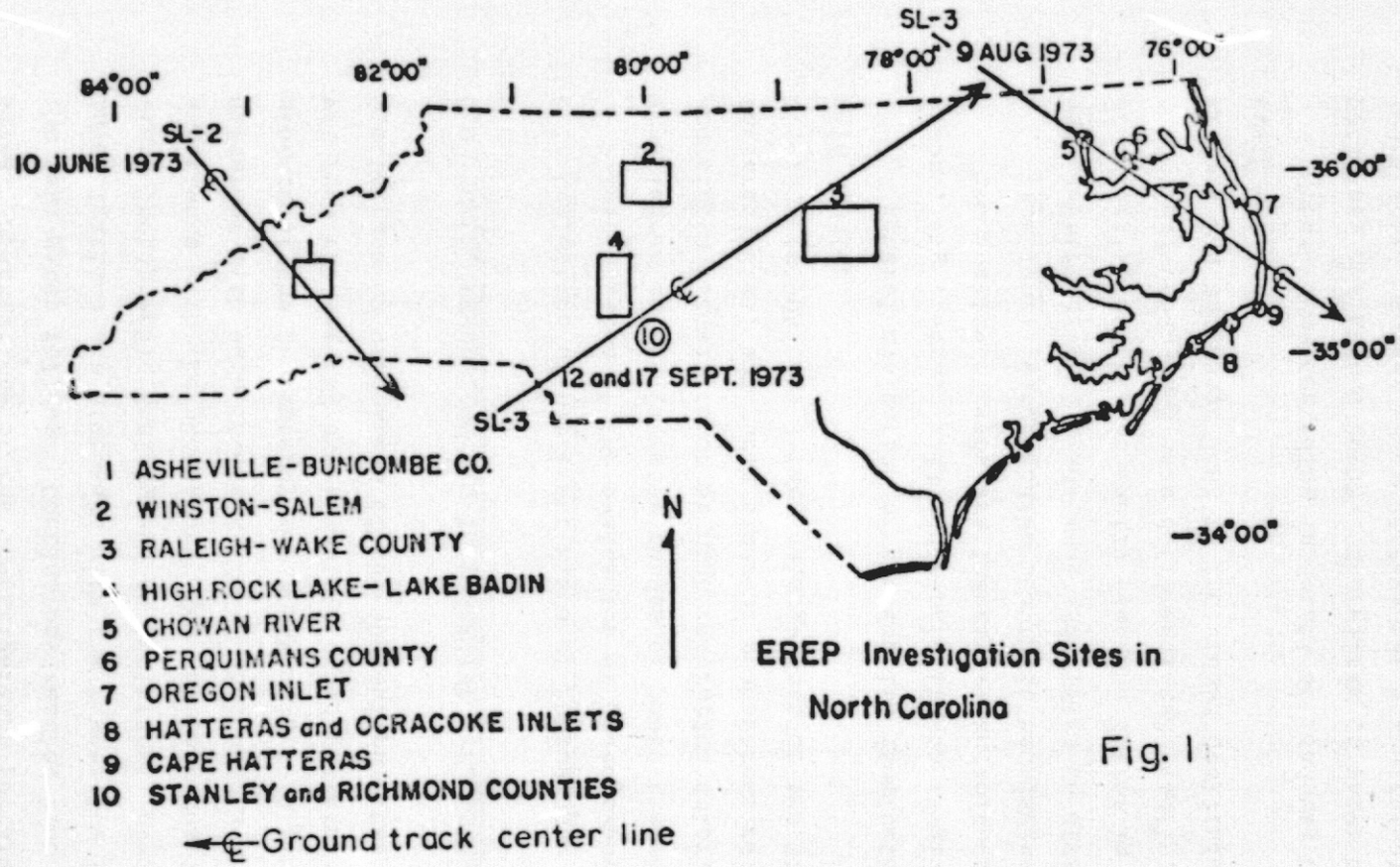


Fig. 1 EREP Investigation Sites in North Carolina

Fair: street patterns obscure, land-use boundaries generally visible but indistinct in urban areas, soil conditions difficult to differentiate.

Poor: photographs usable for many purposes, but detail is obscured by graininess or lack of contrast.

Table 2 shows subjective evaluations under specific instrumental and lighting conditions. Another interpreter working under different conditions and for different purposes could well make different evaluations and could report the usefulness of the photography at different value levels. Although subjective evaluations made by one person are perhaps of limited usefulness, they can provide a potential user of SKYLAB photography with an ordinal measure of the utility of the photography. This measure can be helpful in the making of decisions about which photography should be preferentially selected in attempts to use the SKYLAB material to solve a particular problem.

6.2 Scale and Resolution

6.2.1 Studies with Available Equipment

In connection with various forestry studies using SKYLAB photography several scales of photography were tried for various purposes. The results of these trials are listed below.

(I) 70mm transparencies, Roll 40, Frames 117 and 118, S190A; approximate scale: 1:2,900,000. Instrument used was B & L Zoom 70 stereoscope.

(a) Magnification 7x approximate scale 1:414,300. Land-use boundaries generally identifiable for kinds and sizes of land use encountered; airport runways clearly measurable.

(b) Magnification 13x, approximate scale 1:223,000. Details of streets clear.

(c) Magnification 20x, approximate scalar 1:145,000. Individual dwellings visible but city-block-size parks in urban area not identifiable.

Table 2

SKYLAB photo-evaluation for interpretation of resource uses
(classes: excellent, good, fair and poor)

No.	Kind**	Water				Soil				Forest				Urban			
Roll-Frame		E	G	F	P	E	G	F	P	E	G	F	P	E	G	F	P
S190A Experiment																	
40-117/118	70mm color		x				x					x			x		
46-110/111	9" color		x					x			x				x		
40-117/118	9" color		x				x					x		x			
40-117	9" color		x				x				x				x		
39-117/118	9" CIR*	x					x				x						x
45-110/111	9" CIR*			x					x				x				x
39-117	9" CIR*	x						x				x				x	
S190B Experiment																	
86-292/293	4.5" color		x					x			x				x		
86-292/293	9" color		x			x				x				x			
88-150	4.5" color		x				x				x				x		
88-150	9" color		x				x			x				x			
86-292	9" color											x			x		

*CIR = color infrared

**The nominal 9-inch size represents an enlargement from 70mm (S190B, 3.2x) or 4.5 inch (S190B, 2x) original photography

(d) Magnification 28x, approximate scale 1:103,600. Photo grain is enlarged to obliterate detail such as individual dwellings, but business buildings can be differentiated from their parking lots.

(II) 4.5-inch transparencies, Roll 86, Frames 292 and 293, S190B; approximate scale 1:950,000; instrument used was B & L Zoom 70 stereoscope.

(a) Magnification 11x, approximate scale 1:86,300. Individual dwellings in most areas were visible, football stadium seen in detail, both lanes of an interstate highway were clearly seen. This was considered the optimum interpretation scale for forestry-greenspace analysis purposes.

(b) Magnification 22X approximate scale 1:43,200. This scale was judged to be the maximum useful one for forestry-greenspace purposes.

This stereopair was considered to be the best example of either S190A or S190B photography which was studied under a Wild 3x mirror stereoscope (approximate scale 1:366,700) in this investigation. Interpretative details included individual dwellings, both lanes of an interstate highway, football stadium, and color details in newly disturbed earth in construction projects.

(III) 4.5-inch transparencies, Roll 88, Frame 150, S190B; approximate scale 1:950,000. Instrument used was B & L Zoom 70 microscope.

(a) Magnification 11x, approximate scale 1:86,300. For forestry-greenspace analysis this appeared to be the optimum scale. Individual dwellings, vegetative cover and similar details were detectable. In trials at 14x magnification (approximate scale 1:68,000) graininess degraded the quality of the image and made it less useful than the smaller-scale image. Magnifications up to 20x (1:47,500) were, however, of use to the interpreter.

(IV) 4.5-inch transparency, Roll 88, Frame 150, S190B; approximate scale 1:950,000. Instrument used: B & L Zoom transferscope (ZTS).

(a) Magnification 8x, approximate scale 1:118,800.

This appeared to be the best scale for ZTS interpretation. The same frame in 9-inch format (approximate scale 1:475,000) was found to be better at all magnifications on the ZTS than the 4.5-inch version (scale 1:950,000), but a 7.4x magnification(approximate scale 1:128,300)was considered best.

The 9-inch enlargement of Roll 88, Frame 150(approximate scale 1:475,000)was considered to be the best forestry-greenspace mapping photo received for the North Carolina SKYLAB project. The ZTS in general has the following characteristics for mapping from this 9-inch enlargement: good urban boundary detail at 2x (1:237,500), city street patterns at 4x (1:118,800), excessive graininess at 8x (1:59,400).

6.2.1.1 Interpretation of Lakes by Projection--Buncombe County: SKYLAB imagery was studied for recognition and detection of lakes at different scales for the Buncombe County area. The imagery used was from Rolls 07 (0.7-0.8μm) and 08 (0.8-0.9μm), Frame 251, the black and white infrared bands. Roll 11 (0.6-0.7μm), Frame 251, the red band, was used to show the clouds so that shadows of clouds could not be mistaken for lakes. Three by four-inch rectangles were cut from positive transparencies which were at a scale of approximately 1:800,000. The rectangles were mounted and projected through a color additive viewer onto an exterior screen at a scale of between 1:30,000 and 1:35,000. Lakes approximately three acres in size were measurable on the projection, and smaller lakes were recognized on the basis of shape and reflectance. These latter lakes were estimated to be about 1.5 to 2 acres in total area.

Imagery at the approximate scale of 1:800,000 (Roll 07 (0.7-0.8μm), Frame 251) was examined under a binocular microscope at a magnification of 40x. The scale of view was 1:20,000. Lakes

were recognized as clusters of dots on the photographed material. To the inexperienced observer, they might not have appeared to be lakes; however, their arrangement, the shape of the cluster of dots, the presence of the dots in an infrared band, and, of course, experience leads to the conclusion that these are lakes. Several of the lakes were checked and found to be partially filled quarry pits or settling ponds of the Grovestone Quarry near Highway 70 east of Asheville. Presence of other lakes observed on the imagery was confirmed by field checking. As a matter of speculation, it is possible that the quarry pits may be more sharply set apart from their surroundings than other lakes of equivalent size because of the steep walls which produce a sharp boundary between the water and dry land. It was noted that the quarries appeared more sharply set apart from their surroundings than some of the other lakes. Speculatively speaking, the relationship may possibly be explained on the basis of the nature of the boundaries. In the case of the water-filled quarries steep walls form the boundaries; other lakes gradually shoal toward their edges. Damper land areas near the actual land-water boundary may have a reflectance similar to that of the adjacent shallower water. As a result the boundary between water and land could appear less distinct to the eye than in the case of the quarry boundaries.

Small lakes cannot be seen distinctly on the color infrared imagery in all instances. Lakes must be distinguished from cloud shadows which appear on the infrared imagery and from topographically low areas lying in shadows between ridges or mountainous areas. These low areas are also sometimes dark because of shadow. With practice an observer can probably separate the lakes from shadows on the color infrared film, but it is more difficult to do this with the color infrared film than with the black and white infrared bands.

At least for the Asheville area the color photography shows lakes poorly or not at all because of a lack of contrast between the color of the water and the color of the surrounding land.

It seems possible, although it has not been unequivocally demonstrated during the course of this investigation, that enlargements of suitable scale made from the S190A 70mm SKYLAB photographs can be projected with a good projection device to a scale of approximately 1:15,000 to 1:20,000 and that at this scale water bodies of one to two acres can be recognized if the black and white infrared bands are used. The largest lake or pond that might be mapped using this technique would be two to three acres. Whether this scale of interpretation can be done consistently or not is probably dependent to a great extent upon such things as sun angle, associated topography, and the surrounding land uses.

6.2.2 Laboratory Measurements and Field Measurements

Roll 86, Frame 293 and Roll 88, Frame 150 (S190B, both high resolution color transparencies) made in September 1973 were evaluated for scale and resolution. The study was done using the original 4.5-inch format material (approximate scale 1:950,000). Field checking took place in January 1975. Test sites were Upchurch community in Wake County, North Carolina State University campus, Carter Stadium, and North Carolina State University Farm Unit #2. The purpose of the investigation was to examine the spatial resolution of SKYLAB S190B color photos under nearly ideal conditions where

a) surface features were not obscured by haze or clouds,
b) selected features afforded excellent contrast with surrounding surrounding terrain,
c) the localities were familiar to the interpreter.

Test sites were chosen which had a low likelihood of change during the time interval between the taking of the photograph and the actual ground measurements. A local farmer was consulted to verify that nearby fields and ponds had remained essentially unaltered between September 1973 and January 1975. The photographs were taken in late summer when foliage was at a maximum while the field checks were made in mid-winter. This fact apparently caused

some interpretation problems, as Table 3 indicates, where agricultural features such as fields are bounded by woods and grassy areas. It was found difficult to determine by looking at bare trees at the time the groundtruth was collected in January 1975 how the trees would be recorded on an orbital photograph taken at a time of full foliation. The field boundary recognized on the SKYLAB photograph was of the branch overhang, and the density of leaves on the trees in September 1973. In other words, the field edge lay beneath the overhanging branches, and the measurements on the SKYLAB transparency indicated dimensions smaller than the actual dimensions of the field. Also, even with the shapes and areas of fields preserved, the portion actually planted in a given crop could vary by small amounts between seasons depending upon the farmer's cropping procedures and the extent of weed, bush, and briar growth along edges and corners of fields. Obviously such problems were not encountered with man-made objects such as athletic fields, paved lots, and dams. Consequently, much better measurement accuracy was obtained as Table 3 and accompanying graph (Fig. 2) show. A sketch map of the Upchurch community is shown in Fig. 3 for reference. Measurements on the S190B transparencies were made with the Bausch & Lomb Zoom 70 stereomicroscope with a projected scale micrometer.

The Raleigh-Durham Airport northeast-southwest runway was the best defined ground feature photographed, and since its dimensions were known, it was used along with a two mile (3.2 km) section of U. S. 1 west of Raleigh to determine photo scale. An average of these two measurements gave a scale of 1:933,429. This figure varied by 1.78 percent from the 1:950,000 scale given by the EROS Data Center.

Most of the field measurements made are summarized in Table 3. The only ones omitted are those which could not be separated on the imagery from adjacent features.

TABLE 3

Measurements on SKYLAB-3 S190B Photographs

Object	Photo (Feet) Length	Photo (Feet) Width	Field (Feet) Length	Field (Feet) Width	Percent Error Length	Percent Error Width	± Feet Length	± Feet Width
Sand Ridge		102		75		36.8		27
Trees	270	158	220	125	23.0	26.8	50	33
Riding Ring	205		196		4.59		9	
Field "B"	578		550		5.10		28	
Field "C"		513		545		-5.88		-32
Carter Stadium	364		384		-5.20		-20	
Airport Runway		140		150		-6.66		-10
North Carolina State University Track	578		560		3.34		18	
North Carolina State University Farm								
a) Field 1	1260		1238		1.78		22	
b) Field 2	1792	840	1815	908	-1.26	-7.48	-23	-68*
c) Trees		653		619		5.49		34

*A large tree in one corner obscured the intersection of the measured edges, and the width measurement on the SKYLAB transparency was apparently made on the field side of the tree, resulting in a short measurement.

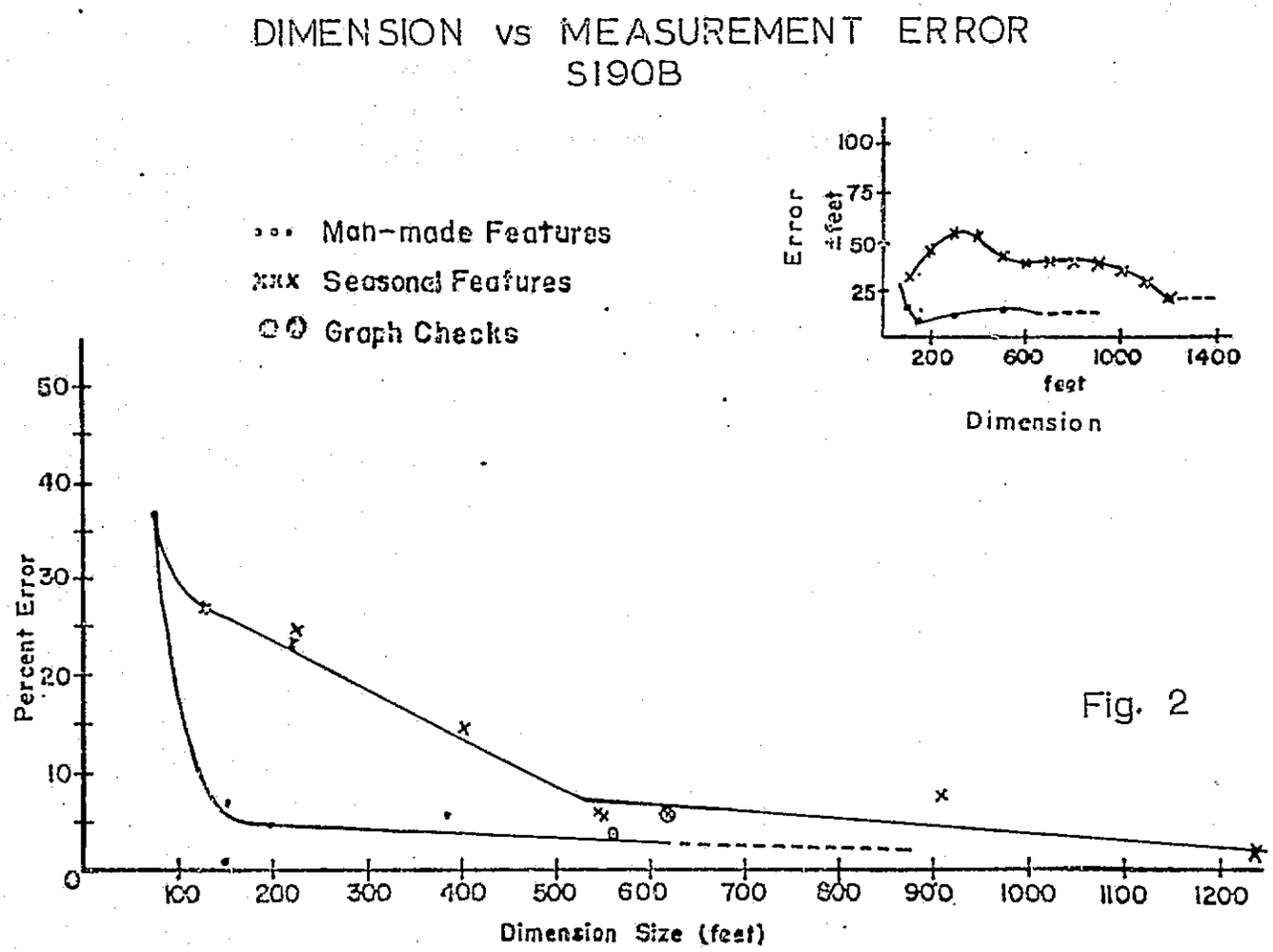


Figure 2 Dimension vs Measurement Error for S190B

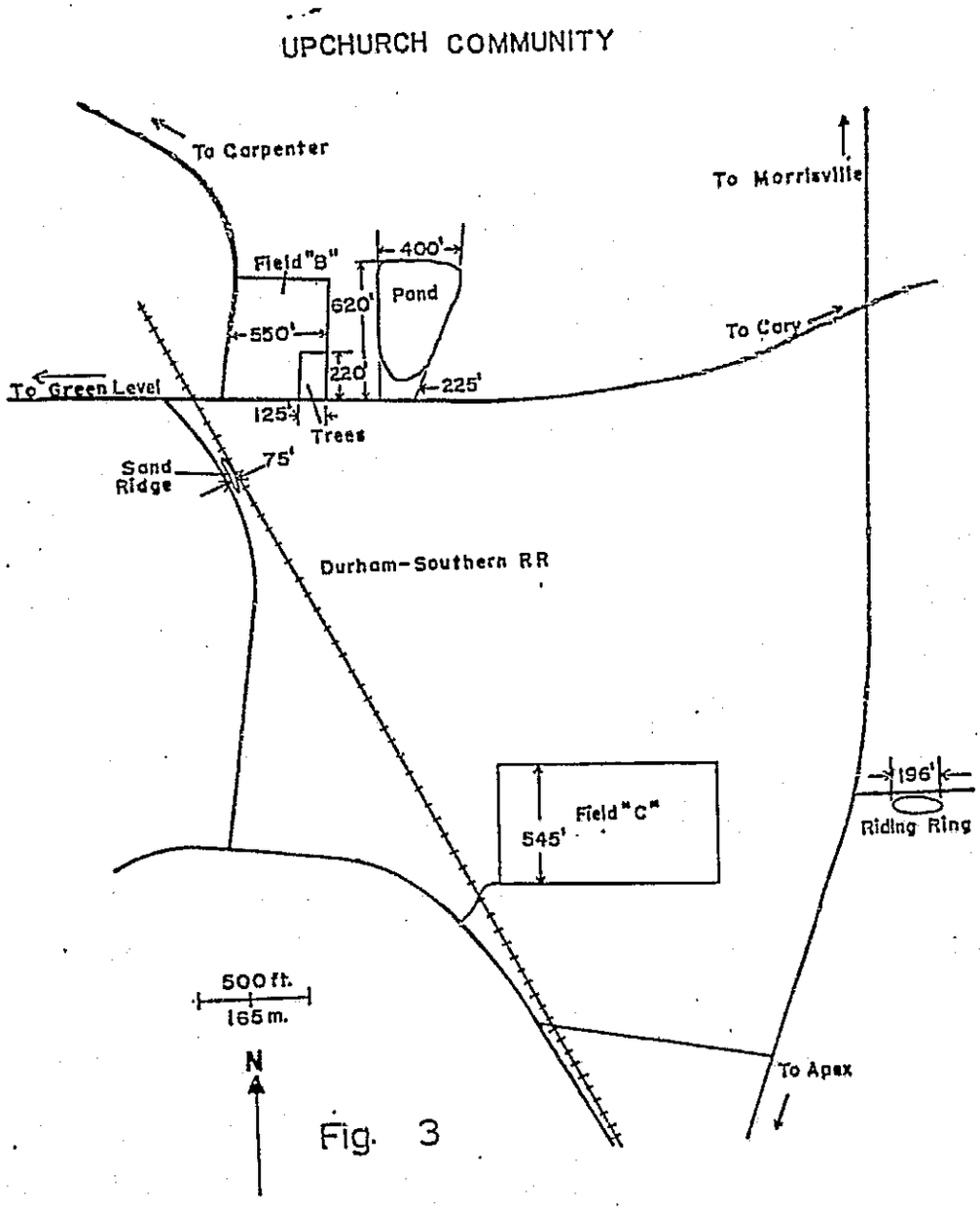


Figure 3 Upchurch Community Test Site

Given below are brief descriptions of the Upchurch sites (Fig. 3).

1. Pond near Upchurch bridge on Cary-Green Level Road.

2. Riding ring off Apex-Morrisville Road. This appears as a "hazy" oval on the photo and measures 196ft x 76ft (58m x 23m) as shown. Since soil within the ring is very much like that of adjacent unsurfaced road, contrast is not very good along the short axis of the oval.

3. Sand ridge adjacent to Durham-Southern Railroad at Upchurch bridge. This was the smallest feature recognizable. It is linear and lies between the railroad and paved road as shown on the sketch. The distance from the center of the railroad to center of the road was measured to be 75ft (22.8m). It is therefore estimated that the lower limit of resolution for the S190B material used is 50ft (15.2m). Objects of this size and smaller either fade into the grain of the photograph or repetitive measurements do not give consistent values, indicating that the features cannot be measured with acceptable accuracy.

4. Trees near Upchurch bridge. This rectangular patch of mixed hardwoods and a few scattered pines produced maximum contrast with surrounding fields. Corners on the 125ft x 220ft (38m x 67m) rectangle appeared sharp and clear but weed growth along the road ditch and field edge apparently lowered the accuracy with which the feature could be measured.

5. Field adjoining trees (above). Accuracy of measurement was better because the field was bounded by a road on one end and a hedge row on the other, rather than by trees, making it more easily distinguished than the patch of trees.

Man-made objects are easily distinguished within the limits of the resolving ability of the camera-film combination. Measurements of dimensions greater than 200 ft (61m) resulted in 5% error or less. Objects 75 ft (22.8m) on a side could easily be resolved, although accurate measurement of such features could not be made with the Bausch & Lomb Zoom 70 stereomicroscope. A finer scale on the micrometer would probably permit measurements of shorter distances.

In one field, for instance, a tree line 30 ft (9m) wide could just be detected as a dark line on the imagery. It was approximately twice the width of the scale pointer. This would explain why (even with the lowest percent error) dimensions of well-defined objects could never consistently be measured to smaller than ± 20 ft (± 6m).

Accuracy on agricultural features was not as good as for other man-made features in the 75 ft - 500 ft (22.8m - 153m) range, but at 1000 ft (305m) the percent error had decreased to nearly that of the man-made features.

In all probability, superposition of other photographic bands and color enhancement would allow the viewer to distinguish between types of vegetation and crop cover, thus greatly improving accuracy. A comparison of S190B and S190A photography revealed that the features discussed in this report could not be identified with the S190A, except on black and white photos in the .6μm to .7μm band. As was to be expected from the design parameters of the S190A and S190B, resolution was not as good nor were boundaries as sharp on the S190A transparencies as on the S190B material.

6.2.3 Scale Determination and Comparison with LANDSAT-1 Imagery

A scale check was made on S190A imagery using the B & L Zoom 70 stereomicroscope and topographic maps having a scale of 1:24,000. Comparisons were also made with the geologic map of the Denton Quadrangle (1:62,500) and a Band 6 infrared image from LANDSAT-1. Table 4 lists the frames and the respective objects measured together with a percent error calculation based on data from topographic maps and the scale data for SKYLAB and LANDSAT-1 imagery from the EROS Data Center.

Similar measurement trials in LANDSAT-1 studies in North Carolina showed errors from one to four percent (Welby, Lammi, and Carson, 1974).

The high resolution black and white film (S190A) from SKYLAB-3 gives acceptable accuracy when measurements are required. The

TABLE 4

Comparison of Measurements, SKYLAB-LANDSAT

	Object	Photo Distance	Map Distance	Scale (EROS) x 10^6	Photo Distance (ft.)	Scale x 10^6	Photo Distance (ft.)	% diff.
Roll 41 Frame 11 .6-.7μm	Length of lake (Dam to I-85)	.02280 ft.	63,500 ft.	1:2.85		1:2.7855 (calculated)		2.28
Roll 41 Frame 11 .6-.7μm	Length of Dam	.00032 ft.	875 ft.				891	1.83
LANDSAT Band 6 .7-.8μm	Distance across "Forks" of Lake	.00214 ft.	6900 ft.	1:3.369	7209	1:3.224 (calculated)		4.3
Roll 43 Frame 11 .8-.9μm	Near Flat Swamp Mtn.	.00244 ft.	6900 ft.				6796	1.50

LANDSAT (ERTS) vs SKYLAB Scale Ratio	"Accepted" (EROS)	$\frac{\text{ERTS}}{\text{SL3}}$	$\frac{3.369 \times 10^6}{2.86 \times 10^6} = 1.182$	Photo (Calculated) $\frac{\text{ERTS}}{\text{SL3}}$ $\frac{2.224 \times 10^6}{2.7855 \times 10^6} = 1.157$	2.11

1.83% difference between calculated and accepted values at the 900 ft (275m) mark is comparable to the accuracy obtained from S190B color photography which was estimated to be about 2% (Fig. 2; Table 4). Apparently, for very large objects the limiting factor in accuracy of measurement is the measuring device itself, in this case the B & L projected scale micrometer.

Finally, some of the frames from SKYLAB-3 were observed in stereo using a B & L stereoscope. Since most of the portion of North and South Carolina studied had relatively little relief (60-250 m), the only features to show elevation differences were clouds. Stereo-viewing does, however, improve the resolution by causing corners and edges of man-made and natural features to be more distinct.

6.2.4 A Guide to the Interpretation of SKYLAB Imagery of Buncombe County, North Carolina

Interpretation and use of SKYLAB imagery in mapping land use employing visual means of interpretation require the interpreter to be familiar with the reflectances of the various land uses. For this reason a descriptive guide was prepared for central and western Buncombe County. It is applicable to similar counties in the Southern Blue Ridge region. A similar county would be one which, like Buncombe County, was mountainous, underlain primarily by metamorphic rocks, was in or near North Carolina, and had approximately the same climatic conditions, and land-use patterns. The use of the guide should reduce the time required for interpreters to learn the characteristic signatures of land uses of such an area. It should also help standardize interpretations of the same areas by different interpreters. The possibility that the existence of such a guide might also increase the use of SKYLAB imagery or other space-acquired data by members of regional planning agencies who need the information was considered, and it seemed that a descriptive guide should be prepared. Particularly is this true in the case of those members of the regional

planning agencies who have not had the opportunity for a conventional photo-interpretation course or to participate in a short course on the interpretation of space-acquired imagery.

The set of photographic transparencies used in preparation of the guide is given in Table 5. They are enlargements to an approximate scale of 1:800,000 of S190A 70mm photographs taken on 10 June 1973 at 0930 EST (1430Z; SKYLAB-2).

Table 5

Photographs used for Buncombe County SKYLAB Interpretation Guide

Roll No.	Frame No.	Film Type	Wavelength (μm)
07	251	EK 2424	0.7 - 0.8
08	251	EK 2424	0.8 - 0.9
09	268	color infrared	0.5 - 0.88
10	267	color	0.4 - 0.7
11	251	Pan-X, SO-022	0.6 - 0.7
12	251	Pan-X, SO-022	0.5 - 0.6

A three-inch (75mm) by four-inch (100mm) section of the appropriate transparency, containing Buncombe County, was cut from each transparency and put in a slide mount. The transparency from Roll 10, Frame 267 was cut to fit a 35mm slide projector, and the transparency from Roll 09, Frame 268 was not cut. A grid was drawn on clear acetate and taped to the slide for reference to areas on the transparency. Slides without the grids were also used in a color additive viewer (Spectral Data Corporation, Model 66) and a grid was put on the viewer screen for reference. The French Broad River was marked on the grid system as well as on the clear acetate so that the imagery could be properly referenced.

Checking of the interpretation and the maps constructed during preparation of the guide was done from color infrared U-2 photography, NASA/MSC 128A, May 1970, Roll 19, Frame 3496, and from a limited ground check.

The descriptive guide is in three parts: one for use of the transparencies with no aid or with a magnifying glass, one for use of the transparencies with a binocular microscope at 10 x magnification, and one for use with the transparencies in the color additive viewer.

Land-use categories were taken from the Geological Survey Circular 671, A Land-Use Classification System for Use with Remote Sensor Data, by Anderson, Hardy, and Roach (1971). Level II interpretation was possible in some urban and water areas; most areas were limited to Level I interpretations. For the color additive viewer the standard setting used was as follows:

Roll No.	Wavelength (μm)	Viewer Setting
08	0.8 - 0.9	Green at 6 1/2
11	0.6 - 0.7	Green at 7 1/2
12	0.5 - 0.6	Red at 6 1/2
08	0.8 - 0.9	Negative, blue at 1 1/2

Table 1 also gives the spectral coverage of the several S190A rolls of film.

Category I: Urban and Built-up Land, Residential

A. Transparencies viewed with a magnifying glass: SKYLAB Rolls 07 and 08 do not show urban development well. A grainy texture darker than the surrounding areas shows the urban development. The dark spots within this texture are usually commercial areas. Roll 11 (0.6 - 0.7 μm) shows houses as tiny dots, often in rows along roads. Roll 12 (0.5 - 0.6 μm) shows housing also, but the film graininess interferes with the clearness of the housing patterns. Roll 10 (0.4 - 0.7 μm) shows residential areas. The contrast between the whitish-orange of houses, commercial areas or industrial areas surrounded by blue-green vegetated areas (fields) makes both the shape and pattern of the areas of construction easy to recognize. Residential areas are not easily recognized on Roll 09.

B. Transparencies Viewed with a Microscope: Residential land use could not be recognized very well on SKYLAB Rolls 07 or 08 under the microscope. This land use can be very easily interpreted on Roll 11, Frame 251 as many tiny white dots, often in rows. Density of urban development can be fairly easily determined also. Scattered patches of houses can sometimes be seen in Roll 11, Frame 251. These show as a series of white dots. The band of residential development along Highway 25 North can be picked out easily on Roll 11. However, on Roll 12, Frame 251 care must be taken to separate houses from the grain of the photograph. Roll 10, Frame 267 shows good examples of residential areas; they are best displayed as whitish-orange dots in rows, and many are seen along roads and highways. Contrast with forest land is clear on most parts of this frame. On Roll 09, Frame 267 residential areas are difficult to recognize.

C. SKYLAB Transparencies in the Color Additive Viewer: At the standard setting houses on SKYLAB material are seen as red dots arranged in a grid pattern. Clear groups of houses and yards can be seen as red spots in a matrix of green (trees). Small fields are sometimes mixed with scattered groups of houses, and the geometric patterns suggest the interpretation. High density housing areas tend to be somewhat more gray than the lower density areas.

Category II: Urban and Built-up Land, Commercial and Services, and Industry

Large commercial and industrial developments cannot usually be differentiated from one another on SKYLAB imagery. In some cases they can be tentatively identified with some degree of confidence using size and location as guides to the identification.

A. Transparencies with a Magnifying Glass: The old commercial section of Asheville shows as a dark spot on SKYLAB Rolls 07 and 08. The dark spots may be water on the roofs of the closely spaced buildings but are more probably asphalt. Less closely spaced buildings or smaller buildings are somewhat dark also.

On Roll 11, Frame 251 both commercial areas and industrial areas are white, and it is hard to separate the two types of land use. When Rolls 07 and 08 are compared with Roll 11, some of the dark areas representing commercial and industrial areas are somewhat less dark. On the other hand, some commercial and industrial areas have a bright reflectance. Roll 12, Frame 251 shows commercial and industrial areas in a manner similar to Roll 11; however, Roll 10, Frame 267 does not show commercial areas quite as well as they are shown on Rolls 11 and 12. Roll 09, Frame 268 shows paved areas which include industrial areas, commercial areas, and roads as blue spots or lines. Bare fields appear whitish to very light blue, and large areas of concrete pavement appear white on the film. Roll 09 (color infrared film) seems to be the only roll on which reflection differences between paved areas and fields could be easily recognized by the interpreter.

B. Transparencies Under the Microscope: On Rolls 07 and 08 commercial and residential areas are nearly as dark as lakes in the area. The old commercial section of Asheville shows as a pattern of white dots of varying sizes with a darker area in the middle. A large commercial or industrial unit looks like a single field on this roll. Roll 12, Frame 251 may show commercial and industrial land use effectively. On Roll 12 individual buildings are recognizable. Roll 10, Frame 267 (color film) shows commercial and industrial areas as a faint white haze if the buildings are small. On the other hand, large units are seen as white on this particular roll and frame. Orange-toned areas apparently are bare ground, such as construction sites. Outside the city orange areas are usually bare fields. Roll 09, Frame 265 shows industrial, or commercial areas in bluish tones.

C. SKYLAB Transparencies in the Color Additive Viewer: SKYLAB imagery at the standard setting in the color additive viewer shows large commercial or industrial units in white, and small one are displayed in either white or red. Large industrial areas may sometimes be mistaken for fields except that they are

isolated, and fields usually occur in groups; thus the geographic relationship of the land use has some bearing on the interpretation.

The same areas which are dark on Rolls 07 and 08 are also somewhat dark in the color additive viewer. These areas represent many closely spaced commercial buildings which have either asphalt roofs or have the area between them paved, or both. Around the darker areas are brighter, halo-like bands which seem to be characteristic of commercial and industrial areas.

Category III: Urban and Built-up Land, Extractive

One major extractive operation was mapped from the imagery. This is Grovestone Quarry in east Buncombe County.

A. Transparencies with a Magnifying Glass: The quarry plant is not visible on Rolls 07 and 08. The lakes associated with the quarry operation are discernible, and the shape of the quarry works can be interpreted reasonably accurately from Roll 11, although the quarry cannot be uniquely distinguished from other industrial operations. In Roll 09, Frame 268 the waterfilled quarry pits cannot be seen, but the quarry plant is recorded as a blue shape which cannot be identified as a quarry without other knowledge.

B. Transparencies with a Microscope: On Roll 11, Frame 251 the Grovestone Quarry works are visible as a white reflection, but they are not clearly identifiable as a quarry. The information gained from Roll 12, Frame 251 is much the same.

C. SKYLAB Transparencies in the Viewer: The combinations of SKYLAB imagery show the Grovestone Quarry generally in whitish or off-white tones. The lakes associated with the quarries are hidden by clouds.

Category IV: Urban and Built-up Land, Transportation and Utilities

A. Transparencies with a Magnifying Glass: Roads show poorly on Rolls 07 and 08 positives on the other hand, they show very well on Rolls 11 and 12. Roads appear orangish in color on the color infrared pictures taken from SKYLAB. Roll 09, Frame 268

shows the roads with bluish tones, but they are not as sharply defined as they are on Roll 10. Roads are often marked by houses along one or both sides, even when the road itself cannot be directly seen. Railroads and power lines could not be uniquely identified.

B. Transparencies with a Binocular Microscope: Highway interchanges in places where the highway widens can be seen on binocular microscopic examination of the SKYLAB imagery. The intersections show particularly well on Roll 10, Frame 267. A power line can be recognized on Roll 11, Frame 251 as a fine white line.

C. SKYLAB Transparencies in the Viewer: Large major roads appear white, and the small roads are red on the viewer screen with the standard setting. The power line is not discernible.

Category V: Urban and Built-up Land, Open and Other

A. Transparencies with a Magnifying Glass: A golf course shows as a bright spot on all near-infrared bands, showing particularly well on Rolls 07 and 08. The golf course is not recognizable on Roll 11, Frame 251 because of the overall high film density and lack of scene contrast of the picture used. It shows as a spot slightly lighter than the surrounding areas and possesses very fine texture on Roll 12, Frame 251. The golf course also shows as a light blue-green spot on Roll 10, Frame 267, and it may be recognized clearly as a medium-to-fine-textured light red spot on Roll 09, Frame 268.

B. Transparencies with a Microscope: The golf course is seen as an area with a density of black dots lower than that of the surrounding area on Rolls 07 and 08 of the SKYLAB photography. It cannot be recognized on Roll 11, Frame 251, but it may be recognized on Roll 12, Frame 251. It appears as a light red spot on Roll 09, Frame 268.

C. SKYLAB Transparencies in the Viewer: Open urban land does not show well on black and white SKYLAB material in the color

additive viewer. The golf course is seen as reddish green and slightly lighter than the surrounding land.

Category VI: Agricultural Land

Agricultural land is seen in two contexts on the SKYLAB imagery of the Asheville area: that of many small-to medium-sized fields in the Asheville basin in north and northwest Buncombe County and that of isolated clusters of large fields of generally undeveloped land in southern Buncombe County. The northern fields can generally be identified by their size, shape, and number. On the other hand, the southern fields can be mistaken for industrial areas because of their size and a similarity in reflectance. However, the fields can generally be identified on the basis of their close spacing, conformance to a contour pattern, conformance to a road between two of the, and by their clustering in groups. In contrast, an industrial complex is usually isolated. Areas with scattered fields or houses are sometimes difficult to separate from agricultural land.

A. Transparencies with a Magnifying Glass: Rolls 07 and 08 of SKYLAB do not show the agricultural areas clearly, but on the other hand Rolls 11 and 12 show them with clarity. The shape of fields approximately 10 acres in size can be determined. Roll 12, Frame 251 appears to show more detail than the material from Roll 12, but it has less contrast than other films. Large, closely spaced fields in the southern part of Buncombe County can be seen very well on Rolls 11 and 12. Roll 10, Frame 267 shows agricultural areas clearly. Bare fields appear with an orangish tint; covered fields appear in green; patches of trees appear in blue-green tones. Farms show as different intensities of white on a red background on Roll 09, Frame 268. Color as well as arrangement helps to separate fields and industry in this frame. The fields appear whitish in many cases, and industrial areas appear in bluish tones.

B. Transparencies with a Microscope: Outlines of individual fields are readily seen. Topographic placement and position with respect to roads aid in separating agricultural areas from

industrial complexes. Most agricultural land follows the topographic contours. Changes from agricultural areas to residential areas in Buncombe County can be spotted by the changes in gray. On Roll 09, Frame 268 the residential areas do not appear to be easily distinguished.

C. SKYLAB Transparencies in the Viewer: Agricultural areas on SKYLAB imagery used in this exercise appear in some cases as white areas, representing large bare fields. In other instances they are reddish. The pattern of reflectances provides a clue as to whether fields are present or whether the reflectance is coming from some industrial or commercial development. Fields are generally very close together in a patchwork pattern. In contrast, the isolated occurrence of large white rectangles usually indicates the presence of industrial or commercial complexes; on the other hand, fields set within a residential area, such as at Warren Wilson College, an agricultural school, may be recognized on the basis of the combination of geometric pattern and whitish to reddish tones on the screen of the color additive viewer.

Category VII: Forest Land

A. Transparencies with a Magnifying Glass: Forest land was studied in two settings. Where there is mountain topography, the texture in forested areas is very smooth, but reflectance may be either medium or low (medium-to dark-gray on the black and white transparencies). In the topographically lower places wooded areas tend to show a very smooth texture and in general a low reflectance (dark-gray in the black and white transparencies). Forested areas are not sharply defined on Rolls 07 and 08 of the S190A material. Roll 11, Frame 251 has such a high contrast that some small, low density residential or agricultural areas are not well displayed, and these areas resemble forested areas. Roll 12, Frame 251 permits separation of the forested land from farms and low density residential areas. The forests are darker-toned. Roll 10, Frame

267 (color) shows the forested areas in blue-green or orange, and on Roll 09, Frame 268 the forests are a prominent red.

B. Transparencies with a Microscope: Forests are generally recognizable without a microscope, but the use of it shows patches of woods in the farm land and also helps the interpreter to pick out isolated houses and farms. Isolated houses and farms may be seen well both on Roll 11, Frame 251 and on Roll 12, Frame 251, and patches of trees and farms are also well displayed on Roll 12, Frame 251. Blue-green coloration gives clues to patches of trees on Roll 10, Frame 267.

C. SKYLAB Transparencies in the Viewer: The use of the color additive viewer did not improve the ease of interpretation of the forest lands. On the other hand, some differences could be brought out by changing the settings on the dials, and if a detailed analysis of the forested areas were being made, the color additive viewer would certainly be a useful tool.

Category IX: Water

A. Transparencies with a Magnifying Glass: Water bodies appear dark on Rolls 07 and 08 of the SKYLAB imagery; it is particularly easy to differentiate rivers and some of the lakes in the Buncombe County area from surrounding land uses.

B. Transparencies with a Microscope: On SKYLAB Rolls 07 and 08 water is seen as a fairly sharp-edged, dense cluster of black dots. Because of the partial cloud cover care must be exercised to avoid misinterpreting cloud shadows for water. The location of clouds on Rolls 11 or 12 aids in separating shadow from water bodies. Also topographic shadows sometimes confuse the picture (Photographs were made at 0930 EST). Water is not particularly well shown on Roll 10, Frame 267. Shallow lakes are lighter toned than undeveloped land in many cases, and on Roll 07, Frame 268 the water is black.

C. SKYLAB Transparencies in the Viewer: At the standard setting for the SKYLAB imagery in the color additive viewer Lake Ashnoca in Buncombe County appears red. This coloration can be compared with the Beech Tree Reservoir which shows less red and with the Asheville Reservoir, which is dark blue. The red is thought to record sediment in the lakes. Both red lakes lie near areas of high-to medium-density residential developments.

By manipulating the color additive viewer, one may separate cloud shadows and lakes. For example, starting from the standard setting in the viewer, the interpreter can turn down all the lights except the light behind Roll 08, leaving the scene from Roll 08 with a green filter. From this arrangement all the dark spots may be identified. Then the light behind Roll 12 may be turned up with a red filter in the system. The clouds will show in red, and the shadows will remain dark. The relative position of the cloud shadow to the cloud will indicate which dark area is actually water and which is cloud shadow.

6.2.5 Use of S190A Data for Quarry Monitoring

SKYLAB S190A 70 mm imagery was evaluated as a tool for monitoring quarry operations, specifically two of the Becker Sand and Gravel operations near Lillington, North Carolina. Of particular interest was potential use of the S190A transparencies to distinguish:

1. Quarry size, shape, and contrast with surrounding vegetation.
2. Location and relative size of water bodies in and around the quarries and the effect of the operation on the Cape Fear River.
3. Types of vegetation within and bordering the quarries.
4. Workings within the pits.
5. Resolution of the smallest measurable features.

Three photographic bands were used in this study: aerial color (0.4 - 0.7 μm), color infrared (0.5 - 0.88μm) and black and white in the 0.6μm - 0.7μm band. The SDC Model 66 Color Additive

Viewer was used to enhance certain features and to aid in mapping the quarries through its enlargement capabilities. Substantiation of the interpretations was made by a site visit. Frame 110 of Rolls 43-47 was used as was Frame 118 of Roll 41 (0.5 - 0.6 μm). All were taken in September 1973 (Table 1).

The two quarries chosen for this investigation will hereafter be referred to as Quarry 1 and Quarry 2 (Fig. 4). Both offered excellent contrast with surrounding culture since the sand and gravel beds gave high reflectance in all three bands. As the maps show, both quarries are nearly the same size with Quarry 2 being only slightly larger.

Both pits are bounded by heavily forested areas: Quarry 1 by a mixture of hardwoods and pines and Quarry 2 almost entirely by pines. At both sites the vegetation in the interior (reclaimed) portion of the operation was pine-dominant since pines were used extensively in reseeding programs. These vegetational characteristics are readily observed, particularly with the aid of the color additive viewer. The color infrared band combined with the 0.6 - 0.7μm band produces a striking difference between hardwoods and pines. The hardwoods are expressed as bright red when white light is passed through the color infrared transparency and a red filter is placed between the 0.6 - 0.7 μm band transparency and the viewing screen. The pines are expressed as a deep purple color. As mixtures of the two grade into hardwood-dominant forests, the imagery shows a change from reddish hues to reddish-purple hues. No attempt was made, however, to obtain exact percentages of tree types either by ground observations or from photographic interpretation. The objective of the study was concerned primarily with general distribution and zones or lines of contact between the two vegetative types and between and vegetation and the quarries.

Water bodies are easily distinguishable in all three bands. Measurements are best done on individual photographs since superposition of the three transparencies in the color additive viewer system tends to mask or blur the details of one band with those

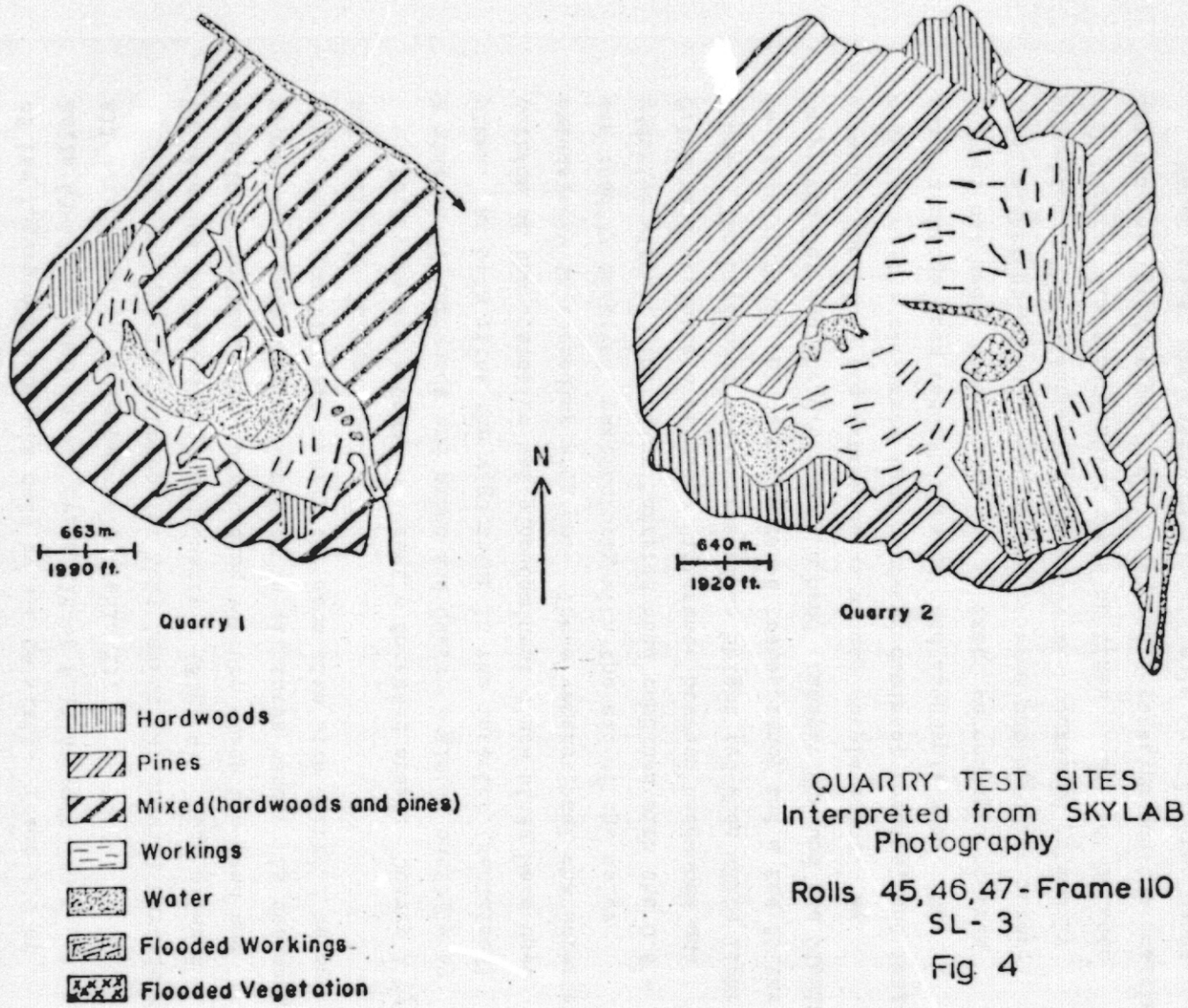


Fig. 4 Quarry Test Sites near Lillington, North Carolina

of another. However, in developing contrast between features or for extracting, in particular, water and vegetative cover, the color additive viewer proves to be an invaluable tool. For example, boundary distinction is not as sharp on the color infrared film as on the black and white, yet on color infrared pictures the bluish-purple color of water makesits distinction from surrounding terrain easier than with use of the black and white infrared bands alone.

Shapes as well as relative depths of holding ponds can also be determined. The aerial color band portrays water in shades of greenish-blue, the lighter shades correspond to shallow water and the darker shades to deeper water. In many places, flooded workings and sediment-laden ponds are only two or three feet deep. Elsewhere, especially in the older excavations of Quarry 2, the water between piles of clay and sand overburden was estimated by a Becker employee to be 10 to 20 feet deep.

Frame 118 from Roll 41 and Frame 110 from Roll 47 show bright reflectances in the Cape Fear River in the vicinity of the discharge stream from Quarry 1. This fact seems to indicate that sediment was entering the Cape Fear from the quarry and/or nearby upstream tributaries at the time of the SKYLAB overflight. Obviously, this assumption could not be verified 18 months later, but it should be pointed out that laws regarding discharge of sediment from quarries have been strengthened since September 1973.

The approximate width of the stream is 100 feet (30.5m), the actual width of the water probably being less. The size of the stream is such that its presence can be recognized, but accurate measurements cannot be made of it on the S190A imagery. Nonetheless, the sediment load entering the Cape Fear River from the stream can be detected on the color infrared film.

It appears that imagery of the resolution of the SKYLAB S190A color infrared film could aid in monitoring sediment discharge from current or abandoned quarry operations and from exposed areas where the receiving waters are about 200 feet (61m) wide. Timely

return of the data to potential users, such as enforcement agencies, would be important requisite of the system.

6.2.5.1 Mining Operations and Imagery Resolution: After the removal of a thin clay overburden (approximately 5 feet (1.5m) thick) the dragging operation excavates sand and gravel beds to a depth of a few tens of feet. Groundwater and surface water must be continually pumped from the regions of active mining until the deposit is exhausted. Then as the operation moves to other locations, water fills the old workings. The photographs clearly show the pattern of the workings and the flooded parts of the excavations.

Several measurements were made on the imagery with the B & L Zoom 70 stereomicroscope and were used in conjunction with the scale furnished with the imagery. Water bodies and other terrian features on the order of 200 ft (61m) in width could easily be resolved and measured, particularly in the black and white 0.6μm to 0.7μm band. Smaller water bodies, 140 to 150 feet (43m - 47m) across, could be recognized but not measured accurately.

The Cape Fear River was measured at the quarries from the imagery and was found to have a width of 441 feet (135m); the width of the river was measured at the U. S. 401 bridge near Lillington also, and the width was determined to be the same as at the quarries. The North Carolina Department of Transportation Engineering files show that the river is 370 ft (113m) wide at this point. Work on scale and resolution described earlier (Fig. 2) indicates an interpretation accuracy of the order of 95 percent for a feature that is determined to be 440 ft (134m) wide on the imagery. The reason for the discrepancy between the values for the river width at Lillington remain unknown. The most plausible explanation appears to be that the Department of Transportation figure is based upon the main channel width, whereas the SKYLAB measurements were based upon the flood plain width.

It appears possible to monitor quarry operations and reclamation efforts in sand and gravel quarries of the size described in this report. Repetitive coverage might be useful if made on a quarterly, semi-annual, or annual basis. The imagery could conceivably be useful for monitoring vegetational changes in and around the quarry site and for obtaining data on the size of standing water bodies associated with the quarries.

Interpretation can be done with relatively unsophisticated and inexpensive equipment. The results obtained with the color additive viewer are possible in almost any laboratory through use of relatively inexpensive projection equipment, provided one has access to the imagery. Two or three slide projectors, a screen, binocular microscope, and suitable filters should enable one to reproduce any number of superimposed color combinations. Alignment of projected images will in all likelihood be the major problem encountered. Regional land-use planning and monitoring could then be accomplished over a fairly large area at relatively low cost by an interested group or individual.

7.0 FORESTRY INVESTIGATION

7.1 Introduction

The kinds of information foresters require of remote sensing include: (1) overall view of the forested areas: their extent, location and relationship to other land uses; (2) the density of the forest; (3) the kind of forest, i.e., coniferous, broadleaved, or mixed; (4) changes taking place such as harvesting, regeneration, encroachment by other land uses or change from forest to other use; (5) hazards to which forests are exposed, particularly the signs of fire damage and the location of insect and disease attacks. In addition to the foregoing the remote-sensed imagery and photography is looked upon as (6) a source of important information about urban forest developments and changes.

SKYLAB photography holds an intermediate place between LANDSAT imagery and high altitude aircraft photography. The high altitude photographs (20,000 meters) provide a rather favorable and easily acceptable format for remote sensing data. These photographs are as easily interpreted with mirror stereoscopes as are normal altitude photos, and, at the same time, they show an expanse of the earth's surface approaching a synoptic view. SKYLAB photographs are somewhat more difficult to interpret, do not show as much detail as the high altitude photographs, but they provide a much larger field of view.

For synoptic views requiring considerable ground detail the SKYLAB photography is excellent. It can be easily used by forestry photo-interpreters using the commonly available interpretation equipment and methodology, in contrast to LANDSAT-1 imagery which requires special laboratory and interpretation techniques.

The SKYLAB photo show: (1) overall views, (2) vegetation densities, (3) kind of forest only occasionally and inadequately, (4) changes within the forest to a limited extent, (5) hazards only ex post facto and if the damaged area is large, (6) considerable detail on urban forest situations.

7.2 Interpretative Studies

Studies of stereopairs and single frames of S190A and S190B SKYLAB photographs show results which are summarized in the following.

7.2.1 Stereostudies with the B & L Zoom 70 Stereomicroscope:

High Resolution Color 70 mm stereopair Roll 40, Frames 117 and 118 (Table 1) from the S190A experiment were used for this study. Urban forest cover densities can be easily seen and mapped into some gross density classes. Forest clearings, two-way roads, and kinds of land use can be identified. Newly bulldozed soil is a particularly noticeable feature on the photography.

The 4.5-inch frames 292 and 293 from Roll 86 (High Resolution Color Film) from the S190B camera permitted forest density classification to be carried out both in rural and urban areas. Forest tree seed orchards are clearly visible and distinguishable by different age classes on the basis of the amount of crown closure. Species (forest type) classification could not be carried out with any consistency - the interpretable differences (color and form) between species and types are only occasionally present on the photographs.

7.2.2 Stereostudies with the Wild Mirror Stereoscope at 3x Magnification

Nine-inch enlargements of the several frames from both S190A and S190B at scales of approximately 1:725,000 and 1:475,000, respectively, were used.

The High Resolution Color stereopair, Frames 110 and 111 from Roll 46 (S190A) provided a good example of the phenomenon of optical enhancement of photographic detail through stereoviewing. Trees, timber stands, vegetative cover type boundaries, and similar phenomena are more easily identified when viewed by stereoscopic means than without it.

Stereoviewing of SKYLAB photography of the Piedmont provides no clearly visible three-dimensional terrain detail. Clouds, however, do show in three dimensions. The main advantage of stereoviewing is, therefore, the optical enhancement described above.

Conifers and broadleaved trees and stands could not be differentiated on the stereopair, Frames 117 and 118 from Roll 40 (S190A). Newly disturbed soil shows in shades of brown on these photographs.

The best resolution of all stereopairs that were studied was found on Roll 86, Frame 292 and Frame 293 (S190B). Some faint differentiation of conifer and broadleaved stands was observed. Newly disturbed soil showed as a reddish-brown area.

Color infrared photography proved better for differentiating tree species (forest types) than did the color photography. The graininess, however, interfered greatly with the delineation of forest type boundaries. Open earth areas show as white patches. The stereopair Frames 117 and 118, Roll 39 (S190A) were used in this study.

7.2.3 Single frame studies with the B & L Zoom 70 microscope: This microscope is convertible to a stereoscope by replacing the objective lens with a rhomboid assembly. As a microscope useful for viewing single frames of SKYLAB photography the lens combinations and magnifications given in Table 6 were used.

Table 6

Lens Combination and Magnifications - B & L Zoom 70 Microscope

Eyepiece	Objective Lens	Magnification
10 x	0.5 x	3.5 x to 15 x
20 x	0.5 x	7 x to 30 x
10 x	2.0 x	14 x to 60 x
20 x	2.0 x	28 x to 120 x

The 4.5-inch High Resolution Color film was studied at various magnifications with the above-described instrument. The nine-inch photographs were not adaptable to the small power pod of this instrument and were therefore used in the Zoom Transferscope (See below).

Frame 150, Roll 88 (S190B) did not reveal any forestry information not available from the ZTS studies. Relative densities of urban forest cover were easily seen.

7.2.4 Single frame analyses with the B & L Zoom transferscope (ZTS)

The ZTS has a zoom magnification of up to 14x. SKYLAB photographs were studied at various magnifications as described earlier in the section entitled Scale and Resolution (6.2).

Relative densities of both rural and urban forest could be mapped on the transparencies of Frame 150, Roll 88 (High Resolution Color, S190B). The classes of forest cover density could be classified as complete, good, poor, and treeless. (See 7.3.2) Further detail within these classes was also mappable. Tree species or classes (conifers, braodleaved, mixed) could not be seen on this photograph. Open soils could be distinguished on the basis of differences in color tones. Several different land uses could be mapped.

7.2.5 Conclusion

SKYLAB-type of photography can be a good source of forestry information. The fact that the program was a transitory, "one-shot," affair made it less interesting to practicing foresters than a continuing program would be. If the same scale and resolution could be made available in recurring satellite imagery or photography, it would attract favorable attention and would be used by many. A dependable source of good information would also provoke action to get equipment and personnel for its utilization.

7.3 Greenspace Studies

7.3.1 Introduction

Greenspace is defined as land covered with some form of vegetation: grass, shrubs, or trees. Urban planners are concerned with greenspace: how to protect and manage what a city now has and to get more where and when needed.

Urban green space is often an amenity that is retrograding. City development tends to engulf most of it with buildings and parking areas. The few areas that escape the initial onslaught linger only long enough to get the attention of the developers of transportation and utilities.

One of the important uses of green space is for air pollution control. Other important uses are for recreation, esthetics, and water regime regulation. For all these purposes the critical attributes of green space are its size, orientation, distribution, location, and vegetational character but not necessarily in that order.

The objective of the SKYLAB greenspace studies was to determine the ways in which the orbital photography could be helpful to urban planners and managers. The test site was the City of Raleigh, North Carolina, for which several sets of SKYLAB photos were available. These photos were supplemented by a high altitude underflight, Flight 73-157, 15 September 1973.

Greenspace research planning and management activities of the Raleigh area are using remote sensing information. However, conventional aerial photographs and the high altitude flight mentioned above are the primary data sources. LANDSAT-1 imagery has been too small-scale to be attractive for most operational uses, and SKYLAB photography has the discouraging characteristic of limited coverage in space and time, thus being useful to only a few users.

7.3.2 Information available from SKYLAB photography

The best SKYLAB photo was the nine-inch color transparency enlargement of Frame 150, Roll 88 (S190B) with an approximate photoscale reciprocal (PSR) of 457,600. The best mapping scale was about PSR 61,800 (7.4x magnification on a B & L zoom transferscope). The visible details related to greenspace on this photograph included:

1. Recently exposed soil
2. Golf courses
3. Urban-rural land boundaries
4. Parking lots
5. Industrial-commercial areas
6. Wooded urban areas by density of forest cover
7. Recently developed vs. older residential areas
8. Individual houses and the greenspace around them

The SKYLAB photography permits a photo-interpreter to observe the entire city and its environs plus details down to streets, individual houses, and park areas the size of city blocks. Land use, vegetative cover, and even the relative beauty and ugliness of the urban landscape can be seen or inferred from the photographs. The proximity and encroachment of commercial-industrial development into good quality residential areas, the tendency of many new residential developments to become open, bulldozed biological deserts are examples of the environmental quality problems visible in SKYLAB photography.

Urban tree cover, an important vegetation in greenspace, can be mapped from SKYLAB photography to provide an indication of the environmental quality of the neighborhood. A general classification useful for this purpose could have four classes: (1) complete, (2) good, (3) poor, and (4) treeless.

The complete tree cover indicates an area that has had only a minor amount of current developmental disturbance. Many of the land units in this class are abandoned farmlands now grown up in coniferous forest. The complete tree cover class usually occurs outside the urban area boundary but some patches are interspersed with other urban land uses.

The good class of urban tree cover is often an indication of high quality older residential areas. In these areas much of the original forest was preserved by environmentally conscious builders and developers. The original tree cover has then been enhanced and thickened by additional planting, fertilizing and arboriculture. The good class of tree cover appears in some suburban areas of fairly recent vintage but is seldom seen in rural areas. In the latter the tree cover is usually complete, poor, or treeless.

The poor class is the most prevalent urban forest cover in the area of this study: Raleigh, North Carolina. The poor cover appears because developers and builders decimate the tree cover on both low-income and middle-income developments. Even the more

exclusive residential areas will show poor cover because of street construction, and carelessness in protecting the vegetation on residential lots.

SKYLAB photography often shows similar reflectivity for poor tree cover and nearby cropland. The difference will be indicated for urban areas by the existence of street patterns, whereas rural areas will show no street construction.

Treeless areas appear on the photography as bright, light-gray spots. They are usually industrial-commercial, central business district, institutional, transportation (parking, airports, etc.) or rock quarries.

An urban greenspace planner and manager can utilize SKYLAB photography in several ways:

1. Identify with considerable precision the boundary between urban and rural land.
2. Reconnoiter the urban and adjacent rural land for problem areas such as environment-destroying developments, conflicts in land uses, and possible needs for greenspace to balance its lack in commercial-industrial or residential areas.
3. Contemplate expected urban sprawl, direction of development or intensification of land use, and the accompanying greenspace availabilities and needs.
4. Give special attention to the effect of transportation and utilities construction on greenspace. Small patches and strips of urban greenspace are "low cost" rights-of-way possibilities. Therefore, they are particularly vulnerable to destruction, yet they are increasingly rare and socially valuable for greenspace uses.
5. Observe the location and size of possible greenspace acquisition and reservation; i.e., to answer the question, "Are the possible areas suitably located

and large enough for ecosystem forests (for environmental protection, water control, for example), for community parks, neighborhood parks, miniparks, streetside greenstrips, or other uses?"

6. Relate the SKYLAB photographic studies of greenspace to existing urban planning which may be based primarily on other data sources. The orbital photography can show gaps and problems in the greenspace plans, thus directing attention to plan revision and to ground studies.
7. Utilize SKYLAB photography, usually in an enlarged format, to provide public relations, intra- and intergovernmental communications and research materials.

7.3.3 General Conclusions

The SKYLAB orbital photography serves many, perhaps most, of the data-supply functions of aerial photography. It has, in addition, many of the desirable synoptic qualities of LANDSAT imagery. For urban greenspace planning, management, and research, SKYLAB photos lack only some of the close-up detail, and, obviously, are available only once and only for limited areas of the state.

8.0 GEOLOGIC APPLICATIONS

In addition to the discussions which follow, there is a discussion of the geologic information contained on SKYLAB-2 photographs in Section 10.4.1.

8.1 Study of the Broad and Catawba River Basins, South Carolina

8.1.1 Introduction

A detailed study of the Broad and Catawba River region of South Carolina was conducted to ascertain the capability of SKYLAB

imagery as a tool for geologic mapping in a heavily vegetated area of the Piedmont. Although strictly speaking it was outside the test area, it was chosen because of the cloud-free nature of the photography and because of the similarity of the geology to the geology of parts of the North Carolina Piedmont. Nearly all photographs of this locality are of excellent quality and very little cloud cover was present on either the S190A or S190B transparencies. Table 6 lists the materials used in the study, and Table 1 the parts of the spectrum covered by the several film rolls.

This area was chosen for investigation because (1) the Fall Line, the boundary between the Piedmont and Coastal Plain provinces, passes through it; (2) there is a wide variety of metamorphic and igneous rocks in the Piedmont including numerous dikes near Rock Hill; (3) cloud cover was absent over most of the region; and (4) the topographic character, the sediment load, erosion patterns, and cultural significance of the rivers and lakes could be studied and compared with recent topographic and geologic maps of the area.

Interpretation of the photographs used both the 9-inch black and white negative enlargements of the S190A rolls in addition to the 9-inch color infrared and black and white positives (approximate scale of enlargements = 1:800,000). The negatives seemed to give better contrast between topographic features.

TABLE 7

Imagery Used in Study of Broad and Catawba River Basins

	Rolls	Frames	Date
S190A	37-42	112-115	12 September 1973
	43-48	106-108	17 September 1973
S190B	86	288	12 September 1973
	88	148	17 September 1973

8.1.2 Geologic Interpretation

A total of four acetate overlays were prepared from the S190A imagery by using the color additive viewer (4x enlargement) and the 9-inch enlargements as described below:

1. 9-inch black and white negative enlargement of Roll 41 (0.6-0.7μm), Frame 114.
2. 4x enlargement in the color additive viewer, into which had been placed the 70mm transparencies of Frame 114 from Rolls 41 and 39. These frames are black and white positives of the 0.6 - 0.7μm portion of the spectrum and color infrared, respectively. This combination was chosen because it seems to emphasize the 0.6-0.7μm portion of the spectrum as recorded on the photographs. The additive enhancement of the color infrared photograph with the black and white infrared band through the color additive viewer made some of the lineaments more distinct than otherwise.
3. 9-inch enlargement of Roll 39, Frame 114 (color infrared).
4. A composite of the above three overlays.

The final product (Overlay #4) was subsequently enlarged using an overhead projector until the scale of 1:250,000 was attained. This is the same scale as the Geologic Map of the Crystalline Rocks of South Carolina (Overstreet and Bell, 1965); hence, the overlay could be superimposed with little error onto the map.

8.1.2.1 Content of overlays: Preparation of the overlays was based upon traces of lineaments and other natural trends, particularly those which showed high vegetative reflectance. Stream drainage patterns were likewise given careful attention, but every effort was made to avoid tracing roads unless they followed some natural feature.

8.1.2.2 Discussion: Study and comparison of the "lineament" map with the Geologic Map of the Crystalline Rocks of South Carolina (Overstreet and Bell, 1965) leads to the following conclusions. SKYLAB imagery of densely forested areas is generally an unreliable tool for geologic mapping. The completed lineament map was essentially one of the drainage pattern of the area. In only two cases were geologic structures or geologic contacts discovered which did not coincide with a stream or river valley; however, one was closely paralleled by a road which may well have served to bias the interpretation. The other was noted at Lake Murray, approximately 15 miles northwest of Columbia, South Carolina.

Lush, leafy foliage gives very high reflectance in the color infrared band as bright red. Since this vegetation type exists in moist low-lying regions of the humid climate of the South Carolina and North Carolina Piedmont, reddish hues appeared along all major streams. On the black and white photographs these same features appear as dark areas. Therefore, the photograph records vegetation coinciding with the topographic drainage network.

In order for SKYLAB imagery in the visible and infrared bands to be a successful geologic mapping device the geology of the area in question must be expressed in some definite way through vegetation patterns or topographic characters of the landscape. In the case of a lineament found in Lake Murray and adjacent areas a string of islands and peninsulas extends across the central and northwestern shores of the lake. These islands are parallel to both the local foliation and the strike of argillite beds which comprise the country rock.

8.1.3 Isoluminous Investigation of Plutons

Portions of Frame 114, Rolls 38, 41, and 42 were enlarged and used in an isoluminous study of a circular outcrop of Permian(?) coarse-grained granite just north of Columbia, South Carolina. The isoluminous technique is one in which the original imagery is

photographically stretched and then masked so that subtle color differences may be brought out. The technique is adequately described in Wenderoth, Yost, Kalia and Anderson (1974). A similar domal structure of granite which bordered the coastal plain near Wateree Pond was studied in all available bands, though without the isoluminous treatment. In both instances the imagery did not record the geology in a definitive manner.

8.2 High Rock Lake Area, North Carolina

High Rock Lake is located in the western Piedmont of North Carolina, between Lexington and Salisbury (Fig. 1). Geologically the area is underlain by Ordovician metamorphic rocks which have been folded, faulted, and intruded by Triassic diabase dikes. There is abundant rock cleavage and jointing, and all these structures, together with bedding planes, exert strong control over the topographic form in the region and the drainage patterns in the lake basin. A major shear zone exists between the Gold Hill and Silver Hill faults, an area 1-1/2 miles (2.4 km) wide and several tens of miles long.

The study was conducted using S190A data, Rolls 37-42, Frame 115, Rolls 43-48, Frames 108 and 109. Interpretation of S190B data was made on Frame 290, Roll 86.

8.2.1 Preparation of Maps

The original 70mm S109A imagery (Roll 43, 0.7-0.8μm, Frame 109) was projected from the color additive viewer to an enlargement of approximately 20x. Resolution was good for the purposes of this investigation even at this magnification. Features on the order of 200 ft (61m) across could be recognized, and one small island 600 ft x 800 ft (183m x 244m) was clearly identifiable and could readily be traced. A lineament map, which might best be described as an arrangment of "straight lines of best fit," was produced for both the lake and the region immediately surrounding it. Comparisons were subsequently made with available topographic and geologic

maps (Stromquist, et al, 1971; Stromquist and Sundelius, 1974) of the lake area. Acetate transparencies originally traced were projected and enlarged so as to coincide with the scale of these published maps.

8.2.2 Discussion

High Rock Lake is characterized by angular offsets of its extensions and tributaries. With only one or two exceptions these topographic expressions could be accounted for by geologic structure shown on geologic maps of the Denton, Salisbury, Southmont, Rockwell, and Gold Hill quadrangles (Stromquist, et al, 1971; Stromquist and Sundelius, 1974).

Two lineament maps were prepared for the region. One was a lineament map of the straight line segments of the lake, and the second described lineaments of the area adjacent to the lake, particularly west of the lake.

Sixty lineaments which extended in all directions from the lake were mapped. Using the available maps and Roll 86, Frame 290 of SKYLAB S190B for verification, the interpreter found the following breakdown of the lineaments:

a) 24 lineaments followed streams and major rivers closely.
b) 29 followed a number of other cultural and vegetative features, such as tree lines, road segments, and fields.
c) One lineament coincided with a rather steep cliff on the campus of Catawba College near the floodplain of Grant's Creek.
d) Six lineaments were obscured by clouds, but according to the maps they were not significant indicators of either topography or geology.

Vegetation patterns did not relate significantly to the geology. Only the lake and major streams with their prominent offsets could be positively and directly related to the geologic structure of their surroundings. Lineaments away from the lake were randomly oriented and bore no observable relationship to the structures at the lake.

A field check of the High Rock Lake area was performed on 8-9 July 1975, beginning north of I-85 in the Grant's Creek area and extending southward and eastward. Twenty-five of the lineaments were examined in the field. Many of the lineaments proved to be vegetative boundaries such as pine thickets within hardwoods. However, six lineaments of the 25 were expressed topographically, being along floodplain boundaries and stream valleys.

For another part of the study area topographic maps were examined. It was found that 16 out of 60 lineaments (27%) followed topographic features of the landscape. This percentage is approximately the same as for the area in which the lineaments were field checked. Three of the 16 paralleled inferred faults found on the geologic map (Stromquist and Sundelius, 1974), and one followed a geologic contact.

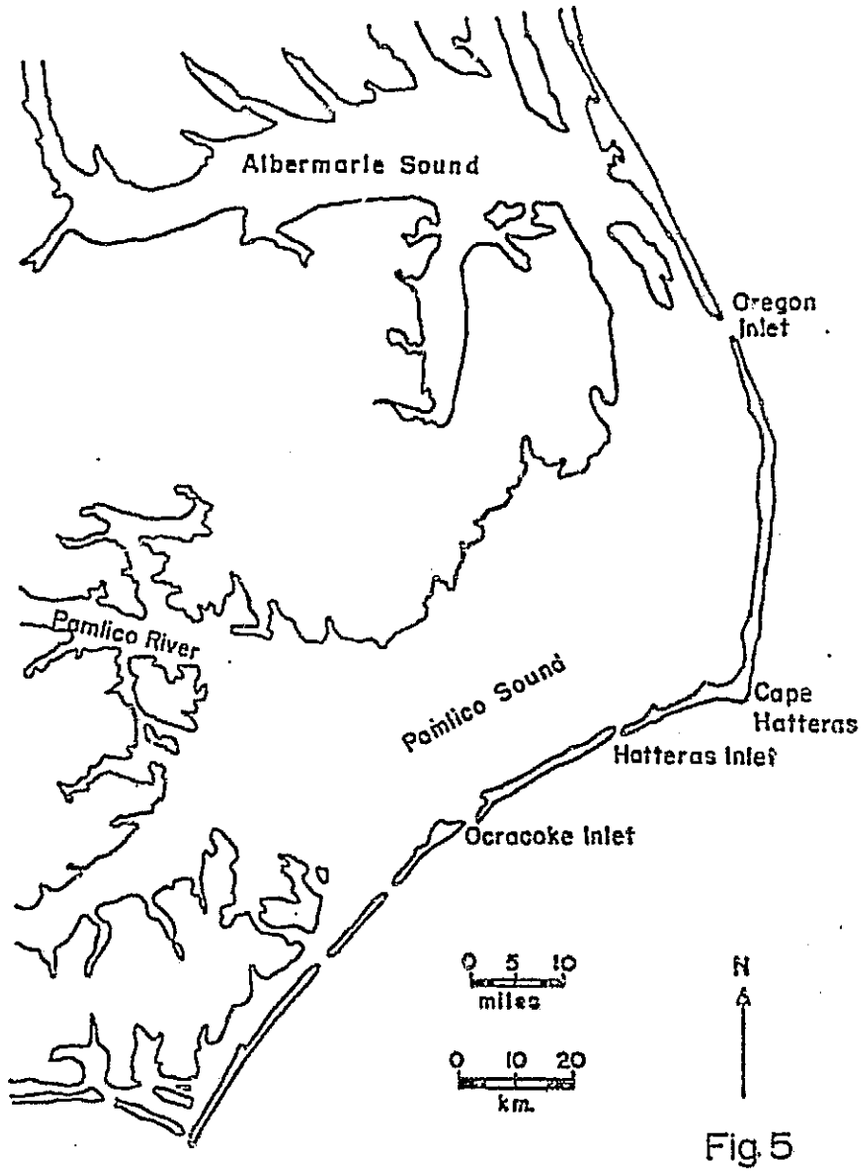
When lineaments are mapped in heavily vegetated areas of the North Carolina Piedmont, probably between one-quarter to one-half of them will be found to follow geologic or geomorphologic features and the rest vegetation boundaries and other culture. If one is familiar with the geography of the area of study this ratio may be improved in favor of geologic implications.

Roll 39 (Color Infrared), Frame 115 from SKYLAB-3 indicates a linear trend parallel to the Gold Hill Fault southwest of High Rock Lake. The several LANDSAT-1 images covering this ares show subtly the Gold Hill Fault Shear Zone.

8.3 Coastal Inlet Study

Three of the tidal inlets cutting the Outer Banks of coastal North Carolina are recorded on pictures made in conjunction with the S190A experiment (Fig. 5). They are Oregon Inlet, Hatteras Inlet, and Ocracoke Inlet, and they may be viewed on Frames 29 and 31, Rolls 25 to 30.

Questions arise in study of the SKYLAB material: "To what practical use may the imagery be placed in managing the inlets or in aiding ongoing studies of them? How could photography



North Carolina Outer Banks

Figure 5 North Carolina Outer Banks Map

from space or images from scanning devices on orbiting satellites improve on scientific studies of inlets similar to those through the Outer Banks? Can the limitations of the relatively low resolution of the SKYLAB photographs be overcome, or conversely can the synoptic view afforded by the imagery provide information which offsets the problems associated with low resolution?" In the final analysis the basic question is, "How can the imagery be utilized in studying and monitoring inlets through barrier islands?"

Although the North Carolina inlets are subject to ongoing detailed studies and SKYLAB imagery may be only a small part of the data base used in understanding them, interpretive techniques developed in this study may aid in studies of other, more remote inlets. Where financial backing for detailed studies is lacking, a reconnaissance view of the inlet and its surroundings may provide investigators with insight into the system and aid in efficient use of limited funds to solve a particular problem.

The key to practical use of space-acquired imagery in managing inlets is the ability of the system to provide repetitive and timely data about the inlet. Interpretation of the SKYLAB imagery in a framework of the fairly extensively studied inlets of North Carolina should then provide some insight to the usefulness of the space-acquired imagery in this respect. The basic techniques can be applied repetitively to images made successively to monitor significant inlet changes.

SKYLAB-3 crossed the Outer Banks on 9 August 1973 at 0847 EST (NASA-Lyndon B. Johnson Space Flight Center). At this time the wind was blowing gently from the northeast at a velocity of between 6 and 10 knots as interpreted from the National Weather Service surface map for 1200Z (0700 EST). Tide tables show that the tide was ebbing, and at Oregon Inlet low tide was scheduled for 1013 hours EST.

8.3.1 Methods of Study

The images have been studied using standard air-photo interpretation techniques. They have been studied in a color

additive viewer and have been projected to various scales. Also, density slicing has been employed. No attempts have been made to evaluate the resolution of the photographs as markers suitable for this type of determination are not available. However, the bridge across Oregon Inlet is recorded on the imagery, and its width (31 ft; 9.5m) gives one measure of the spatial resolution for this feature which is between two and three miles (3.2-4.8 km) long.

The study was undertaken to determine what features could be recognized and how the information could be used to understand the processes associated with the formation and maintenance of the inlets, both natural and artificial. Preliminary examination of the imagery suggested that studies of the ebbtide- and floodtide dominated channels could be done with the imagery, that an inventory of the channels through the inlets and in the tidal deltas would be possible, and that from the inventory an "updating" of the navigational charts might be possible, although actual water depth values could not be accurately assigned because of the absence of detailed, up-to-date groundtruth. Also, it was felt that major sedimentary features such as large sand waves might be pinpointed. From their position and aspect a better understanding of sediment movement through the inlets and across the ebb and flood deltas could possibly be developed. The form of the spits and shallow submarine bars could also be studied and evaluated for changes that have occurred since the latest nautical charts were prepared. Numerous air photographs of the inlets have been made at one time or another, and a few of these have been used in this study.

8.3.2 Oregon Inlet

The main channel through Oregon Inlet is oriented in a northeast-southwest direction. On the inside of the barrier island the tidal channel breaks into several smaller channels. The northernmost channel is flood-dominated, and the major southern one (Davis Slough) is ebbtide- dominated (J. Singer, oral communication, June 1974). Current flow in these channels averages

between 2 and 3 knots. Charts of the area indicate that the southern channel is subject to continual change. Because of the orientation of the inlet northeasterly winds accentuate the floodtide flow, and southwesterly winds accentuate ebbtide flow.

Comparison of an enlargement of Frame 31, Roll 28 (approximate scale = 1:150,000) (Fig. 6) with the latest available nautical charts of the area (Fig. 7) reveals that the ebb channel is wider and longer than is indicated on the charts and that there are numerous smaller channels present in the flood delta which are not clearly recorded on the charts. This color photograph was chosen for study because it showed the channel pattern details better than the color infrared photograph. The black and white (Roll 30) photograph (0.5-0.6μm) shows similar detail.

The flood delta is oriented in a west to south-southwest direction. The main flood-dominated channel at its northern boundary enters Pamlico Sound in a northwesterly direction and then turns westward, being maintained in part along this stretch of its course by dredging. Study of the flood delta shows that the same arcuate pattern is present to one degree or another southward from the flood channel. The axis of bending extends in an east-southeast direction, and its projection intersects the barrier island about 4.2 mi (10 km) south of the inlet. The maximum westward extent of the delta is about 12 mi (19 km).

The SKYLAB imagery of Oregon Inlet emphasizes the asymmetric form of the flood delta. The patterns of the smaller channels along with the sand bars and submerged spits imply that a greater portion of the sediment carried through the inlet is spread southwestward than is spilled out of the flood channel in a northward direction. Even though a major portion of the water entering and leaving Oregon Inlet does so through the two main channels, the SKYLAB pictures suggest from the textural patterns and patterns of reflectances that a significant amount of water spreads across the bars at current velocities sufficient to transport the available sand. The pattern of bars and spits

Figure 6A North Carolina Outer Banks SKYLAB-3, Roll 28, Frame 031 (S190A)

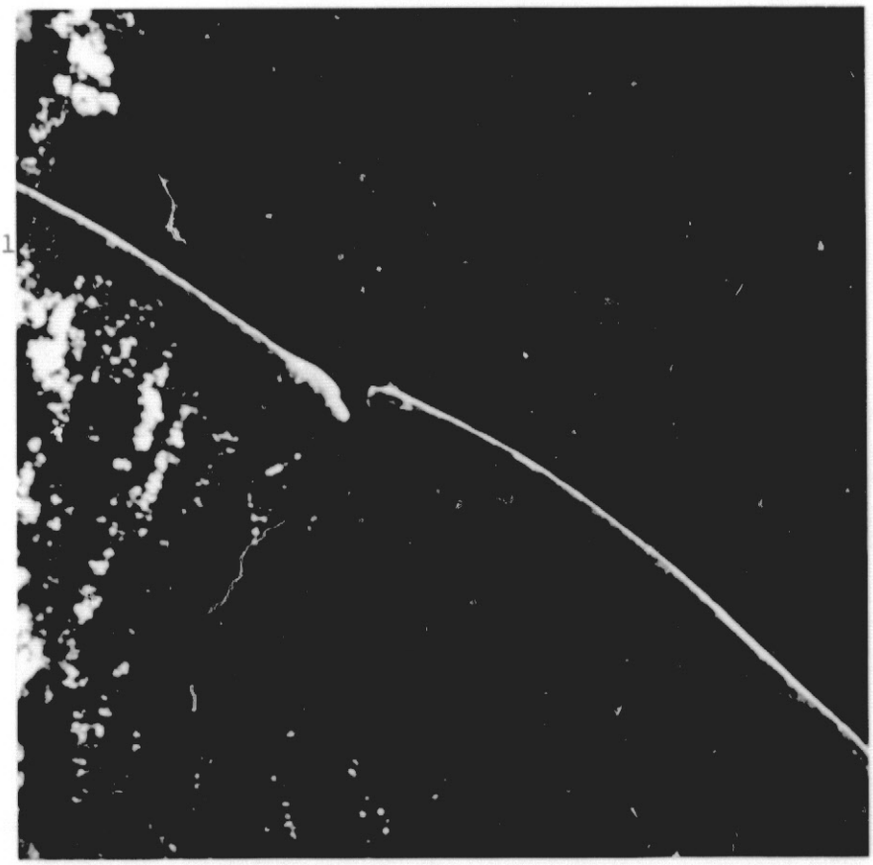


Figure 6B Detail of Oregon Inlet

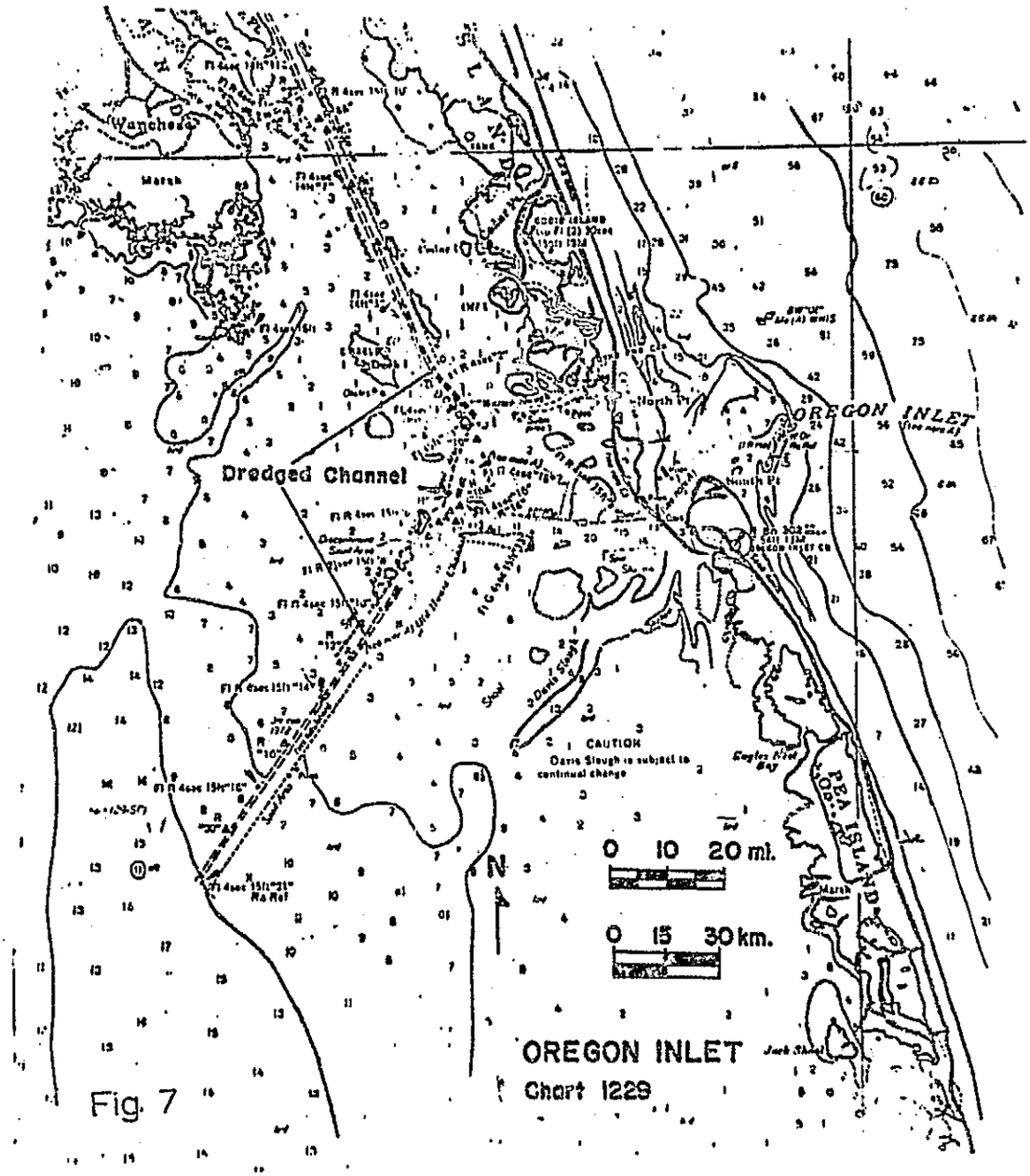


Figure 7 Oregon Inlet Area Map

implies that a greater portion of this material is spread westward and southwestward. If this apparent relationship is true, then the implication exists that the water mass moves to a large extent in this direction also as well as through the tidal channels. Winter season winds are dominantly from the northeast (C. E. Knowles, personal communication, 1974) and may play a major role in this sediment pattern.

Dredging of the floodtide channel is required periodically along its westerly extremity (Old House Channel, Fig. 7). A broad apparently shallow channel extends northwestward from near the middle of the ebbtide channel toward this location. The latter channel is not well known, and conceivably during flood tide it could be the path along which material is carried to the western end of the flood channel (J. Singer, oral communication, June 1974). Unfortunately no flow data exist for this subsidiary channel; so its effectiveness as a contributor to the filling of the main flood channel is solely a matter for speculation. On the other hand, its presence was not recognized by people working on current movements in Oregon Inlet until the SKYLAB imagery was examined (J. Singer, personal communication, June 1974). If its presence had been known, current meters might have been placed in it during an oceanographic investigation of Oregon Inlet in the summer of 1973 (J. Singer, personal communication, June 1974). Thus it is possible that orbital photography can contribute to better maintenance of navigable channels.

As seems to befit the period of relatively low wind velocity existing at the time of the satellite pass, the suspended load outside Oregon Inlet appears to be low. Recorded suspended matter is restricted to within about 4.5 mi (7.5 km) of the mouth of the inlet. Mairs (1970) and Welby (1974) have described Oregon Inlet plumes recorded from space.

8.3.2.1 Details of delta development: The chief sedimentation patterns in the Oregon Inlet flood tidal delta may be interpreted from (S190A) Frame 31 of Rolls 25, 26, 29, and 30 as well as Rolls 27 and 28. Imagery from Rolls 25 and 26 show only two faint areas of reflectance. These are located where sand bars protrude above the water near the confluence of the two main channels.

Examination of the material from Rolls 29 and 30 under a 40x magnification discloses a sediment pattern in the flood delta which in turn suggests that water overstepping the northern, flood-dominated channel is spreading a wave of sand southwestward across some of the older southwestward-trending channels. These latter channels are believed to be older distributary channels from the flood-dominated channel (Fig. 7).

On the south side of the ebb-dominated channel a major tributary to the ebb-dominated channel runs northward approximately parallel to the barrier island. West of this channel a bulbous sand deposit is apparently working its way southwestward over earlier deposits and over small flood-dominated distributary channels which trend southwestward. The imagery suggests that flood-dominated sand waves too small to be recognized individually on the imagery may be present.

During ebb tide water moves through Oregon Inlet in a northeasterly direction from the confluence of the two main channels. Langfelder et al (1968) suggest a dominance of southward littoral drift from a point about three miles (2 km) north of the inlet southward along the coast. However, study of the SKYLAB photographs indicates that another set of circumstances may obtain. The northern side of the inlet is being deflected westward as a series of gently curved spits reflecting transport of sediment on the flood tide into the sound. On the south side of the inlet two recurved spits which hook westward and southwestward can be seen. Growing northeastward from the seaward side of the base of the recurved spit is a generally submerged spit-like feature whose base extends across the northeastern-facing portion of the recurved spit.

Attached to the seaward side of the barrier bar north of Oregon Inlet, a generally submerged triangular feature appears to be forming. Its base lies at the shore along the widest part of the northern spit, and its apex lies at a small island which barely protrudes above the water of the near maximum ebb tide occurring at the time the picture was taken.

If the mouth of the inlet can be treated as an orifice, in a manner suggested by others (Bates, 1953; J. Machemehl, personal communication, January 1975), then the ebb flow is building up lateral bars on either side of the tidal channel through which water issues into the ocean. In support of the idea that the seaward end of Oregon Inlet can be considered an orifice, the northeastern extremity of the bars on the south side of the inlet is hooking northwestward and appears to be closing toward the apex of the triangular shaped bar on the northside of the inlet. This curvature suggests that a lunate bar typical of natural orifices is forming (Bates, 1953; Price, 1963) or has formed below the depth to which reflectances could be returned to the S190A camera system. Additionally, the position of the bar is about four orifice diameters seaward of the mouth of the inlet, and this position is to be expected (Price, 1963) for tidal deltas.

If the drift pattern shown by Langfelder et al (1968) represents the present current littoral drift, then the southward-flowing currents north of Oregon Inlet are deflected to a considerable degree by the currents flowing from the Oregon Inlet orifice during ebb tide. They probably swing seaward near the triangular shaped bar and may continue southward around the bar attached to the southern side of Oregon Inlet. The form of the turbid zone offshore from Oregon Inlet can be interpreted as supporting this idea, for it bulges southeastward with its widest dimension being slightly south of the mouth of the inlet (Fig. 6).

8.3.3 Ocracoke Inlet

To evaluate the usefulness of the SKYLAB photography for study of channel changes in the inlets through the barrier islands, a comparison was made of an enlargement of the 9 August 1973 imagery of Ocracoke Inlet (Rolls 25 to 30, Frame 30) and the most recent navigational chart of the area (U.S. C&GS Chart 1232, December 1973 edition, scale of 1:80,000). Cloud cover restricted the area which could be studied.

The shoal areas and channels shown on the SKYLAB pictures were traced onto transparent material from an enlargement (1:160,000) of Frame 30, Roll 28. A transparency made from the chart was also prepared by a direct copy process. Two overhead projectors were aligned so that the two transparencies were projected onto a piece of frosted acetate at an approximate scale of 1:16,850 and registered on each other. Location of channels and major shoal areas as interpreted from the SKYLAB imagery were plotted on the acetate, and then the similar features were plotted on the acetate from the projection of the chart.

8.3.3.1 Results: A number of minor differences are apparent in the position of small shoals, and these may be attributed to slight errors in the projection process as well as to actual positional differences. However, there are also some major differences, especially in the center of the inlet and in the area east of the dredged channel from Pamlico Sound to Ocracoke (Fig. 8).

The navigational chart suggests the presence of a main channel extending from the center of the inlet approximately 5.5 mi (9 km) into Pamlico Sound. This channel has two major bifurcations. On the SKYLAB imagery only a single channel seems recorded, and it makes a sharp easterly bend about 2.5 mi (4 km) in from the mouth of the inlet. About 1700 ft (500 m) farther into Pamlico Sound the channel turns northerly and eventually dead-ends against a horseshoe-shaped shoal.

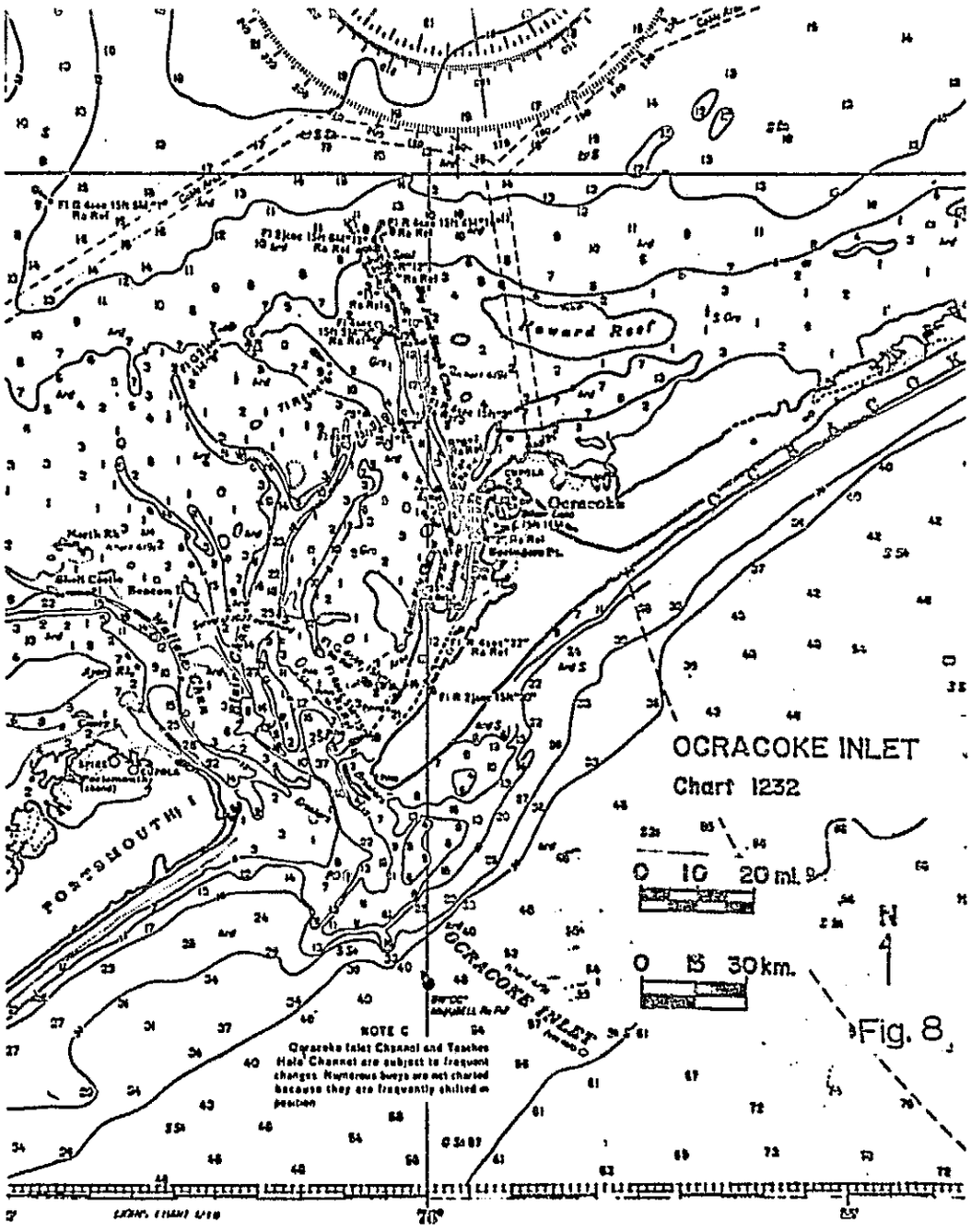


Figure 8 Ocracoke Inlet Area Map

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The dredged channel leading to Ocracoke Harbor cuts through the western end of a major shoal. On the navigational chart this shoal seems to be represented mostly by Howard Reef and a shoal axis extending to the dredged channel in a westerly direction and eastward toward Cape Hatteras (Fig. 8). The sound side of the shoal is curvilinear, and the seaward side is more irregular. A finger of dredge spoil outlines the channel in the sound direction from the shoal.

The east end of Portsmouth Island (Fig. 8) has a configuration somewhat different from that shown on the chart. The spit as represented on the chart is no longer free-standing. Sediment has filled behind it so that a low sandy area extends from the main part of Portsmouth Island to the spit as a more or less continuous feature. The bluish coloration on the color infrared picture implies a high moisture content, and a small pond appears to be present near the former base of the spit.

A line of small shoals or inlets extends toward the sound. The line is gently convex toward the west, and shallow channels cut between shoals. In comparison, the navigational chart shows a continuous spit extending soundward from the main part of Portsmouth Island (Fig. 8).

A small ebb-tide delta appears to be building out from the western one-half of Ocracoke Inlet. It is attached to Portsmouth Island. Presence of such a feature is suggested by the bottom contours on the chart, although the configuration shown by the SKYLAB imagery and that shown on the chart differ in detail.

Data on the currents flowing through the channels as they existed in October 1962 have been supplied by the Wilmington District, U. S. Army Corps of Engineers. The main channel through the inlet lay in about the present position of the main channel. However, the shoal and channel pattern was somewhat different inside the inlet from that shown on both the 1973 chart and the SKYLAB imagery. Maximum ebb flows are of the order of 3 knots, and maximum flood flows are of the order of 2 knots.

Data analysis from current studies made in Ocracoke Inlet is presently underway. It appears from these studies (J. M. Welch, personal communication, July 1975) that most of the flood flow through the inlet is through Teaches Hole Channel, the northernmost channel. Whether Wallace Channel (the southernmost channel) is ebb-dominated or not has not been established at this time. However, the presence of the U-shaped sand bar at its mouth which is shown on the SKYLAB photographs is strongly suggestive that it is ebb-tide-dominated. The southern arm of the bar appears to be linked with the northeastern edge of Portsmouth Island.

8.3.4 Hatteras Inlet

The purpose of this part of the investigation was to evaluate the SKYLAB S190A imagery for use in interpreting the channels and water depths of a coastal inlet. Hatteras Inlet was chosen for this particular study because it was relatively cloud-free at the time of the SKYLAB-3 pass and because subsequent to the SKYLAB overpass some depth determinations were made by students in the N.C.S.U. Department of Geosciences. Groundtruth information was also taken from U. S. C&GS Chart 1229, December 1973. Three identifiable channels trend northward across the tidal delta on the sound side of the inlet. A channel is maintained by dredging between Hatteras Island and Ocracoke Island (Figs. 6, 9)

Initial study of the imagery showed that the several channels that traverse the inlet could be seen on most of the S190A photographs. Also the shallow bars and shoals that lie beneath the water could be identified in a general way. However, the water depths over the shoals could not be determined, and it was decided to use the density slicing technique to see if bottom depth contours could be established from the imagery. A Spatial Data Model 703 Data Color System was used.

Because there were no depth measurements actually made at the time of the SKYLAB overpass, it became necessary to correlate the density slice information with the depths determined in July 1974 and from the December 1973 chart.

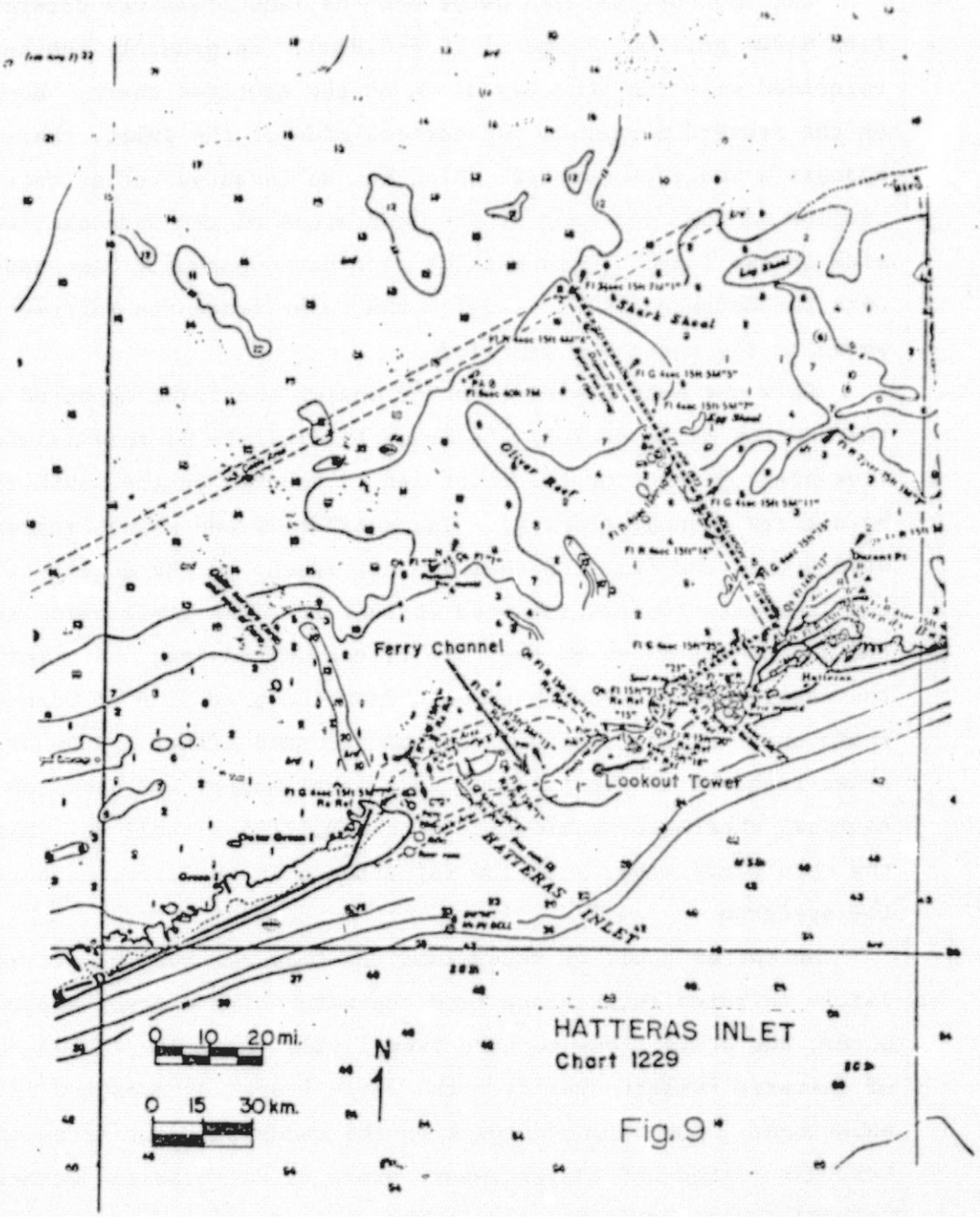


Figure 9 Hatteras Inlet Area Map

The boundary between water and the land areas was determined from S190A Roll 26, Frame 31 (0.8-0.9μm). In general, the boundary coincided with the boundary drawn on the nautical chart. However, on the seaward corner of the eastern side of the inlet, there appears a wedge of material which has an infrared reflectance similar to that for many of the land areas on the Ocracoke (west) side of the inlet. This mass of sand has apparently been added onto the Hatteras Island side of the inlet since the information shown on the chart was compiled.

Only one moderate-size island inside the inlet appeared on the density slice of Roll 26, Frame 31 (infrared); this island lies near the axis of the inlet and is fronted on the south side by a ferry channel (Fig. 9). The smaller island which lies eastward across the ferry channel did not appear on the density slice and is apparently not recorded on Roll 26. The implication is that the island was awash at the time of the SKYLAB pass. Similarly, the shallow bar extending seaward from the east side of Ocracoke, shown on other photographs, was not recorded either. None of the other features of the inlet found on the imagery and shown on the nautical chart was recorded on either Roll 25 or Roll 26. Most of the open sandy areas show low reflectance in the infrared part of the spectrum.

As far as could be determined the film recorded relatively little infrared reflectance from the water of the ocean and the sound, and there seems to have been little variation in the amount of infrared reflectances from the water bodies as measured in this experiment. Low reflectances from the sandy interior areas of Ocracoke Island and the shoreward areas of Hatteras and Ocracoke are interpreted as being related to the presence of moisture in the sand. Areas where vegetation is concentrated on the portions of the islands above sea level show reflectances near the middle of the total density range of the photographs.

Density slices of 32 steps, or contours, were made of Frame 31, Rolls 29 and 30 to investigate the feasibility of using the imagery to characterize the channel pattern in Hatteras Inlet.

In addition, the same frame from Roll 30 was studied with 16 steps. In general, it can be said of the frame from Roll 31 that the 32-step density slice gave more detail of areas adjacent to the channels than did the 16-step configuration. However, both formats showed the presence of the four major channels (Fig. 6, 9) and several smaller ones. For both Rolls 29 and 30 the deeper portions of the outer channels appear as lower reflectances, and can be recognized without optical enhancement. However, density slicing permitted the contouring of the edges of the channels, emphasizing the abruptness with which the bottom drops off into them.

Some of the smaller channels which are not outlined on the chart appear in the photography and are emphasized by the density slicing. One of these is the small channel system approximately N 20 W of the Lookout Tower at the south end of Hatteras Island (Fig. 9).

Most of the sediment in the Hatteras Inlet area falls into the medium- to fine-sand size range and is composed dominantly of quartz and shell fragments (Puckett and Ingram, 1969). The principal investigator's experience with other sandy areas indicates that this material should give a relatively high reflectance in all bands. Within the inlet environment the thickness of the water cover and turbidity of the water will affect the reflections off the bottom. Also, the nature of the bottom affects the albedo, and the less sandy, more muddy portions of the bottom can be expected to have a lower reflectivity than the more sandy portions of the bottom.

8.3.4.1 Results: Figure 10 is a picture of the density slice of Frame 031, Roll 30 (0.5-0.6μm). The orange pattern coincides with depths 10 feet or greater whereas the shoal areas are indicated by the yellow and cyan colors, the darker cyan indicating water depths between one and two feet. Yellow indicates sandy areas that are above water and below water down to depths of approximately one foot (0.3 m).

Figure 10 Hatteras Inlet
32-step Density Slice of Roll 30, Frame 031
(S190B), SKYLAB-3

The effect of bottom character on reflectance is shown on the west side of the inlet where the charts show the water depth to be between one and two feet, or less. Here the magenta pattern, recording a low reflectance, coincides with water depths of one to approximately five feet (0.3-1.5m). The sediment here falls in the Marginal Lagoon facies of Puckett and Ingram (1969), and is characteristically fine-grained and dark-colored. Again the near-surface bars reflect in the yellow to cyan range, and the orange pattern records water depths in the five-to ten-foot (1.5-3m) range. The boundary between the magenta and the orange marks approximately, within the cartographic accuracy of the groundtruth and the cartographic accuracy of the projection methods used, the five-foot (1.5m) water depth contour. Similar results were obtained from the density slice of Frame 31, Roll 29, although the general reflectivity was somewhat lower. However, the near-surface bars and shoals reflected in the upper end of the reflectivity range.

Potential washover areas can be seen on the imagery of Ocracoke Island. These are seen in the black and white imagery as narrow fingers of low reflectivity (more dense areas on the film) between areas of higher reflectivity. These may represent the location of former inlets through the barrier island system.

8.3.5 Summary and Conclusions

Attention has been given chiefly to the usefulness of SKYLAB imagery for the study of inlet changes. The major differences between the most up-to-date chart and the SKYLAB information has been described. Also the potential usefulness of the imagery for determining water depths and monitoring channel shifts in inlets has been studied. Within the limits of the resolution of the SKYLAB S190A System Rolls 25 and 26 are good for determining land-water interface along the barrier islands (Outer Banks) of North Carolina. Roll 29 and Roll 30 can be used to map channels through the tidal deltas and to make semiquantitative determinations of water depths if minimal depth information is available as

groundtruth. Because bottom conditions do play a role in the nature of the reflections off the shallow bottoms, knowledge of bottom conditions becomes an important input into the interpretative procedure.

It appears that the channel patterns and the shifting of the shoals within the inlets could be monitored successfully from a space platform and that updating of charts using space-acquired data is feasible. High Resolution Color, High Resolution Color Infrared, as well as multispectral photography such as used in the S190A experiment are all useful. The black and white multispectral photography is perhaps the more versatile for determining bottom contours, but channels and larger sedimentary features are also shown on the color film. The technique would be especially useful after the passage of a major storm or hurricane. Computerized interpretation might be economically feasible for an ongoing monitoring and charting program.

Greater cartographic accuracy would be required for an operational system than was achieved in this experiment; however, if distribution of space-acquired data to local agencies interested in monitoring channel configurations and water depths in the inlets were done on a systematic, routine basis, those most familiar with the area could make the proper interpretations and could keep the information at hand for use, and procedures assuring the cartographic accuracy could be set up.

If complete coverage of the coastal area had been made during the SKYLAB program, it seems probable that an inventory of potential washover areas along the Outer Banks could have been assembled.

It is apparent that imagery taken at the approximate 1:2,900,000 scale of the 70mm S190A is useful for monitoring changes in inlets such as those found along the barrier islands of North Carolina. A satellite with the capability to image at the scale and resolution the SKYLAB 70mm S190A materials could provide up-to-date, accurate maps of the inlets; if the maps were presented on a shaded relief

format with geographic grid and bottom contours overprinted, they would probably find considerable use among those who use the inlet on a regular basis.

8.4 Cape Hatteras Plume

The vagaries of the plume arising at Cape Hatteras have been described elsewhere (Welby, 1973; 1975). SKYLAB-3 passed over the area during a period of relatively calm water, and the plume appears restricted to the vicinity of the shoals off the Cape. Its internal structure suggests a wave-like mechanism or a "dripping" from the point. This relationship contrasts with the 38 to 40 mi (60 to 70 km) finger-like protrusion often seen extending to the northeast on LANDSAT-1 imagery (Welby, 1975).

8.5 Groundwater Occurrence

The original proposal called for evaluation of the SKYLAB photography as an aid in groundwater exploration in the crystalline rocks of the North Carolina Piedmont. This part of the investigation was to relate lineament patterns to groundwater occurrence. When it became evident that lineament mapping in the North Carolina Piedmont using the available SKYLAB imagery would be very difficult and that rock type differentiation was virtually impossible, efforts were suspended.

From the preliminary work done in this phase of the investigation it is judged that available space-acquired imagery should not be ignored when a groundwater exploration program is undertaken in areas of crystalline rocks. However, in relatively humid areas, such as North Carolina, which have a thick soil and saprolite cover over most of the bedrock, use of the imagery for routine groundwater exploration is probably not justified. On the other hand, when the problem addressed is of a region-wide concern, then space acquired photography and imagery may prove useful not only

in showing existence of linear features which may control ground-water movement, but also in showing cultural features and land-use patterns which may suggest broad regional features of the ground-water regime.

9.0 WATER QUALITY

It was hoped when the SKYLAB project was undertaken that the space photography would be useful in North Carolina for study of water quality problems. The Chowan River was of concern to a number of agencies, and for this reason it was chosen as a test site. Also, High Rock Lake was chosen as a test site because it was known from general knowledge that a considerable sediment load was entering it and that there might be other water quality problems.

Cloud cover restricted the applicability of the SKYLAB photography as well as that obtained from an aircraft underflight. Groundtruth was collected at the time of the 9 August 1973 pass across the Chowan River by personnel of the North Carolina Office of Environmental Management; however, these data did not show any trends that might be picked up on the SKYLAB imagery, and most of the sample points were located beneath clouds or in areas of cloud shadow. Usefulness of the data from the aircraft underflight is limited because of cloud cover. However, in the vicinity of Holiday Island there seem to have been some temperature differences imaged by the RS-14 Airborne Thermal Scanner. The meaning of these differences is not clear at this time, and the data will be re-examined in the coming months in conjunction with a University of North Carolina Water Resources Research Institute multispectral photography project.

The multispectral photography and the color infrared photography aided in interpretation of the SKYLAB data where there was no cloud cover along the northern edge of Albemarle Sound.

9.1 Evaluation of Imagery

9.1.1 Raleigh area

In connection with forestry studies with SKYLAB photography, some observations were made on detection of water quality differences.

The best photography for overall observations of water resources appeared to be color infrared. Stereo studies of 9-inch enlargements of S190A color infrared frames were useful in detecting water bodies, whereas in color photographs the reflections from water and from green fields were often indistinguishable. Sediment loads in water bodies were, however, visible in both color and color infrared photography.

S190A stereopair Frames 117 and 118, Roll 40 (0.4-0.7μm) at a 3x magnification was found very useful for differentiation of various concentrations of sediment load in water bodies in the Raleigh, North Carolina, vicinity. Good results were also indicated by use of stereopair Frames 110 and 111, Roll 46. The two stereopairs were 9-inch enlargements from the S190A photography. The 4.5-inch color stereopair, Frames 292 and 293, Roll 86 (S190B), also showed the variable sediment contents of ponds.

Non-stereo observations of sediment in water bodies can be made on both the original 4.5-inch transparencies and the 9-inch enlargements of Frame 150, Roll 88 (S190B). The gradations of water quality from heavy sediment load to fairly clear water can be readily seen. No attempt was made to quantify these differences.

9.1.2 Lake Murray, South Carolina

A difference was noted between S190A photographs of Lake Murray and the surrounding area on the two different passes of SKYLAB. On the 12 September 1973 pass (Rolls 37-42, Frames 112-114) black and white, color, and color infrared photographs show what appears to be a heavy sediment load in the lake. The photographs from the 17 September (Rolls 43-48, Frames 105-107) pass do not show evidence of turbidity. In addition, the

12 September frames appear much darker in all wave lengths. It is suggested that this difference may have been caused by processing or handling differences rather than by natural phenonema.

Climatological data from the National Oceanic and Atmospheric Administration were studied with the following results. No precipitation was recorded for the Columbia station on either 17 September or for three days prior to this date. However, on 9 September 1.43 in (36mm) of rain fell; on 10 September a trace was recorded; and shortly after midnight on 12 September (10 hours before the pictures were taken) 0.39 in (10 mm) of rainfall was reported. Precipitation in the amount of 0.5 in (12.5 mm) also fell at Newberry some 20 miles northwest of Lake Murray on 11 September. No other locality near the lake reported rain on or about 12 September, and the climatological data disclose that during this time no rain fell in the vicinity of any other lake shown on the SKYLAB photographs. No other major lakes in the entire state showed the level of sediment clouding that is apparently present in Lake Murray. The distribution of sediment in the lake was strikingly revealed in all of the 12 September imagery with the exception of the infrared black and white (Rolls 37 and 38).

It appears that the rainfall pattern is reflected by the sediment load in the lakes photographed by SKYLAB. The relation appears to suggest that SKYLAB-type photography or imagery could be used to study relations between rainfall distribution and sediment runoff and could be used as well as an agent to study water pollution and response of a drainage basin to a specific amount of rainfall.

9.1.2.1 <u>Sun Angle effects</u>: Another point is the effect of the relationship between sun angle and camera viewing angle upon the interpretability of the space-acquired photographs. Rolls 39 through 41, Frames 112-114 were taken when Lake Murray was ahead of the SKYLAB nadir. The sun was near the local (34° Lat.) noon position (approximately a 56° angle with the horizontal) when

Frame 112 was taken. No photographic record of sediment in the lake was obtained on Frame 112. In the two succeeding pictures made as the spacecraft passed almost directly over the lake and beyond (Frames 113, 114) the sediment-derived turbidity of the lake was recorded photographically. In Frames 113 and 114 the lake was put in a position between the sun and the spacecraft so that the camera came into the plane of the most direct incident and reflected rays. In the earlier frame the reflections from the lake were not so direct, and the presence of the sediment load was not recorded. Consequently, when a rather heavy sediment load is present, it may go unnoticed unless a careful examination is made from as many camera angles as possible and with careful attention to the case in which the camera, the incident rays and the reflected rays, and the object being studied lie in nearly the same plane.

9.1.3 High Rock Lake

A heavy sediment load is indicated in three general zones of High Rock Lake by all bands of SKYLAB-3 imagery except for the black and white infrared (Rolls 37, 38, 43, 44). The greatest influx is in (1) the northern reaches of the lake, near Interstate 85. Lesser but significant amounts occur in (2) shallow, near-shore inlets, and (3) below the dam on the Yadkin River. The color of this suspended material is a light red-brown on all color imagery of S190A and S190B.

Sediment load downstream from High Rock Lake is discussed in conjunction with the description of the results of the S192 investigation. No actual measurements of turbidity were made, but observations made during a low-altitude overflight on 12 September 1973 confirm in general the suspended sediment pattern.

10.0 LAND USE

From the time of the receipt of the first space-acquired photographs, it has been recognized that the synoptic views from space could be used to inventory land use. The LANDSAT and

SKYLAB-EREP programs exist in part as the result of the recognition of this fact. Consequently, in the North Carolina program, considerable time and effort were spent in studying and evaluating the S190A and S190B photography as data bases for land-use studies. Where possible, an investigation was undertaken to demonstrate how the photographs might have been useful as input into the information required for the planning of a particular facility. In two cases, planning of the facilities is still going on and in one case an environmental impact statement is still in preparation. Also, studies were made to evaluate the photographs as a data base for local and regional planning agencies.

10.1 Transportation Routes

The transportation facilities observed in SKYLAB photography include streets, secondary roads, highways, parking lots, airports, railroads, and transmission lines. The detail with which these facilities can be seen depends on the kind of photography (color, color infrared black and white) and on the quality of the individual transparency or stereopair, as well as on whether the photography is from the S190A or S190B experiment.

Observations with the B & L Zoom stereomicroscope on the 70 mm stereopair, Frames 117 and 118, of Roll 40 (0.4-0.7μm) indicated excellent detail of transportation facilities. Streets and roads, except narrow roads under tree cover, are easily seen. Parking lots can be differentiated from the buildings which they serve. Airport runways are distinct to the degree that measurements can be made of their width, length, and other features (Section 6.2.2; Table 3). The stereopair, Frames 292 and 293, Roll 86 (S190B) clearly shows both lanes of Interstate Highway I-40.

Further stereostudies with a Wild mirror stereoscope showed quality variations between photographs. The color stereopair, Frames 110 and 111, Roll 46 (S190A) had barely discernible street patterns, whereas Frames 117 and 118, Roll 40 (S190A) had very clear street detail. On the other hand, the street details in color

infrared stereopairs from the S190A experiment, Frames 117 and 118, Roll 39, and Frames 110 and 111, Roll 45 were relatively indistinct. The latter stereopair was especially grainy, and street patterns were not recognizable at 3x magnification (approximate scale 1:242,000) from 9-inch transparencies (approximate scale 1:725,000) enlarged from the 70 mm originals.

Various individual frames studied in the B & L Zoom transferscope indicated greater detail in the color photography than in the color infrared. In color photo Frame 292, Roll 86 (S190B) street patterns were clearly visible; railroads could be recognized and mapped and power transmission lines observed. The latter could be distinguished from railraods by the fact that they were straighter and softer in tone. Color Frame 150, Roll 88 (S190B) clearly shows both lanes of the Interstate Highway, I-40. S190A Frame 117, Roll 39 (color infrared) is not as clear as the color photographs. This relation was expressed particularly as a lack of clarity in street patterns.

10.1.1 Discussion

If a little care is exercised in selecting the SKYLAB photography from the color transparencies, all common transportation facilities can be observed in considerable detail. Narrow roads or streets in forested areas may, however, be obscure. Color infrared photography in S190A is inferior to color or high resolution color photographs for transportation study purposes because of excessive graininess. It is suggested that city planners might profitably use S190B type of information for updating street maps in developing suburban areas.

10.2 Raleigh-Durham Airport Expansion

Land-use patterns around an airport are of immediate concern when planning for an expansion of the facility is undertaken. In the case of the Raleigh-Durham Airport one proposed plan was turned down in 1968 ostensibly, at least, because it would have required

the taking of a considerable portion of Umstead State Park. In subsequent years another plan, Plan B, has been proposed and is currently being reviewed by citizens' groups and the FAA, which has given its preliminary approval to it. This plan requires construction of a runway parallel to I-40 (Fig. 11) and at right angles to the present runway, and controversy has arisen over potential noise levels that might occur over west and northwest Raleigh and over the Research Triangle in the opposite direction.

The several documents prepared for the Airport Authority (J. J. Greiner, Inc., 1974) consider the environmental effects only out to about 5 miles from the end of the proposed new runway. However, people living up to 10 miles away from the end of the proposed new runway are concerned with air traffic patterns and noise levels.

One group of alternatives to Plan B for this report can be grouped under the term Plan C. In this plan, a new runway would be constructed parallel to the present runway and north of it. Arguments partially unrelated to this SKYLAB investigation made the Airport Authority choose Plan B. However, there are those in the community of users who feel that Plan C is the better plan, partially because they think that fewer people will be affected by the noise generated by increased air traffic and larger jet aircraft.

To test the possible usefulness of SKYLAB photography as a tool for those ultimately responsible for siting of the Raleigh-Durham Airport expansion facilities, land-use maps were prepared for strips extending 10 miles out from either end of the proposed Plan B runway and 10 miles out from either end of the present runway, which would be paralleled by a new runway under Plan C.

One question to be answered by an appropriate agency or agencies is that concerned with the potential number of people who might be adversely affected by increased air traffic beyond the 5-mile distance used in the planning studies. Because of the sheer number of conventional aerial photographs that would be required to map the land uses in a strip 20 mi x 4 mi (32 km x 6.4 km) wide, space photography provides an opportunity to assess

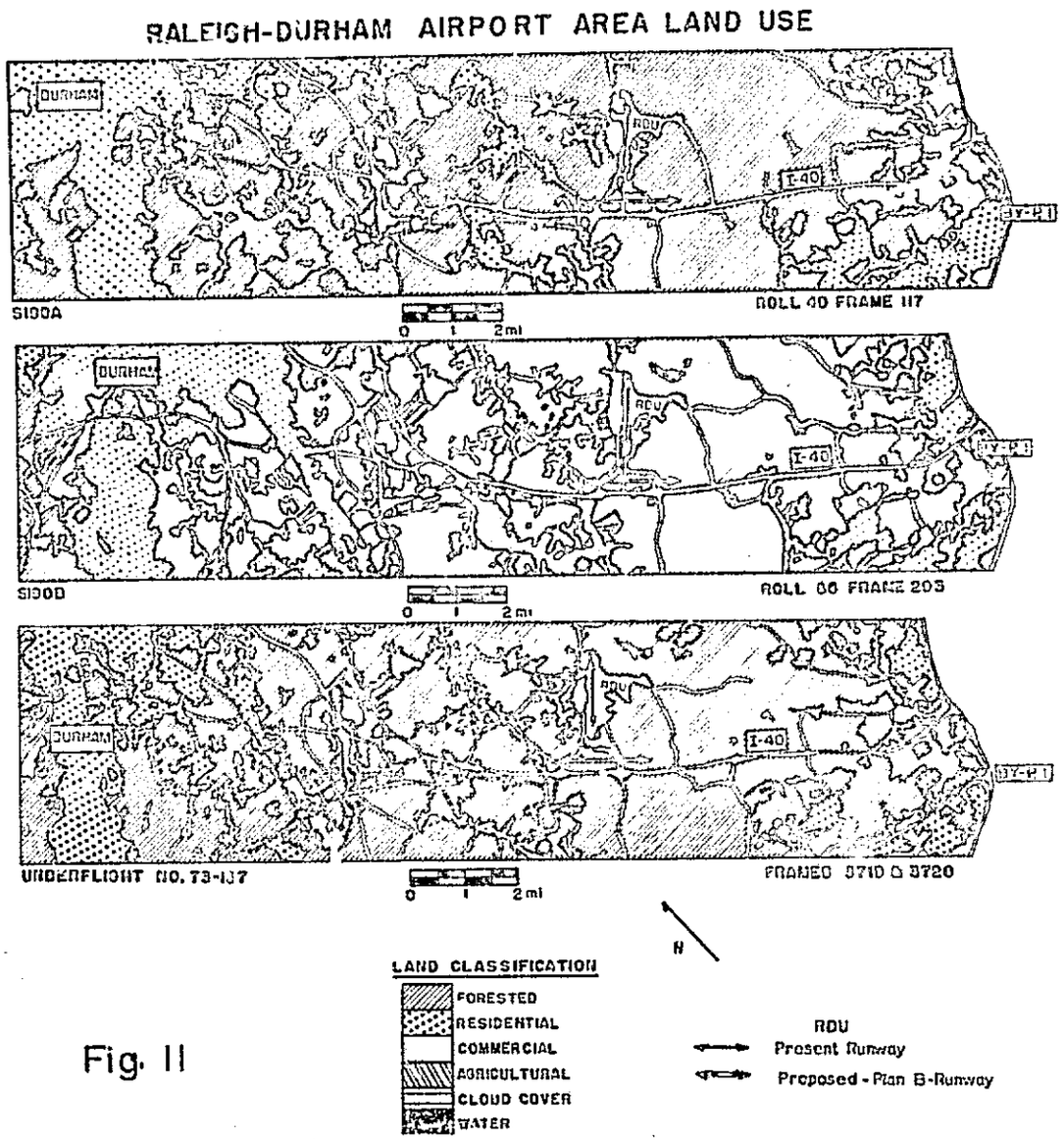


Fig. 11

Figure 11. Raleigh-Durham Airport Expansion Plan B Runway Configuration-Surrounding Land Use

the land-use patterns along the proposed runways as a factor in making the final decision.

The present study presents maps made from S190A and S190B imagery and discusses the accuracy of interpretation and the time required to make the studies. No judgement is made concerning the preferred runway orientation.

10.2.1 Plan B runway configuration

In setting up this part of the study the investigators had in mind two general purposes: (1) determination of the extent to which SKYLAB photography could be used to compile a portion of an environmental impact statement for the proposed new runway at the Raleigh-Durham Airport in the configuration given in Plan B (J. J. Greiner , Inc., 1974) and (2) determination of the time required to complete a map and the accuracy with which interpretation of SKYLAB photography can be accomplished by relatively untrained interpreters.

Three land-use maps of the area involved, a strip four miles (6.4 km) wide running approximately ten miles (16 km) between Raleigh and Durham and parallel to I-40, were made. Four broad land-use categories were identified: (1) forest land, (2) residential, (3) agricultural, (4) commercial and/or industrial. The first map was made from the S190A photography. A 9-inch enlargement from a 70 mm positive transparency (Roll 40, Frame 117) was projected with a delineascope (Beseler) projector.

While using this technique the interpreter must take care to see that the plane of the transparency in the projector is parallel to the plane of the projected image. Otherwise, scale changes from one part of the projected image to another part of the image occur. This was avoided by measuring the distances and angles between three identifiable points on a map. The resulting triangle was enlarged to the scale desired for the projected image. The projector was manipulated until the three points of the triangle lined up with the three points on the projected image.

The projected image was rather grainy, and attempts were made at that time only to outline areas of obviously different land uses. No effort was made to interpret. Interpretation was later done by means of the Bausch & Lomb (B & L) Zoom 70 stereomicroscope. Each area was classified into one of the four land-use categories.

A second map was constructed from the photography made during a U-2 underflight (Fig. 11). The color infrared positive transparencies (Flight #73-157, 15 September 1973, Frames 3719 and 3720) were projected with an overhead projector and aligned as for the first map. Outlining was done with the projected image, and interpretation was done with the Old Delft scanning stereoscope. The underflight map because of its larger scale was theoretically more accurate than the maps made from the SKYLAB photography and was, therefore, used as the basis for groundtruth activities.

A third map, Fig. 11, was made from a S190B 4.5-inch High Resolution Color transparency, Roll 86, Frame 293. This transparency was projected through a color additive viewer and was interpreted by use of the B & L Zoom stereomicroscope.

The percentage of land in each of the four categories for the three maps was determined by using dot grids (100 dots per square inch). The results were as follows:

	S190A	S190B	U-2
Residential	29%	31%	17%
Agricultural	2	6	7
Industrial	8	6	4
Forested	61	57	72

The U-2 photography was considered to give the most accurate map. The maps made from the S190A and S190B photography both showed a higher percentage of land in the residential and industrial classification than the map made from the U-2 photographs. The percentage of areas in the agricultural and

forested land classifications were lower for both the S190A and the S190B photography than the percentage of areas from the U-2 photography.

The differences in the percentages could probably be explained by the greater resolution of the U-2 photography. The better spatial resolution meant that the lines drawn between residential and forested areas were probably drawn in closer to the housing areas. The distinction between residential and forested areas was easier to make on the U-2 photography. Smaller units of forested land could be differentiated from residential land than was possible on the S190A or S190B photography.

Interpretation was easier with the S190B photography than with the S190A photography because of the better spatial resolution. This relation was especially evident under magnification. When the S190A and S190B photographs were magnified by the same amount the S190A appeared more grainy than the S190B material. The High Resolution Color transparency from the S190B was more easily and more accurately interpreted than the infrared S190A film.

Some of the differences between the three maps were probably due to the differences in the methods of projection. The least satisfactory projection method was that using a standard overhead projector for the U-2 photography. The best was that using the color additive viewer as a simple projector. The quality of the projector used probably had some effect on the results.

The total of hours spent on this project was 118. This time was spent as follows:

Reading and becoming familiar with equipment	12
First draft of S190A map	41
First draft of U-2 map	19
First draft of S190B map	14
Final maps and calculations	32
Total	118 hours

As might be expected, the first map took the longest to prepare. This is attributable to the inexperience of the interpreters and to the varying quality of photography and to trials with methods of projection. The U-2 map took about one-half the time required for the S190A map in spite of the fact that it was made at a larger scale. The S190B map took the shortest amount of time, probably because of (1) the increased familiarity of the interpreters with the area, (2) the increased familiarity of the interpreters with the equipment, and (3) the superiority of the photography and method of projection. The preparation of the final maps and the calculations of areas, scales, and percentages took about 32 hours.

10.2.2 Plan C runway configuration

SKYLAB photography from both the S190A and S190B was used in this portion of the study. Roll 86, Frame 293 (S190B), Rolls 37-42, Frame 118 (S190A), and Rolls 43-48, Frame 110 (S190A) form the basis for the interpretations. The swath chosen extended for 10 miles (16 km) out from either end of the present runway; it is four miles (6.4 km) wide, centered on the center line of the present runway. A relatively experienced photo-interpreter, who is knowledgeable about the area, did the interpretation. Both maps were prepared in 2.5 man-days, and approximately one-man day was spent field-checking the interpretations.

Six land-use categories were chosen for mapping purposes:

(1) commercial and/or industrial
(2) agricultural and other cleared land
(3) low density residential
(4) medium density residential
(5) forests
(6) water bodies 10 acres or larger.

S190A color infrared and S190B aerial color frames were projected from a color additive viewer onto frosted acetate mounted on a clear glass viewing screen. The projection scale

was 1in= 2 mi (1 cm = 1.3 km) corresponding to the map scale (1:126,520) of North Carolina Department of Transportation county road maps. Major roads were first traced to serve as references; then other cultural features and topographic information were added, and boundaries between various land uses drawn in. Interpretation of the imagery was then done with the aid of a binocular microscope with up to 40x magnification. The two maps are presented in Fig. 12.

Interpretation of the S190B photography was supplemented by use of the color infrared and the black and white infrared photographs from the S190A experiment to pinpoint the water bodies. The presence or absence of water bodies as interpreted from the S190B photograph was then checked.

Interpretations for the S190A map were made using all of the available photographs. The color infrared S190A photograph was the most useful for outlining areas of different reflectance, but the other photographs enhanced the interpretative capabilities of the investigator.

The map prepared from the S190B imagery proved to be the more accurate of the two maps. The lower resolution and smaller scale of the S190A photographs forced the combining of two or more categories of land use into one in a number of instances. Some cleared areas, for example, were also residential areas as well as agricultural areas, but because of the scale and resolution limitations, no houses could be distinguished. The same problem exists, though to a lesser degree, with the S190B imagery.

The chief difficulties encountered on both sets of photographs were (1) the inability of the interpreter to separate cleared croplands from industrial zones having a similar reflectance, (2) the inability of the interpreter to separate forests from crops of similar reflectances or from areas of scrub tree growth, and (3) the inability of the interpreter to distinguish between low and medium density residential areas. A railroad was initially mistaken for a highway.

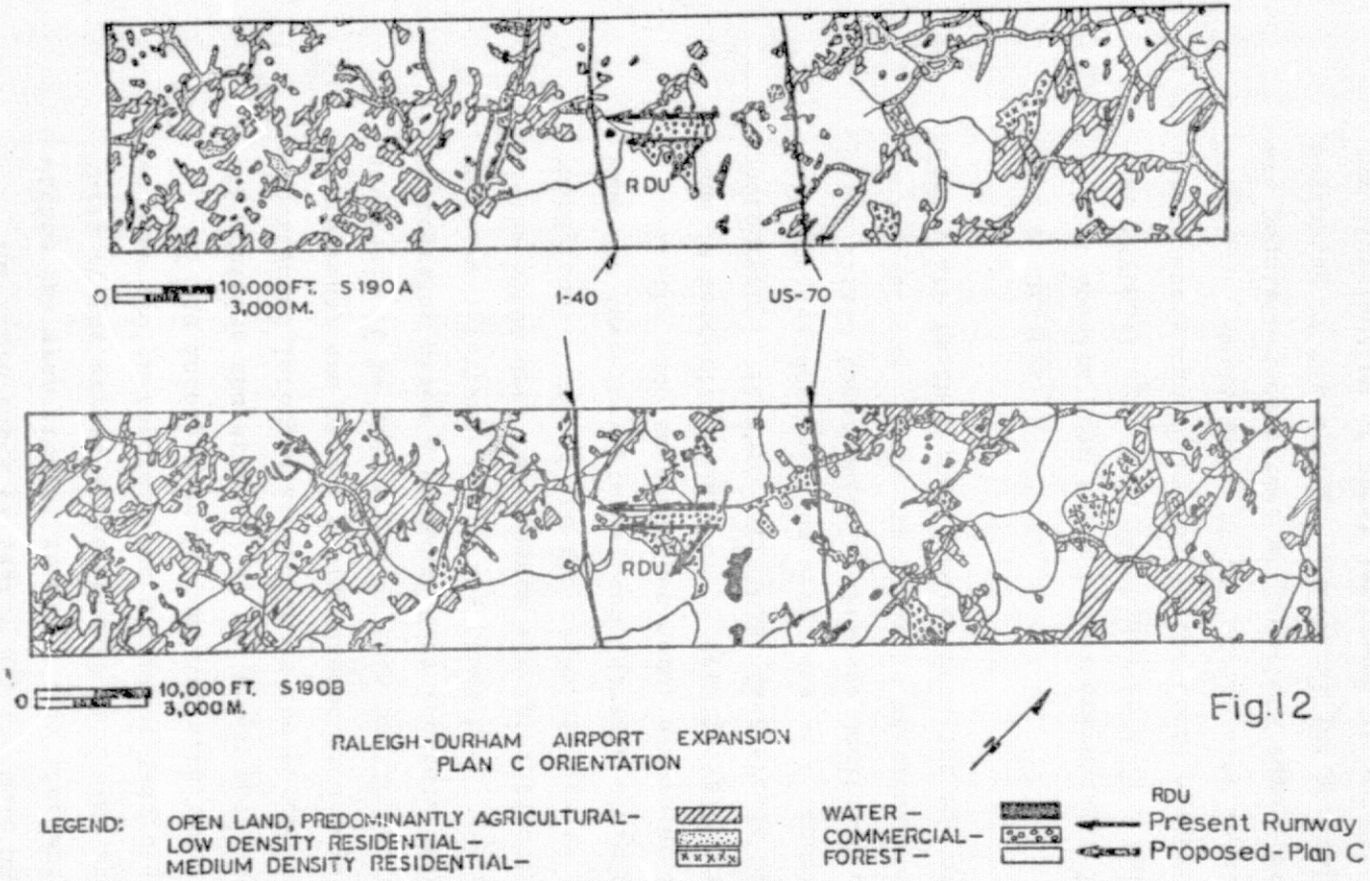


Figure 12. Raleigh-Durham Airport Expansion Plan C Runway Configuration-Surrounding Land Use

The field check of nearly all the main and secondary roads within the area brought to light only four errors of interpretation. Three of the errors arose because of a similarity of reflectances between two juxtaposed, but different, land uses.

If the interpreter is familiar with the area being mapped, he can minimize the errors. It was shown that when used by an experienced interpreter who knows the particular area the S190B photography can permit a high degree of accuracy in land-use studies. It is also shown by this particular study that the S190A photography gives a somewhat less accurate result in the hands of the same interpreter. On the other hand, the multispectral aspect of the S190A data can enhance the interpretation of the S190B photography. Use of the two types of data to solve a particular land-use inventory problem can increase efficiency.

In the problem presented here, errors of interpretation were made in borderline cases or in details which cannot be seen on the photography. In this particular case errors were mostly associated with non-residential land uses, and as a consequence, would probably be of little importance in ultimate decisions concerning runway configurations. This statement is particularly true where the errors are farther than 5 miles from the end of a runway.

10.2.3 Discussion

It appears from these two experiments in land-use interpretation that SKYLAB imagery, in the hands of even a relatively inexperienced interpreter, can be useful in the early stages of airport runway location. Among the various factors that should be considered are population densities at locations some distance beyond the beginning of the average commercial jet aircraft glide path and the distribution of other land uses within certain distances of the airport runway. Particularly important would seem to be the distribution of forests and wooded areas, for they can seemingly play an important role in determining the positions of Noise Exposure Factor (NEF) contours.

Obviously, accurate estimates of the number of people who may be affected by noise from the landing and take-off activities at an airport can only be determined by methods other than interpretation of SKYLAB photographs. On the other hand, it would seem wise on the part of planners to consider, in a reconnaissance fashion at least, areas of concentrated population beyond the minimal distances required by agencies such as the FAA. Because of its synoptic view and because it is possible to interpret from it patterns of population density, SKYLAB-type data, if available, should prove useful to planners and engineers concerned with airport development. It is conceivable that if SKYLAB-type information had been available and used in evaluating the various runway alternatives, some of the present controversy over Plan B might have been avoided. Also, use of the data might have eliminated the possibility of further delays in the construction of a much-needed facility.

The acreage assigned to the several land uses, as determi. ed from the SKYLAB imagery in this part of the investigations, could have been determined in one of several ways. This information could then serve as an input into an environmental impact statement or into consideration of the orientation of the runway in terms of its overall effect on people, industry, agricultural use and park use of the land in this part of the Raleigh-Durham area. That the actual computation of the areas of the several land uses was not done in this investigation only means that it did not seem that it was a necessary undertaking in demonstrating the usefulness of the SKYLAB imagery. However, if the imagery were to be used in the design of an airport or a similar large transportation facility, or perhaps in planning transportation routes and the effect of the routes on the surrounding countryside, then one of several simple methods of acreage determination could be used.

10.3 An Evaluation of SKYLAB-EREP Photographs for Land-Use Mapping of Urban and Rural Areas in the North Carolina Piedmont

Land-use planning being done in many areas of North Carolina today requires that information on current land use be obtained on county-sized areas as rapidly as possible. Land-use mapping from aerial photographs is one of the most rapid methods of gathering such data. However, the small area covered by each unit of conventional photography makes mapping of large areas a time-consuming project, albeit still a much faster one than conducting a ground survey. Orbital photographs such as those taken during the SKYLAB missions offer the possibility of covering large areas with sufficient resolution to allow construction of moderately detailed land-use maps in a much shorter period of time than could be done with conventional aerial photographs.

The purpose of the study was to evaluate the various types of imagery obtained from the SKYLAB Earth Resources Experimental Package (EREP) for land-use mapping in North Carolina. Land-use maps on a scale of 1:126,520 were prepared from this imagery that included both urban and rural land-use patterns. These maps were then compared to a groundtruth map prepared from information from a high altitude (65,000 ft.) color infrared photograph that was augmented by field checking. The EREP maps were evaluated for accuracy of interpretation, accuracy in determining boundaries between different land uses, and for the amount of detail that could be obtained from the satellite imagery. In addition, the amount of time needed to prepare the maps was recorded for comparison with other mapping procedures. The general location of the area is shown in Fig. 1, and the map of Fig. 13 shows the area in relationship to Raleigh, North Carolina.

10.3.1 Materials and Methods

It was felt that the techniques used in preparing the land-use maps should be similar to those available to personnel preparing such maps on a county-wide basis. For this reason, composite

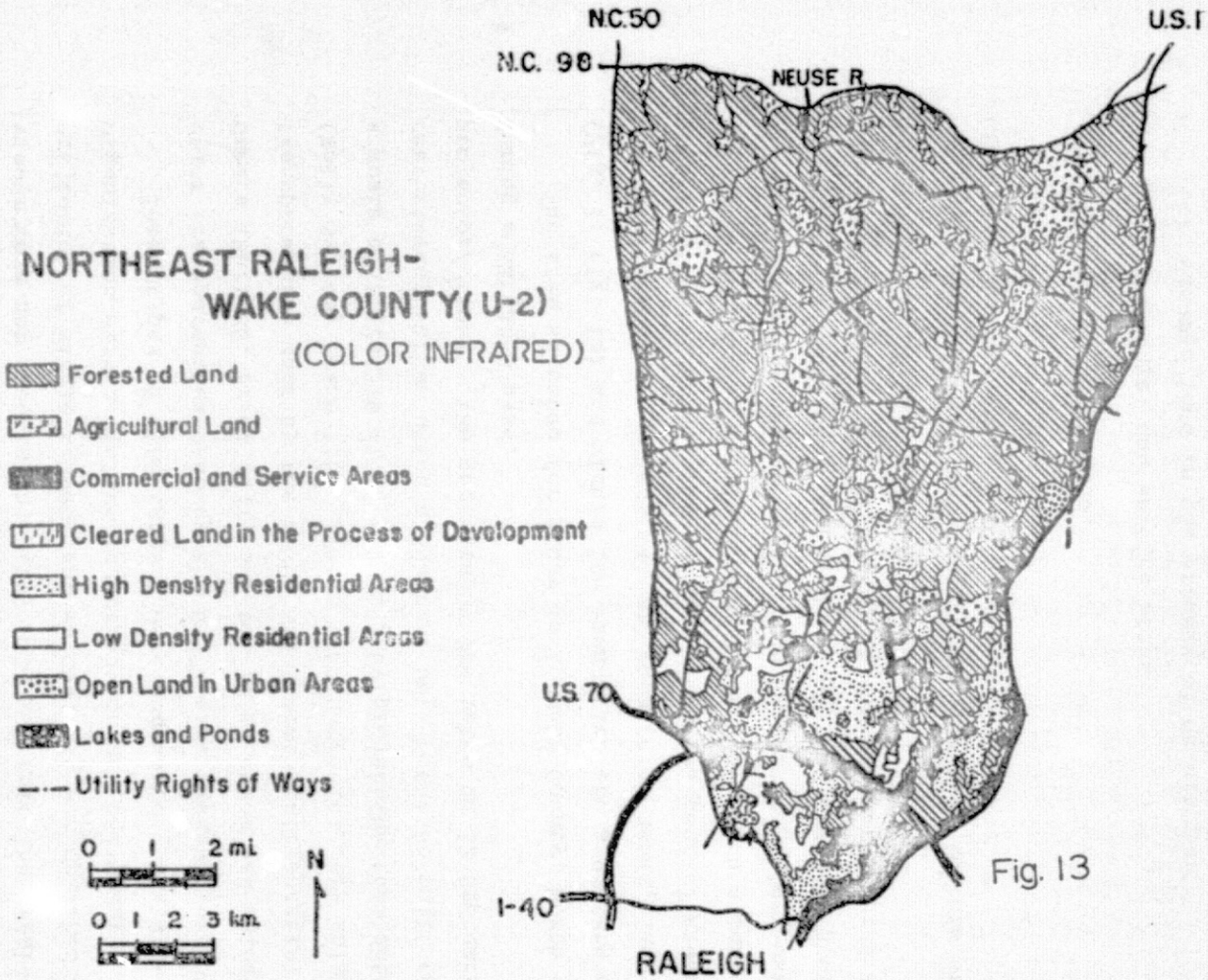


Figure 13. Northeast Raleigh - Wake County Land Use Interpreted from U-2 Aircraft Color Infrared Photography

images such as those that could be prepared using a color additive viewer were not used in the study. It was felt that rear-screen projection of single transparencies could be accomplished by any organization with a minimum investment in new equipment.

Three types of EREP imagery were evaluated: the 4.5-inch color transparencies made by the S190B experiment's Earth Terrain Camera (Roll 86, Frame 293), and the 70 mm color and color-infrared transparencies made by the S190A experiment's multispectral camera (Rolls 39, 40, Frame 118). These transparencies were enlarged to a scale of 1:126,520 (1 in = 2 mi) by projecting them onto a rear-viewing screen using a Spectral Data Model 66 multispectral projector/viewer. The photography was taken on 12 September 1973 during a SKYLAB-3 pass.

The area selected for study is in Wake County, North Carolina, (Fig. 1; Fig. 13) and within its boundaries are a variety of urban and rural features: industrial and commercial zones, land in the process of development, old and new urban residential areas, apartment complexes, farmland, and woodlands. Such a land-use mix provides a reasonable test of the imagery as a land-use mapping tool. Haze over the area at the time the EREP photographs were taken decreased the sharpness of the photography and made interpretation of some features difficult.

The following land-use categories were used in this study (Anderson, et al, 1971):

(1) Forested land
(2) Agricultural land
(3) Commercial and service areas
(4) Cleared land in the process of development
(5) High density residential areas
(6) Low density residential areas
(7) Open land in urban area
(8) Lakes, rivers, and ponds
(9) Utility rights-of-way.

Mapping was done on frosted acetate sheets, and the resulting maps are given in Figs. 13, 14, and 15.

To obtain an evaluation of the accuracy with which the land-use maps were prepared, a grid sampling method was used to compare the groundtruth map with those made from the EREP imagery. A 0.25-inch (6.25mm) square grid (1 square = 0.25 sq mi; 0.64 sq km) was placed beneath the groundtruth transparency, and then an EREP map was placed over the two. Since the grid was visible through both maps, the accuracy of the EREP map for a particular area could easily be checked. The contents of each square on the grid was then checked for accuracy. Minor differences in placement of boundaries separating land-use types due to errors in mapping were not considered as errors. Omission of a land-use type within a square on an EREP map when it was shown on the groundtruth map caused the entire square to be rated as an error (omission). Similarly, inclusion of a land-use type within a square when the groundtruth map showed that there was no such type caused the square to be rated as an error (commission). The results of this evaluation are given in Table 8.

Table 8

Accuracy of EREP Maps Compared to Groundtruth Maps, Wake County

	Percent of squares having given error type (Average of two samples)			
Film Type	Omission	Commission	Both Types	Total
S190B Color	8.15	1.25	0.31	9.71
S190A Color	7.69	1.57	0.47	9.73
S190A Color IR	10.68	4.71	0.47	15.86

It was felt that this system for evaluating the accuracy of the mapping took into account large errors in placing land-use boundaries as well as the misinterpretation of accurately mapped areas. In rural areas it was found that groups of several houses

strung out along country roads could not be distinguished from open areas. (See also Section 10.2.2.) The classification of agricultural land was accepted for these areas when scoring the EREP maps.

In addition to the quantitative evaluation of the EREP maps, a brief description of how each of the land-use categories appeared on the different types of imagery is given in Section 10.3.3.

Estimates of the amount of time needed to prepare each of the maps were also made and are shown in Table 9.

10.3.2 Discussion

Maps prepared from color transparencies taken with the S190B camera and the multispectral camera (S190A) were found to have almost the same accuracy when assessed with the square grid sampling method, even though the color transparencies from the S190B had greater resolution than those from the S190A color film. The more precise mapping that the S190B film should theoretically have allowed did not result, possibly because of the scale at which the mapping was done.

Errors that occurred on both maps made from color transparencies were mainly omissions of land-use types shown to be present by the U-2 photography and/or by field checking. Most of the omissions occurred in the urban area and resulted from failure to map small commercial or wooded areas. Also, differences in placement of boundaries between low-and high-density residential areas contributed to these errors. Rural areas were mapped much more accurately than urban areas, as might be expected because of the simpler land-use patterns. Small clusters of houses and farm buildings in rural areas are difficult to detect.

Boundaries between land-use types on maps made from color film were accurate when compared to the groundtruth map made from the high altitude photography and augmented by field studies. This fact is also indicated by the small number of commission errors for maps prepared from color film. If boundaries had been

TABLE 9

Time Required to Prepare EREP and Ground truth Maps

Activity	Time required to complete each activity (hours) by film type			
	U-2 (Ground truth)	S190B Color	S190A Color	S190A Color IR
Setting up projector	0.5	1.0	1.0	1.0
Drawing land-use boundaries	6.0	5.0	5.0	4.0
Interpretation and coloring land-use areas	8.0	7.0	6.0	5.0
Ground check	6.0	0	0	0
Final check	8.0	5.0	5.0	4.0
Total time	28.5	18.0	17.0	14.0

inaccurately placed, some land-use types would have appeared in squares where they did not occur on the groundtruth map. A similar situation would have resulted from misinterpretation of accurately mapped areas.

The map prepared from the S190A color infrared film (Fig 14) was less accurate than those prepared from the color films (Fig. 15). Resolution of this film was poorer than either of the color films and made accurate placements of boundaries between land-use types much more difficult. Agricultural land was consistently mapped much larger than it appeared on the groundtruth map, resulting in commission-type errors in rural areas. Poor resolution also resulted in misplaced boundaries in the urban areas, and more omissions of commercial areas and wooded areas than for the color films.

The color infrared film is superior to color film in identifying water features, although this superiority is not reflected in Table 8 since omissions of water features were not scored on any of the maps. A map made by using color infrared film to locate water features and color film to determine land-use categories should be more accurate than one made from color film only (Section 10.2.2).

The area mapped in this study was approximately 115 sq mi (294 sq km). As can be seen in Table 9, the time required to map the area varied with film resolution and the resultant amount of detail the map contained. At the rate of 115 sq mi/18 man-hours (294 sq km/18 man hr) it would require approximately 135 man-hours to map an area the size of Wake County, North Carolina, using color film, at the resolution and scale provided by the S190B experiment (Fig. 15). Detailed familiarity with an area should reduce considerably the time per square mile required for this particular problem. As a judgement based upon the Principal Investigator's subjective evaluation of the imagery and techniques used, it might be anticipated that an area in Piedmont North Carolina the size of Wake County could be mapped by one man using S190B type photography in about 3 weeks time.

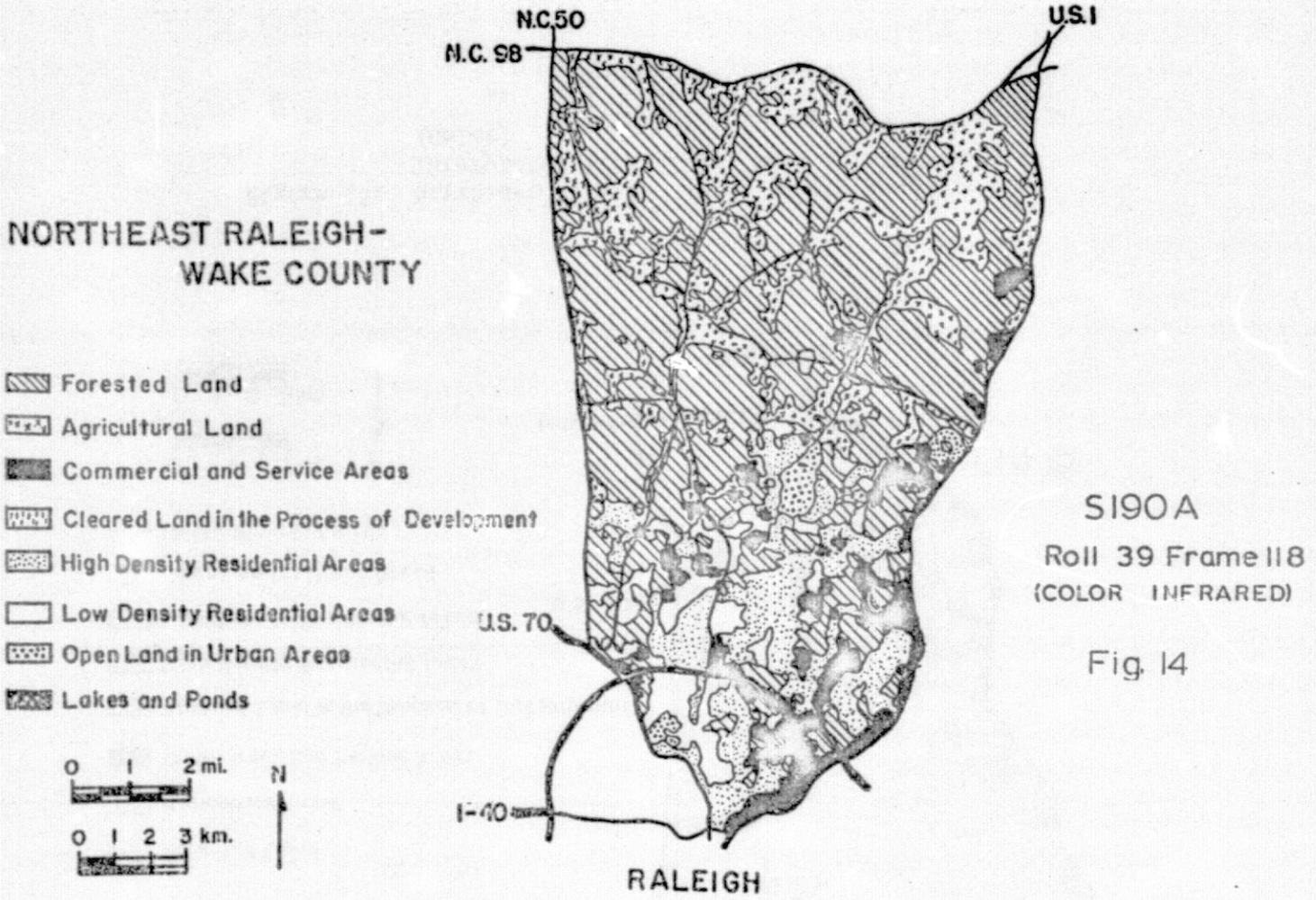


Figure 14. Northeast Raleigh - Wake County Land Use Interpreted from S190A, Roll 39, Frame 118 (Color Infrared)

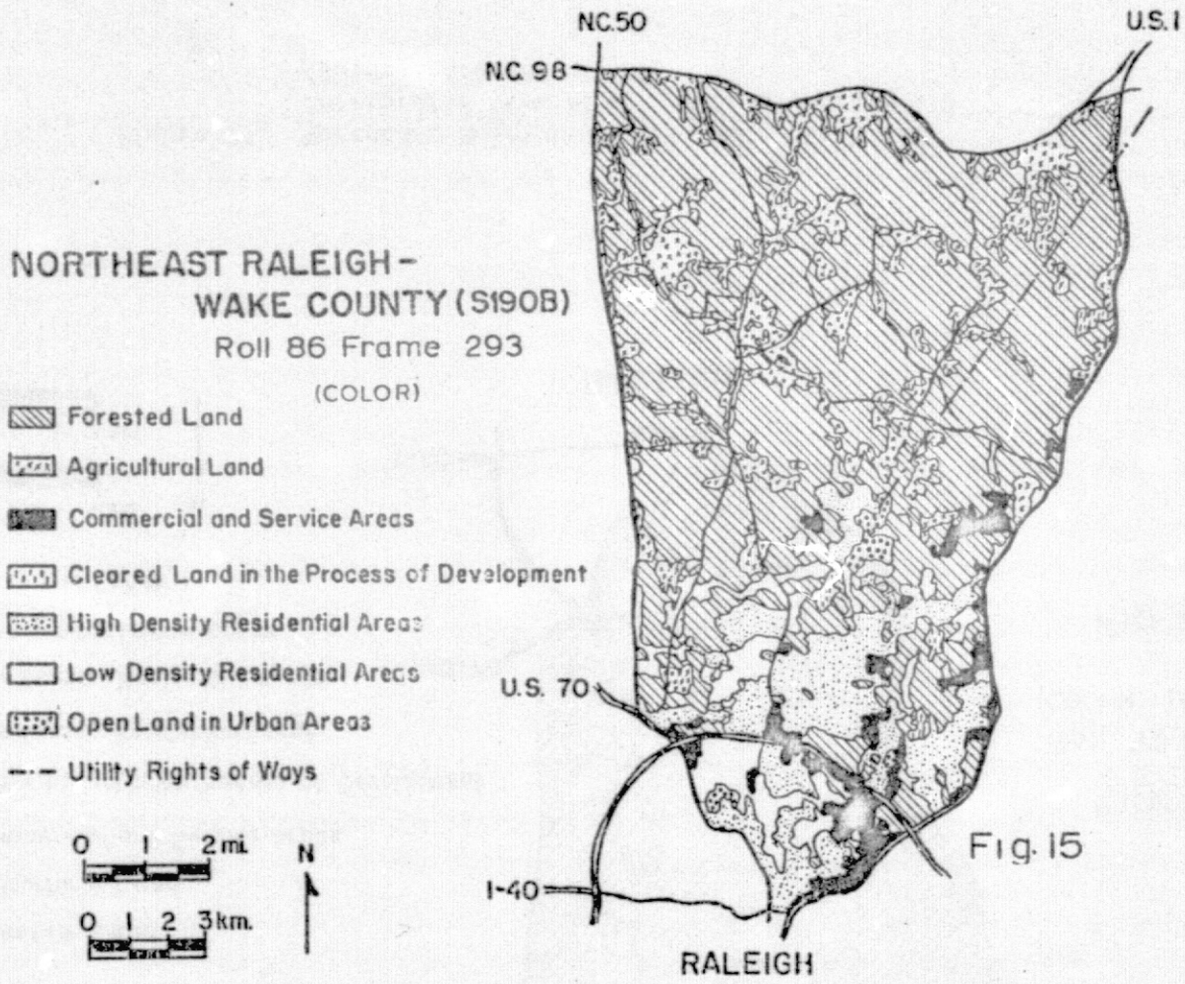


Figure 15. Northeast Raleigh - Wake County Land Use Interpreted from S190B, Roll 86, Frame 293 (Color)

In short, mapping of areas the size of Wake County (approximately 864 sq mi; 1382 sq km) using high-resolution satellite photographs can be accomplished with an accuracy of greater than 90% using the categories chosen in this report. Areas having a higher proportion of urban areas with complex land-use patterns will probably result in less accurate maps at the scale used in this study.

10.3.3 Description of the appearance of the land-use categories on the EREP transparencies for a typical area in the North Carolina Piedmont

1. S190A Color Infrared Film

Forested land - Forested land appeared as dark, solid red areas with no speckling. Some differences in color between pine and mixed hardwood stands were detectable, but due to the irregular shapes of such stands, the poor resolution of the film, and the haze over the area, no mappable distinctions were possible.

Agricultural land - Agricultural land varied in appearance because of differences in cover types. Open, harvested fields appeared as light-colored (high reflectance) areas, while fields and pastures with vegetation on them ranged in color from bright red to pink and grey.

Commercial areas and land cleared for development - The high reflectance of cleared land, large roofs, and parking lots give areas in these categories a light bluish or white color. In most cases the location of these areas (as well as the regular shapes of the buildings), serves to distinguish them from bare agricultural fields. Land cleared for development could be distinguished from existing commercial areas on the high altitude color infrared photos but no such distinction could be made on the EREP color infrared photographs.

Residential areas - Residential areas around Raleigh have a bluish or grayish cast presumably due to the mixture of housetops (high reflections) and trees and grass. High-density residential

areas differed from low-density residential areas in that this bluish cast was less intense in the lower density areas. The decision to place a given area in the high-density or low-density category was in some cases very difficult and did not always agree with groundtruth. However, there was enough agreement so that separation of high- and low-density residential areas was felt to be worthwhile.

Lakes and Ponds - Lakes and ponds appeared as light-to dark-blue areas, and most larger lakes could be identified. Small ponds two to three acres in size could not be identified because of the resolution constraints of the film.

Open areas in urban areas - Most of these areas were golf courses and were pink in color. Their location in urban areas distinguished them from agricultural land.

2. S190A Color Film

Forested areas - Forested areas were solid dark green. No differences between mixed hardwoods/pine and pine could be distinguished.

Agricultural lands - Bare fields appeared whitish, and fields and pastures with cover crops ranged from light green to brown.

Commercial areas and land cleared for development - These two types were very light colored on the S190A color photographs with differences between rooftops and parking lots less apparent than they were on the color infrared photographs. Existing commercial areas and cleared land could not be separated.

Residential areas - Because of the high resolution of the color film, streets could be distinguished in many residential areas, and no further characteristics were needed to identify these areas. The spacing of the streets and the amount of high reflectance areas (rooftops and driveways) adjacent to them were taken as indicators of the density of housing in the area. The boundaries between high-density and low-density residential areas did not always agree with those on the groundtruth map but since distinct boundaries between these two types do not exist in actual fact, some discrepancy may be expected.

Lakes and Ponds - Lakes and ponds could not be separated from agricultural and forested areas on color photos.

Open land in urban areas - Except for their location these areas were indistinguishable from agricultural areas.

3. S190B Color Photographs

Forested land - Forested land appeared as described for 70mm color film.

Agricultural land - Agricultural land appeared as described for 70mm color film.

Commercial land and areas cleared for development - In some cases, land cleared for development appeared as reddish areas due to the reflectance from reddish clay subsoil that had been exposed and thus could be distinguished from commercial areas which were white in color. Such cleared areas were distinguishable from open but partially vegetated fields, none of which had a reddish color.

Residential areas - The S190B color film had greater resolution than the S190A color film, and in some instances individual houses as well as streets could be seen. Boundaries between low- and high-density urban areas corresponded more closely with the groundtruth map than did those of the map made from 70mm color film.

Lakes and Ponds - As with the 70mm color film no lakes or ponds could be distinguished on the 4.5-inch color film.

Open land in urban areas - These areas appeared as described for the 70mm color film.

10.4 Winston-Salem/Greensboro Area

A state park has been proposed for an area south of I-40, between Winston-Salem and Greensboro, North Carolina. In an attempt to evaluate SKYLAB imagery for developing information about the land-use patterns in the area, S190A imagery was studied and attempts were made to prepare maps showing land use around the proposed park site. Frame 116 of Rolls 37, 38, 39, 40, 41, and 42 was used.

10.4.1 Interpretation

Examination of the 70mm transparencies of the color S190A pictures of the Winston-Salem/Greensboro area showed them to be of limited usefulness. Areas of open land and sites of development activity can be recognized on the imagery, but the general even blue-green tones on these particular photographs do not permit adequate interpretation for a general land-use map.

On the 70mm transparencies and the enlargements to a 9-inch format the developed areas are relatively well defined, and the forest can be differentiated into dominantly deciduous and mixed (about 50% each coniferous and hardwood). It is more difficult for an inexperienced interpreter to separate the mixed forests from pure pine stands, although an experienced interpreter knowledgeable about the region could probably do so with an accuracy of approximately 90%. Fields with crops in them show as the brightest red on the imagery, and the larger ones can be mapped in part on the color infrared film on the basis of both color and shape.

When the color and color infrared pictures were projected up to a mapping scale of 1 in = 2 mi (1:126,520 scale), many of the distinctions seen clearly on the 70mm color infrared transparencies were lost, presumably because of light diffusion in the projection process and because of film grain characteristics. The haze existing over the area at the time of the photography also contributed to difficulties of interpretation by reducing the sharpness of the photographs.

The black and white photographs from the S190A experiment were examined individually and in combination by projection to various scales through a Spectral Data Corporation Model 66 color additive viewer. In general the four black and white images from the S190A appeared to minimize any haze effects, although the frame from Roll 42 (0.5 - 0.6μm) appeared to be affected by haze.

The best combination of Frame 116 for use in the interpretation at the 1 in = 2 mi scale was that using Roll 38 (0.8 - 0.9μm) and

Roll 40, (0.6 - 0.7μm). The negatives of Rolls 41 (0.6 - 0.7μm) and 42 (0.5 - 0.6μm) can be used effectively to outline the road patterns, and water bodies show best on Rolls 37 (0.7 - 0.8μm) and 38 (0.8 - 0.9μm).

With the combination of images used and the colors used in the viewer to study them it appeared difficult to separate with any degree of surety areas of large flat buildings, large paved areas, and open fields. However, a person knowledgeable about the detailed geography of the area could probably make appropriate distinctions, but an interpreter without this knowledge must conservatively lump them together. In general, the areas of high-density structures give moderate to high reflectances in the visible bands and somewhat lower reflectances in the infrared. Thus, in the color additive viewer these areas appear in intermediate color combinations when images from Rolls 41 and 38 are compared. Areas of moderate residential density exhibit somewhat lower reflectances than the first two, and the total reflectances are such that in the color additive viewer the colors appear as about an equal balance of the two colors being used.

Agricultural land and low-density residential look much alike in the imagery and can be separated only within their geographic context. Finally, forested areas and residential areas within an area of abundant forest cover appear as relatively low reflective areas except that in the infrared bands forested areas dominated by deciduous trees may show greater reflectances than those with a significant amount of pine trees. The images of forested areas made on Roll 41 are dominantly dark in the positive format.

Figure 16 shows the land-use map of the Winston-Salem area made using Frame 116, Rolls 38 and 41 in a color additive viewer. The site of the proposed urban area park lies to the east of the area mapped. Groundtruth consisted of general knowledge of the land use along the I-40 corridor and central Winston-Salem. No attempt was made to determine the accuracy of the interpretation, but a generalized evaluation made from driving along I-40 and

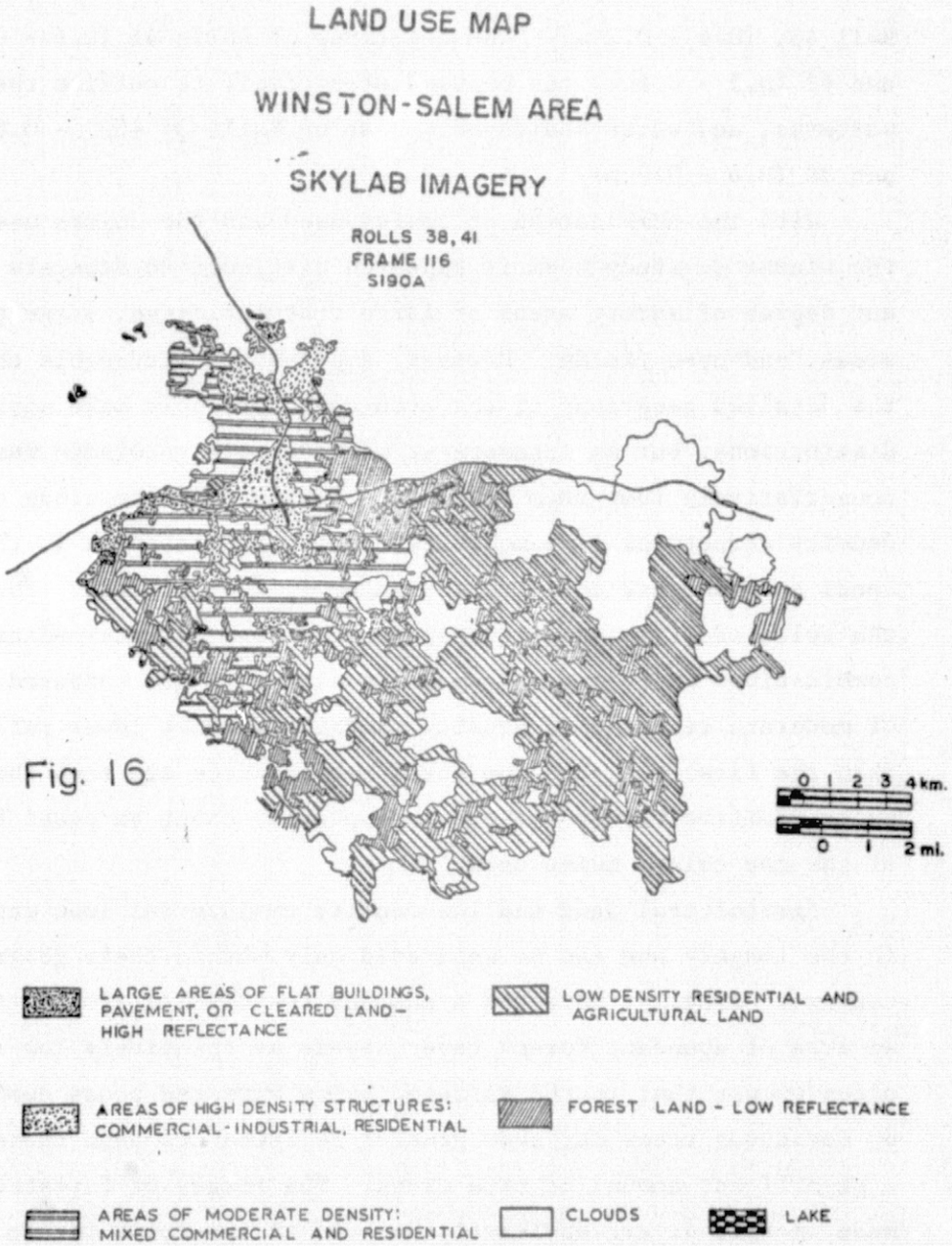


Figure 16. Land-Use Map, Winston-Salen, North Carolina Interpreted from S190A, Rolls 38, 41; Frame 116 (Black and White: 0.8 - 0.9μm; 0.6 - 0.7μm)

through Winston-Salem indicates an accuracy comparable to that generally reported for other test sites used in this investigation.

Much of the interpretative work done on this particular aspect of the investigation was done by a person who was unfamiliar with airphoto interpretation and who had only a limited knowledge of the geography of the Winston-Salem area. He was given a minimal amount of instruction and a minimal amount of supervision intentionally. The investigation then had a second purpose, namely to see how well an interested, but uninitiated person could use the imagery. From this part of the overall experiment it is concluded that it takes only a short time for an interested person to make effective use of the imagery, no matter what his previous training in its use might be.

10.5 Buncombe County and Asheville

It seemed that a comparison of LANDSAT imagery and SKYLAB photography would be useful in this study. The first SKYLAB data available were those from the Buncombe County area, coming from SKYLAB-2 (Fig. 1). They were collected one 10 June 1973. Much of the investigation centered on comparison of the two types of remote sensing data for geological purposes. However, land-use maps were prepared from both types of data (Fig. 17, Fig. 18).

SKYLAB photography and LANDSAT imagery of Buncombe County, North Carolina, were examined for four types of information pertaining to land-use planning and the effectiveness of the orbital data at showing this information was evaluated. The information sought was the present use of the land, the geomorphology, the geology, and vegetation of the area. Soil type was not considered and mapping of vegetative types was limited.

Buncombe County is in the Blue Ridge Mountains of western North Carolina. A low area of rolling hills called the Asheville Basin lies in the northwest, north-central portions of the area and extends in a narrow band along the French Broad River to

the south. The lowland is often farmed. Closer to Asheville it is used predominantly for housing and industry. Mountainous areas are either left in the natural state, used for forestry or are sparsely populated. The highest elevation, north of Graybeard Mountain, is about 5000 ft (1500m) and the lowest, along the river, is about 2000 ft (600m).

LANDSAT imagery and SKYLAB photographs examined for their effectiveness at showing the various types of information were from the SKYLAB-2 S190A experiment. Rolls 07, 08, 11, 12, Frame 251, Roll 09, Frame 267 (color infrared), and Roll 10, Frame 267 together with (color). LANDSAT-1 images 1137-15380, 1299-15380- and 154-15331, Bands 4, 5, 6 and 7 were used.

The imagery was examined in several ways. Seventy millimeter transparencies were studied with no aid, with a microscope and with a color additive viewer with the internal projection mode. Positive and negative transparencies at the scale of 1:1,000,000 (LANDSAT) and approximately 1:800,000 (SKYLAB) were examined with no aid, with binocular microscope, and in a color additive viewer with both the internal and external projection modes. Also transparencies were projected by means of an overhead projector and by means of a 35mm projector. The best method found was that of projecting part of a 1:800,000 scale enlargement of a color SKYLAB transparency with a 35mm slide projector. The next best method was found to be that of using 70mm-size pieces of 1:800,000 scale enlarged imagery in the color additive viewer and projecting the image onto the viewer screen.

For determining present land use SKYLAB photography was found to be easier to interpret by visual means than LANDSAT imagery. Individual houses, or at least blocks, can often be seen on the SKYLAB photographs (S190A and S190B). On LANDSAT-1 imagery they show up as a fine-grained texture, but individual blocks cannot be seen. Large cleared areas, such as industrial complexes, appear on SKYLAB transparencies as light-gray, clear areas recording a relatively high reflectance. Nearby residential

areas are recorded in darker gray tones and with a speckled appearance because the houses (light-gray tones; high reflectance) are surrounded by lawns or woods (dark-gray tones; low reflectance). LANDSAT imagery generally shows less contrast between the large cleared areas and the residential areas. Industrial sites are sometimes difficult to distinguish from medium- to high-density residential areas on the LANDSAT imagery. Residential areas are often difficult to distinguish from undeveloped areas on LANDSAT imagery.

The shapes of fields 0.25 mile (0.4km) wide, with crops can usually be relatively easily determined on color SKYLAB photographs, and the shapes of bare fields are almost always determinable. On LANDSAT imagery, however, the fields with standing crops could not be identified by shape, and the gray tones associated with the fields are often close to those shown by surrounding forested areas. Bare fields appeared blurred and of low contrast.

Major roads are clearly seen in the color SKYLAB photographs. Major roads showed distinctly on Band 5 of LANDSAT, but they are poorly displayed on Bands 6 and 7. For showing water, however, LANDSAT bands 6 and 7 were as good as SKYLAB data and sometimes better.

Planners and managers working with LANDSAT and SKYLAB data need to enlarge them to various scales. Thus the two types of imagery for the Asheville area were compared by projection through the optical system of a SDC Model 66 color additive viewer. The maximum enlarged scales used in this project were 1:32,000 for SKYLAB data and 1:40,000 for LANDSAT imagery. This enlargement was accomplished by projecting the imagery onto an exterior screen with the color additive viewer.

Black and white SKYLAB photography enlarged to a scale of 1:250,000 was compared with LANDSAT imagery enlarged to the same scale. Enlargements were made on EK 2420 aerial duplicating film. The SKYLAB photographs were slightly blurred, and the LANDSAT image had a grainy texture which reduced detail.

10.5.1 Geologic Aspects

For determination of the geomorphology of the Buncombe County area LANDSAT imagery proved generally more useful than the SKYLAB photography. This fact can be attributed in part to the clouds and haze recorded in the available SKYLAB photographs. These low clouds obscure the crests of high ridges and some of the detail in topographically lower areas. Also, LANDSAT imagery is available from different seasons of the year. This availability is an advantage because snow, frost or particular, season-dependent vegetational reflections can enhance some features.

The SKYLAB color infrared material proved useful for measuring stream segments and slope orientation, but LANDSAT imagery seemed to show features more distinctly and in greater detail. The infrared bands of the LANDSAT imagery were particularly useful in interpreting geomorphologic features.

The black and white SKYLAB infrared photographs (0.7 - 0.8μm; 0.8 - 0.9μm) are the most useful of the black and white materials for geomorphologic interpretations. Contrast in the 0.5 - 0.6μm and 0.6 - 0.7μm intervals (SKYLAB S190A photographic stations 5 and 6) was too low for effective geologic interpretations. The color SKYLAB photographs show geomorphologic features poorly.

Drainage patterns are clearly visible on LANDSAT imagery (Bands 6 and 7), color infrared, and SKYLAB black and white in the near infrared bands. Direct drainage into the French Broad River is visible on some LANDSAT imagery but is not shown as well on the SKYLAB materials. Streams smaller than one stream order less than that of the French Broad River generally cannot be recognized, but valleys in which there are likely to be streams can be seen.

Geologic mapping deals with rock type, structure, and other effects of deformation such as faulting, fracturing, jointing, and foliation. Neither SKYLAB nor LANDSAT imagery is suitable for detailed mapping of rock type in Buncombe County. The imagery shows that the rock is crystalline (igneous or metamorphic) and generally massive. However, in this area the different rock types

cannot be distinguished on conventional aerial photography. In areas such as the Valley and Ridge Province where different rock types can be separated on aerial photography, they also can be differentiated on LANDSAT and SKYLAB imagery.

The structure and folds noted on Hadley's geologic map of the Knoxville Quadrangle (Hadley, 1971) generally do not show on the map or the imagery. Strike, dip or foliation cannot be seen.

Lineaments, including joints, fractures, and faults can be seen excellently on LANDSAT imagery of Buncombe County. Identification of them as joints, fractures, or faults has not been possible, since the different rock types cannot be recognized. Some of the lineaments can be seen better at one season of the year than at another which is an advantage of the LANDSAT material. Color infrared and black and white SKYLAB photographs showed lineaments well in clear areas, but the color SKYLAB material showed lineaments poorly.

10.5.2 Land-use aspects

Farm vegetation could be distinguished better on the SKYLAB transparencies than on LANDSAT images. In general, color infrared SKYLAB was the best format, followed by color, and the black and white. Different tones of blue-green could be seen in the planted fields in the color SKYLAB photography. Bare fields appear in whitish tones. These areas could probably be mapped in detail, field checked, and an interpretative guide made for use in crop identification. It was not possible to separate the pine stands from the hardwoods on SKYLAB. It might be possible to separate them on LANDSAT imagery by using imagery from different times of the year. The land-use maps prepared in this portion of the study are given as Fig. 17 and Fig. 18 for comparison.

An examination of density slices of LANDSAT and SKYLAB imagery of Buncombe County did not find them to be of great value for land-use mapping. Slight differences in texture are important

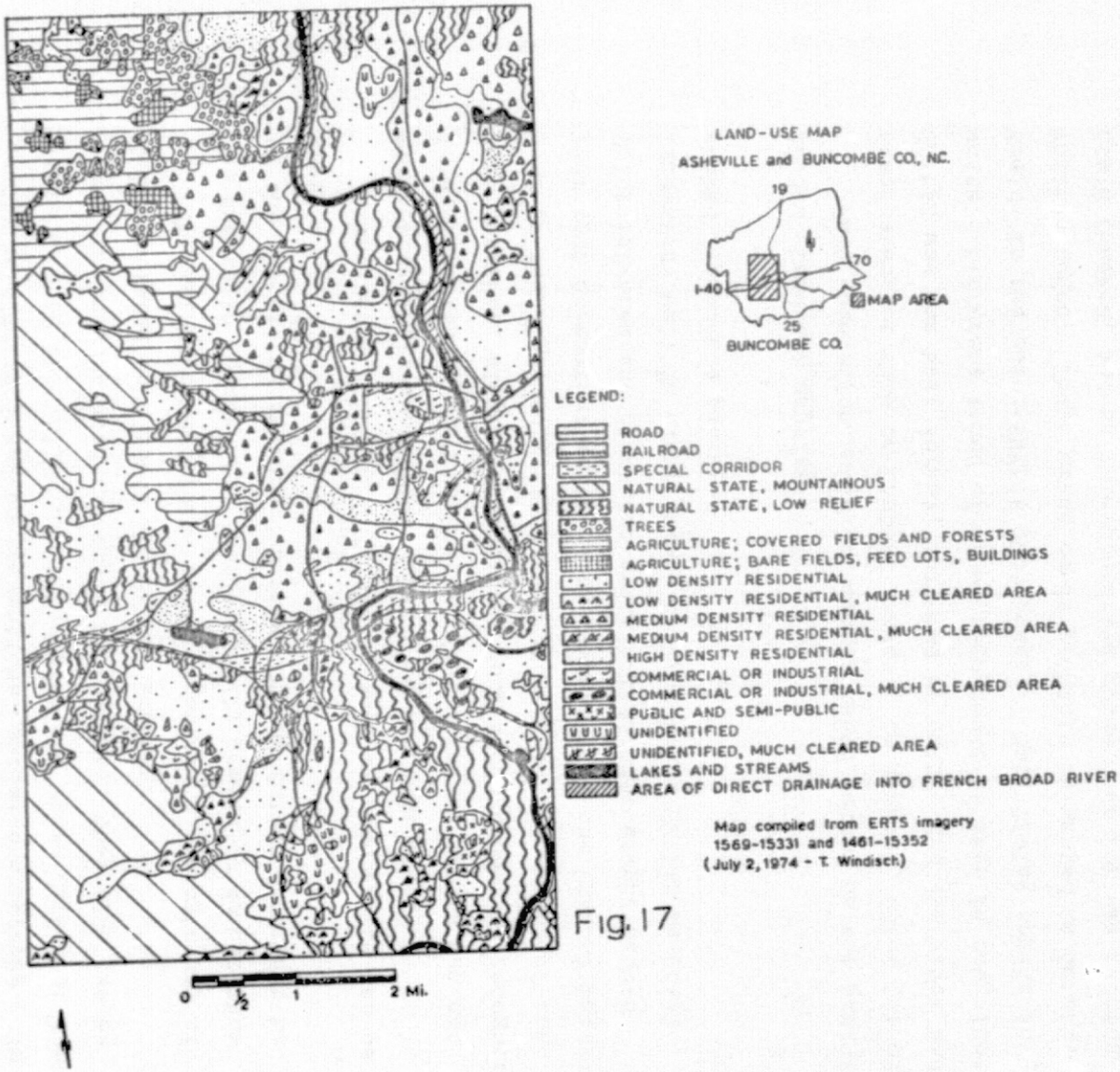
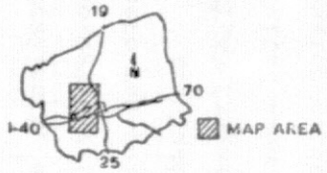


Figure 17. Asheville and Buncombe County Area Land Use Based on Interpretation of LANDSAT-1 Imagery

LAND-USE MAP
ASHEVILLE and BUNCOMBE CO. N.C.



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- RAILROAD
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- MEDIUM DENSITY RESIDENTIAL
- HIGH DENSITY RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- PUBLIC AND SEMI-PUBLIC
- UNIDENTIFIED
- LAKES AND STREAMS

Map from Skylab June 10, 1973 imagery
Roll 10 (color), Frame 267.
(June 19, 1974 - T. Windisch)

Fig. 18

Figure 18. Asheville and Buncombe County Land Use Based on Interpretation of Frame 267, Roll 10 (Color) S190A SKYLAB-2

in land-use interpretation and mapping, and the density slices did not show them. Some general trends were much more obvious than on the original imagery, but it is not presently thought that this technique will be useful for land-use interpretation in the Asheville area.

10.5.3 Discussion

It has been found that for Buncombe County, North Carolina, present land-use patterns are most easily seen on color SKYLAB photography, while LANDSAT imagery is less useful. Water is shown about equally well by near-infrared LANDSAT and SKYLAB material. Topography and drainage are displayed well on LANDSAT imagery because of its clearness and lack of clouds. Rock type is not displayed well on either type of orbital imagery. Little structure can be recognized, but LANDSAT imagery shows lineaments excellently and over a large area. The usefulness of SKYLAB photography is limited by the presence of clouds and the fact that there was only one pass, in June.

It should be possible to make an interpretative crop key for SKYLAB imagery, but this exercise was not undertaken because of the limited amount of data available due to the weather and SKYLAB mission constraints. It should also be possible to make a crop key for the LANDSAT imagery by use of special color effects in the color additive viewer with imagery from different seasons.

The most efficient mapping method was that of projecting 1:800,000 scale color SKYLAB photography in a 35mm slide projector and tracing areas of similar reflectance characteristics as recorded by the film. These areas were then identified by examining the 70mm transparencies under a microscope (Fig. 17, 18).

10.6 Asheville Land Use

The objective of this study was determination of the extent to which SKYLAB-2 photography of 10 June 1973 could be used in constructing a land-use map of Asheville, North Carolina by an

experienced photo-interpreter. Another purpose was to compare the land-use map with an earlier interpretation (Section 10.5; Fig. 18), and lower altitude aerial photography over Asheville, North Carolina. Also, this study was aimed in part at quantifying the interpretative accuracy in contrast to the earlier study which was qualitative in nature. Additionally, a more concentrated effort was made to separate forest types than was done in the earlier study.

The study location is the city of Asheville, located in Buncombe County, North Carolina, within the Blue Ridge Mountains. The area mapped is encompassed by the U.S.G.S. 7.5-minute Asheville Quadrangle. Elevations vary from 1950 to 3500 ft (600 to 1100m), and the area consists of 33,780 acres (53.61 sq mi; 137 sq km), including Asheville and surrounding areas.

Asheville is a large tourist and recreational center located near the Great Smoky Mountains National Park and the Blue Ridge Parkway and is the seventh largest city in the state. Like all recreational areas it is undergoing growth, and the investigation tests the ability of space-acquired imagery at SKYLAB scales to provide meaningful land-use information about the mountain province of North Carolina.

10.6.1 Methods

SKYLAB-2 photography made on 10 June 1973 was used as the data base for a land-use map of Asheville. Developed and undeveloped areas surrounding the city were outlined together with their associated patterns. SKYLAB S190A imagery (Rolls 09 and 10, Frame 267) proved to be the most useful format for this phase of the study.

Field studies were first conducted at eighteen training sites to correlate land-use categories with their photographic response (Fig. 19). These sites were chosen because collectively they represented the range of reflectance characteristics observed on the transparencies of the study area.

Figure 19. Asheville Area Training Sites

After the sites were analyzed from the photography, a land-use map was prepared for the area using the following techniques. A scaled drawing was reduced to a nominal scale of 1:36,500 from a U.S.G.S. 7.5-minute Asheville Quadrangle map. Maximum resolution was attained at a scale of approximately 1:62,500, but part of the experiment was to find the largest scale at which mapping could be done using a color additive viewer. The area of the quadrangle map (53.6 sq mi; 137 sq km) was outlined on the S190A color and color infrared positive transparencies. The color photography of S190A (Roll 10, Frame 267) and the color infrared photography of S190A (Roll 09, Frame 267) were used to inventory the basic land-use categories. The photography from the S190B camera (Roll 81) could not be used because the study site was not included within the area covered by the Asheville area photography from this camera. Further detailed mapping was done using different combinations of the multispectral stations (S190A, Rolls 08-12, Frames 267 and 251) as viewed through a Spectral Data Model 66 Color Additive Viewer.

Two major land-use categories of developed and undeveloped areas formed the larger divisions of the classification. Developed areas were further subdivided into five classes which consisted of commercial, industrial, residential, agricultural and semipublic. The commercial division consisted of shopping centers, public service and business activities. Industrial areas were manufacturing, railroad facilities and processing plants. Residential acreage was divided into high-, medium- and low-density concentrations of housing. Agricultural areas were separated into old field (bare or pasture) and cultivated fields (annual crops). Finally, the semipublic subdivisions consisted of parks, golf courses, cemeteries, schools, or historic locations.

Undeveloped area, the second major land-use grouping, was further subdivided into forest, floodplain and water categories. The forest category was further separated into pine (loblolly, shortleaf, white pine but included also hemlock), hardwood (oak, hickory, maple, beech and birch) and mixed (oak, loblolly and

shortleaf). The floodplain category consists of a flat tract of land bordering the French Broad River which contains alluvium deposited by the river. The water category includes the French Broad River, reservoirs and lakes.

Seventy millimeter squares were cut from 9-inch enlargements (approximate scale 1:800,000) of S190A multispectral camera transparencies and were projected onto the viewing screen of the color additive viewer at a 4x enlargement. Slides of the different multispectral combinations were made and compared using two slide projectors. Also, the imagery was projected onto a vertical, clear glass panel with frosted acetate mounted on it through the external projection mode of the viewer. SKYLAB S190A imagery was also studied with a binocular microscope.

Accuracy of the photographic interpretation was determined with the aid of color infrared photography obtained from a U-2 flight (NASA/MSC 128-A) made in May 1970, with the aid of black and white aerial photographs made for the North Carolina Department of Natural and Economic Resources in April 1975 (1 in = 400 ft; 1 cm = 48 m), and by random ground site evaluation. The land-use map constructed from the SKYLAB S190A multispectral imagery was compared to the U-2 aerial photography by means of an Old Delft scanning stereoscope.

Within the 53.6 sq mi (137 sq km) mapping area five sites, each one square mile (2.5 sq km) in area, were chosen for the random site analysis. A five place random number table combined with a square-inch grid system was used to determine the row and column for each site position. Within each square of the grid system are 25 randomly placed dots. T e locations of the random sites are illustrated on Fig. 20. Each pair of numbers in the random number set was used to define the position of the test site. If any point of the site overlapped or fell outside the quadrangle, another random number set was chosen.

Field checks were made of each random test site, and errors of interpretation determined. On the imagery the acreage of each

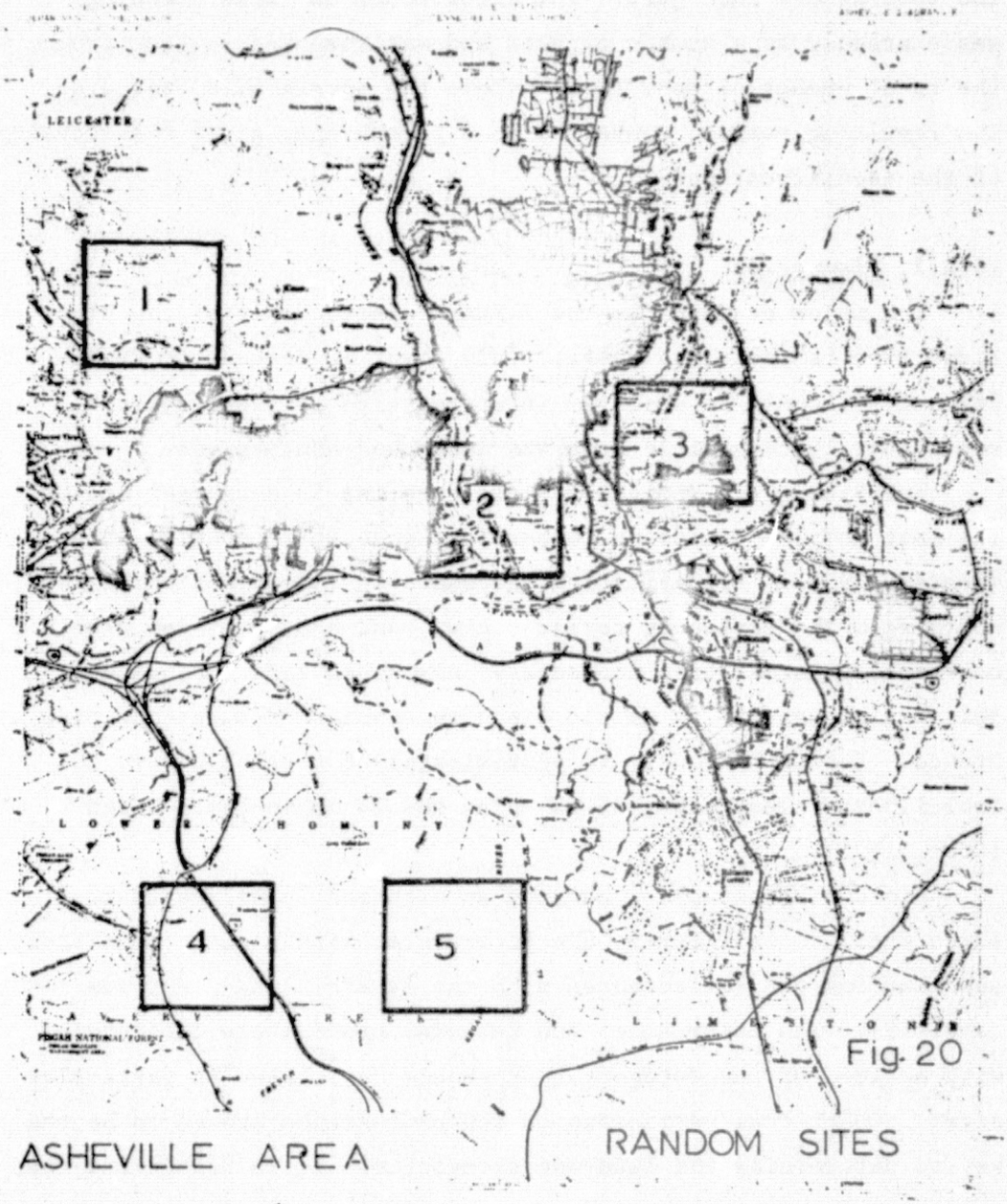

Figure 20. Asheville Area Random Sites

category found within the test sites was determined by use of a 100 dots/square inch grid. The error found on field checking was expressed as a number of dots and was then subtracted from the total number of dots (100) within the square mile test area. The resulting number, converted to a percentage, gives the accuracy of the identification.

10.6.2 Discussion

The major drawback to the SKYLAB-2 photography of the Blue Ridge area is the cloud cover. Only about 50 percent of Frames 267 and 251 could be used for interpretative purposes. Cloud cover over the Asheville area was less than one percent.

The Blue Ridge region of North Carolina is characterized by the most complex deciduous forest in the southern Appalachians (Oosting, 1956). Precipitation decreases in all directions except north from the deciduous forest center, and a drought-resistant oak-hickory association dominates. Abandoned land throughout this region results in an old field succession of subclimax pine stands. Buncombe Country is approximately 83% oak-hickory, 10% loblolly-shortleaf pine, 6% oak-pine and 1% maple-beech-birch (Cost, 1975).

Field studies were conducted at eighteen locations (3 to 5 acres each) to familiarize the interpreter with plant communities, associations and reflectances from the several land-use types (Fig. 19). The color tones and patterns provide the interpreter with an idea of the category that should be located in particular sites. Color tone variations on the photographs proved to be the key to determining the land-use categories. It is recognized that a different interpreter might see the different land uses as slightly different colors and that film processing exerts a control on the product used for interpretation. However, description of what one interpreter sees is useful for teaching others to use the SKYLAB data.

10.6.2.1 Category signature with color and color infrared transparencies: This part of the investigation was conducted using color and color infrared SKYLAB-2 photography taken 10 June 1973. It was studied in combination through use of a color additive viewer. The colors described below are chiefly those found on the S190A color infrared transparency. The developed areas contained commercial, industrial, residential, agricultural and semipublic sites. Commercial sites usually appeared bluish-white, and the color is attributed to the highly disturbed surface conditions and pavement which produce a high reflectance in the visible part of the spectrum in contrast to the infrared part.

Industrial sites had the same general reflectance as commercial sites and could only be separated by their association with transportation facilities (roadway, railroad and river). In some cases the reflectance appeared whiter than that of a commercial site. The more highly disturbed surface conditions associated with the industrial sites appear to be the cause for the reflectance differences.

The three different residential densities were high-density (bluish-purple), medium-density (purplish-white) and low-density (reddish-purple). It appears from field checking that the differences in photographic response can be attributed to different concentrations of vegetation. Different balances between the visible reflections and the near infrared are probable causes for the differences in appearance.

Both agricultural sites are easily distinguishable by their geometric pattern with old fields appearing blue to white and cultivated fields being bluish-red. The blue and white of bare fields and pasture is apparently related to a greater reflectance from the soil, and the mixed pattern of bluish-red on the color infrared transparencies indicates an annual crop (usually corn in the Asheville area).

Semipublic sites were determined by a combination of associations and reflectance characteristics. Many of these sites were in the

city limits and had blue tones associated with a pink color. The pink color was attributed to lawn grass and blue with adjacent facilities.

The undeveloped areas contained the forest, floodplain and water categories. Pines appear on the infrared imagery in dark purplish tones, and hardwoods are a bright red. Reflectances from the mixed forest vary in color tone between the two end member types. The French Broad River floodplain contains alluvial deposits of high reflectance. Some of the floodplain is used for annual crops and for industrial or commercial sites. A bluish-white reflectance seems characteristic of the alluvial deposits and was recorded as a background reflectance even though the fields had immature crops of corn growing on them.

The reflectance from the French Broad River and lakes was recorded on the film mostly as a dark blue to black hue; however, some highly turbid farm ponds show as a medium bluish tone on the infrared transparencies.

10.6.2.2 Multispe ral photography: The six station multispectral photography was analyzed using a color additive viewer (Spectral Data Model 66). SKYLAB imagery data can be found on Table 10. Black and white photography from stations 1, 2, 5, and 6 was compared with the color photography from stations 3 and 4 in terms of the quality of the ocular interpretation of the study area. This comparison can be seen in Figs. 21 and 22. The four multispectral bands of black and white photography when combined into a color composite in the color additive viewer had better spectral resolution characteristics and thus could be used more effectively for detailed mapping than the color films. However, under the conditions of the experiment there could be no meaningful determination of the relative spatial characteristics. A stereomicroscope could be used to make measurements on the color and color infrared transparencies but measurements of similar precision could not be made on the screen of the color additive viewer.

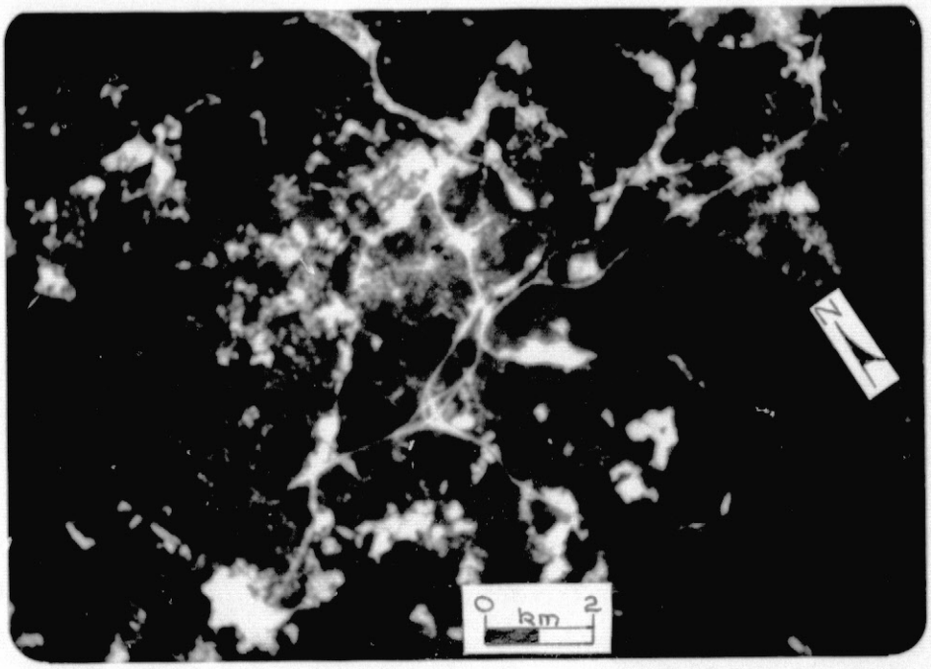

Figure 21. False Color Composite of Asheville, North Carolina Area Made from Stations 1, 2, 5, and 6; S190A, Rolls, 7, 8, 11, 12, Frame 267

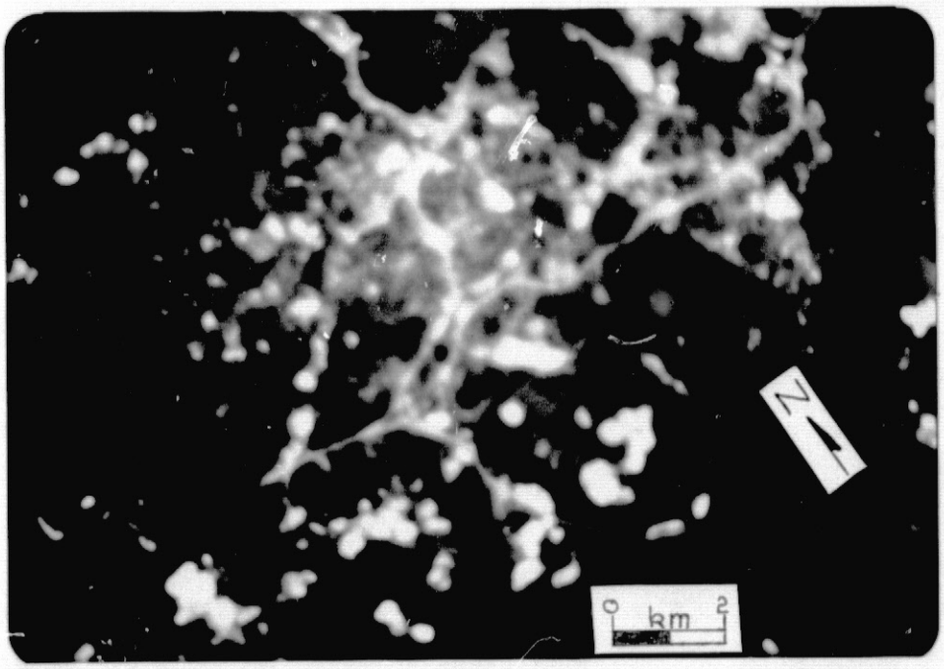

Figure 22. Combination of Color and Color Infrared, Stations 3, 4; S190A, Rolls 9, 10. Asheville, North Carolina Area.

Advantages of the two color films are that more color saturations are present, more roadways can be defined, and vegetation, especially in the agricultural category, can be separated. The main reason for the better resolution evident in the black and white stations was due to the film characteristics noted in Table 10.

The next step in the analysis was to compare the four multispectral black and white photographs with different combinations of the color and black and white photographs. This comparison can be seen in Fig. 22 and Fig. 23. Little difference was evident between the many combinations tried. The only distinction between the two color film formats and the various combinations was that combinations enhanced different categories making them more easily recognizable than when color alone or pure black and white combinations were used. Accuracy of interpretation could be increased from one format to another, depending on the land-use category chosen for analysis.

10.6.2.3 Random ground sites: Five ground sites each one sq mi (2.5 sq km) in area were chosen at random to determine accuracy (Fig. 20) of interpretation. The detailed classification of land uses on each site is shown in Table 11.

Site 1 was located north of West Asheville, just north of Route 63. In some instances separation of high residential from commercial sites proved difficult. Also separation of some pine from mixed forests sites was difficult. Errors made in the interpretative process led to an accuracy of 93%. The high reflectance and similar saturation patterns of high residential and commercial areas sometimes made a distinction impossible. Difficulty in interpreting whether a particular forested area consisted of mixed or conifer stands accounted for approximately one-half of the error.

Random Site 2 lies in the downtown Asheville area. A 3.5% error resulted from interpretation of floodplain as a high residential site. Central city photo-interpretation is very difficult with the spatial resolution of SKYLAB S190A imagery.

TABLE 10

Multispectral Camera Data

Station	Filtered Band (μm)	Film	Estimated Ground Resolution	Roll	Frame
1	.7 - .8	B & W infrared EK-2424	73-79 meters	7	251
2	.8 - .9	B & W infrared EK-2424	73-79 meters	8	251
3	.5 - .88	Color I. R. EK-2443	73-79 meters	9	267
4	.4 - .7	Color SO-356	40-46 meters	10	267
5	.6 - .7	B & W Pan-X 50-022	30-38 meters	11	251
6	.5 - .6	B & W Pan-X 50-022	40-46 meters	12	251

Source: SKYLAB Earth Resources Data Catalog, 1974

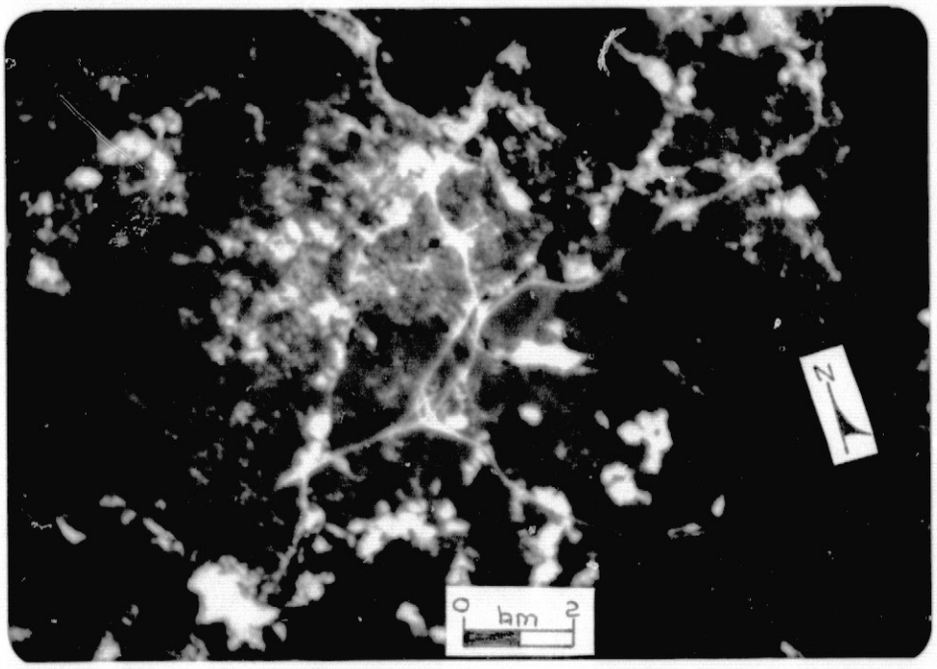

Figure 23. False Color Combination of Asheville Area Made from S190A Photography

Color - blue; Roll 7 (0.7 - 0.8μm) - red; Roll 11 (0.6 - 0.7μm) - green; Color Infrared - white; Frame 267

TABLE 11

Land Uses on Random Ground Sites

(Classifications are in percent)*

Site No.	Commercial	Industrial	Residential High	Residential Med.	Density Low	Annual Crop	Pasture	Forest Pine	Forest Mixed	Forest Hardwoods	Water	Flood Plain	Percent Error
1	6	--	2	47	2	6	11	4	18	--	--	--	7
2	9	10	42	--	--	--	--	--	21	9	9	--	3.5
3	14	--	49	3	--	--	--	8	17	15	7	--	0
4	12	--	--	--	9	34	--	11	22	8	4	--	0
5	--	--	--	--	--	12	16	8	42	19	--	3	0

*Figures do not add to 100% because of rounding.

There is still some difficulty even when the original scale is 1:20,000 because of the close spacing of the buildings. In many cases the photo-interpreter has to make a judgement decision as to the land-use category found on a certain site such as this one.

Random Site 3 was located between Route 81 and Route 70 in the Kenilworth area of Asheville. Lake Kenilworth, representing the water category, was determined to occupy 7% of the area. Groundtruth from field checks and aerial photographic interpretation showed the interpretation from the SKYLAB S190A photography to be completely accurate.

Random Site 4 was located just south of the intersection of Interstate 26 and NC 191, southwest of Asheville. Water is 4% of the area, being represented by Westerly Lake. Accuracy was determined to be 100% because no errors were encountered during ground checks. Random Site 5 lies to the east of Random Site 4 and borders the French Broad River.

Interpretation accuracy for all random ground sites varied from 93% to 100%. The largest problem encountered lies in the differentiation of land-uses within the city limits. Some categories have very similar reflectances and are easily mistaken for one another. The greatest error arises from attempts to differentiate industrial from commercial, and commercial from high residential sites. Much of this type of interpretation is a matter of judgment because of the resolution limits imposed by the SKYLAB S190A imagery. Errors can also be made in separating pine from mixed forest stands. Care must be taken not to overlook any surrounding water body that could make a mixed stand appear to have reflectance characteristics of pine stands, although the infrared bands of the black and white imagery assist in any interpretation.

In addition to the French Broad River several lakes and ponds were studied. Color photography of SKYLAB S190A could not be used to define the exact boundaries of many of the lakes. Color infrared photography could be used to recognize lakes as small as approximately 600 ft (185m) in one dimension, but here

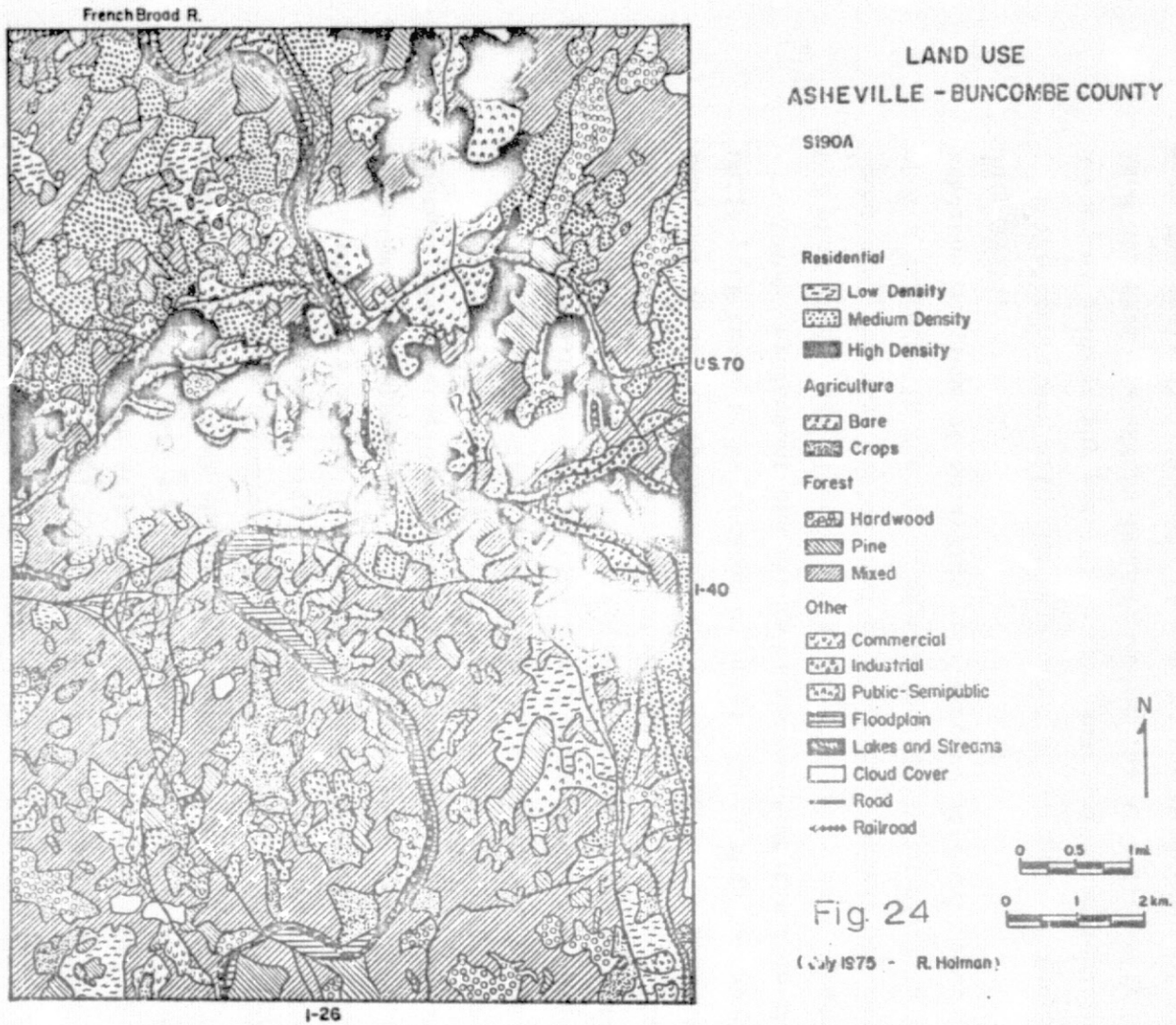

Figure 24. Land Use Map of Asheville Area. Interpretation Made from S190 Photography

again the shorelines were not sharply defined. Figure 24 is the land-use map derived from the study.

10.6.2.4 Comparison with other sources: The complete land-use map of the Asheville area could only be indirectly compared with three other data sources because of the time that had elapsed since the flights were conducted or because categories did not include the same elements. These three sources were U-2 color infrared photography flight (NASA/MSC 128-A) made in May 1970, black and white aerial photography made for the North Carolina Department of Natural and Economic Resources in April 1975, and another interpreter's analysis of the same area using SKYLAB data.

Good correlation was found between the U-2 photographs of May 1970 and the SKYLAB land-use map. Coniferous and mixed forests were much easier to define with this higher resolution imagery. Small isolated pine stands were missed in the SKYLAB analysis. Color infrared U-2 photography viewed in stereo also verified that hardwoods are found along the western slopes of mountains while pine tends to be located on drier slopes than hardwoods.

Urban development had changed somewhat from the time the U-2 photography was flown. There appeared to be an increase in commercial and high residential development. Recent census data show a decrease in the urban population and an increase in the suburban sections of Asheville (C. Tessner, personal communication, July 1975).

The comparison with the Department of Natural and Economic Resources photography pointed to many small misinterpretations of land use from the SKYLAB imagery within the Asheville city limits. With the scale of 1 in = 400 ft used by the Department of Natural and Economic Resources industrial, commercial and residential sites can be separated more easily than with SKYLAB imagery. The Biltmore Forest area located south of Asheville has medium- to low-density residential dwellings as indicated from the large-scale photography and ground checks. The majority of land was interpreted as mixed

forest and pine forest for the SKYLAB land-use map. The residential areas lie in mixed and pine forests, but few of the actual dwellings can be seen on even the large-scale black and white photography. SKYLAB imagery indicated simply different forest types. Overall correlation with the high resolution photography showed a high degree of accuracy when the SKYLAB spatial resolution is taken into account.

The final comparison was with a land-use map constructed by T. C. Windisch (1974) using SKYLAB imagery (Fig. 18). A few problems and differences were encountered while reviewing the two land-use maps. There was not as much detail in the earlier land-use maps, and in many areas the categories were more generalized than in the present study. Separation of residential, commercial, and industrial land-uses is difficult on the imagery at best, and there are some differences of interpretation between the two studies (Compare Fig. 18 and Fig. 24). However, the overall results indicate that the two interpreters (Windisch and Holman) were able to construct land-use maps which agreed except in a few details and in the area south of Asheville. For this area the interpretation of residential and agricultural categories differed. (See also Section 6.2.4.)

10.6.2.5 Conclusion: The land-use map drawn in 1974 (T. C. Windisch) showed light residential areas that were forest and agricultural areas on the 1975 (R. Holman) version. Both land-use categories were correct, depending on the specific viewpoint about the land use that was chosen. If the interpretation was made for natural resource evaluation, most areas would probably be interpreted as dominated by a forest or agricultural category; on the other hand, an interpretation from an urban planner's probable viewpoint would show the area as one of low-density residential. Also, for the same reasons, there were differences in the assigning of densities within residential sites. This difference was found mainly within the Asheville city limits.

The only significant error encountered in the 1974 land-use map was with the interpretation of some floodplain sites as industrial. These sites could be easily mistaken for industrial land-use by an interpreter unfamiliar with details of the area and with little groundtruth available to him. Both reflectances were similar and the surrounding land-use was the only clue to proper identification of the site. Most sites in the Biltmore Estate were actually corn fields with the highly reflective sediments evident between rows of the young crop. Multispectral combinations in a color additive viewer (Spectral Data Model 66) of color (Stations 3, 4) and black and white (Stations 1, 2, 5, 6) gave the most detail and greatest interpretation accuracy when compared with use of black and white stations alone.

A land-use map of Asheville, North Carolina, derived from SKYLAB photography seems to have a high degree of indirect correlation from other sources. Two photo-interpreters analyzing the same study area came up with very similar land-use maps. Random sample sites used in one study (Table 11) reveal an overall interpretation accuracy of better than 93%.

Land-use categories were usually determined by association with adjacent sites and color tones produced by their particular reflectances. Problems were encountered in differentiating residential, commercial and industrial sites within the city limits of Asheville because of the spatial resolution limitations of the imagery.

It was found during interpretation that time must be taken to weight carefully several relationships (color tone, adjacent sites, water) before assigning a particular land-use category. Familiarity of the interpreter with the area and the interpreter's level of photo-interpretative experience with the type of imagery used and his acquired skills in its use are two of the major factors in precise visual analysis of photographs or images from spacecraft.

Benefit - Cost Evaluation

A land-use map can probably be drawn for a 50 to 100 sq mi (128 to 256 sq km) area similar in its characteristics to the Buncombe County area within a two-day period after sufficient ground data are provided for the particular area.

Local and regional governmental agencies were compiling land-use data on Buncombe County and Asheville during the period covered by this investigation. Attempts were made to acquire from them information on which a cost/benefit analysis of the use of SKYLAB data could be based. However, the data were not available, and so it is not possible to give more than the general statements provided in this section.

One major benefit believed demonstrated by this study is that the North Carolina Division of Forestry, the Agricultural Extension Service, and State Planning Office could use space-acquired imagery in information compilation for their various purposes.

Resolution of the SKYLAB imagery limits the use it might have with urban planning. Most of this type of planning is very detailed (scale 1 in = 400 ft; 1 cm - 48 m), and SKYLAB imagery falls far short of their needs.

10.7 Eno River Study

The objective of this particular study was to examine the extent to which SKYLAB-3 photography of 12 September 1973 could be used to evaluate some environmental parameters of an area where proper land use is a matter of controversy. Another purpose was to develop an acceptable and accurate technique for interpreting the imagery of an area in the North Carolina Piedmont.

The study location is the site of the proposed Eno River State Park, located in the central Piedmont region of North Carolina within Orange and Durham Counties (Fig. 1). The proposed park follows the Eno River, which flows east from Hillsborough, south toward Interstate 85 and then northeastward on the north side of Durham. Consisting of 8,750 acres, the proposed park area includes

a large tract east of Hillsborough extending southward from the river to Interstate 85. Figure 25 shows the location of the proposed park (Allen Eakes, personal communication, July 1975) and boundaries as initially proposed.

The Eno River has played an historic role in the commerce and recreation activities of the local residents because of its natural beauty and location. In recent years the Eno Basin has been heavily used for hiking, fishing, swimming, canoeing, and rafting. There are urban pressures on the site arising mostly from the northern Durham area (Wuenscher and Starrett, 1973). An environmental evaluation of this area from a watershed approach would help determine the impact that present and future development may have on the proposed park. Questions concerning the location of the recreational facilities within the park arise because of the infringing urban development. The answers are important to successful planning.

The North Carolina State Park System considers that one of the purposes of a state park is to preserve and protect natural areas of unique or exceptional scenic value (Principles for the Establishment of State Parks, 1974). Natural areas usually depend heavily on the vegetation found within the proposed park site. An analysis of vegetation, together with a study of patterns of encroaching development, therefore, are important contributions that might be made through interpretation of SKYLAB photography.

10.7.1 Methods

SKYLAB-3 photography was used as an environmental mapping tool for the proposed state park site. Developed and undeveloped areas surrounding the park were outlined together with their association, and impact on the park site analyzed. SKYLAB S190A imagery (Roll 39 and 40, Frame 117) proved to be the most useful format for this particular study.

Field studies were first conducted at fifteen sites (training sites) to correlate land-use categories with their photographic response (Fig. 25). After these sites were analyzed from the

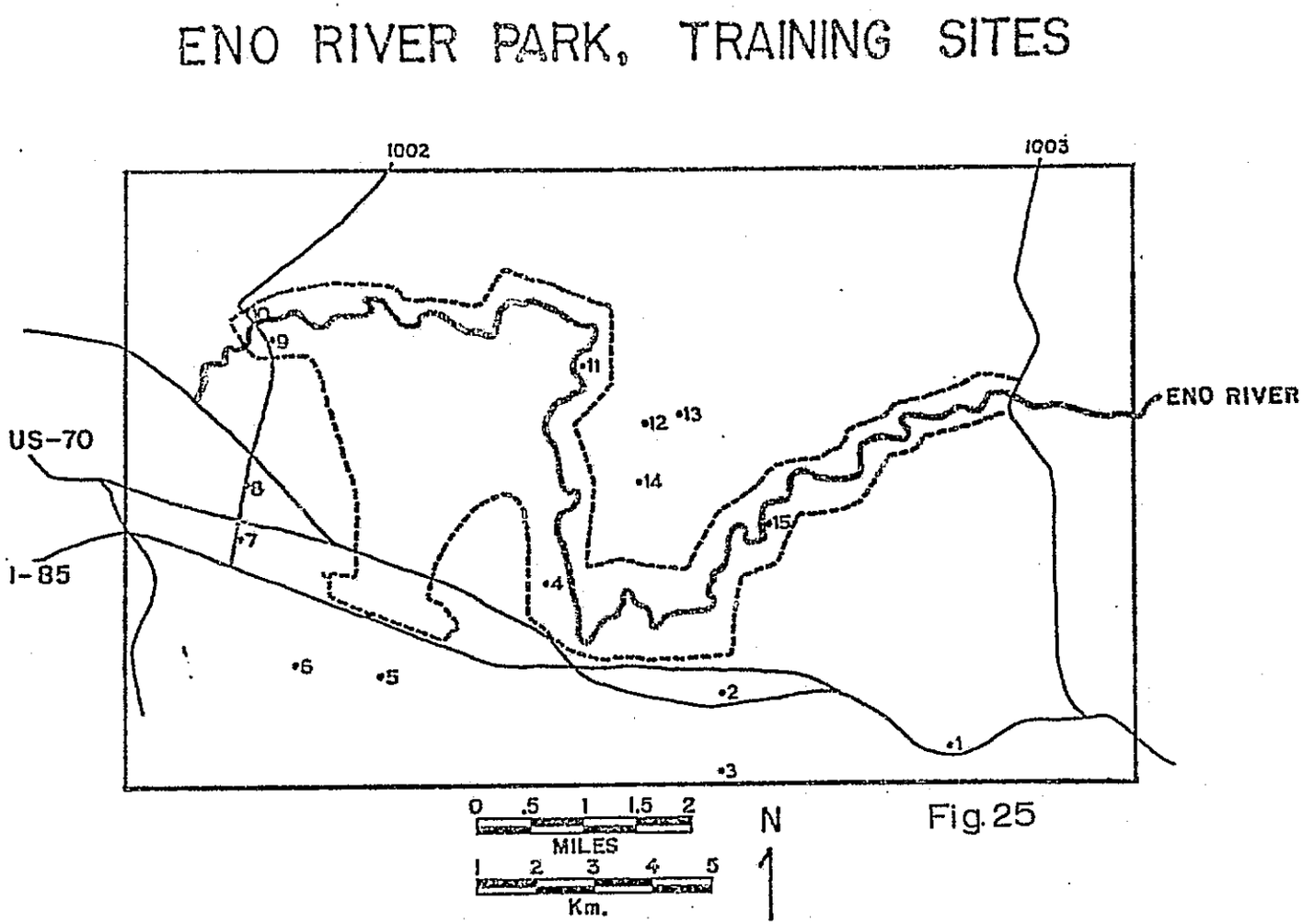

Figure 25. Eno River Park - Training Sites

photography, a land-use map was prepared for the whole area using the following techniques. A scale drawing was prepared from two U.S.G.S. topographic quadrangle maps at a nominal scale of 1:62,500. The park boundaries were drawn in from a map provided by the North Carolina Division of State Parks. A Bausch and Lomb zoom transferscope was used. An area of 38,400 acres (60 sq mi; 154 sq km) was outlined on the S190A color and color infrared positive transparencies. The color photography of S190A (Roll 40, Frame 117), color infrared photography of S190A (Roll 39, Frame 117) and S190B (Roll 86, Frame 292) were used to inventory the several land-use categories.

Two major land-use categories, developed and undeveloped, form the larger divisions of the classification. Developed areas were further subdivided into three classes which consist of commercial, residential, and agricultural. The commercial division consisted of public service, business, and golf course facilities. Residential areas were private dwellings that were completed or under construction. Finally, the agricultural subdivisions consisted of pasture, old fields, and annual crops[1]. Roll 40, Frame 117, and Roll 86, Frame 292, were used for mapping developed areas.

Undeveloped area, the second major land-use grouping, was further subdivided into forest and water categories. The forest category was further separated into pine (loblolly, shortleaf, and Virginia), hardwood (oak, maple, sycamore, elm, poplar, and sweetgum) and mixed (oak, poplar, maple, and loblolly). The water category includes the Eno River and many scattered lakes. The S190A color infrared photography proved most useful for this mapping (Roll 39, Frame 117).

[1]This division could have been further separated into individual crops but was not necessary in this study.

Seventy millimeter squares were cut from 9-inch enlargements (approximate scale 1:800,000) of S190A 70mm color transparencies and were projected onto the viewing screen of a color additive viewer at 4x enlargement. Also, the imagery was projected onto a vertical, clear glass panel with frosted acetate mounted on it through the external projection mode of the viewer. SKYLAB S190A and S190B imagery were also studied with a binocular microscope and Beseler projector.

Accuracy of the photographic interpretation was determined with the aid of color infrared photography obtained from a U-2 underflight (Flight 73-157) made on 15 September 1973 and by random ground site evaluation. The land-use map constructed from the SKYLAB S190A and S190B imagery was compared to the U-2 underflight using an Old Delft stereoscope for land-use categories. Within the 60 sq mi (154 sq km) mapping area six sites, each one sq mi (2.56 sq km) in area, were chosen for the random site analysis. A five-place random number table combined with a square-inch grid system was used to determine the row and column for each site position. Located within each square of the grid system are 25 randomly placed dots. The location of the random sites is illustrated on Fig. 26. Each pair of numbers in the random number set was used to define the position of the test site. If any point of the site overlapped or fell outside the 60 sq mi area, another random number set was chosen.

Field checks were made of each random test site, and errors of interpretation determined. The acreage of each category found within the test sites was determined by use of a 100 dots/square-inch grid applied to the imagery. The error found on field checking was expressed as a number of dots and was subtracted from the total number of dots (100) within the square mile test area. The resulting figure, converted to a percentage, gives the accuracy of the identification.

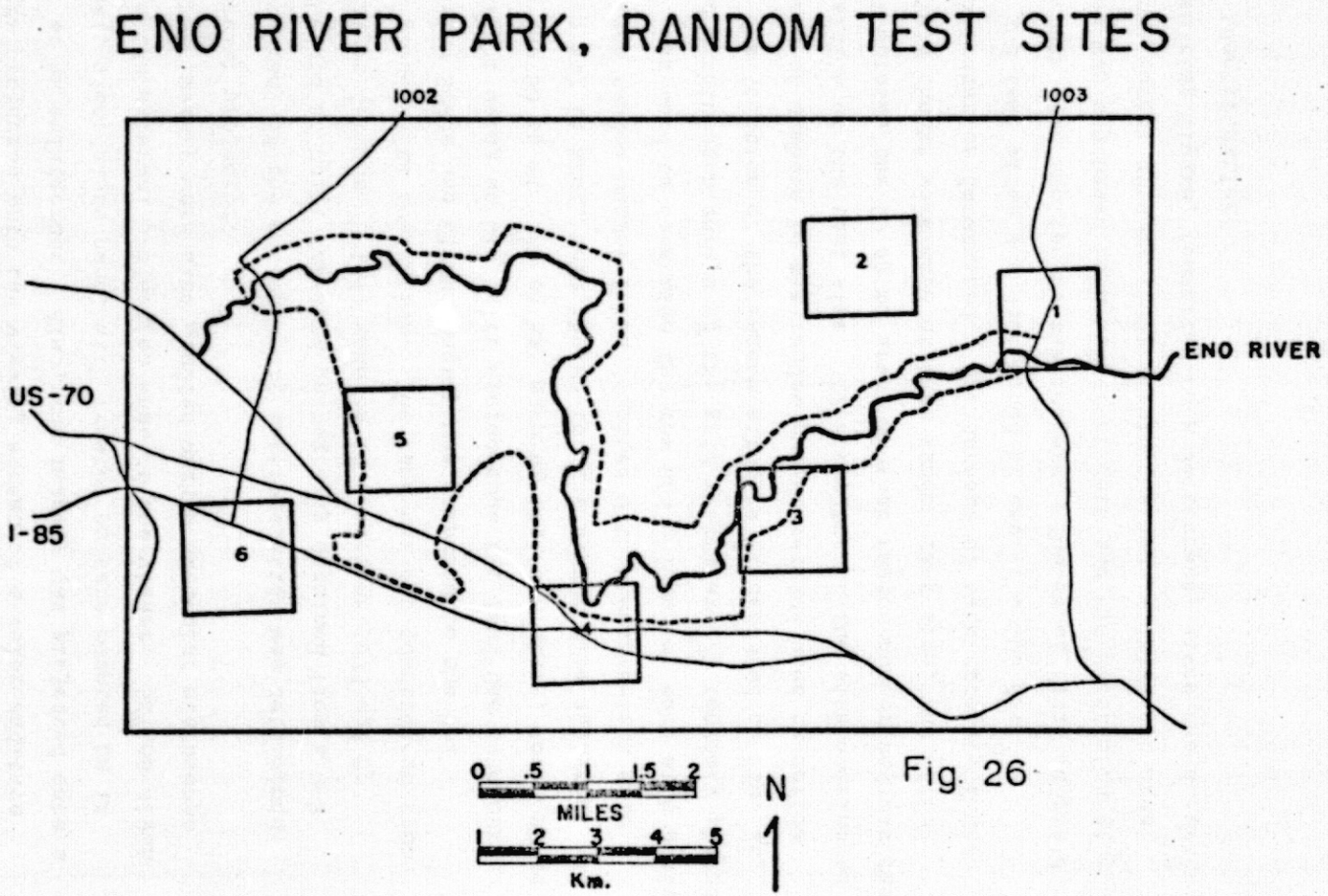

Figure 26. Eno River - Random Test Sites

10.7.2 Discussion

The major drawback to the Piedmont imagery is the cloud cover which was present in the central North Carolina region at the time of the SKYLAB-3 pass in September 1973. Only about 60% of Frame 117 could be used for interpretation purposes. Cloud cover over the Eno River area was less than one percent.

The northern Piedmont region of North Carolina is characterized by an oak-hickory climax forest (Oosting,1942). Soils are well-drained with a firm subsoil. Durham County soils are derived from metavolcanic slate, and many of the soils of adjacent Orange County are developed on granitic material (Wuenscher and Starrett, 1973).

The Eno River Basin has many forest communities related to topographic control. Upland communities are dominated by different species of oak while lowland communities are mixed species of hardwood and pine. The forest communities are listed in Table 12. Within the boundaries of the proposed state park the forest communities occupy over 92% of the acreage.

TABLE 12

Forest Communities Located in the Eno Basin (Wuenscher and Starrett, 1973)

Upland

1. White, black, and red oak
2. Post and white oak
3. Blackjack and post oak

Lowland

1. Birch and sycamore
2. Sweetgum, yellow poplar, winged elm, ash, and red maple
3. Beech, maple, white and red oak
4. Loblolly, shortleaf, and Virginia pine

Field studies were conducted at fifteen locations to familiarize the interpreter with plant communities, associations, and reflectances from the several land-use types (Fig. 25).

The color patterns provide the interpreter with an idea of the category that should be located in particular sites. Color tone variations proved to be the key to determining the land-use categories.

The ground resolution of the photography was determined by using ocular and graphical techniques and compared closely with the experience of others. Klemas et al (1975) estimated S190A ground resolution with high contrast to be between 20 and 40 meters and S190B between 10 and 20 meters. Experience in this investigation supports these conclusions in general. However, for the undeveloped categories, the color infrared photography did not always permit recognition of vegetational boundaries with this precision. (See also Section 6.2.)

10.7.2.1 Category signatures with color infrared transparencies: This part of the investigation was conducted using color infrared S190A SKYLAB-3 photography taken 12 September 1973. The developed areas contained commercial, residential, and agricultural sites. Commercial sites usually appear bluish-white with the exception of golf courses which appear pink. The bluish-white color is attributed to the highly disturbed surface conditions and pavement which produce a high reflectance in the visible region. The pink hue is attributed to the infrared reflection characteristics of lawn grasses.

Both completed and uncompleted residential sites were studied. The reflectance from completed dwellings was gray-white, and reflectance from those under construction gives a somewhat whiter appearance on the photographs. Agricultural sites were the easiest to distinguish because of their geometric patterns. Colors recorded for these sites varied from green to various shades of red. The different tones are probably related to the different crop types and/or percentage of area of exposed soil.

The undeveloped areas contained the forest and water categories. Pines appear on the imagery in dark purplish tones, and hardwoods

are a medium red. The reflectance from the mixed forests is between the two end types and is recorded on the film chiefly as dark red.

The reflectances from the Eno River and the many lakes were recorded on the film mostly as a dark-blue to black hue, however, some highly turbid lakes show as medium- to light-blue tones.

10.7.2.2 Proposed park site: The park site included 8,750 acres of rolling hills varying in elevation from 310 ft to 780 ft (103 m to 260 m). More than 92% of the area is forest-covered. The undeveloped area within the proposed park consists of 35% hardwoods, 51% mixed, 7% pine, and 1.5% water. Of the mixed forest category more than 50% consists of hardwoods. The mixed hardwoods together with the Eno River give the area a scenic character highly valued by some, and knowledge of the tree distribution is important in the design of the park.

Urban development comprises 4%; agricultural, 1%; commercial and residential, 0.5% of the area. Most of the agricultural sites are abandoned fields or pasturelands.

The major disturbance within the proposed park boundaries is the commercial activity associated with the presence of an electric power substation. Four major power lines cross the site, leaving a scar along their route; these may be seen on the photography. For some people the esthetic value of the area is reduced by the presence of the power lines.

Residential development within the site was minor at the time of the SKYLAB pass, but intense residential development is encroaching on the eastern edge of the site.

10.7.2.3 Area surrounding the park: A belt extending approximately one-mile out from the park boundary was used to define the land use of the surrounding area. This surrounding area covered 29,650 acres. Residential and commercial development accounted for 40.5% of the land use. Commercial sites were only 4%, and they are mainly

located within the Durham city limits. Some expansion was found along Interstate 85, west from Durham. Residential sites represented the largest percentage (20.5%), and this type of development is situated along the eastern park boundary. The greatest concentration of residential construction is located on the northern bank of the Eno River. This supports the findings of Wuenscher and Starrett (1973) about the direction of expanding development from Durham.

Agriculture represents 16% of the land use and is concentrated in the northwestern region of the study area. Pastureland and annual crops are the most common agricultural use of the land. Figure 27 illustrates the developed portion of the land-use map.

Undeveloped acreage accounts for 58.5% of the total land use adjacent to the park site. Other inventory items are hardwood (80% of all species) 12%, mixed (50% hardwood) 40.5%, pine (80% of all species) 6%, and water 1%. The map of Fig. 28 illustrates the character of the undeveloped areas as determined from the SKYLAB imagery.

10.7.2.4 Random ground sites: Six ground sites (each, one sq mi; 2.56 sq km in area) were chosen at random to determine the degree of accuracy (Fig. 26).

The detailed classification of land uses on each site is shown in Table 13.

Site 1 is located north of Durham on Guess Road, and the percentage of each category was determined using a 100 dots/square inch grid overlay. Cloud cover prevented interpretation of 2% of Site 1. Groundtruth determinations showed the interpretation to be completely accurate.

Random Site 2 lies northwest of Durham and adjacent to Site 1. The water body is a lake and is easily recognized because of the highly turbid conditions present within the water mass.

In some instances separation of residential from agricultural land proved difficult, and errors made in the interpretation process reduced the accuracy to 94%. Interpretation is difficult

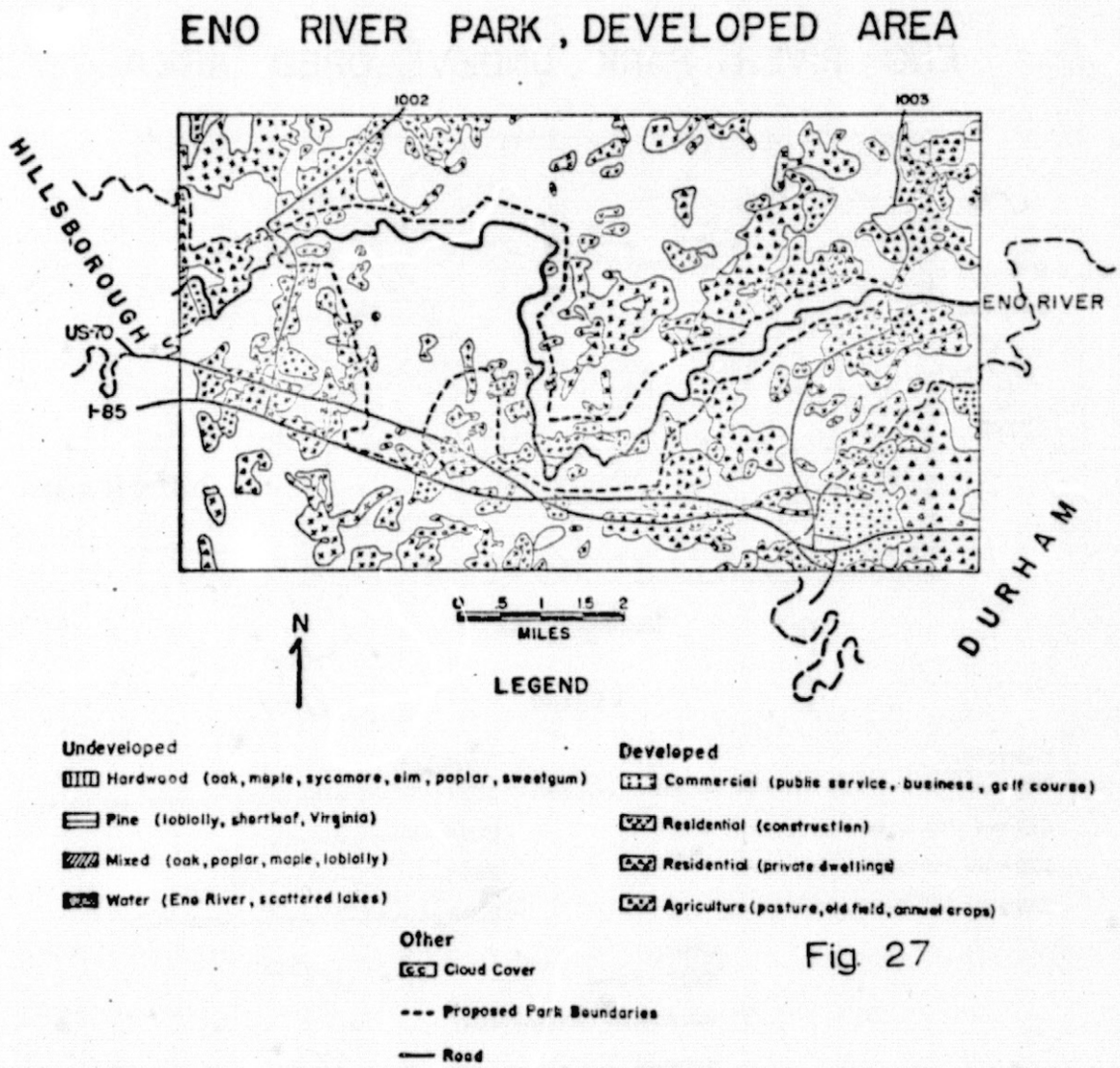

Figure 27. Eno River Park - Developed Area

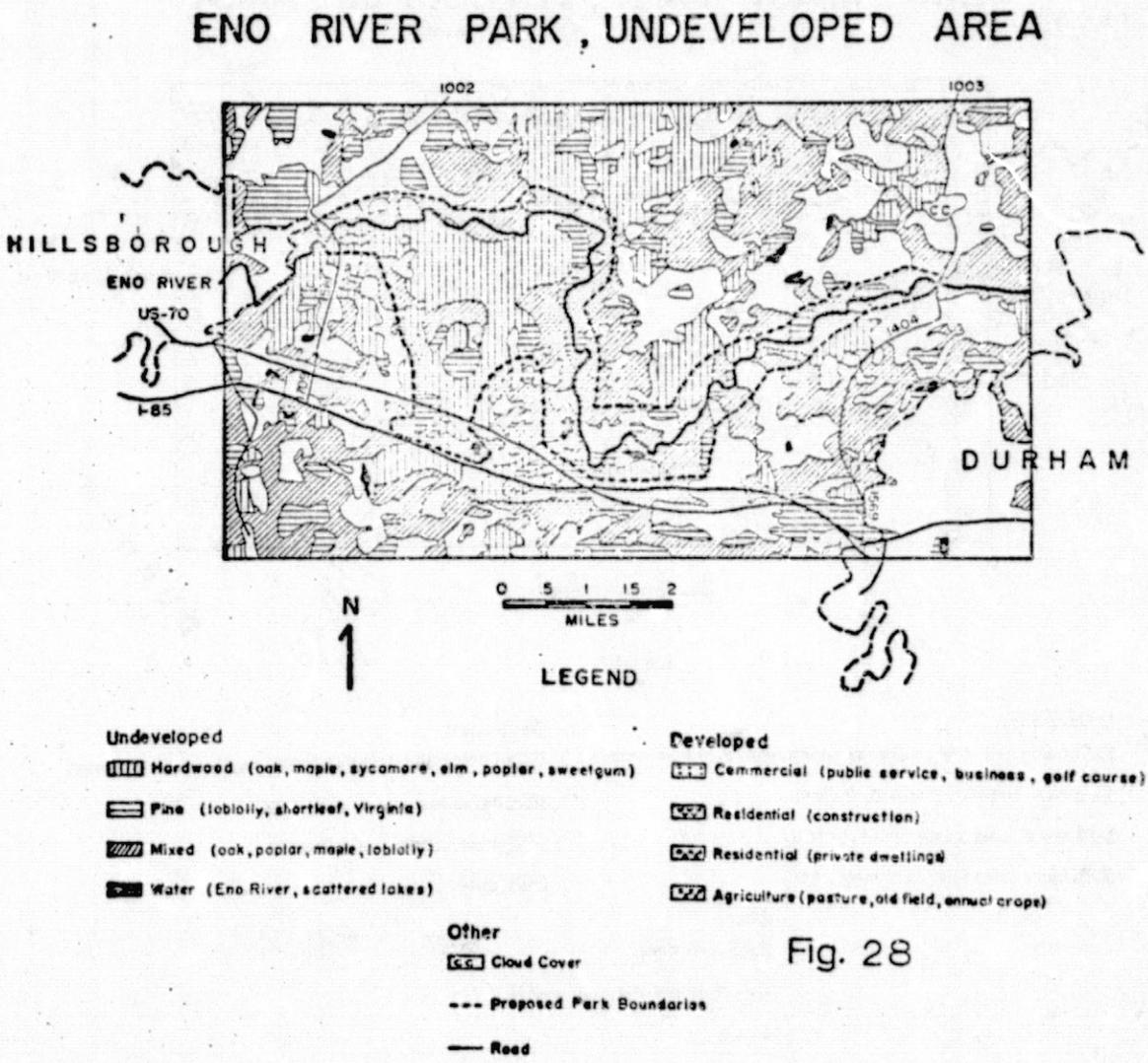

Figure 28. Eno River Park - Undeveloped Area

TABLE 13

Land Uses on Random Ground Sites

Eno River State Park Vicinity

(Classifications are in percent)*

Site No.	Commercial	Residential	Agriculture	Forest			Water	Cloud Cover	Percent Error
				Pine	Mixed	Hardwood			
1	--	39	--	2	54	--	5	2	0
2	--	43	--	7	47	1	2	--	6
3	--	47	10	3	31	4	4	--	7
4	19	--	5	35	31	8	2	--	8
5	--	4	16	11	24	42	--	3	5
6	6	18	14	8	47	5	2	--	0

*Figures do not add to 100% because of rounding.

when areas representing the two categories are adjacent to each other and the area of residential property is relatively large.

Random Site 3 lies northwest of Durham between Interstate 85 and Guess Road. Water is 4% of the area, being represented mainly by the Eno River. A 5% error resulted from interpretation of agricultural sites as residential areas because of their close proximity to each other and general similarity in appearance on the photography. Pine was misinterpreted as mixed forest in 2% of the site because of small scattered clusters of pine stands which are too small to be outlined accurately on the SKYLAB S190A imagery. Overall accuracy for Site 3 was 93%.

Random Site 4 was located at the junction of Interstate 85 and U. S. 70 between Hillsborough and Durham. Misinterpretation of residential areas for commercial sites arose because a trailer court within the test site gave a reflectance similar to that for a commercial site. Accuracy was 92% at this test site.

The location of Random Site 5 was to the east of county road 1561 and north of U. S. 70. Errors were found in the interpretation of some residential and agricultural sites. Accuracy was determined to be 95% for Site 5. Random Site 6 was located southwest of Hillsborough, bordering Interstate 85. There were no errors encountered in the interpretation of this site.

Interpretation accuracy for all random ground sites varied from 92 to 100%. This level of accuracy can in general be attributed to the interpreter's familiarity with the area. The largest problem encountered lay in the differentiation of agricultural from residential sites when they were adjacent to each other. Some large residential plots can be easily mistaken for an agricultural field, especially when they are abandoned fields. Errors can also be made in separating some commercial sites from residential sites. The level of construction activity seems to influence the reflectances, with trailer courts and subdivisions having a high reflectance which is easily mistaken for reflectance from some commercial sites. Incorrect interpretation

of forested areas was minor except within small isolated patches dominated by pines. The water category contained mainly the course of the Eno River. The tree canopy blocking the reflectance of the river prevented tracing the whole course of the river. This change of river reflectance also caused problems in separating on the photographs dominant pine stands from mixed stands. Most of the lowland area associated with the river is predominantly mixed forest (50% hardwood) that should have a dark red reflectance, but with the combined tree canopy and river reflectance sometimes it appears purple an is easily mistaken for pine.

Many lakes are found within the study area. Color photography of SKYLAB S190A and S190B could not be used to define boundaries of most of the lakes. Color infrared photography could be used to recognize lakes as small as approximately 600 ft (135m) in one dimension. However, some highly turbid lakes in the area could be outlined even though they are less than 600 ft (135m) in maximum dimension.

Figure 29 shows the land-use map derived from this study.

10.7.2.5 Multispectral photography: The six station multispectral photography was analyzed using a color additive viewer (Spectral Data Model 66). Table 10 gives the pertinent data on the multispectral photographs. Black and white photography from Stations 1, 2, 5, and 6 was compared with color photography from Stations 3 and 4 in terms of the quality of the ocular interpretation of the study area. Development was viewed best when the 0.5 to 0.6μm band was in the green mode and the 0.6 to 0.7μm band imagery in the red mode. This pair of images and colors was combined with the color photography in the viewer. A better separation of the categories in the color photography occurred because of an increased number of hues and saturations over those found when a composite of 0.7 - 0.8μm, 0.8 - 0.9μm, 0.6 - 0.7μm, and 0.5 - 0.6μm imagery alone was used. When three stations (two black and white, one color) were superimposed, more detail became apparent, and there

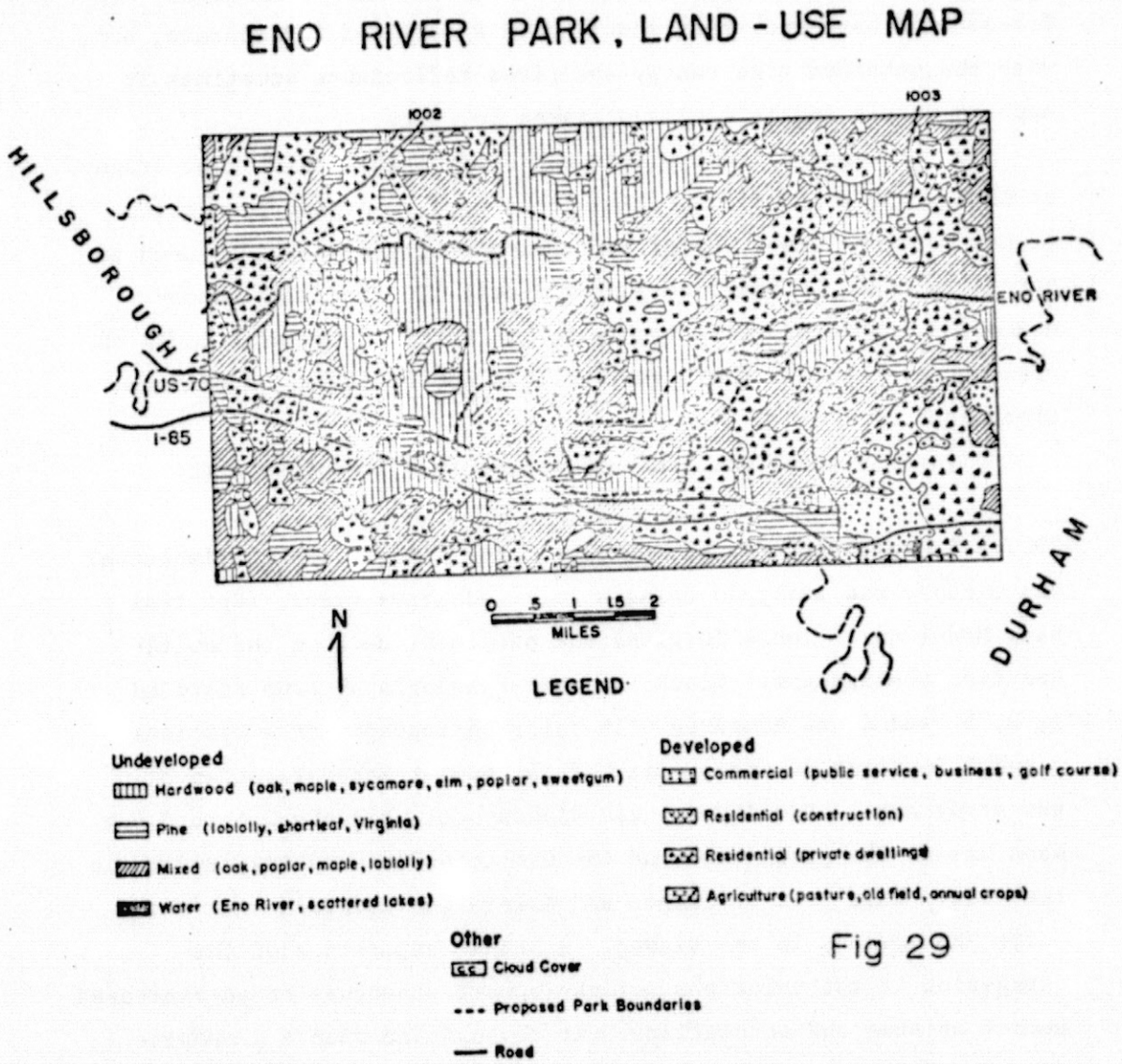

Figure 29. Eno River Park-Land Use Map. Interpretation Made from SKYLAB-3 Photography

was a better definition of the several categories than when the color photography was viewed alone.

Undeveloped areas were recognized best with 0.7 - 0.8μm in the green mode and 0.8 - 0.9μm in the red mode. This arrangement was compared with the color infrared photography, and better separation of the categories resulted with the use of the color infrared photography alone. The wider range of hues and saturation levels in the color infrared photography made it the better tool for interpretation. When all three stations, 0.7 - 0.8μm, 0.8 - 0.9μm and color infrared, were superimposed, a better category separation became evident than with the color infrared alone; actual percentage differences were not computed because of the small scale at which the interpretation was being done.

10.7.2.6 Comparison with other sources: The complete land-use map of the proposed state park site (Fig. 29) was compared to part of a case study of the Eno River basin (Wuenscher and Starrett, 1973) and a regional development guide (Research Triangle Regional Planning Commission, 1969). These land-use maps could not be statistically compared because of the time elapsed since the two studies were completed. An indirect approach was taken by comparing representative locations occupied by various land-use types.

The land-use map of Wuenscher and Starrett (1973) was broken down into pine, hardwoods, mixed forests, agricultural, and intensive development. These categories were sufficient for comparison except that the intensive development category includes several of the subdivisions of the "Developed" category of this study. A land-use map compiled by the Research Triangle Regional Planning Commission (1969) was used because intensive development was further separated into residential and commercial sites.

Color infrared photography taken during a U-2 underflight, Flight (73-157) on 15 September 1973 provided a direct means for checking the SKYLAB interpretation. The same interpretation

problems previously encountered in the random sample sites were verified through a comparison with the aerial photography. Good correlation between the land-use map and the U-2 imagery exists. Wuenscher used 1966 Agriculture Stabilization and Conservation Service photographs of a scale 1:20,000 while the SKYLAB S190A photography original scale was approximately 1:2,900,000.

Results of the current study show a high degree of correlation between the locations of the general categories on all three land-use maps. Some of the small isolated pine stands were not present on the land-use map derived from SKYLAB data because of the scale and resolution levels. Isolated residential dwellings could not be identified on the SKYLAB photography in general and were mapped with the dominant land-use.

The greatest change over the seven year interval was the increase in residential development accompanied by a decline in the agricultural and forest acreage. Residential development has progressed from the south bank of the Eno River to the north bank in northwestern Durham (approximate estimated change 440 acres). The infringement along both sides of the river in this area is significant and development relatively intense. The westward extension from Durham of commercial and residential development along Interstate 85 can be determined by comparing the SKYLAB data with the older maps (approximate total of 270 acres).

10.7.3 Summary and Conclusion

Color and color infrared photography from SKYLAB-3 appeared to be the best of the multispectral stations for environmental land-use mapping when only optical photointerpretation techniques can be utilized. When color or color infrared photography was superimposed with three of the black and white bands, more detail could be seen than when either the black and white photography by itself was interpreted using a color additive viewer or when color photography alone was interpreted. Use of a combination of black and white multispectral imagery in conjunction with color

and color infrared photography appeared to improve the accuracy of interpretation.

A land-use map of the proposed Eno River State Park in central North Carolina derived from SKYLAB photography seems to have a high degree of correlation with earlier maps prepared from other sources as well as with information gathered from interpretation of high altitude U-2 photography. Random sample sites revealed an overall interpretation accuracy of more than 91%.

Land-use categories were usually determined by association with adjacent sites and color tones produced by their particular reflectance. Problems were encountered in differentiating some large residential plots from agricultural land, usually abandoned fields, because of the small scale involved.

It was found that time must be taken to weigh carefully several relationships (color tone, adjacent sites, water) before assigning a particular land-use category to a given site. The best photo-interpretation analysis is accomplished when the interpreter is familiar with the area.

Most of the Eno River water course through the proposed park site is covered by a canopy of lowland hardwoods and pines. This fact made identification of the Eno River impossible in most sections, even with high altitude U-2 photography.

The most important characteristic for identification of small water bodies in this region was found to be related to the amount of suspended sediment in the water. Field studies showed that most of the lakes contained one amount or another of tannish- to reddish-colored suspended sediment. The lakes are juxtaposed to residential areas and agricultural areas, both good sources of sediment. The more turbid the water mass the smaller the size of the lake that could be recognized.

The proposed Eno River State Park site is composed of 92% mixed hardwood-pine forest with hardwoods comprising over 50% of the total forest. Hardwoods are considered a stable type of forest cover and are considered by many to possess a high esthetic

value in terms of park development and use. Intense developments along the eastern boundaries of the park pose many problems for the North Carolina Division of State Parks. The SKYLAB photography gives a good perspective to the relationships, and similar data could be useful in rapidly outlining similar potential park sites.

It was observed during the course of the Eno River study and in conjunction with the Asheville study that as the interpreter worked on an area whose mix of land uses was chiefly agricultural-forest-residential the errors of identification were less than when he worked with more intensely urbanized areas. The reflectances coming from the various land uses within the more urbanized area were apparently close enough in character so that the interpreter could confuse the land-use types more easily than in areas of medium- to low-density urban-type of development. In many cases a commercial or industrial complex in a suburban setting can be identified by a combination of its reflectance characteristics, geometry, and geographic setting. Within an urban complex the geometry and reflectance characteristics recorded on the film are not necessarily unique. On the other hand,for some industrial and commercial complexes the position with relation to transportation networks can provide clues to the type of land use.

10.7.4 Benefit-Cost Evaluation

Environmental assessment of an area similar to the Eno River site can probably be accomplished within a two-day period after sufficient ground data are provided for the particular area. There is no way to compare the costs of previous studies of the area with the present one. However, it appears that two or three man-days would be required to prepare from SKYLAB data land-use maps equivalent to those given in Wuenscher and Starrett (1973). Information about the time element in Wuenscher and Starrett's work was not available, but it presumably took longer than three days to prepare.

One major benefit demonstrated by this study is that the North Carolina Division of State Parks could use space-acquired imagery in the evaluation of future park sites. This method would produce a quick and low cost land-use map from one image. It appears that sufficient detail could be produced from this one source to satisfy most of the needs for general evaluation of a park site.

State and local planners could also benefit. Land-use maps made from LANDSAT-1 data collected in 1972 could be quickly produced and superimposed on an up-to-date map from SKYLAB or later LANDSAT imagery to follow development trends. Cost and time would be reduced considerably with a more accurate map produced from the up-to-date source.

10.8 Vegetational Analysis in Coastal North Carolina

The overall objective of this particular study was to determine the extent to which SKYLAB-3 imagery could be used in interpreting vegetational classes located in northeastern North Carolina. Additionally, a demonstration of the limits of usefulness of the imagery to a semiskilled photointerpreter in making a vegetational map was another objective, and Perquimans County, North Carolina, was used as the test site for this part of the study. This particular investigation has demonstrated that it is possible to recognize and map at an acceptable level of accuracy the several species chosen for study.

Past investigators have found color infrared photography to be superior to standard color for vegetational analysis. Wood (1953) applied this then new film technique to an aerial forest survey and obtained better results than with color film. Studies of marshland by Anderson (1968) indicated that color infrared photography was superior for differentiation of vegetative types within an estuary. Thamon and Sanger (1971) used many remote sensing techniques in analyzing agricultural crops. Their results indicated that color infrared photography was the best

sensing means for identifying crops. Many other uncited studies also record the usefulness of color infrared photography for vegetational analysis.

The present investigation was conducted in the northeastern portion of North Carolina because of the presence of diverse coastal environments and because of the nature of the crops grown in this region. Population is relatively low in this region, and few botanical studies have been made. In addition, various types of vegetation and crops occur in relatively large acreage units so that the need to recognize small plots is minimal.

10.8.1 Method

Three coastal vegetation classes in terms of species composition and distribution in northeastern North Carolina were chosen for study. Color infrared photography, Roll 27, Frames 029-031, SKYLAB-3 imagery proved to be the most useful format for this study. Figure 30 is a map of the northeastern region of North Carolina. Three sites (1,3,5) were designated as control sites, and their vegetational composition was determined by on-site inspections. Three other experimental sites (2,4,6) were chosen, and the SKYLAB photographs interpreted on the basis of the results from the control sites. All sites had an area of about one square mile (2.56 sq km).

Field studies were made of the three control sites to correlate vegetation with its photographic response. The SKYLAB photography of three experimental sites believed to possess the same vegetation class as the control areas were examined under a binocular microscope. After the experimental locations had been analyzed from the photography, ground examinations were performed to verify the interpretation and the degree of accuracy.

Accuracy of the photographic interpretation was determined by the following steps. A scaled drawing was first constructed from an enlargement of a U.S.G.S. topographic map. Next, the percentage of each category determined from the photographic

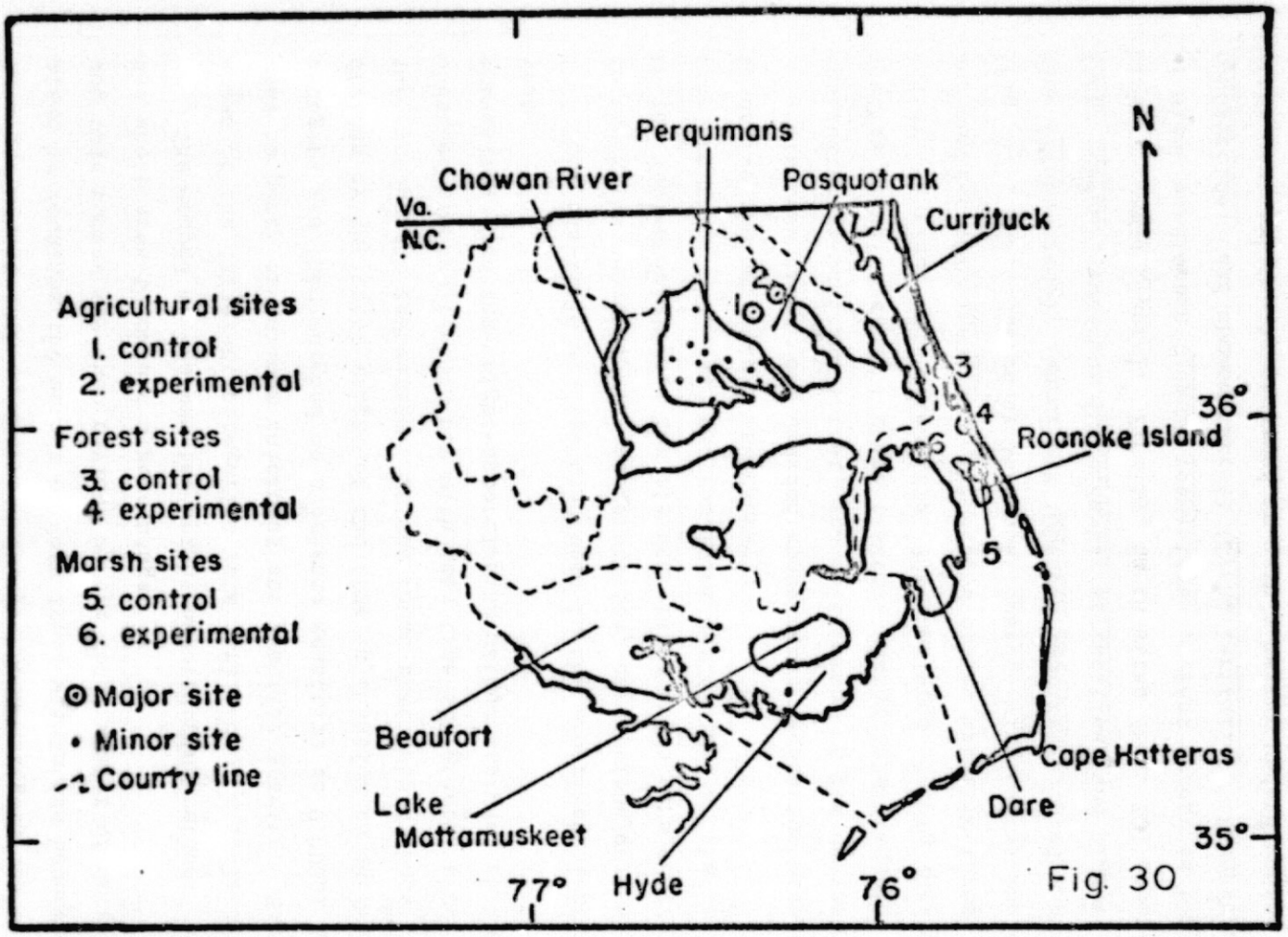

Figure 30. Map of Study Sites in Northeastern North Carolina

interpretation was determined using two methods. The grid overlay method involved the use of a dot grid consisting of one hundred dots per square inch on a transparency. Each category was determined by counting the number of dots found within its boundaries, and this number was then divided by the total number of dots in the whole area to obtain a percentage.

The second method was the weight-apportioning method. The areas of the different categories were outlined on a scale drawing made on paper of uniform thickness and specific gravity. Each category was then weighed on a balance sensitive to 0.00001 mg and divided by the total weight of the area in question to determine the appropriate percentage. It was found that both methods obtained similar results but with less time and greater accuracy prevailing when the weight-apportioning method was used on large areas.

From the field studies conducted in the experimental areas to check the photographic interpretation, corrections were made on the scaled drawings. The misinterpreted areas were subtracted from the total area, and the remainder was divided by the total area to derive the percentage of accuracy.

Six test sites were divided among three vegetation classes: agricultural, maritime forest, and salt marsh. A few dominant species occupied each of these classes, making interpretation easier. Agricultural sites (Fig. 30) consisted of corn (Zea mays) and soybean (Glycine max). The second class, maritime forest (Fig. 30), was occupied by live oak (Quercus virginiana) loblolly pine (Pinus taeda), laurel oak (Quercus laurifolia), red maple (Acer rubrum), sweetgum (Liquidambar styraciflua) and pignut hickory (Carya glabra). Finally, marsh sites (Fig. 30) consisted of black needlerush (Juncus roemerianus), giant cordgrass (Spartina cynosuroides) and common cattail (Typha latifolia). Seventeen sites were originally observed to gain a better understanding of the vegetational types present in the study area. Sites 1, 3, and 5 (Fig. 30) were chosen as control sites.

The second part of the investigation concentrated on preparation of a vegetation map of Perquimans County and comparison of the map with other published information. Heavy cloud cover over most of the region at the time of the SKYLAB overpass limited the choice of the test site. Perquimans County lies near the center of the cloud-free area north of Albemarle Sound, on Frame 030, Roll 27. (See also Fig. 30). The test site was mapped using the following broad land-use categories: agricultural, non-agricultural, and forest. These categories were then further divided into types. Agricultural types chosen were corn, soybean, cleared (plowed), and pasture or old field. Non-agricultural types were residential or commercial and cleared areas. The third category, forest, was divided into conifers, hardwood, and mixed.

The mapping technique consisted of selecting the area of interest on 9-inch color and color infrared transparencies enlarged from 70mm S190A positive transparencies (approximate scale 1:800,000). The color photography (Roll 028, Frames 029-031) was used specifically for ground reference points such as roads and buildings. This film had better resolution than the color infrared film. Welch (1974) using a microdensitometer edge trace with graphical and digital techniques estimated resolution on the color to be 85 meters and color infrared film to be 145 meters for the S190A experiment. (See also Section 6.2.2.)

The imagery was studied utilizing 70mm squares cut from the enlarged S190A transparencies which were projected onto the viewing screen of a Spectral Data Model 66 color additive viewer. Also the imagery was projected through the external projection mode of the viewer onto a vertical, clear glass panel with frosted acetate mounted on it. Additional interpretation was made by study of the imagery with a binocular microscope.

Ground verification was made at twelve sites within Perquimans County. The sites are shown on Figure 31. Simple spot checks were made at seven sites. These were small areas for which the interpreter questioned the identification from the imagery. The

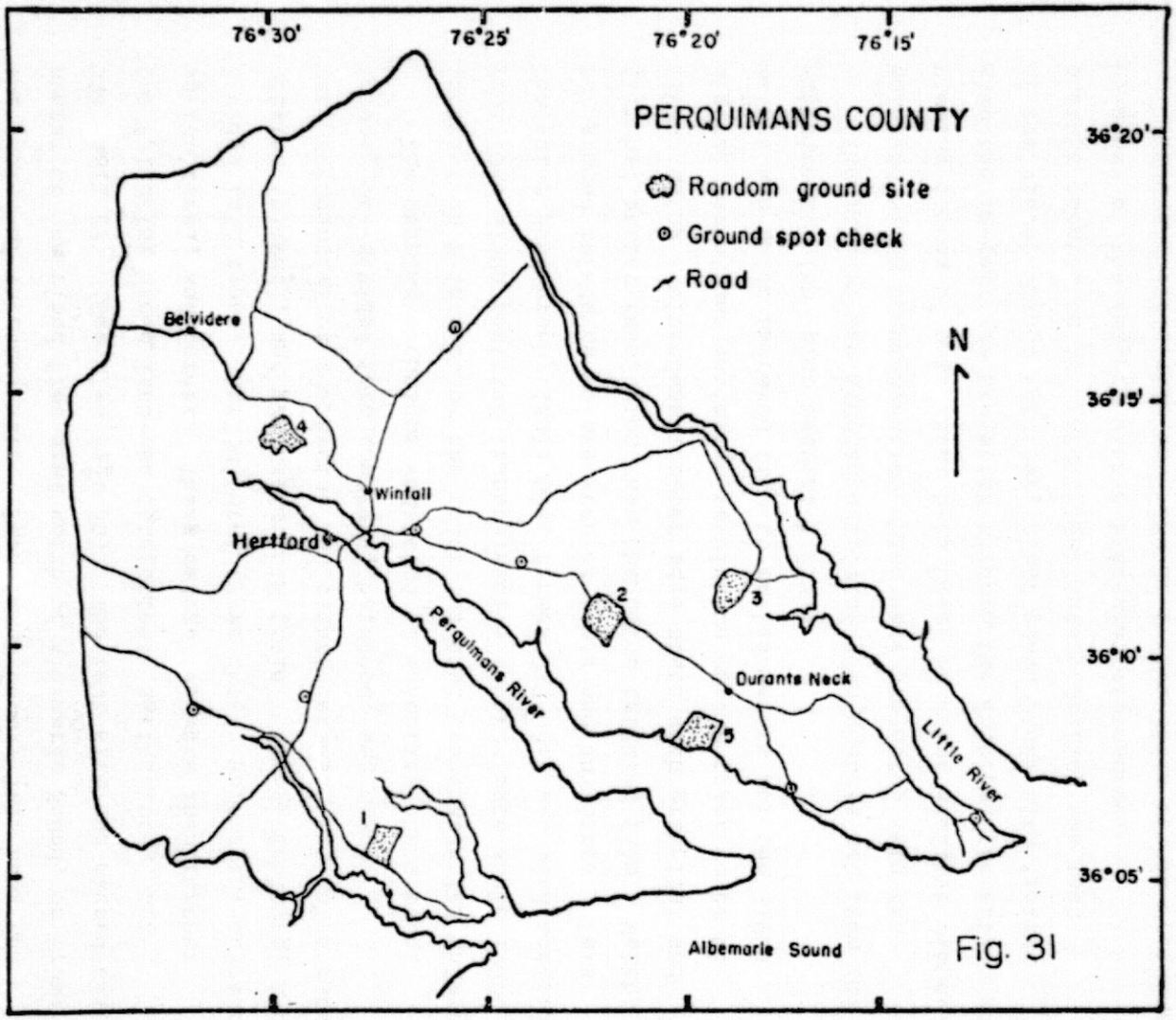

Figure 31. Ground Verification Sites - Perquimans County, North Carolina

five other sites, each having an area of about one square mile (2.56 sq km), were analyzed in detail. The five test sites were chosen by using a five-place random number table combined with a grid overlay of the county at an appropriate scale. Each pair of numbers in the random number set was used to define the position of the test site. The first pair of digits was used to determine the row and the second the columns within the grid system. Field checks were made of the test sites and errors of interpretation determined. In addition to the field checks, U-2 photography (Flight Mission 73-185) taken two months after the SKYLAB mission, was used to evaluate the accuracy of the vegetation map.

10.8.2 Discussion

The major drawback in this study of the coastal vegetation was the extensive cloud cover over northeastern North Carolina. Only about 25 percent of this region could be used for interpretation purposes. Dare and Perquimans Counties (Fig. 30) had the least amount of cloud cover. The vegetation map was constructed for Perquimans County because only 18.5 percent cloud cover existed over the entire county.

The SKYLAB-3 photography was compared to LANDSAT-1 imagery of the northeastern region. Figure 32 shows LANDSAT-1 imagery and can be compared with Figure 33, the SKYLAB photography. Resolution appears to be better in the SKYLAB photography, a fact most easily explained on the basis of the difference in the method of data acquisition (SKYLAB photography vs LANDSAT-1 electronic scanning). An interpreter can recognize vegetational differences easily on the SKYLAB film. Even when the LANDSAT-1 imagery was observed with the aid of a color additive viewer, the vegetational differences did not appear to be as well defined as on the SKYLAB imagery. Separation of vegetational components in this area is also discussed in Section 11.1.

Ground studies were conducted at the three control sites (1,3,5) to familiarize the interpreter with zonation patterns

Figure 32. LANDSAT-1 Image of Northeastern North Carolina (Image 1403-15134-5, 30 August 1973)

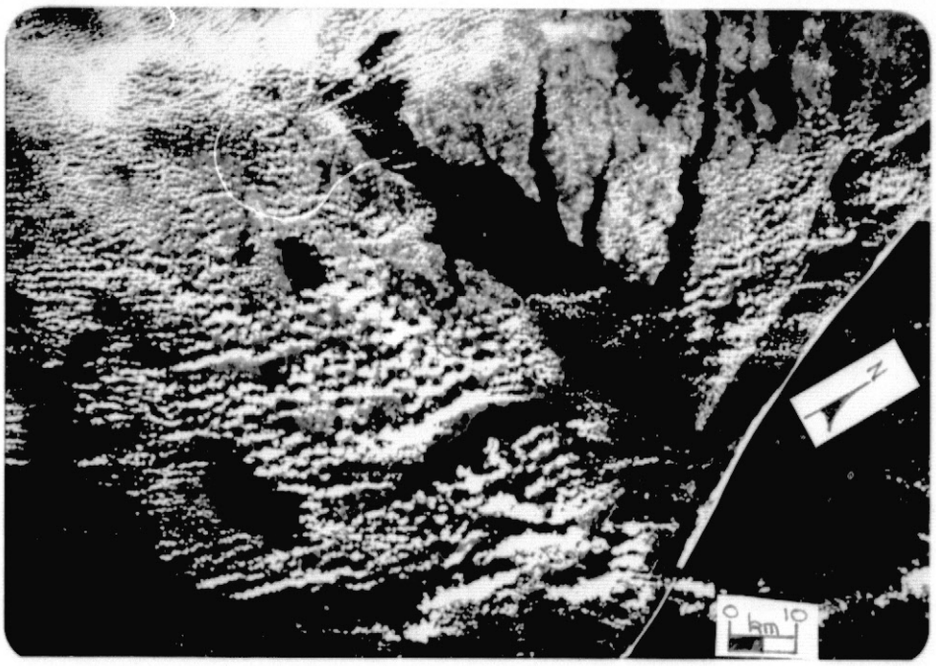

Figure 33. SKYLAB-3 Photograph of Northeastern North Carolina. S190A Color Infrared, Roll 27, Frame 030.

and color tones transmitted by the species existing there. The zonation patterns established from the ground studies were useful in providing the interpreter with an idea of what species should and should not be present in similar sites. Color tone varied within vegetation classes and usually was the key to species identification.

The interpretations were made under a binocular microscope at 20x magnification. At greater magnifications color tones could not be interpreted adequately because the grain of the film scattered the light and made identification of a specific color difficult. Welch (1974) evaluated the SKYLAB photography and concluded that resolution estimates were 20 percent below expected values for color infrared images. He estimated that ground resolution should be 145 meters. Resolution targets, wooded strips in the forest category, had the best contrast and were determined to be 58-70 meters by ocular and graphical techniques with further magnification resulting in problems with the film grain. (See also Section 6.2.2.)

10.8.2.1 Plant signature with color infrared: SKYLAB-3 photography taken on 9 August 1973 formed the basis for the interpretations. The agricultural class mainly consisted of two crops, corn (*Zea mays*) and soybean (*Glycine max*). Both crops transmitted quite distinct colors. *Zea* sp. transmitted a bright red while the color tone from *Glycine* sp. was a scattered pattern of blue, red, and white. Forest vegetation could only be recognized as conifers and hardwoods. Conifers appear as violet to dark purple, and hardwoods are a dark red color on the photographs (See also Section 11.1.) Finally, two dominant marsh species were identified. These were black needlerush (*Juncus roemerianus*), transmitting a medium-blue color and giant cord grass (*Spartina cynosuroides*) appearing medium red. *Juncus* sp. could be differentiated from water because the medium blue of the former contrasted with dark blue to black of the water. A summary of the species encountered in the sites is given in Table 14.

TABLE 14

Species List of Dominant and Minor Vegetation Identified in the Ground Study Sites

Major

Pinus taeda - loblolly pine
Quercus virginiana - live oak
Taxodium distichum - bald cypress
Juncus roemerianus - black needlerush
Spartina cynosuroides - giant cordgrass
Zea mays - corn
Glycine max - soybean

Minor

Quercus laurifolia - laurel oak
Acer rubrum - red maple
Liquidambar styraciflua - sweetgum
Carya glabra - pignut hickory
Pinus serotina - pond pine
Chamaecyparis thyoides - Atlantic white cedar
Ilex opaca - American holly
Cornus florida - flowering dogwood
Fagus grandifolia - American beech
Nyssa aquatica - tupelo gum
Nyssa sylvatica - swamp tupelo
Arundinaria gigantea - giant cane
Typha latifolia - common cattail
Phragmites communis - marsh reed
Iva frutescens - marsh elder
Baccharis halimifolia - groundsel tree

10.8.2.2 Major vegetation sites: The agricultural sites were located around Elizabeth City in Pasquotank County, which borders Perquimans County on the east. Figure 34 is a copy of a color infrared image of the experimental site selected for interpretation from SKYLAB photographs (Site 2 in Fig. 30). One problem existed in obtaining ground studies of this vegetation class. Each year the crops are harvested and replanted with a different species. Fortunately, most of the rotation was between *Zea mays* and *Glycine max*. Experimental Site 2 was estimated to be 37% *Zea* sp., 51% *Glycine* sp., and 13% old field.

Interpretation of the old fields presented some difficulties. The recorded color tone was very similar to that of *Glycine* sp., being a scattered pattern of blue, red, and white. There was no difficulty in separating *Zea* sp. from *Glycine* sp.

Accuracy of identification was concluded to be 87% based on comparison with the groundtruth information. A review of the interpretation revealed a slight signature difference between the old field and *Glycine* sp. types, but a difference that is difficult to recognize. The mixture of the three colors was mostly red and white with small amounts of blue present in the old field zone; in contrast, the mixture for *Glycine* sp. was mostly red and blue with less white. (See also Section 11.1.)

Maritime forests, Sites 3 and 4 on Fig. 30, are located in Dare county near Kitty Hawk. Figure 35 shows a SKYLAB color photograph of experimental Site 4. Specific species could not be determined. Only differences between dominant stands of hardwoods and conifers were established. Experimental Site 4 was determined to be 85% hardwoods and 15% conifers by weight-apportioning and grid overlay methods. Loblolly pine (*Pinus taeda*) was the main conifer, and live oak (*Quercus virginiana*) was the main hardwood. Most of the other species encountered were hardwoods. Accuracy was considered to be 100% because the main type was easily established.

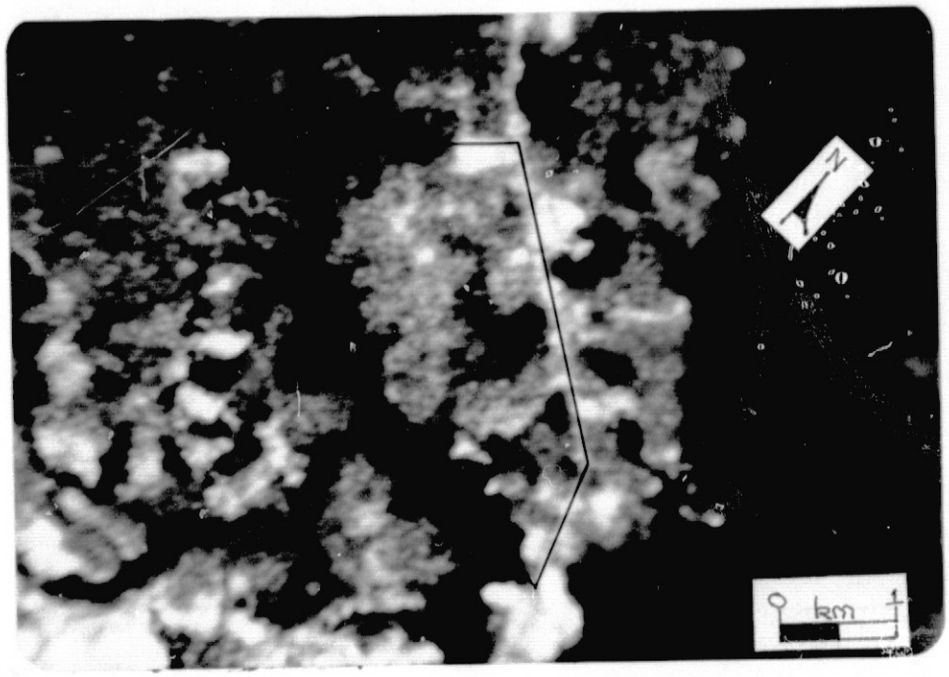

Figure 34. Agricultural Site 2, Northeastern North Carolina.
SKYLAB-3 (S190A), Roll 27, Frame 030, 9 August 1973

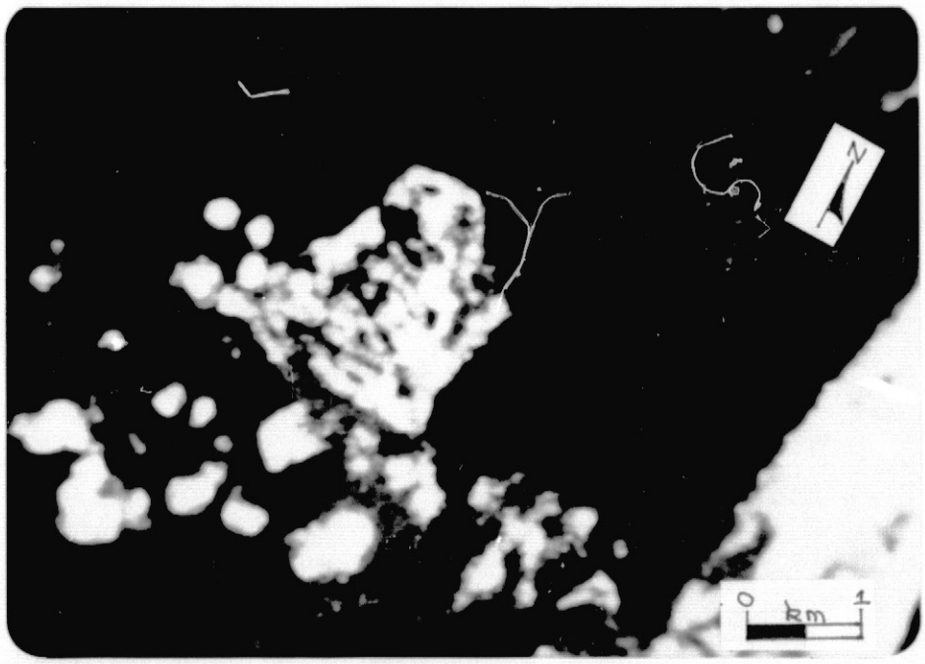

Figure 35. Maritime Forest Site 4, Northeastern North Carolina.
SKYLAB-3 (S190A), Roll 27, Frame 030, 9 August 1973

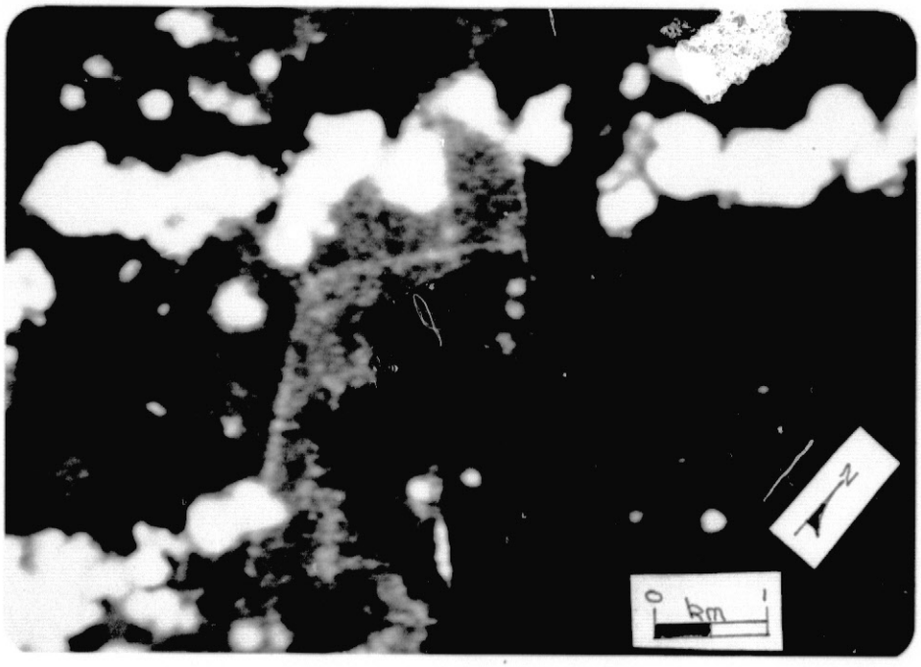

Figure 36. Marsh Site 6, Northeastern North Carolina.
SKYLAB-3 (S190A), Roll 27, Frame 030, 9 August 1973

Marsh test sites were located in Dare County around Roanoke Island. Figure 36 shows a SKYLAB color infrared photograph of the experimental Site 6. Irregularly flooded salt marshes typify this area (Wilson, 1962). Salt marsh is an ideal vegetation class because few species survive in this harsh environment. The experimental site was determined to be 75% needlerush (Juncus roemerianus), 21% giant cordgrass (Spartina cynosuroides), and 4% common cattail (Typha latifolia). Two other minor species were identified as marsh shrubs.

Problems were encountered with the interpretation of Typha sp. Color tone of the reflectance is the same as for Spartina sp. Both species show a medium-red color. There was no difficulty in separating Juncus sp. from Spartina sp. because of the greater albedo which probably results from the more horizontal leaf angle and greater height of Spartina sp. Accuracy was concluded to be 96% because Typha sp. could not be separated from Spartina sp.

10.8.3 Vegetation map

A vegetation map was constructed from color and color infrared photographs of Perquimans County, North Carolina. Color (Roll 28, Frame 030) and color infrared (Roll 27, Frame 030) photographs of this area may be compared in Fig. 37 and Fig. 38. Infrared imagery was found to be ideal for this type of interpretation, and color imagery was used mainly for establishing cultural ground reference points. Cloud cover of 18.5% prevented mapping of the entire county. Fig. 39 is the completed vegetation map of Perquimans County.

One problem encountered during the mapping was in differentiating between soybean (Glycina max) and old field and pastures in some areas. Interpretation accuracy was evaluated through two approaches.

Color infrared photography taken during a U-2 flight in November 1973 (Flight 73-185) provided general data for checking the SKYLAB imagery. At this time of the year most of the agricultural crops had been harvested and fields plowed, although

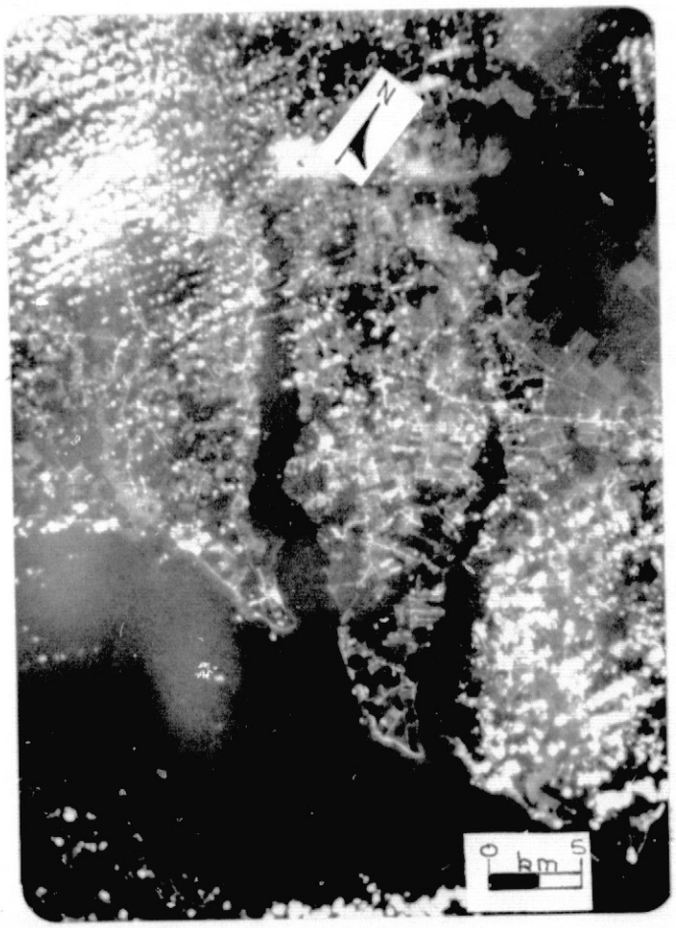

Figure 37. Color Photograph of Perquimans County, North Carolina. SKYLAB-3 (S190A), Roll 28, Frame 030, 9 August 1973

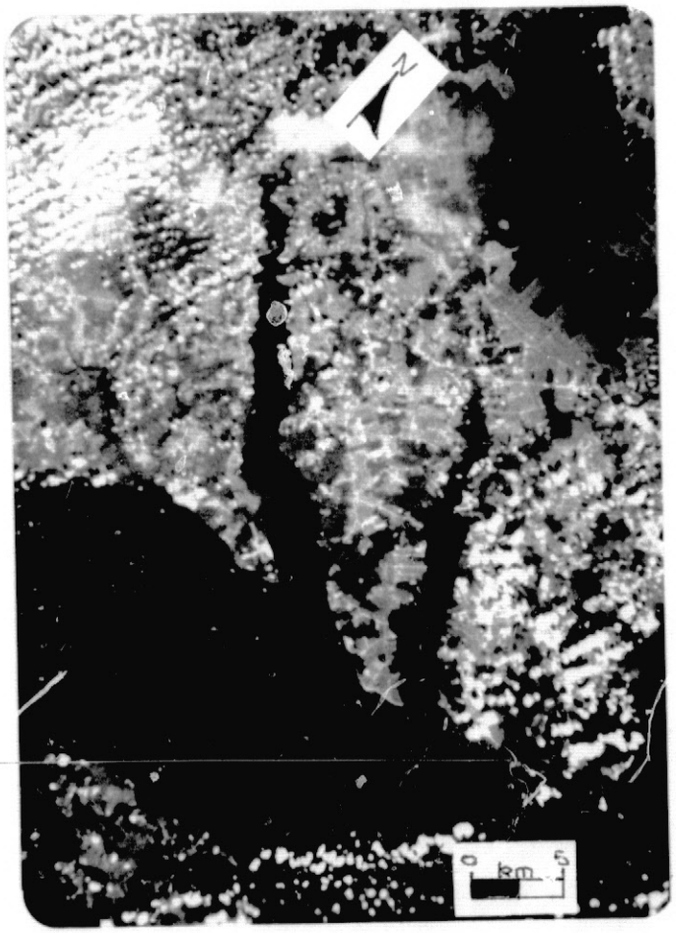

Figure 38. Color Infrared Photograph of Perquimans County, North Carolina. SKYLAB-3 (S190A), Roll 27, Frame 030, 9 August 1973

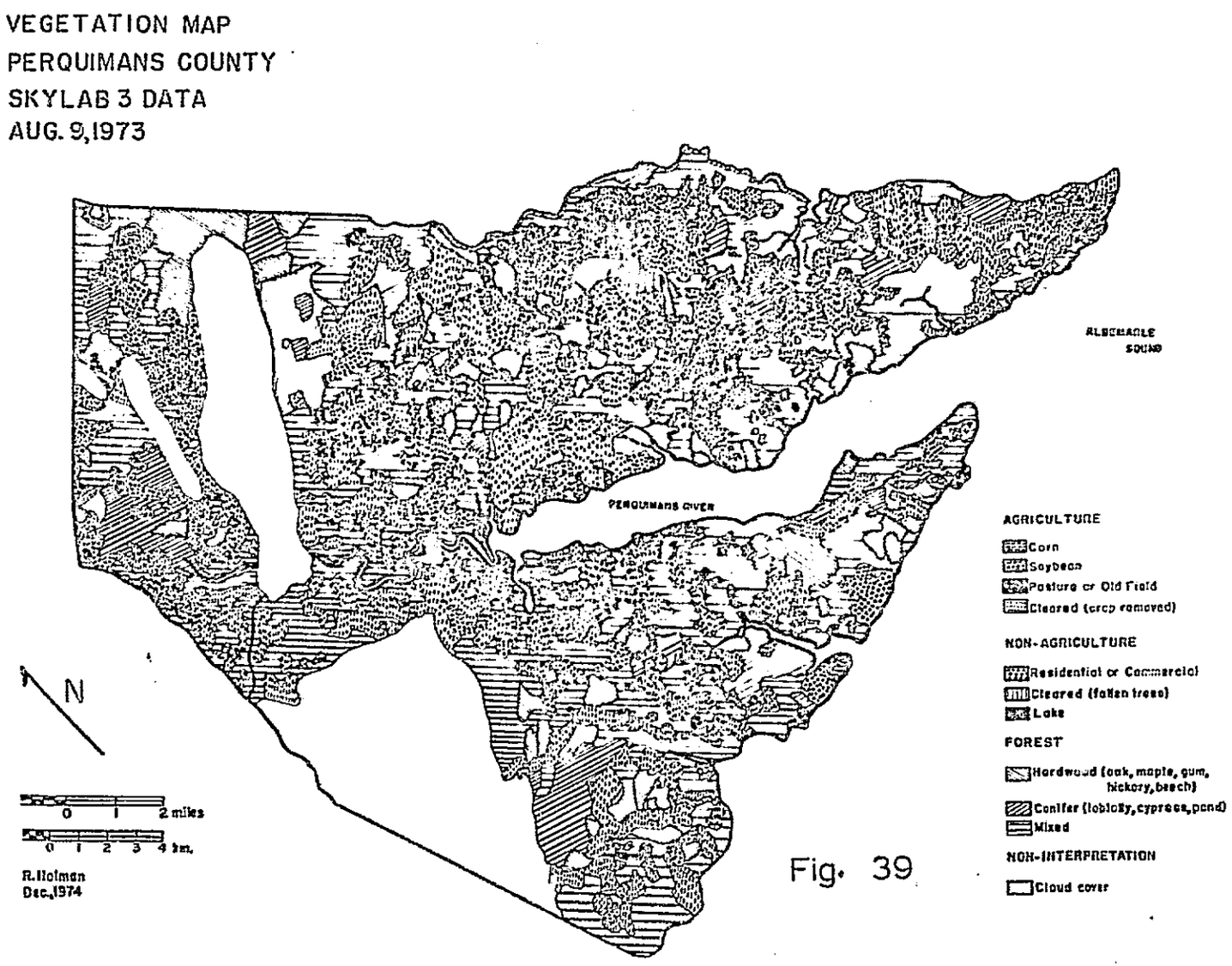

Fig. 39

Figure 39. Vegetation Map, Perquimans County, North Carolina. Interpretation Based on SKYLAB-3 S190A Data

some crops still persisted; fields and forest vegetation could be readily verified. There was a good correlation between the vegetation map and the U-2 imagery.

Ground verification at the five randomly chosen sites provided specific data for checking the SKYLAB photography. Location of these sites is noted on Figure 31, and each site has an area of approximately one square mile (2.56 sq km).

Random ground site 1 is located six miles due south of Hertford, the approximate center of Perquimans County. This site was determined to be 6.3% conifer and 43.9% mixed of the forest category. Agricultural elements were 35.4% corn, 4% soybean, 6.1% old field, and 4.3% pasture. An error reduced the interpretation accuracy to 89.6% because old field and pasture could not be separated clearly from soybeans on the SKYLAB photography.

The location of random ground site 2 is 6 miles southeast of Hertford. Forests consisted of 27.2% mixed. The agricultural division was 38.4% corn and 34.4% soybean. Cloud cover obscured about 7% of the site. Interpretation accuracy of the cloud-free areas was 100%.

Random ground site 3 is located 8 miles southeast of Hertford. The forest category was 18.1% conifer and 36% mixed. Agricultural division consisted of 22% corn and 24% soybean. Corn could not be distinguished from a young pine plantation. The reason for the difficulties of interpretation was that giant cane (Arundinaria gigantea), whose signature resembled the corn, was growing between the young pines. The signature of the pines was therefore modified, and the modified signature resembled that received by the camera from a similar-size area of corn. The same height of pine and cane (8 ft; 2.4m) combined with the similar leaf angle of cane and corn made it impossible to distinguish corn from the young pine plantation. The interpretation accuracy for this site was 84.5%.

Random ground site 4 is located 3 miles northwest of Hertford. This site was made up of 12% hardwood and 54% mixed forest. The

agricultural category was 30% corn and 4% soybean. A minor error attributed to cloud cover made the interpretation accuracy 92.4%.

Random ground site 5 is located 7 miles southeast of Hertford. Forests consisted of 34.7% conifer and 29.6% mixed. Two elements were found in the agricultural category. These were 5.5% cleared and 5% soybean. Problems were encountered in interpreting wooded swamps. These regions produced a dark reflectance similar to conifers and are easily mistaken for conifer stands when a mixed stand of hardwoods (Nyssa aquatica and Nyssa sylvatica and conifer (Taxodium distichum) actually exist. For the imagery used the explanation lies in part at least in the presence of the trees. The water reduces the reflectance. Accuracy of interpretation for this test site was 94.6%.

Interpretation accuracy for all the random ground sites varied between 84.5 and 100%. The two largest errors were caused by cloud cover and by the presence of giant cane between trees on a young pine plantation.

A comparison of SKYLAB interpretive results with statistics obtained from the North Carolina Department of Agriculture was made. Vegetational types were mainly defined in the SKYLAB photography by color tone association. Areas with the same color tone were combined to obtain a percentage for particular vegetation type. Acreage totals were compiled by the North Carolina Department of Agriculture from Farm Census Supervisors and Township Listers. A summary of the information obtained from both sources is given in Table 15. The major drawback in comparison of the two sources was that different components were included and omitted in the same major categories.

A review of the forest category revealed that both estimates were similar (36%). No further division of this category was made by the State Agriculture Department.

The *non-agricultural* category showed the largest differences between the two data sources. *Residential* and *commercial* areas (3.8%) were placed in this category in the interpretation made

TABLE 15

A Comparison of Crop Statistics of SKYLAB and North Carolina Department of Agriculture

Category	Agriculture Dept. (harvested)	SKYLAB (total farm land)
A. Agricultural	36.0%	42.2%
1. soybean	20.2%	11.6%
2. corn	11.9%	27.5%
3. peanuts	2.2%	--*
4. pasture	2.0%	2.1%
5. other grains	1.7%	--*
B. Non-agricultural (no agricultural production)	26.0%	3.8%
1. residential or commerical	----	2.2%
2. cleared	----	1.6%
C. Forest	36.0%	35.4%
1. conifers	----	12.4%
2. hardwoods	----	6.8%
3. mixed	----	16.2%
D. Cloud Cover *	----	18.5%
Total	100%	100%

* 18.5% of the county was covered by clouds over area where peanuts and "other grains" were concentrated.

from SKYLAB photography. On the other hand, all areas of no significant agricultural production (26%) were lumped together for the compilation made by the State Department of Agriculture. The 22.2% difference can be almost any other type of land use except *agricultural* land use in the figure compiled by the State Department of Agriculture.

The interpretation of the SKYLAB photographs gave a higher percentage (42.2%) of land devoted to agriculture than did the Department of Agriculture figures (36%). This difference is attributed to the fact that the state estimates were for harvested crops while SKYLAB figures were on standing crops. The percentage of the *pasture* category mapped from the SKYLAB data agreed in general with the state's estimate (2%). *Peanuts* and *grain crops* were not included in the SKYLAB figures because the northwestern part of the county in which these crops are concentrated was cloaked with cloud cover. The areas hidden below the clouds were later interpreted by U-2 photography to be around 25% forest and 75% agricultural, indicating the standing crop should be larger than the figures given in Table 15.

Soybean and *corn* percentages from the SKYLAB imagery and from the Department of Agriculture data do not agree. SKYLAB percentages for *corn* are 27.5% and 11.6% respectively; the corresponding figures from state data are 11.9 and 20.2 percent. These differences may be due to the error arising from misidentification of young pine plantations. However, another possibility is that the State Department of Agriculture survey might fail to include all fields away from accessible road sites. The ground verification of SKYLAB interpretations which separated *corn* from *soybeans* showed the interpretation to have an accuracy of 100%. It is possible that SKYLAB-type imagery can be used to obtain more accurate acreage values for these two crops in North Carolina than is possible by present methods.

10.8.4 Summary and Conclusions

Color infrared photography from SKYLAB-3 appeared to be superior to LANDSAT-1 imagery in a vegetational study of northeastern North Carolina. An accuracy of 87% was achieved in delimiting species composition and zonation patterns of three coastal vegetation classes with SKYLAB photographs. A vegetation map of Perquimans County, North Carolina, seemed to have a high degree of correlation with information provided by high altitude U-2 photography. Random verification sites revealed an overall interpretation accuracy above 84%.

Comparison of maps drawn utilizing SKYLAB photography with North Carolina Department of Agriculture estimates of crop acreage revealed some marked discrepancies. The chief difference lies in the non-agricultural category in which there is a 30% difference. There appears to be a difference between the definition of non-agricultural land uses used in this investigation and that used by the State Department of Agriculture. Another interesting difference is that found in the differences between acreage figures for various crops given by the State Department of Agriculture and the interpretation from SKYLAB photography. It was not possible to resolve the reasons for these differences, but it should be noted that the SKYLAB photography provides a permanent record of the crops and the various land uses.

Two difficulties were encountered in using SKYLAB photography. Cloud cover limited the area available for study, and a number of possible study sites were either eliminated or restricted in area by the cloud cover. Ocular and graphical techniques revealed a resolution of 58 to 70 meters. Resolution was poorer in this study than other uncited studies because of difficulties encountered in estimating the actual extent of the vegetation zone because of film characteristics.

10.8.5 Benefit-cost evaluation

Vegetational analysis can be accomplished within a week's time after sufficient ground data are provided for a coastal

county the size of Perquimans. The rate at which the work can be done depends on the familiarity of the interpreter with the area in question, and it can be reasonably assumed that if repetitive imagery were available to a person familiar with an area the information could be extracted in only a day or so.

Perquimans County has a rather low population density, and changes in the agricultural category would probably be the most significant in terms of numbers and area than in any other category. These changes would represent crop rotation chiefly. Future expansion will probably be made in the croplands as forested areas are cleared and converted to seasonal crops. It can also be expected that there will be population increases in the future, but they will be at a much slower rate than the agricultural expansion and changes.

One major benefit demonstrated by this study is that the State Agricultural Department could keep more up-to-date and accurate records of crop yield, crop expansion, and potential problem areas through the use of space-acquired imagery. As the investigators have no way of assessing the man-hours required to gather and tabulate the acreage figures for the various crops, they cannot provide an accurate benefit-cost evaluation. However, for an area such as Perquimans County the ability to gather needed crop statistics on the part of an Agircultural Department employee in a matter of a day or so could be an important benefit in administering various agricultural programs. Space-acquired imagery could save many of the man-hours involved in mailing out questionnaires, tabulating the answers, and in bringing the data and its interpretation to a central location for later disbursement. On the other hand, the time between data acquisition and receipt of them by the user determines the ultimate usefulness of the orbital imagery. In crop inventory acquisition procedures a short time interval is needed.

A measure of the benefits, of course, is the importance attached by the various agencies to crop inventories and the

speed with which the data need to be processed. If a requirement exists for essentially within season crop inventories from northeastern North Carolina, space-acquired imagery at a scale comparable to that of SKYLAB on a repetitive basis should prove of considerable economic benefit. If knowledge of patterns of crop rotation is of economic importance, space-acquired imagery may be the least expensive, most accurate way to accumulate this information over a period of years. The images and pictures are a permanent record of what exists.

In either case a single county in northeastern North Carolina could probably be studied and mapped at a cost of two or three man-days with a light table, a binocular microscope, and some suitable means of measuring areas, such as a projected scale micrometer. Skill of the interpreter would control the accuracy of the determinations, but a skilled interpreter knowledgeable about the area could probably achieve a 90-95% or better accuracy. For some crop studies the rapid inventorying could be of considerable advantage.

11.0 MULTISPECTRAL SCANNER (S192) INVESTIGATION

11.1 Coastal Investigation

When SKYLAB-2 passed over the North Carolina coast on 9 August 1973 the area was partly cloud covered and only parts of the test site could be studied. Multispectral scanner data were investigated for three areas: Cape Hatteras and portions of the Outer Banks, Perquimans County on the northern shore of Albemarle Sound, and the Chowan River. The method of study was to examine the black and white transparencies of the multispectral scanner (S192) with simple magnification by a hand lens and/or a binocular microscope. The imagery was density sliced on a Spatial Data Model 703, 32 step Image Analyzer.

Because of the cloud cover the underflight aerial photography was of limited use in this study, and also the aerial photography

did not cover parts of the study area. The Chowan River was almost completely cloud covered except in the area of Holiday Island. Cape Hatteras was chosen as a test site simply to evaluate the imagery in terms of the vegetational characteristics, recognition of man-made objects, and the effects of reflectances from the sand. A general knowledge of the Cape Hatteras area aided in interpretation of the reflectances in these terms without the specific identification of the man-made objects, such as parking lots and buildings. Density slicing of the Perquimans County area was compared with the information gathered during the vegetational study described in Section 10.8 of this report. Table 16 gives the nominal characteristics of the 13 bands.

11.1.1 Cape Hatteras

All of the bands studied by density slicing, Bands 5, 6, 7, 11, 12, and 13, showed a sharp boundary between the water surrounding the barrier islands and the islands themselves. On the Band 5 imagery the areas that stand topographically higher on the barrier islands have a somewhat greater reflectance than those that stand lower, nearer to sea level. Because most of the sand areas are rather narrow, there is an edge effect from the density slicer, and it is difficult to see any range of reflectances between the narrow thread that represents the island and the water body adjacent to it. In Band 6 broad vegetational patterns at Cape Hatteras are shown in the mid-range of 32 steps. Band 7 showed more detail of the vegetational pattern at Cape Hatteras than either Band 5 or Band 6, and also most of the man-made features are expressed by a high reflectance. Where the sand bodies are relatively wide, the beach sands show a high reflectance. The beach areas in general have a reflectance approximately 4 steps (0.60D) less than the reflectance in the vegetation. The reflectivity in Bands 5, 6, and 7 of the water on either side of the barrier islands is approximately equal. Band 10 can be used to separate the sandy areas and marshes in

TABLE 16

S192 Multispectral Scanner Parameters

Band no.	Bandwidth (μm)	Atmospheric transmission, percent	Noise equivalent reflectivity, percent (a)
1	.41 to .46	45	1.2
2	.46 to .51	45	.9
3	.52 to .56	55	.8
4	.56 to .61	55	1.1
5	.62 to .67	60	1.9
6	.68 to .76	65	1.5
7	.78 to .88	70	1.4
8	.98 to 1.08	80	1.2
9	1.09 to 1.19	50	.9
10	1.20 to 1.30	80	2.0
11	1.55 to 1.75	70	1.6
12	2.10 to 2.35	70	2.0
13	10.2 to 12.5	90	[b]1.25° K

[a]Scene reflectance, 20 percent (diffuse); angle of incidence, 45°.

[b]Blackbody source, 300° K.

Source: EREP Investigators' Handbook
NASA - SKYLAB Program
MSC - 07874

the water. The definition of all three of these types of surfaces is very sharp, and within the vegetation there may be some separation of the various types of vegetation. However, detailed vegetational maps were not available, and the possibilities of separation of coastal vegetation was not pursued.

The very bright reflectances from the sandy areas come only from the topographically higher areas; the lower areas which presumably are wetter seem to reflect in the middle range of the 32 steps. Band 11 did not show any significant reflectance differences that appear to be useful in an area such as Cape Hatteras. Band 12 seems to have differentiated the low marshy areas on the south side of the barrier islands from the more highly reflective sand. As for other bands the higher dune areas seem to exhibit a greater reflectivity than the topographically lower ones. Band 13 differentiates between the water and land areas and seems to indicate that on Cape Hatteras at the time of the SKYLAB-2 pass (0847 EST) the dune sands all had much the same temperature. The reflectivity from the sand seems to have been the same on Cape Hatteras as well as on the islands to the north and south of it.

11.1.2 Chowan River

With the exception of Band 11 the reflectivity from the Chowan River seems to have been essentially constant. There are some reflectance differences just south of Holiday Island which suggest perhaps a current structure in the river. However, it is difficult to separate the possible effects of clouds from the possible current or water body effects. On Band 11 the reflectances from the land areas adjacent to the river and the reflectance from the water are very close as measured by the density slicing, but the water-land boundaries can be distinguished.

11.1.3 Perquimans County

A discussion of the interpretation of this area using S190A photography is given in Section 10.8.

The lower bands, Bands 1 through 4, do not seem to provide much information about the land-use patterns in the Perquimans County area. Band 4, for example, separates the water and land areas, but little other information seems to come through.

The other bands appear to be useful in distinguishing vegetative cover, open areas of land, and between crops in some cases. Band 6 distinguishes between mixed forest cover and crops. It also appears to be useful for separating large fields of soybeans from those containing corn in June 1973 (See also Section 10.8.) The soybean fields appear to be lighter than the bulk of the forests and darker than the corn. Because of the low resolution of the scanner, it is probable that there is some overlap in the reflectances as they are seen in the image that has been studied, but for the larger fields that are clear and distinct these separations can be made.

On Band 7 conifers are barely separable from the mixed forests. Also, corn and soybeans apparently have a similar reflectance and have a slightly higher reflectance than that shown by the forest. The difference in the reflectances between the forests and the crops is approximately three steps of the total of 32. On Band 8 the mixed forest areas have reflectances very close to those of pure pine stands. Soybeans seem to have reflectances similar to mixed forests and similar to low areas along some of the streams. Corn, on the other hand, has a relatively high reflectance, one that is at the upper part of the density range on the transparency. The land-water boundaries are sharp.

Band 9 seems to be a useful band for separating crops (soybeans and corn) in this area from forests and woods. Corn, in some cases, has a lower reflectance than soybeans, and in other cases its reflectance is about the same. Forests tend to be darker than the crops. The Band 10 imagery shows a density distribution such that in only approximately half of an interpreter's attempts is he able to separate the corn and soybean acreage on the image display unit of the density slicer. Many of the small fields that

are planted in these two crops lie within areas of mixed forests, and the crop areas appear to blend into the forested areas because of the small scale associated with the scanner. It is difficult to separate conifers from mixed forests on this band of the imagery.

Band 11 imagery suggests that topography is a control on the reflectances, or conversely that the reflectances are related to the topographic position of the particular vegetative type. There is no discernible relationship between the crops, woods, and the density as found on this particular image. The darker areas may be topographically lower; the pattern seems to be modified by crops and forests. On the Band 12 imagery crops were separated from the forested areas and land and water. Many fields lie within forested areas, but these fields are too small to be resolved from the forested areas. So they are recorded, of course, as forests.

Band 13 imagery does not provide any information about the vegetation or the differences between the water and land in Perquimans County as far as can be told from this study of the imagery.

11.1.4 Conclusion

The multispectral scanner, based on the density work done in this study, seems to be a useful tool for differentiating various types of crops. The capability of the scanner to separate the infrared part of the spectrum into fairly small band widths seems to be a useful technique. It might be useful in separating young pine plantations from corn (Section 10.8.3), although no studies were conducted along this line. In an area such as Cape Hatteras, which is underlain by sand and bordered by water and coastal vegetation, the multispectral scanner probably is of limited usefulness. On the other hand, where broad land-use maps are necessary and are not available, this type of information could be useful. In North Carolina it is not, largely because of the fact that the space-acquired imagery is of such small scale.

Cloud cover over the Chowan River area prevented any significant work being done on this area, although at the time of the SKYLAB pass it was considered a prime test area. Shortly after the pass of SKYLAB in August 1973 there were several significant algal blooms in the river. It would have been interesting to have investigated the capability of the multispectral scanner to assay these algal blooms. It is believed that the relatively narrow band widths of several of the bands would have been helpful in mapping the extent of the blooms and the concentrations of the blooms within the Chowan River.

The multispectral scanner imagery would probably be useful to crop inventory in North Carolina if the resolution were improved. This is particularly true of coastal North Carolina where each county has, because of soil and climate conditions, a relatively limited number of crops, and these are planted in relatively large acreage units. Density slicing of larger scale multispectral scanner imagery either optically or by computer, would probably help agricultural interests to monitor the crop acreage as well as possibly to study on larger plots potential disease and moisture stress.

11.2 Piedmont Area

Multispectral scanner imagery taken on 17 September 1973 was studied in three ways. All 13 channels were examined under a binocular microscope and evaluated for various levels of gray and for those features that could be readily recognized in this manner. Combinations of the bands were inserted into a color additive viewer and studied, and two or three bands were compared with one another. The third method involved the use of density slicing.

In general, broad land-use patterns could be separated from one another. For example, areas of mixed hardwoods and pines could be separated from cropped areas and areas of open bare fields. No particular band seemed to be especially useful in

making these distinctions, and combinations of the bands as seen in the color additive viewer were at times useful. However, one part of the investigation did indicate that cropping practices and types of crops could be distinguished even in mid-September. Cloud cover prevented any attempt at making an extensive evaluation of these observations in other parts of the Piedmont of North Carolina. Nonetheless, it is believed that it is possible to distinguish crops and cropping patterns on the imagery as it was received. It appears that three bands (Section 11.2.1) are particularly useful in this conjunction.

11.2.1 Results

Bands 5, 6, 7, and 8 were studied in the color additive viewer, and it was found that there are differences in reflectances between Bands 6 and 7 which enabled the interpreter to distinguish between the two crops, soybeans and corn. A combination of Bands 5, 6, and 8 placed in the color additive viewer showed three areas of field as one color. One of these field areas lies in an oxbow or bend on Rocky River, which is a tributary to the Pee Dee River in Stanly County (Fig. 40). It had soybeans in it on 17 September 1973 (B. D. Creech, letter 7 August 1975). The other area of two or more fields lies on the north side of the Pee Dee River where this river forms a boundary between Richmond and Anson Counties (Fig. 40). The areas along the Pee Dee River consist chiefly of cornfields with intermixed areas of fallow grass- and weed-covered fields. (D. E. Stegall, letter, 21 August 1975). Interspersed among the trees to the north of these fields are open fields. The larger ones appear as very bright reflections (whitish) mixed within the tree-covered areas. The corn was brownish in September having reached maturity in contrast to the soybeans which were nearly mature but still green.

Combination Bands 5, 7, and 8 enabled the interpreter to distinguish between the two crop areas. In the case of the Rocky River field the reflectances were somewhat brighter when these

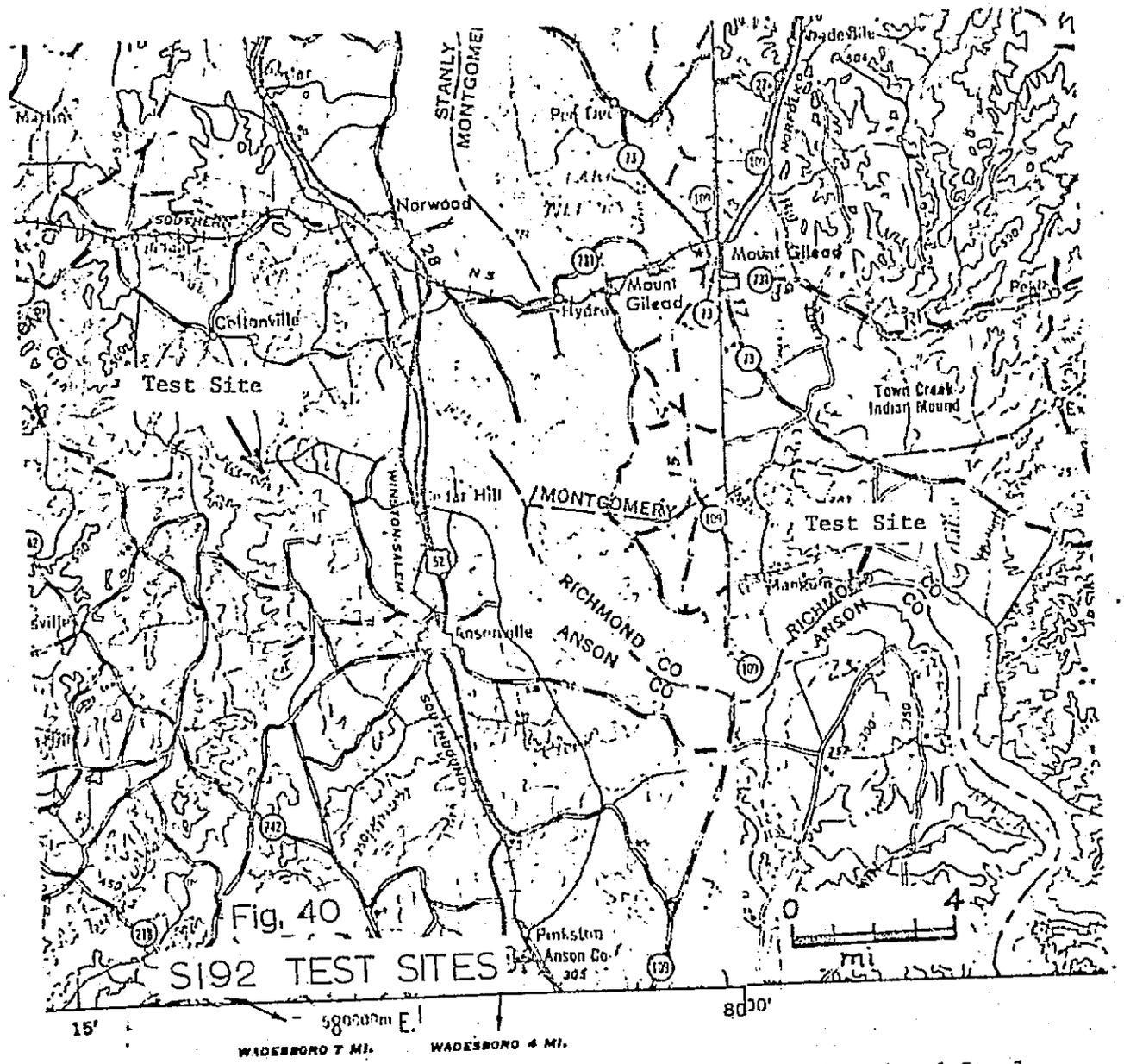

Figure 40. Multispectral Scanner, S192, Test Sites, Richmond and Stanly Counties, North Carolina

three bands were used than were the reflectances from the two fields on the north side of the Pee Dee River to the south. In the latter case the color shown on the color additive viewer for these two fields was that which had been inserted into the color additive viewer for Band 5. The color for the field in the Rocky River bend was that which formed as a result of a combination of the colors put into Bands 5 and 8 with some influence from Band 7. Thus when Bands 5, 7, and 8 were in the color additive viewer with a red filter for Band 5, a blue filter for Band 7, and a green filter for Band 8, the Rocky River field showed as yellowish and the fields on the north side of the Pee Dee River showed red (Fig. 41 and Fig. 42). Areas of high infrared reflectance as shown on the color infrared photographs of the S190A experiment showed in this combination as cyan or turquoise. The apparent ability of Band 7 to separate soybeans from corn and grain in September contrasts with its failure to do so in June in Perquimans County (Section 11.1.3). This fact emphasizes the importance of crop stage on making the distinctions. In June both crops were actively growing; in September they were at different stages of their growth cycles. In the case of the Band 5, 6, and 8 combination the same wooded areas or high reflectance areas showed a dominance of reflectances from Bands 6 and 8. This was true both in areas adjacent to the Rocky River fields and to those areas adjacent to the fields on the north side of the Pee Dee River.

Density slicing of the four bands disclosed that the fields on the north side of the Pee Dee River in general had lower reflectances than the field found in the bend of the Rocky River. For Band 6 there seemed to be a lower reflectivity recorded from the Rocky Creek field than from the field on the north side of the Pee Dee River. The difference was perhaps more marked in Band 6 than it was in Band 7.

Microscopic examination of the imagery of the field areas confirmed the fact (noted in the density slicing experiment) that

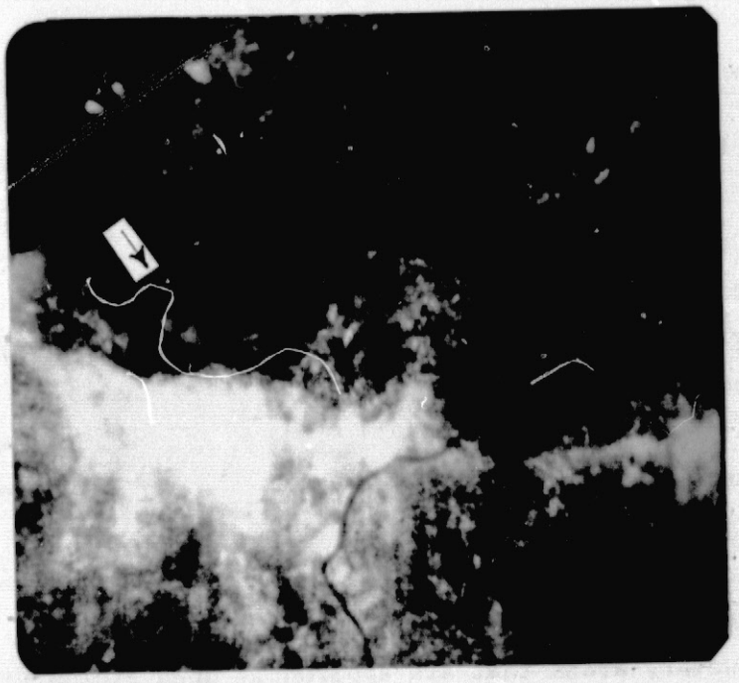

Figure 41. Rocky River Test Site, S192, Multispectral Scanner; Bands 5, 7, and 8. SKYLAB-3

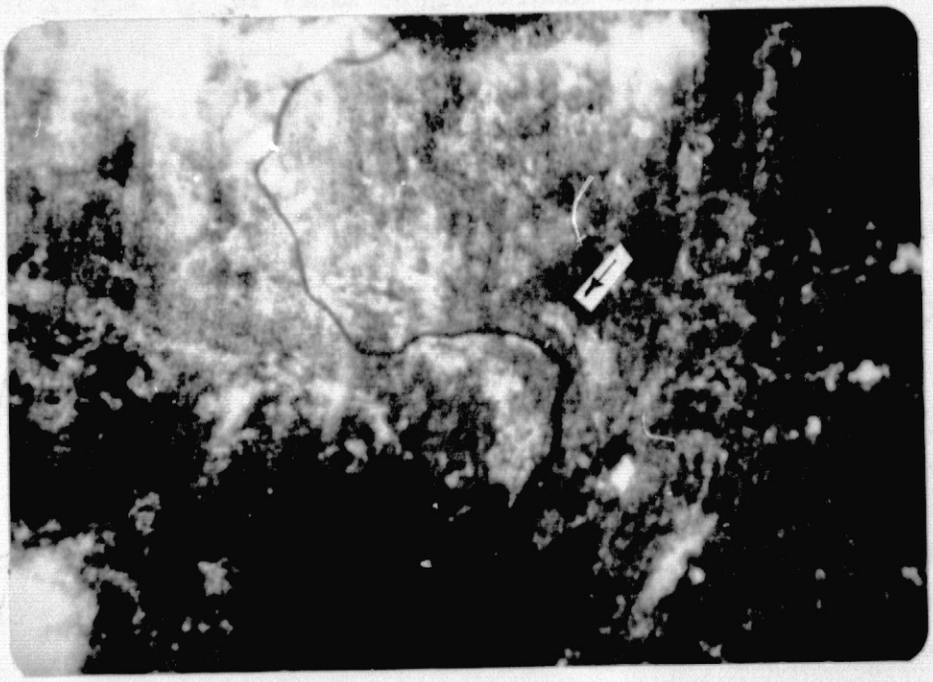

Figure 42. Pee Dee River Test Site, S192, Multispectral Scanner; Bands 5, 7, and 8. SKYLAB-3

the Rocky River area seemed to have a somewhat higher level of photographically recorded reflectivity than the fields found on the north side of the Pee Dee River. Some of the dark areas within the field on the Rocky River are approximately the same level of gray as that found on the fields on the north side of the Pee Dee River; therefore, there seems to be a mix of reflectivities in the Rocky River area, but the overall effect is to make the Rocky River field have a somewhat higher level of reflectivity.

Combinations of other bands did not emphasize apparent crop or land-use differences quite so sharply as did Bands 5, 6, 7, and 8. However, areas that are apparently open fields within wooded areas were brought out by color additive combinations of one type or another. There seemed to be no particular distinctive pattern to these relationships.

The study of the combination of Bands 10, 11, and 12 in the color additive viewer points out that there is a better separation of the agricultural-related land uses when the three bands are used than if single bands or just pairs of Bands 10, 11, or 12 are used. When only two bands are used, the broad outlines of the major land uses may be discerned on the viewing screen of the color additive viewer, and it is possible to divide land uses in general into crops, open fields, and forested areas, but the addition of the third band emphasizes differences within these broad groupings, or emphasizes small acreage uses, or slight variations of the uses within the broad groups.

Based on the color additive viewer interpretation, when Bands 10, 11, and 12 are used in conjunction, the open fields show as high reflective areas. But when Bands 11 and 12 alone are used, it appears that the open fields have reflectances that are approximately equal in each band. When Bands 11 and 12 together are used, the three fields studied in conjunction with the Rocky River and Pee Dee River test site appear as bright colored areas. When green and red are used in the color additive

viewer, yellow or yellowish tints are the predominating color. The mixed woods in between the fields and adjacent to the fields are chiefly brown. The areas that have a particularly high level of brightness on the color infrared S190A imagery appeared green. This is especially true of the wooded area adjacent to the Rocky River test site.

The capability of the multispectral scanner to detect suspected sediment was brought out in the study of the Pee Dee River area. Frame 109, Roll 45 of the S190A experiment shows lighter blue colors in High Rock Lake and in the upper reaches of Lake Tillery (Fig. 40). The multispectral scanner recorded only the upper reaches of Lake Tillery. Badin Lake lying upstream from Lake Tillery, was mostly obscured by cloud cover. Suspended sediment coming into the upper reaches of Lake Tillery shows best on Band 5. When Band 5 is compared with Bands 7 and 8, the color seen on the screen of the color additive viewer is that of Band 5. When Band 3 is compared with Band 7 on the color additive viewer, the color picked to represent Band 3 appears only in the lower part of the sediment plume. Upstream the water in Lake Tillery appears dark, and the sediment in the river is not uniquely distinguished. It appears then that Bands 3, 4, and 5, when used and compared with one of the infrared bands, Band 7 or above, enable an interpreter to depict and possibly quantify the amount and distribution of the suspended sediment. There was no groundtruth obtained for this particular part of the investigation, and thus it is impossible to say anything about the actual concentrations of the suspended sediment in the lake waters.

Within the area covered by the multispectral scanner data there were several small towns and cities. Examination of the imagery under the microscope, in the color additive viewer, and on the density slicer did not indicate any unique signatures or combinations of signatures that could be used in interpreting urbanized areas. On the other hand, Bands 10, 11, and 12 did record many of the agricultural areas and open field areas of

the upper Coastal Plain with considerable degree of clarity. Band 11 seems to be the best band for these particular phenomena. Bands 7 through 12 were particularly effective in penetrating the cloud cover along the Pee Dee River near junction with Rocky River in Stanly County.

Bands 1, 2, and to a certain extent Band 3, did not give any particularly useful information when viewed in the color additive viewer in combination with other bands. The one exception to this statement is the fact that Band 3 did provide information about the suspended sediment load in Lake Tillery. Band 13 was completely useless for any sort of interpretive work.

11.2.2 Conclusions

It is evident from the investigation that Bands 5, 6, 7 and 8 are useful for distinguishing between various crop types and possibly between some forest types. Although no detailed work was done on distinguishing between forest types, woodlands, and mixed land uses in areas of combination forest and crop lands, it appears from a general observation of the imagery that Bands 9, 10, and 11 and 12 could be put to effective use under certain circumstances. On the other hand, Bands 1, 2, and to a certain extent 3, appear to have limited usefulness in identifying land-use patterns and crops in the Piedmont of North Carolina.

One of the effective techniques of using the multispectral scanner and the types of data that can come from it, assuming better resolution, is that of color additive viewing. By putting two or more of the bands into the color additive viewer and studying the imagery with various colors and intensities of colors, it is possible to bring out information that is not otherwise easily obtained. The advantage of the color additive viewer in a study such as this is that it is a relatively simple way to get at the information desired. It is one that does not require a high degree of competence in a very technical field, and a person who is trained in its use can extract a large amount of useful

information from viewing the multispectral scanner imagery. The viewer can also be used to ratio density slices of various bands.

The breaking of the near-infrared portion of the spectrum into a series of relatively narrow bands appears to be a very useful approach to acquisition of earth resource information. Particularly is this statement true for an area such as the Piedmont of North Carolina. It appears that the separation of soybeans, corn, perhaps milo, even in small fields, given an adequate resolution, could be obtained by this technique. The question of benefit-cost arises in the evaluation of the usefulness of the multispectral scanner, and it then becomes a question of whether the knowledge that can be obtained from this sort of instrumentation can be useful to the agricultural community. That question cannot be answered as a result of this investigation.

12.0 CONCLUSIONS

Several studies which were a part of this project proved that SKYLAB photography and imagery can be effectively used in land-use mapping of both rural and urban areas, quarry monitoring, forest reconnaissance, urban greenspace analysis, and investigations of geological and coastal phenomena.

Land-use planning, the object of great current interest in North Carolina and elsewhere, can receive much essential information from orbital photography. The results of this investigation show that natural resources and their existing and potential uses can be identified to a remarkable degree from SKYLAB photography. The resolution permits recognition of single family dwellings in both urban and rural settings and water bodies down to about 1.5 acres in size. Rural and urban land use and vegetative cover could be readily mapped and identified through most of Level II (Anderson, et al, 1971). A generalized land-use map for an area of 50 to 100 square miles (128 to 256 sq km) can be prepared with 3 to 4 man-days of effort. Even an initially unskilled photointerpreter can acquire within a very short time adequate skill to interpret

the photography with standard techniques at accuracies approaching 90 percent. A skilled interpreter with knowledge of the area in North Carolina may be able to interpret the photography consistently with accuracies of 90 to 95%.

One phase of the investigation indicated some possibilities for using SKYLAB data for evaluating the impact of airport expansion on local residents. These data can be used in the analysis of alternative construction plans, preparation of environmental impact statements and discussions with local politicians and disturbed citizenry.

Agricultural crop monitoring can be done from SKYLAB photography and imagery better than with existing techniques of ground surveys. The latter lack the 100% coverage of all fields that exists in the photography. One serious drawback to this particular orbital imagery was its "one-time-only" occurrence. Because of legal and political time constraints a land-use inventory will probably have been compiled before a suitable satellite is operational; therefore, for North Carolina purposes any future satellite should be planned for a minimal of SKYLAB S190B scale and appropriate orbital and time configuration.

With the present status of North Carolina land-use planning the potential user groups do not accept SKYLAB photography because of real or imagined unfavorable benefit/cost ratio. In several instances also lack of knowledge of the techniques of using these data and possibilities for their applications to operational problems deter acceptance. However, if multispectral orbital imagery at the S190B scale were to become available on a regular basis, many agencies would probably find it useful for change detection.

In geological studies SKYLAB photography was enlarged to the same scale as local geologic maps (1:250,000) to permit direct comparison between the orbital data and cartographic records. Isoluminous (Wenderoth, Yost, Kalia, and Anderson, 1974, p 12-1) investigations of the photography accompanied conventional

instrumental and groundtruth studies, but the heavy vegetation in North Carolina greatly restricted detection of surface and subsurface detail. Rock types could not be unequivocally separated, and in general soil groups could not be separated. However areas of wet lowland soil types, such as floodplains and swampy areas, could be differentiated. The chief geologic features recognizable are lineaments, most of which have some geomorphic expressions. An inadequate data base prevented any study of fracture patterns and ground water occurrence.

Studies of coastal processes revealed information on the dynamics of currents, sands, and channels. Density slicing techniques were used to interpret both underwater and shore topography. SKYLAB photography proved to be useful in revealing sediment in various water bodies, although no quantitative relationships between reflectances and water quality were established. The effect of a period of precipitation upon sediment discharged into a major lake in South Carolina was recognized, and use of orbital imagery for measuring relations between rainfall and sediment load in a drainage basin was shown to be possible.

During the course of the studies various tests were made of photographic scales and interpretation techniques. The best interpretation was probably achieved by use of a 70mm High Resolution Color stereopair. In a color additive viewer the photography could be magnified to a scale of 1:30,000 and still be clear enough for interpretation and mapping. Using the color additive viewer, an interpreter can combine the several bands of the multispectral camera (S190A) to extract useful information. One particularly promising technique is to combine the color infrared photograph with one or more of the black and white multispectral photographs to enhance land-use patterns. For instance, by combining the color infrared photograph with the red band (0.6 - 0.7μm), the interpreter can sharpen those distinguishing features which separate hardwoods from mixed forests in the September imagery.

In order to facilitate use of the SKYLAB photography by those unfamiliar with photointerpretation techniques, a procedure and accompanying materials for self-teaching were assembled for Buncombe County. Additionally guides to photointerpretation of Piedmont SKYLAB photography were developed. These portions of the study demonstrated the feasibility of a rather simple approach for improving interpretation performance and thereby enlarging the potential user group.

The SKYLAB data source was found to be useful for many resource management purposes. The scale, resolution, and image characteristics approached that of conventional aerial photography, and the photography was therefore easily used and understood by air-photo interpreters. The S192 (Multispectral Scanner) experiment demonstrated a favorable potential for use in crop and vegetative mapping. The breaking of the near-infrared portion of the spectrum into relatively narrow bands should prove to be a useful tool in this connection once a larger scale and cartographic accuracy become available.

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